Understanding The Universe

QUARKS, LEPTONS AND THE BIG BANG

Manjunath.R

Understanding the Universe: Quarks, Leptons and the Big Bang

"The only true wisdom is in knowing you know nothing."

— Socrates

Manjunath.R

#16/1, 8th Main Road, Shivanagar, Rajajinagar, Bangalore560010, Karnataka, India

*Corresponding Author Email: manjunath5496@gmail.com

*Website: http://www.myw3schools.com/

"There is nothing new to be discovered in physics now. All that remains is more and more precise measurement."

– **Lord Kelvin, 1900**

"Physics is mathematical not because we know so much about the physical world, but because we know so little."

− **Bertrand Russell**

"If I am given a rod of proper length and proper place to hook its one end, I can lift the earth with the help of a lever."

− ARCHIMEDES (287B.C − 212 B.C)

"Science is a wonderful thing if one does not have to earn one's living at it."

− **Albert Einstein**

"Scientific knowledge is a body of statements of varying degrees of certainty − some most unsure, some nearly sure, none absolutely certain."

− **Richard Feynman**

Mechanics	The theory of the motion of material objects
Thermodynamics	The theory of heat and temperature
Electromagnetism	The theory of electricity, magnetism and electromagnetic radiation
Special Relativity	The theory of invariance in nature
General Relativity	The theory of gravitation

- **Cosmological Principle:**

  The universe is the same everywhere.

- **Homogeneous:**

  The universe looks the same from every point.

- **Isotropic:**

  The universe looks the same in every direction.

  But WHY?

Kaons are particles that carry a quantum property called strangeness

Unpredictability (randomness) lies at the heart of science dealing with the behavior of matter and light on the atomic and subatomic scale.

Why No Antimatter?

Matter and antimatter were created in the Big Bang. Why do we now see only matter except for the tiny amounts of antimatter that we make in the laboratory and observe in cosmic rays?

"….. In an infinite universe, anything that could be imagined might exist somewhere."

Superposition

↓

The feature of a quantum system whereby it exists in several separate quantum states at the same time

More Mysteries

Schrödinger's Cat

↓

A thought experiment in which a cat trapped in a closed box can be alive and dead at the same time – provided that nobody lifts the lid to take a look.

Universe Accelerating?

The expansion of the universe appears to be accelerating. Is this due to Einstein's Cosmological Constant? If not, will experiments reveal a new force of nature or even extra hidden dimensions of space?

Dark Matter?

Invisible forms of matter make up much of the mass observed in galaxies and clusters of galaxies. Does this Dark Matter consist of new types of particles that interact very weakly with ordinary matter?

"Since I have introduced this **Λ** term, I had always a bad conscience. But at that time I could see no other possibility to deal with the fact of the existence of a finite mean density of matter. I found it very ugly indeed that the field law of gravitation should be composed of two logically independent terms, which are connected by addition. About the justification of such feelings concerning logical simplicity it is difficult to argue. I cannot help to feel it strongly and I am unable to believe that such an ugly thing should be realized in nature"

– **Albert Einstein, in a September 26, 1947, Letter to George Gamow**

- $dS > \frac{dQ}{T}$ for irreversible system
- $dS = \frac{dQ}{T}$ for reversible system

Mass Annihilation:

Electron + positron → 2 gamma photons

Schrödinger Equation is the central equation of quantum theory that governs the wave function of a quantum-mechanical system. It describes how any quantum mechanical system will behave and how its observable qualities are likely to manifest in an experiment.

Thus the last and most successful creation of theoretical physics, namely quantum mechanics (QM), differs fundamentally from both Newton's mechanics, and Maxwell's e-m field. For the quantities which figure in QM's laws make no claim to describe physical reality itself, but only probabilities of the occurrence of a physical reality that we have in view. (**Albert Einstein, 1931**)

I cannot but confess that I attach only a transitory importance to this interpretation. I still believe in the possibility of a model of reality - that is to say, of a theory which represents things themselves and not merely the probability of their occurrence. On the other hand, it seems to me certain that we must give up the idea of complete localization of the particle in a theoretical model. This seems to me the permanent upshot of Heisenberg's principle of uncertainty. (**Albert Einstein, 1934**)

$E=mc^2$: Einstein's equation that gave birth to the atom bomb and heralded a new world of atomic physics

- E = Energy
- m = Mass
- c^2 = Speed of light squared

Classical physics would have been much different

if …

A stone had fallen on Newton’s head instead of the apple.

1678 AD ISAAC NEWTON TRIES TO INVENT GRAVITY

The backwards-moving electron when viewed with time moving forwards appears the same as an ordinary electron, except that it is attracted to normal electrons - we say it has a positive charge. For this reason it's called a positron. The positron is a sister particle to the electron, and is an example of an anti-particle. ..This phenomena is general. Every particle in Nature has an amplitude to move backwards in time, and therefore has an anti-particle. (Feynman, 1985)

For many years after Newton, partial reflection by two surfaces was happily explained by a theory of waves,* but when experiments were made with very weak light hitting photomultipliers, the wave theory collapsed: as the light got dimmer and dimmer, the photomultipliers kept making full sized clicks - there were just fewer of them. Light behaves as particles. * This idea made use of the fact that waves can combine or cancel out, and the calculations based on this model matched the results of Newton's experiments, as well as those done for hundreds of years afterwards. But when experiments were developed that were sensitive enough to detect a single photon, the wave theory predicted that the clicks of a photomultiplier would get softer and softer, whereas they stayed at full strength - they just occurred less and less often. No reasonable model could explain this fact.

This state of confusion was called the wave - particle duality of light. (Feynman, 1985)

$$\text{Compton wavelength} = \frac{\text{Planck constant}}{\text{rest mass} \times \text{speed of light in vacuum}}$$

The Compton wavelength of a particle characterizes the length scale at which the wave property of a given particle starts to show up. In an interaction that is characterized by a length scale larger than the Compton wavelength, particle behaves classically (i.e., no observation of wave nature). For interactions that occur at a length scale comparable than the Compton wavelength, the wave nature of the particle begins to take over from classical physics.

“The shell game that we play ... is technically called 'renormalization'. But no matter how clever the word, it is still what I would call a dippy process! Having to resort to such hocus-pocus has prevented us from proving that the theory of quantum electrodynamics is mathematically self-consistent. It's surprising that the theory still hasn't been proved self-consistent one way or the other by now; I suspect that renormalization is not mathematically legitimate. (Feynman, 1985)”

WARNING!

BLACK HOLE!

KEEP AWAY!

Do black holes really exist? If they exist, why we HAVEN'T observed one hole yet? Can black holes be observed directly, and if so, how? If there are no black holes, what are these things we detect ripping gas off the surface of other stars?

Mechanics

Motion

Forces

Energy

Kinematics	The science of describing the motion of objects
Dynamics	The science of describing the motion of objects under the action of forces
Statics	The branch of mechanics dealing with objects at rest or in equilibrium

Energetics

A branch of mechanics that deals primarily with energy and its transformations

Who would set a limit to the mind?
Who would dare assert that we
know all there is to be known?

— Galileo Galilei

Motion

- **Translational motion:** Motion that results in a change of location
- **Oscillatory motion:** To and fro motion of the object about its fixed position
- **Rotational motion:** Motion that occurs when an object spins
- **Random motion:** Kind of motion where an object moves in any direction and the direction keeps changing continuously

$v = \frac{dx}{dt}$ } How fast object moves

$\omega = \frac{d\theta}{dt}$ } How fast object spins

Translatory motion

- **Rectilinear motion:** motion in a straight line
- **Curvilinear motion:** motion in a curved path

- **Uniform motion:** The motion of a object along a straight line with steady speed

  { Zero acceleration }

- **Non-Uniform motion:** The motion of a object along a straight line with variable speed

  { Non-Zero acceleration }

Chaos { Complete disorder and confusion

Quantum mechanics is not chaotic − but probabilistic.

The correspondence principle

Classical mechanics is the classical limit of quantum mechanics

Chaos Theory

{ The principles and mathematical operations }

↓

Deal with **nonlinear** things that are effectively impossible to predict or control, like turbulence, weather, the stock market, our brain states, and so on.

Classical probability is a simple form of probability that has equal odds of something happening.

Quantum chaos is a branch of physics which is concerned with establishing the relation between chaotic systems quantum systems.

Is One Star's End is a Black hole's beginning?

There is no Escape from A black hole in classical theory, but Hawking Radiation process Enables energy And information to escape. Does the Hawking Radiation process continue until the black hole dissipates completely Away or does the Radiation stop After A finite Amount of time Leaving black hole remnants is still in?

Would the tidal forces kill an astronaut?

Since gravity weakens with distance, the earth pulls on your head with less force than it pulls on your feet, which are a meter or two closer to the earth's center. The difference is so tiny we cannot feel it, but an astronaut near the surface of a black hole would be literally torn apart.

An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer.

– **MAX PLANCK, 1858 TO 1947**

"The black holes of nature are the most perfect macroscopic objects there are in the universe: the only elements in their construction are our concepts of space and time."

– **Subrahmanyan Chandrasekhar, 1910 TO 1995**

Micro Black Holes:

Where can we find them?

What will they look like?

Observed?

If the production of **micro black holes** is feasible, can the LHC create a black hole that will eventually eat the world?

What is our space-time made of? Why Cosmological constant (a parameter in **Einstein's equations**) gives space-time an inherent tendency to expand? Is space-time fundamentally continuous or discrete?

Trap a **GRAVITATIONAL WAVE DUDE!**

Gravitational waves are vibrations in the 4 dimensional fabric of space-time. Gravitons are their quanta.

Why the accelerated massive bodies emit gravitational waves? What will they teach us about the universe?

Are Neutrinos Massless?

If not they could contribute significantly to the mass of the universe.

The

Theory of Everything?

"Einstein's Unfinished Symphony"

"Another very good test some readers may want to look up, which we do not have space to describe here, is the Casimir effect, where forces between metal plates in empty space are modified by the presence of virtual particles. Thus virtual particles are indeed real and have observable effects that physicists have devised ways of measuring. Their properties and consequences are well established and well understood consequences of quantum mechanics."

— Gordon L. Kane

Cosmic Inflation: during which the universe grew exponentially at a rate α to e^{3Ht} and cooled at a rate proportional to its expansion.

Is the theory of cosmic inflation correct, and, if so, what are the details of this inflation? Did inflation left remnants like black holes or gravitational waves? What is the hypothetical field that powered inflation? Why the inflation made the universe flat, homogeneous and isotropic?

The strong force binds the nucleus of an atom	The electromagnetic force binds electrons to the nucleus of an atom
The weak force changes a neutron into a proton in a process called nuclear decay	The gravitational force keeps planet in orbit and curves the space around the sun

One electron volt is equal to 1.602×10^{-12} erg

$$p = \frac{h}{\lambda}$$

The shorter the **wavelength of the electromagnetic energy**, the larger is the momentum carried by the photon.

$$\underbrace{\Delta E \times \Delta t \geq \frac{\hbar}{2}}$$

Small amount of energy ΔE can be transmitted for a very short time Δt − in violation of the energy conservation law.

The two up quarks spins in an opposite direction to the down quark for the proton to have spin $\frac{1}{2}$

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

At v = 0.83 c, the length of an object is shortened to 50% of its original value.

A red quark can transform into a blue quark by emitting a red-blue gluon

The energy E_g of a single graviton (**the quantum of gravity**):

$E_g = h \times \upsilon_g$ → The frequency of gravitational waves

h → Planck's constant

Black hole singularity → All matter and radiation squeezed into infinite density − creating infinite gravity and infinitely warped space-time

Black hole singularity → All of the original matter of the star has been crushed out of existence and all that remains − infinitely warped space-time

The gravitational binding energy of a sphere of mass $\sqrt{\frac{\hbar c}{G}}$ and radius $\sqrt{\frac{\hbar G}{c^3}}$:

$$E_g = \frac{3Gm_{Planck}^2}{5L_{Planck}}$$

$$\boxed{E_g = \frac{3}{5} \times \text{Planck energy}}$$

A **light-year** is the distance traversed by light in 1 year at 300,000 km/sec velocity

Standard big bang model

$\downarrow$

There was no vacuum of space around the **gravitational singularity**. All space was created after the big bang explosion − simultaneously with the expansion of the universe

A condition in which gravity is so intense that spacetime itself breaks down catastrophically

Free Lunch Theory of Creation

$\downarrow$

Our universe emerged − not from a **spacetime singularity** − but from instability of the vacuum of space that led to the creation of matter.

- At distance $\leq \sqrt{\frac{\hbar G}{c^3}}$: it is impossible to integrate quantum mechanics with **Albert Einstein's general theory** as gravity becomes infinite.

- Radiation Energy Density $= \frac{4\sigma T^4}{c}$
- Emittance $= \sigma T^4$

The radius of the horizon: $r_{horizon} = \underbrace{\frac{2GM_{universe}}{c^2}}$

Maximum space in which a given universe can expand and no matter or radiation can escape

$$\text{Velocity} \, \mathbf{?} \, \frac{\text{motive force}}{\text{resistance}}$$

$$\text{Velocity} \, \alpha \, \frac{\text{motive force}}{\text{resistance}}$$

Aristotle (b. 384 BCE, Stagira, Chalcidice, Greece—d. 322 BCE, Chalcis, Euboea)

We need DNA to create enzymes in the cell, but we need enzymes to unzip the DNA. Which came first, proteins or protein synthesis? If proteins are needed to make proteins, how did the whole thing get started?

Newton's second law of motion:

Force = mass × acceleration

"Science is uncertain. Theories are subject to revision; observations are open to a variety of interpretations, and scientists quarrel amongst themselves. This is disillusioning for those untrained in the scientific method, who thus turn to the rigid certainty of the Bible instead. There is something comfortable about a view that allows for no deviation and that spares you the painful necessity of having to think."

− Isaac Asimov (1920 − 1992)

Newton's third law of motion:

To every action there is always an equal and opposite reaction

Dark colors absorb more light energy than do light colors.

The energy of the universe is constant.

The entropy of the universe is increasing.

$$P_{Planck} \times V_{Planck} = \frac{R \times T_{Planck}}{N_A}$$

$$P_{Planck} = \frac{R \times T_{Planck}}{N_A V_{Planck}}$$

$$V_{Planck} = \frac{R \times T_{Planck}}{N_A P_{Planck}}$$

$$T_{Planck} = \frac{N_A \times P_{Planck} \times V_{Planck}}{R}$$

- **The Clausius statement** ⟶ Heat never flows spontaneously from a cold object to a hot object.

Kelvin–Planck statement

↓

It is impossible to devise a heat engine that can absorb energy in the form of heat as well as produce work of an equivalent amount.

Waves transfer energy, momentum and information – but not mass

Sound intensity ∝ (frequency of sound)^2 × (amplitude of the sound wave)^2 × density of medium in which sound is traveling × speed of sound

↓

- The denser the medium, the more intense the sound wave.
- The faster the sound wave travels, the more quickly it transmits energy.
- The greater the amplitude of the sound wave, the more intense the wave.
- Higher the frequency of sound wave, the more intense the wave is.

Loudness

↓

How loud or soft a sound seems to a listener

An observer behind the source would hear the sound with a lower frequency, while an observer in front would hear a higher frequency than is being produced by the source. This shift in frequency is called the Doppler Effect.

"Truth is ever to be found in simplicity, and not in the multiplicity and confusion of things."

– Sir Isaac Newton

Noise	Music
Sound which is not pleasant to hear	Sound which is pleasant to hear

Huygens' Wave theory of light	Newton's Corpuscular theory of light
Reflection	Reflection
Refraction	Photoelectric effect
Diffraction	
Interference	

Neither theory accounted for polarization of light

Newton's corpuscular theory of light suggested that velocity of light in a denser medium is greater than in rarer medium. **Foucault** and **Michelson** experimentally verified that light in denser medium has lower velocity than in rarer medium.

Brightness

$\downarrow$

How much light appears to shine from something

Incandescence	The emission of electromagnetic radiation from a hot matter as a result of its high temperature (T $\geq$ 800 K).
Luminescence	The emission of light when excited electrons fall to lower energy levels (in matter that may or may not be "hot")

- **Chemiluminescence:** The emission of light by a substance as a result of a chemical reaction.
- **Bioluminescence:** The emission of light by a substance as a result of an enzymatic reaction.

Why the Universe is a pretty big place seems like an awful waste of space?

- Nearest star: 4.22 light-years.
- Nearest galaxy: 2.44 million light years.
- Galaxies within our horizon are 40 billion light-years away.
- Universe beyond horizon: 10 to the 10 to the 100 times bigger.

The inherent goal of unification is to show that all of these forces are, in fact, manifestations of a single force. We can't perceive this unity at the low energies of our everyday lives, or even in our most powerful accelerators at CERN. But close to the Big Bang temperatures, at inconceivably high energies…

If the forces unify, the proton can be unstable, and eventually decay …

Proton → positron + neutral pion

Neutral pion → 2 gamma ray photons

Is some other form of life might be possible with many other variations of physical constants?

Sun emits 2×10^{38} neutrinos per second but only 30 neutrinos are interacting in a person per year.

"Experiment is the only means of knowledge at our disposal. Everything else is poetry, imagination."

− Max Planck

Simulation of the map of the cosmic microwave background that is being obtained by **NASA's Microwave Anisotropy Probe (MAP)** shows that the CMB is not perfectly smooth. But has Ripples in it.

"Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are a part of the mystery that we are trying to solve."

−Max Planck

We know that virtual photon is to electromagnetism, why not to gravity?

- Cosmic radiation prevents humans from spending years in space.
- Only two photons of every billion emitted by sun are used to warm the Earth.

What lies beyond the quarks and the leptons? Do the quarks or leptons have any substructure, or are they truly elementary particles? Why are there 6 quarks and 6 leptons? These questions still block the mind of Dr. Science.

$$\boxed{G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}}$$

$G_{\alpha\beta} \rightarrow$ Curvature of space

$T_{\alpha\beta} \rightarrow$ Distribution of mass or energy

$\frac{8\pi G}{c^4} \rightarrow$ Constant

But WHY?

Maybe because matter and energy warp time and cause the time dimension to mix with the space dimensions?

The entire electromagnetic spectrum — from radio waves to gamma rays, most of the light in the universe — resembles nothing but transverse waves of energy $E = \frac{hc}{\lambda}$, which in turn are vibrating Maxwell force fields differing only in their wavelength $\lambda = \frac{h}{p}$.

"Things are as they are because they were as they were."

− THOMAS GOLD

Quantum mechanics

A fundamental theory of the mechanics of atoms, molecules and other physical systems that are subject to the **Heisenberg uncertainty principle** or indeterminacy principle

Speed = $\frac{\text{Distance}}{\text{time}}$

- Speed $\propto$ distance when time is constant
- Speed $\propto \frac{1}{\text{time}}$ when distance is constant

I still struggle with the same problems as ten years ago. I succeed in small matters but the real goal remains unattainable, even though it sometimes seems palpably close. It is hard, yet rewarding: hard because the goal is beyond my abilities, but rewarding because it makes one oblivious to the distractions of everyday life.

Albert Einstein

Synthetic geometry

The geometry that uses logic to test proofs

Analytic geometry

Algebraic symbolism and methods are used to represent and solve problems in geometry

Elasticity

Ability of a deformed body to return to its original shape and size when the forces causing the deformation are removed

Hooke's Law

The force needed to extend or compress a spring by some distance is proportional to that distance

Buoyancy

The force exerted on an object immersed in a fluid

Magnetic Force

The attraction or repulsion between charged bodies in motion

Inertia is the resistance to change in velocity

Weight = Buoyancy

$\downarrow$

A person floats in still water

- acceleration $\propto$ net force when mass is constant
- acceleration $\propto \frac{1}{\text{mass}}$ when net force is constant

Momentum = mass × velocity

Force = mass × acceleration

Yank = mass × jerk

jerk is the rate at which an object's acceleration changes with respect to time

Tug = mass × snap

snap is the rate of change of jerk with respect to time

Snatch = mass × crackle

crackle is the rate of change of snap with respect to time

Shake = mass × pop

pop is the rate of change of **crackle** with respect to time

Kinetic energy

The energy associated with motion

Potential energy

The energy associated with position

Mass is a measure of resistance to acceleration

- When a system does work on its surroundings: the total energy of the system decreases. Work is done by the system.
- When the surroundings does work on a system: the total energy of the system increases. Work is done on the system.

What you learn from a life in science is the vastness of our ignorance.

– David Eagleman

WORMHOLE:

Existence of Worm Holes is still?

If wormholes exist, they could provide shortcuts between distant points in space?

When we say that space has three dimensions, we mean that it takes three numbers— length, breath and height— to specify a point. If we add time to our description, then space becomes space-time, with four dimensions.

WHY 4 DIMENSIONS?

Extra dimensions (x, y, z, t) + w, v … exist? If they exist, they could solve many known fundamental problems?

Dear "**Dr. Science**," I hear that scientists have now made antiprotons and antielectrons…

My question is: if you mixed antiprotons with antielectrons, could you make anti-oxygen?

If so, could it be used to put out combustion, rather than supporting it?

Yours,

Curious Harris.

Hmmmmmm ??

?

Hmmmmm

mmmmmmmmmmmmmmmm….

Dear Curious Harris.

Unfortunately, Dr. Science is currently unable to provide a response to your recent query…

I think your question might have blocked his brain.

String theory:

- Different Vibrations → Different Particles
- String Combinations → Particle Interactions

Higgs theory:

- Different masses → Different strengths of interaction with the Higgs field

Which explanation is right?

STRING or HIGGS

The new physics will raise new questions and point to even more discoveries at the TeV scale and opens the door beyond the Standard Model.

If the **Higgs field** generate masses for the W and Z, and for the quarks and leptons— does it generate its own mass and if so how? What is its mass?

The Coulombic repulsive force between two protons inside the nucleus is 10^{36} times the gravitational force between them. The nuclear attractive force between two neutrons is 10^{38} times the gravitational force between them.

Very likely, we are missing something important. Why is gravity so weak?

May because of hidden extra dimensions?

- **Motion** is the change of state of an object.

The equation $v = \sqrt{gh}$ gives the speed v with which apple hits the ground after falling from a tree.

↓

The velocity is proportional only to the square root of the height.

The larger p = mv is, the harder it is to stop the object.

Galileo's principle of relativity

↓

It is impossible by mechanical means to say whether we are moving or staying at rest

The force of gravitation between the sun and the earth:

Entropy measures the degree to which energy is mixed up inside a system.

$$F_{G_{sun-earth}} = \frac{GM_{sun}m_{earth}}{r^2}$$

$$F_{G_{sun-earth}} = \frac{(6.673\times10^{-11})\,(2\times10^{30})\,(6\times10^{24})}{(1.5\times10^{11})\,(1.5\times10^{11})} = 3.557 \times 10^{22}\ \text{N}$$

The force of gravitation between the earth and the moon:

$$F_{G_{earth-moon}} = \frac{GM_{earth}m_{moon}}{r^2}$$

$$F_{G_{earth-moon}} = \frac{(6.673\times10^{-11})\,(6\times10^{24})\,(7.4\times10^{22})}{(3.84\times10^{5})\,(3.84\times10^{5})} = 2\times10^{26}\,N$$

$$\frac{F_{G_{sun-earth}}}{F_{G_{earth-moon}}} = 0.00017785$$

$$F_{G_{sun-earth}} < F_{G_{earth-moon}}$$

Led **Johann Titius** to predict the existence of another planet between Mars and Jupiter in what we now recognize as the asteroid belt.

Titius-Bode Law:

The **distance** d of the n^{th} **planet** from the Sun is given by:

$$d = a + 2^n b \text{ with } a = 0.4AU \text{ and } b = 0.3AU$$

The integer take values $n = -\infty$ for mercury, n = 0 for Venus, n = 1 for the Earth, and so on.

Planet	n	Actual distance in AU	Predicted distance in AU
Mercury	$-\infty$	0.387	0.4
Venus	0	0.723	0.7
Earth	1	1.00	1.0
Mars	2	1.52	1.6
Planetoids	3	2.2 to 3.2	2.8
Jupiter	4	5.20	5.2
Saturn	5	9.55	10.0
Uranus	6	19.2	19.6
Neptune	7	30.1	38.8
Pluto	8	39.5	77.2

Predicted the amount of space between the planets

Refraction

Waves change direction when they change medium

When waves add up or cancel each other out: they interpenetrate each other.

Heisenberg's Uncertainty Principle:

$$\Delta p \times \Delta x \geq \frac{\hbar}{2}$$

$$m\Delta v \times \Delta x \geq \frac{\hbar}{2}$$

Only for the exceedingly small masses of atoms and subatomic particles the product of the uncertainties becomes significant.

$$\Delta v \geq \frac{\hbar}{2\ m\ \Delta x}$$

The position and the velocity of a subatomic particle cannot both be measured exactly, at the same time − even in theory.

$$\Delta p \times \Delta x \geq \frac{\hbar}{2}$$

$$\Delta k \times \Delta x \geq \frac{1}{2}$$

$$\Delta p = \frac{h}{\Delta \lambda} = \hbar \Delta k$$

k = angular wave number

It is impossible to specify both the position of a light signal and its wavelength with full precision

Loschmidt's number

The number of gas molecules in one cubic centimeter at 0° C and one atmosphere pressure

2.687×10^{19} molecules per cubic centimeter

Because

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

A pairs of virtual particles appear together at some time, move apart, then come together and annihilate each other.

"It is a great adventure to contemplate the universe, beyond man, to contemplate what it would be like without man, as it was in a great part of its long history and as it is in a great majority of places. When this objective view is finally attained, and the mystery and majesty of matter are fully appreciated, to then turn the objective eye back on man viewed as matter, to view life as part of this universal mystery of greatest depth, is to sense an experience which is very rare, and very exciting. It usually ends in laughter and a delight in the futility of trying to understand what this atom in the universe is, this thing — atoms with curiosity — that looks at itself and wonders why it wonders. Well, these scientific views end in awe and mystery, lost at the edge in uncertainty, but they appear to be so deep and so impressive that the theory that it is all arranged as a stage for God to watch man's struggle for good and evil seems inadequate.

Some will tell me that I have just described a religious experience. Very well, you may call it what you will. Then, in that language I would say that the young man's religious experience is of such a kind that he finds the religion of his church inadequate to describe, to encompass that kind of experience. The God of the church isn't big enough."

— Richard P. Feynman (1918−1988)

The faster you move,

The shorter and the heavier you are.

And that is the Theory of Relativity.

- Did you know that the static on your television is caused by radiation leftover from the Big Bang?

Because $\Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{v^2}{c^2}}}$, can you travel back in time and kill your grandfather before he conceive your father? If not, why the universe avoids the paradox?

Time Travel − Science Fiction?

"Actually, everything that can be known has a Number; for it is impossible to grasp anything with the mind or to recognize it without this."

— **PHILOLAUS (C. 470 – C. 385 BC)**

What is GRAVITY?

- **Newtonian view:** Force tells Mass how to Accelerate. Accelerated Mass tells WHAT Gravity is.
- **Einsteinian view:** Mass tells space how to curve. Curved space tells what gravity is.

Motion and gravity makes the clock tick slower

Observations of galaxies indicate that the universe is expanding: the distance D between almost any pair of galaxies is increasing at a rate V = HD.

BUT WHY?

Are there elementary particles that have not yet been observed, and, if so, which ones are they and what are their properties?

- Material, such as gas, dust and other stellar debris that approach the black hole prevent themselves from falling into it by forming a flattened band of spinning matter around the event horizon called the accretion disk. And since the spinning matter accelerates to tremendous speeds ($v \approx c$) by the huge gravity of the black hole the heat and powerful X-rays and gamma rays are released into the universe.

"Get your facts first, and then you can distort them as you please."

— **MARK TWAIN**

Thermal energy

The energy contained within a system that is responsible for its temperature

Heat

$\overbrace{\text{The flow of thermal energy}}$

$$\textbf{Joule} = \text{Newton} \times \text{meter} = \frac{\text{Kilogram} \times (\text{meter})^2}{(\text{second})^2}$$

Heliocentrism

In the center of all rests the Sun

"For those who want some proof that physicists are human, the proof is in the idiocy of all the different units which they use for measuring energy."

― **Richard P. Feynman**

The object will also move in a straight line in the absence of a net external force.

Conservative force	**Non-Conservative force**
The total work done in moving a particle from one point to another is independent of the path taken by the particle.	The total work done in moving a particle from one point to another is dependent of the path taken by the particle.

- Gravitational
- Electric
- Elastic

- Friction
- Air resistance
- Tension in cord

1 horsepower = 33,000 foot pounds per minute

1 horsepower = 550 foot pounds per second

Translational	**Rotational**
Force = mass × acceleration	Torque = moment of inertia × angular acceleration
For every action there is an equal and opposite reaction. (Here action and reaction refer to forces.)	For every action there is an equal and opposite reaction. (Here action and reaction refer to torques.)
Power = Force × velocity	Power = Torque × angular velocity

Pascal's law

When an object is immersed in a fluid, it experiences equal pressure on all surfaces.

Archimedes' principle

A body immersed in a fluid is subjected to an upward force equal to the weight of the displaced fluid

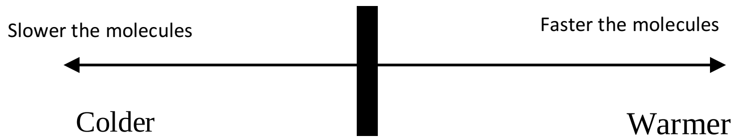
Any particle smaller than an atom is called a **subatomic particle**

- Atoms of the same element are the same.
- Atoms of different elements are different.

Archimedes was the most famous mathematician – certainly the greatest scientist of the classical age. He is most famous for discovering the law of hydrostatics − sometimes known as **'Archimedes principle'**.

373.15 K	Normal boiling point of water
309.9 K	Average human body temperature
273.16 K	Triple point of water
273.15 K	Normal freezing point of water

Kinetic theory of gases



- The gas is composed of molecules.
- Molecules are small.
- Molecules are in constant random motion.
- Collisions between molecules are perfectly elastic.
- The temperature of a gas is a measure of the average kinetic energy of the molecules.
- All molecules have energy, but the energy varies depending on the temperature the sample of gas is in.
- The higher the speed of the molecules, the higher their temperature.

"For the first half of geological time our ancestors were bacteria. Most creatures still are bacteria, and each one of our trillions of cells is a colony of bacteria."

—RICHARD DAWKINS

Because $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$, a particle with imaginary mass can travel faster than the speed of light. This particle is termed the **tachyon**. However,

Do tachyons exist and if they exist, how can they be detected is still a?

"Who are we? We find that we live on an insignificant planet of a humdrum star lost in a galaxy tucked away in some forgotten corner of a universe in which there are far more galaxies than people."

− Carl Sagan

Sending the Beatles song across the Universe and pointing the telescopes in Deep Space Network towards the North Star, Polaris, we seek to find intellectual beings like us outside the sheer number of planets, our solar system, and our own Milky Way galaxy. How awe hunting for them across the empty stretches of the universe would be to acquire a bit of confirmation that either we're alone in this universe or we are not. However, we are not the only life-form in the universe, is reasonable to expect, but

Where's the evidence?

The Burden of evidence is On the Believer?

"If I saw further than others, it is because I was standing on the shoulders of giants."

– Isaac Newton

"Gravity is the force that rules the Universe. To understand its workings, to the finest degree, is to understand the very nature of our celestial home."

—**M. Bartusiak in Einstein's Unfinished Symphony**

- Space: the potential habitable worlds around ten thousand billion billion stars; ours is just one.
- Time: a cosmic history of nearly 14 billion years; life took less than ½ billion years to start here.

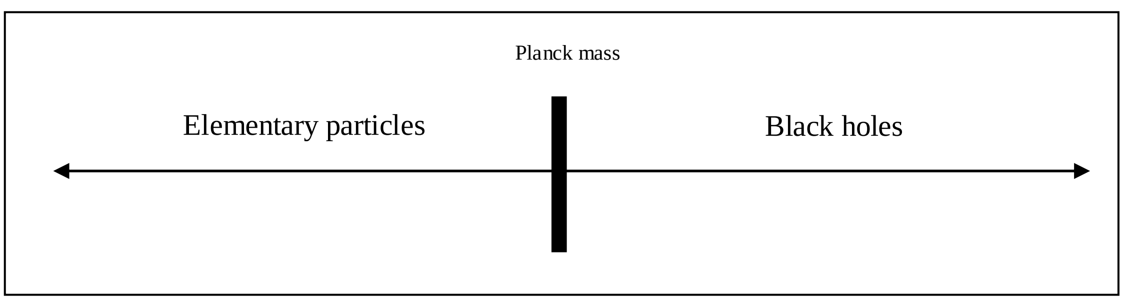
Energies equivalent to the Planck mass did occur in the early universe according to big-bang theory.

"If they not be inhabited, What a Waste of space."

– Thomas Carlyle, Scottish Essayist (1795–1881)

- Gamma ray bursts may happen when a neutron star falls into another neutron star or black hole. The resulting explosion sends out particles and radiation all over the spectrum.
- Neither of these extremes would have allowed for **the existence of stars** and life: A slightly stronger weak force, all the neutrons in the early universe would have decayed, leaving about 100 percent hydrogen, with no deuterium for later use in the synthesizing elements in stars. A slightly weaker weak force, few neutrons would have decayed, leaving about 100 percent helium, with no hydrogen to fuel the fusion processes in stars.
- By analyzing Stellar Spectrum, one can determine both the temperature of a star and the composition of its atmosphere.
- Electric and magnetic forces are far stronger than gravity, but remain unnoticeable because every macroscopic body contain almost equal numbers of positive and negative electrical charges (i.e., the electric and magnetic forces nearly cancel each other out).

Planck mass = $\sqrt{\frac{\hbar c}{G}} \approx 2.17 \times 10^{-8}$ kg is the fundamental unit of mass constructed solely out of the three fundamental constants that govern spacetime, the strength of gravity and the quantum world: $\hbar = \frac{h}{2\pi}$, G and c. The description of an elementary particle of this mass requires a quantum theory of gravity. The **Planck mass times speed of light squared** is so large that even the Large Hadron Collider in CERN only reaches an insignificantly tiny fraction of this energy.



Throughout all of the formulations of the basic equations of gravitation, quantum mechanics, electromagnetism, the nuclear physics and their application to the real world, there appear again and again certain fundamental invariant quantities called the fundamental physical constants.

Name	Symbol	Antiparticle	Charge (e)	Spin	Interaction mediated	Existence
Photon	γ	Self	0	1	Electromagnetism	Confirmed
Gluon	g	Self	0	1	Strong interaction	Confirmed
Graviton	G	Self	0	2	Gravitation	Unconfirmed

The electrostatic force of repulsion between 2 electrons is given by:

$$F_E = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

Fine structure constant:

$$\boxed{\alpha_C = \frac{e^2}{4\pi\varepsilon_0 \hbar c}}$$

$$F_E = \alpha_C \times \frac{\hbar c}{r^2}$$

The gravitational force of attraction between 2 electrons is given by:

$$F_G = \frac{Gm_e^2}{r^2}$$

Gravitational coupling constant:

"Gravity is a far weaker force than the electromagnetic interaction" since α_G is 42 orders of magnitude smaller than α

$$\boxed{\alpha_G = \frac{Gm_e^2}{\hbar c}}$$

$$F_G = \alpha_G \times \frac{\hbar c}{r^2}$$

where: α_G = (Planck time) ^{2} × (Compton angular frequency of the electron) ^{2}

Schwinger limit → The **theoretical limit** of the strength of electric field (beyond which electron-positron pairs will be created spontaneously), which has a value of about 1.32×10^{18} V/m.

$$E_c = \frac{m_e^2 c^3}{e\hbar}$$

$$E_c = \frac{m_e^2 c^4}{\hbar^2} \times \frac{\hbar}{e\,c}$$

$$\boxed{E_c = (\text{Compton angular frequency of the electron})^2 \times \frac{\hbar}{e\,c}}$$

$$E_c = \frac{\alpha_G}{(\text{Planck time})^2} \times \frac{\hbar}{e\,c}$$

$$\boxed{E_c = \alpha_G \times \frac{\text{Planck force}}{e}}$$

Stoney mass:

$$m_S = \sqrt{\frac{e^2}{4\pi G\,\varepsilon_0}} = \sqrt{\alpha} \times m_{Planck} = 1.859 \times 10^{-9}\ \text{kg}$$

One second of arc = $\frac{1}{3600}$ th of a degree

- $\alpha \rightarrow$ fine structure constant and $m_{Planck} \rightarrow$ Planck mass

The gravitational force of attraction between two **Stoney masses** is:

$$F_G = \frac{Gm_S^2}{r^2}$$

$$F_G = \frac{G}{r^2} \times \frac{e^2}{4\pi G\,\varepsilon_0} = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

F_G = electrostatic force of repulsion between 2 electrons

$$m_S^2 = \alpha\ m_{Planck}^2$$

$$F_G = \alpha \times \frac{Gm_{Planck}^2}{r^2} = \alpha \times \frac{\hbar c}{r^2}$$

Stoney charge

$$\underbrace{q_S = e}_{1.6022 \times 10^{-19}\ \text{C}}$$

Stoney mass	$m_S = \sqrt{\frac{e^2}{4\pi G\,\varepsilon_0}} = \sqrt{\alpha} \times m_{Planck}$	1.8592×10^{-9} kg
Stoney Length	$L_S = \sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^4}} = \sqrt{\alpha} \times L_{Planck}$	1.3807×10^{-36} m
Stoney Time	$t_S = \sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^6}} = \sqrt{\alpha} \times t_{Planck}$	4.6054×10^{-45} s

There are no known physical models able to describe temperatures greater than Planck temperature (**1.416784×10^{32} K**): a quantum theory of gravity would be required to model the extreme energies attained.

Dirac large numbers hypothesis:

- The strength of gravity, as represented by the gravitational constant, is inversely proportional to the age of the universe:

$$\boxed{G \propto \frac{1}{t}}$$

- The mass of the universe is proportional to the square of the universe's age:

$$\boxed{M \propto t^2}$$

- Physical constants are actually not constant. Their values depend on the age of the Universe.

Bremermann's limit:

The maximum computational speed of a self-contained system in the material universe.

$$\boxed{\frac{c^2}{h} \approx 1.36 \times 10^{50} \text{ bits per second per kilogram}}$$

Gravitational strain:

$$h = \frac{2GM}{c^2 R}$$

Reveals how far we are from any possible horizon

Gravity is strong near black holes, near the horizon of the universe and at extremely high particle energies.

Strong gravity occurs when the mass M and the distance scale R obey:

$$\frac{2GM}{c^2 R} \approx 1$$

Science is the acceptance of what works and the rejection of what does not. That needs more courage than we might think.

– Jacob Bronowski

Black night sky imply that our cosmos once was extremely small and then expanded rapidly

Novae	Luminosity < 10^{31} W
Supernovae	Luminosity < 10^{36} W
Hypernovae	Luminosity < 10^{37} W

A black hole is independent of how it has formed and of the materials used when forming it

Supermassive black holes	10^5 to 10^{11} solar mass
Intermediate black holes	50 to 10^5 solar mass
Stellar black holes	1 to 50 solar mass
Primordial black holes	Below 1 solar mass
Micro black holes	Below 1 gram

The **Mesoscopic scale** is the length at which quantum mechanical behaviors in liquids or solid can be described by macroscopic concepts.

- In nature there is no rest.
- There is motion inside any substance that has mass and takes up space by having volume.
- In nature there is no perfectly straight or perfectly uniform motion.

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} \left\{ \text{10,000 times smaller than an atom and is roughly the length scale at which renormalization becomes significant in quantum electrodynamics} \right\}$$

Any length scale containing e is a quantum length scale and not a classical length scale – because e is the quantum of electric charge.

Interference between 2 different photons never occurs.

Faster-than-light motion is possible in the **quantum world** → { **Tachyonic particle** }

The quantum mechanics implies:

- There is no **state of remaining unchanged indefinitely** in nature
- The vacuum is not empty
- Matter particles behave like waves

Quanton → Any **quantum entity** that shows the properties of both a particle and a wave

The transition from the classical case to the quantum case → quantization

A quantum system with average energy E takes at least time $t = \frac{\pi\hbar}{2E}$ to evolve into an orthogonal state.

Newtonian limit is a mathematical approximation applicable to physical systems exhibiting:

- Weak gravitation.
- Objects moving very slowly compared to the speed of light ($v \ll c$).
- Completely static gravitational fields

A particle is called ultrarelativistic when its speed is very close to the speed of light c.

$$v \approx c$$

$$KE = \sqrt{p^2c^2 + m_0^2c^4} - m_0c^2$$

$$pc \gg m_0c^2$$

$$\boxed{KE = pc}$$

Thermodynamic limit:

$$N \rightarrow \infty,\ V \rightarrow \infty,\ \frac{N}{V} = \text{constant}$$

If black holes have finite entropy, they

should also have a finite temperature.

The law of gravitation is derived from classical statistical mechanics applied to the holographic principle that states that the description of a volume of space can be thought of as N bits of binary information, encoded on a boundary to that region, a closed surface of area A. The information is evenly distributed on the surface with each bit requiring an area equal to L_{Planck}^2, the so-called Planck area, from which N can thus be computed:

$$N = \frac{A}{L_{Planck}^2}$$

where L_{Planck} is the Planck length. The Planck length is defined as:

$$L_{Planck} = \sqrt{\frac{\hbar G}{c^3}}$$

where G is the universal gravitational constant, c is the speed of light, and $\hbar$ is the reduced Planck constant. When substituted in the equation for N we find:

$$N = \frac{Ac^3}{\hbar G}$$

The statistical equipartition theorem defines the temperature T of a system with N degrees of freedom in terms of its energy E such that:

$$E = \frac{Nk_B T}{2}$$

where k_B is the Boltzmann constant. This is the equivalent energy for a mass M according to:

$$E=Mc^2$$

The effective temperature experienced due to a uniform acceleration in a vacuum field according to the Unruh effect is:

$$T = \frac{\hbar a}{2\pi c k_B}$$

where a is that acceleration, which for a mass m would be attributed to a force F according to Newton's second law of motion:

$$F = ma.$$

Taking the holographic screen to be a sphere of radius r, the surface area would be given by:

$$A = 4\pi r^2.$$

From algebraic substitution of these into the above relations, one derives Newton's law of universal gravitation:

$$F = m\frac{2\pi c k_B T}{\hbar} = m\frac{4\pi c E}{\hbar N} = m\frac{4\pi M c^3}{\hbar N}$$

$$F = m4\pi\frac{GM}{A}$$

$$\boxed{F = \frac{GMm}{r^2}}$$

White light is polychromatic since it is made up of multiple wavelengths – whereas red, orange, yellow, green, blue and violet lights are **monochromatic**.

Single frequency

Helium was discovered in 1868 by an English scientist and astronomer **Sir Joseph Norman Lockyer** in the spectrum of a solar eclipse.

Polarized light has electric fields oscillating in one direction – whereas Unpolarized light has electric fields oscillating in all directions

The law of reflection

When a ray of light reflects off a surface, the angle of incidence is equal to the angle of reflection.

A current of **one ampere** is the transfer of approximately 6.2415×10^{18} elementary charges per second.

Geomagnetism is the study of the magnetic field of the Earth.

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

- When q_1 and q_2 have the same sign **their product is positive** – which means the force is repulsive.
- When q_1 and q_2 have the opposite sign **their product is negative** – which means the force is attractive.

$$F = m \times \frac{dv}{dt}$$

Cause of change = resistance to change × rate of change

An inertial reference frame is one that is not accelerating.

Einsteinian Special theory of relativity

The demolition of the concept of absolute time and absolute distance

Correspondence principle

All equations in special theory of relativity reduce to classical equations at low velocities.

The equation $p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}}$ **reduces to** $p = m_0 v$ **at** $v << c$.

Gravitational time dilation:

$$\text{Dilated time interval} = \frac{\text{Original time interval}}{\sqrt{1 - \frac{2GM}{c^2 r}}}$$

r = Distance that the clock is from the black hole

The dimension of h is the product of energy multiplied by time, a quantity called action. Planck's constant is often defined, therefore, as the elementary quantum of action. $\hbar$ is the quantum of angular momentum

$r > \frac{2GM}{c^2}$	Outside the black hole	**Time slows down** (Dilated time interval > Original time interval)
$r = \frac{2GM}{c^2}$	Event horizon	**Time stops** (Dilated time interval = ∞)
$r < \frac{2GM}{c^2}$	Inside the black hole	**Time is mathematically imaginary**
r = 0	Singularity	**Time has no meaning**

Basic principles of relativity + Quantum mechanics = **Modern physics**

Quantum mechanics is certainly imposing. But an inner voice tells me that this is not yet the real thing. The theory says a lot, but does not bring us any closer to the secrets of the "old one". I, at any rate, am convinced that He is not playing at dice.

— Albert Einstein

- In the very early Universe, the pair production and recombination processes were in equilibrium

The steady-state theory of the universe

The universe expands eternally, with continual creation of matter securing a constant density of mass.

- **Perfect Cosmological Principle:** On a very large scale, the universe is uniform both in space and time.

"In general relativity a very wide range of models is available … The number of free parameters is so much larger than the number of observational points that a fit certainly exists." (**Bondi & Gold 1948**)

"If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations — then so much the worse for Maxwell's equations. If it is found to be contradicted by observation— well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

— **Sir Arthur Eddington, 1915**

"Never before and never since has a single human enriched science in such short time by so much as did Einstein enrich physics in this **annus mirabilis**."

(Albrecht Fölsing, 1993, p. 143)

"I spent ten years of my life testing that 1905 equation of Einstein's, and, contrary to all my expectations I was compelled in 1915 to assert its unambiguous experimental verification in spite of its unreasonableness since it seemed to violate everything that we knew about the interference of light."

(**Robert Millikan**, Reviews of Modern Physics 21 (1949):1-13.)

- Helium, from Greek, helios = sun

"It was quite the most incredible event that ever happened to me in my life. It was as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you. On consideration, I realized that this scattering backwards must be the results of a single collision, and when I made calculations I saw that it was impossible to get anything of that order of magnitude unless you took a system in which the mass of the atom was concentrated in a minute nucleus. It was then that I had the idea of an atom with a minute massive center carrying a charge."

— Ernest Rutherford, 1937

Nobel Prize 1908, birth of the modern concept of the nuclear model of the atom

Louis-Victor-Pierre-Raymond, 7th duc de Broglie (1892−1987)

Doctoral thesis 1924: "It would seem that the basic idea of the quantum theory is the impossibility of imagining an isolated quantity of energy without associating it with a certain frequency... However, it is difficult to understand precisely the physical sense of the frequency in the Einstein equation [E = hf]... But it apparently describes a certain internal ‘cyclic process’."

Planet formation models

- Planets formed from condensed gases ripped from an all ready formed Sun.
- During a close stellar encounter, Sun captured material out of which planets formed.
- Planets formed at the same time as the Sun in the same gas cloud.

Since time is affected by relative motion, length will also be different:

$$\text{Relative length} = \text{proper length}\sqrt{1 - \frac{v^2}{c^2}}$$

- **Olbers' paradox** → The night sky should be infinitely bright!

"Time and space and gravity have no separate existence from matter"

– Albert Einstein

Lorentz's solution

- Fields are not directly observed
- Acceleration is directly observed

- **Newton's spectrum:** Particles of different colour assumed to travel with different speeds

An act of desperation ...

I had to obtain a positive result, under any circumstances and at whatever cost

Planck, in 1931, recalling his situation in 1900

- **Photoluminescence** – Stokes Rule: frequency of emitted line is always less than that of the absorbed light

Ekpyrotic Model of the Universe

Our current universe arose from a collision of two three-dimensional worlds in a space with an extra fourth spatial dimension

Bulk universe

An extra-dimensional region beyond the 4 dimensions − 3 spatial dimensions and one temporal dimension of our universe

As the radius of the object becomes smaller than a critical value "$\frac{2GM}{c^2}$", the spacetime curvature becomes infinite.

BLACK HOLE

where density is infinite and time ends

Light emitted close to $\frac{2GM}{c^2}$ is severely red-shifted (the photon frequency is lower) and at $\frac{2GM}{c^2}$, the redshift is infinite.

The dangers of getting too close to a black hole.....

A body would be stretched along the direction toward the black hole and squeezed in the perpendicular directions

Spaghettification

- A light ray emitted tangentially to the event horizon at a distance < $\frac{3GM}{c^2}$ would be captured.
- When the distance is = $\frac{3GM}{c^2}$, light goes around in a circular orbit.

$$\left\{ \text{An observer at Distance} = \frac{3GM}{c^2} \text{ would be able to see the back of his head!} \right\}$$

Birkhoff's theorem

The external gravitational field of any spherically-symmetric system is static and is described by Schwarzschild metric.

	Angular momentum = 0	Angular momentum ≠ 0
Charge = 0	**Schwarzschild**	**Kerr**
Charge ≠ 0	**Reissner–Nordström**	**Kerr–Newman**

In 1916 the German physicist and astronomer Karl Schwarzschild calculated the size and behavior of a non-rotating, electrically-charged, static black hole on the basis of general relativity.

$\frac{2GM}{Rc^2} \geq 1$ } **Black Hole**

Charles Messier – a French astronomer – discovered 20 comets and created a catalog of 103 diffuse astronomical objects, which have since been discovered to be gas nebulae, star clusters and galaxies.

Albert Einstein, a German-born theoretical physicist (widely acknowledged to be one of the greatest physicists of all time) who gave the world the theory of relativity, E = mc^2, and the law of the photoelectric effect, obviously had a special brain. So special that when he died in Princeton Hospital, on April 18, 1955, the pathologist on call, Thomas Harvey, stole it.

Some other important theories other than the Big Bang theory are:

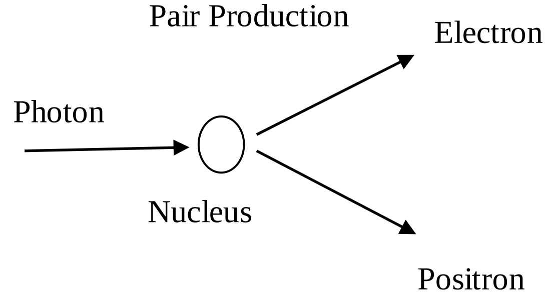
- The Steady State Universe Theory **[Fred Hoyle]**
- The Oscillating Universe Theory **[George Gamow]**
- **The Nebular Hypothesis:** This model states that the Sun, the planets, and all other objects in the Solar System formed from nebulous material billions of years ago.
- **The Fission Theory:** This theory proposes that the Moon was once part of the Earth and somehow separated from the Earth early in the history of the solar system.
- **The Capture Theory:** This model, proposed by Michael Mark Woolfson in 1964, posits that the Solar System formed from tidal interactions between the Sun and a low-density protostar.
- **The Accretion Theory:** The particles that formed after the big bang slowly clustered together to form asteroids, planets, and even stars.
- **The Planetary Collision Theory:** This model, published in 2012 by Robin M. Canup, suggests that the Moon and the Earth formed from a massive collision of two planetary bodies, each larger than Mars, which then re-collided to form what we now call Earth.
- **The Stellar Collision Theory:** Coming together of two or more astrological bodies [**stars**] which merges and forms into a larger unit, through the forces of Gravity.
- **The Gas Cloud Theory:** Galaxies formed over billions of years from galaxies merging together. Giant gas clouds in the early universe could have powered one of the most energetic eruptions.

Schrodinger equation:

$$\frac{-\hbar^2}{2m} \bigtriangledown^2 \Psi(\mathrm{r}) + V(\mathrm{r})\, \Psi(\mathrm{r}) = E\, \Psi(\mathrm{r})$$

Kinetic energy + potential energy = total energy

Defines electron with wave function

<table>
<tr><th>Wave theory</th><th>Particle Theory</th></tr>
<tr><td>EM-Wave theory
(Maxwell’s Equations)</td><td>Photo-electric Effect
$K_{max} = h\upsilon - \varphi$</td></tr>
<tr><td>Propagation of EM-waves at speed 3×10^{8}m/s
(Hertz experiment etc)</td><td>Compton Effect
$\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$</td></tr>
<tr><td>Young’s double slit experiment
(interference phenomena)</td><td>Pair Production


The rest mass energy of an electron or positron is 0.51 MeV (according to $E = MC^2$).
The minimum energy required for pair production is 1.02 MeV.
Any additional photon energy becomes the kinetic energy of the electron and positron.
</td></tr>
<tr><td>Diffraction</td><td>Gravitational red-shift</td></tr>
</table>

Gauss's law → Total electric flux through any closed surface, is equal to $\frac{1}{\varepsilon_0}$ times the total charge enclosed by the surface.

Application of QM:

- Quantized energy
- Tunneling effect

Probability of finding an electron at a given position and time is related to the mod squared of its wave function by the equation:

$$P(x, t) \propto |\Psi(x, t)|^2$$

The photoelectric effect cannot be explained on the basis of electromagnetic theory.

The failure of classical physics → The theory of the Energy distribution law of the Normal Spectrum → advent of quantum mechanics

Einstein's photoelectric equation:

$$K_{max} = h\upsilon - \varphi$$

φ called the work function of the metal surface is the minimum energy that must be given to an electron to liberate it from the surface of a particular metal.

Assuming φ to be constant for a particular metal:

$$h\upsilon = \varphi + \frac{m_0 v^2}{2}$$

$$h\frac{d\upsilon}{dt} = \frac{m_0}{2} \times \frac{d(v)^2}{dt}$$

Rate of change of photon energy =

↓

Electron momentum × acceleration of the electron

Visible light on Metals other than Alkali Metals

↓

No photoelectrons

Visible light on Alkali Metals

↓

Photoelectrons

$$\Delta L \times \Delta\theta \geq \frac{\hbar}{2}$$

Phase Velocity × Particle Velocity = c^2

But **Particle Velocity** is always < c

Phase Velocity > c

De-Broglie waves will move faster than the particle and hence the waves would leave the particle behind.

$L \rightarrow$ angular momentum and $\theta \rightarrow$ angular position

If $\Delta\theta$ is measured accurately i.e. $\Delta\theta \rightarrow 0$:

$$\Delta L \rightarrow \infty$$

According to the concept of Bohr Model, energy of an electron in an orbit is constant i.e. $\Delta E = 0$.

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

$$\Delta t \rightarrow \infty$$

All energy states of the atom must have an infinite life-time.
But the excited states of the atom have life–time ~ 10^{-8} s.

Concept of Bohr Model violates Uncertainty Principle

In 1928, British physicist Paul Dirac wrote down an equation [**Dirac Equation**] that combined quantum theory and special relativity to describe the behavior of an electron moving at a relativistic speed. In his 1933 Nobel lecture, Dirac explained how he arrived at this equation and speculated on the existence of a completely new cosmos made out of antimatter:

"If we accept the view of complete symmetry between positive and negative electric charge so far as concerns the fundamental laws of Nature, we must regard it rather as an accident that the Earth (and presumably the whole solar system), contains a preponderance of negative electrons and positive protons. It is quite possible that for some of the stars it is the other way about, these stars being built up mainly of positrons and negative protons. In fact, there may be half the stars of each kind. The two kinds of stars would both show exactly the same spectra, and there would be no way of distinguishing them by present astronomical methods."

- The Earth's Schwarzschild radius is about a centimeter; the Sun's is about 3 km.
- Matter entering the **event horizon of a black hole** will experience enormous tidal forces that will both heat it enough to radiate and tear it apart.

Stoney mass × Stoney Length × Stoney Time = (Fine structure constant) $^{3/2}$ × Planck mass × Planck Length × Planck Time

The reduced Compton wavelength of proton:

$$\lambda_C = \frac{\hbar}{mc} = 2.103\,089\,103\,36 \times 10^{-16}\ \text{m}$$

The Schwarzschild radius of proton:

$$R_s = \frac{2Gm}{c^2} = 2.4 \times 10^{-54}\ \text{m}$$

For a proton:

$$\frac{\lambda_C}{R_S} \sim 8.7628 \times 10^{37}$$

Its reduced Compton wavelength is much greater than its Schwarzschild radius. At what mass are these two length scales equal?

$$\frac{2Gm}{c^2} = \frac{\hbar}{mc}$$

$$m = \frac{m_{Planck}}{\sqrt{2}}$$

The Schwarzschild radius of earth:

$$\sqrt{\frac{2G \times 6 \times 10^{24}\ \text{kg}}{c^2}}$$

$8.84 \times 10^{-3}\text{m} \approx 9$ mm

The earth's diameter would have to shrink to less than 2 cm for it to become a black hole.

The escape velocity of the earth = $\sqrt{\frac{2G \times 6 \times 10^{24}\ \text{kg}}{6 \times 10^{6}\ \text{m}}}$

The escape velocity of the earth = 11550 m/s

It is impossible, by means of any local experiment,

- To distinguish between the frame of a falling body and an inertial one.
- To distinguish between an accelerated frame of reference and a frame at rest in a gravitational field.

$$\frac{GMm}{r^2} = mg \rightarrow \text{consequence of the Principle of Equivalence}$$

- Einstein's GTR → provides for an additional condition on the Riemannian manifold of spacetime – the metric tensor g (u, v).

Physics of the Future:

- Future of the Computer: Mind over Matter
- Future of AI: Rise of the Machines
- Future of Medicine: Perfection and Beyond
- Nanotechnology: Everything from Nothing?
- Future of Energy: Energy from the Stars
- Future of Space Travel: To the Stars
- Future of Wealth: Winners and Losers
- Future of Humanity: Planetary Civilization

"Did the genome of our cave-dwelling predecessors contain a set or sets of genes which enable modern man to compose music of infinite complexity and write novels with profound meaning? …It looks as though the early Homo was already provided with the intellectual potential which was in great excess of what was needed to cope with the environment of his time."

SUSUMU OHNO, 1928 TO 2000

What is Science? Quotes from Famous Scientists

"The great tragedy of Science — the slaying of a beautiful hypothesis by an ugly fact."

THOMAS HUXLEY: BIOLOGIST, 1870

"…science consists in grouping facts so that general laws or conclusions may be drawn from them."

CHARLES DARWIN: BIOLOGIST, 1887

"It is the function of science to discover the existence of a general reign of order in nature and to find the causes governing this order. And this refers in equal measure to the relations of man (social and political) and to the entire universe as a whole…"

DMITRI MENDELEEV: CHEMIST, 1901

"The real value of science is in the getting, and those who have tasted the pleasure of discovery alone know what science is. A problem solved is dead. A world without problems to be solved would be devoid of science."

FREDERICK SODDY: CHEMIST, 1912

"The aim of science is to seek the simplest explanations of complex facts. We are apt to fall into the error of thinking that the facts are simple because simplicity is the goal of our quest. The guiding motto in the life of every natural philosopher should be, Seek simplicity and distrust it."

ALFRED NORTH WHITEHEAD: MATHEMATICIAN, 1919

"Science begets knowledge; opinion begets ignorance."

HIPPOCRATES: PHYSICIAN, c. 400 BC

"Our society, in which reigns an eager desire for riches and luxury, does not understand the value of science. It does not realize that science is a most precious part of its moral patrimony. Nor does it take sufficient cognizance of the fact that science is at the base of all the progress that lightens the burden of life and lessens its suffering."

MARIE CURIE: CHEMIST, PHYSICIST, 1923

"Science is a wonderful thing if one does not have to earn one's living at it. One should earn one's living by work of which one is sure one is capable. Only when we do not have to be accountable to anybody can we find joy in scientific endeavor."

ALBERT EINSTEIN: PHYSICIST, 1951

Pulsar: A neutron star that is highly magnetized − rotating at high speed − and emitting radio pulses out of its magnetic poles

Characteristics of the Sun:

Mass	1.989×10^{30} kilograms
Radius	696,340 km
Mean density	1.41 g/cm³
Surface temperature	5,778 K
Luminosity	3.828×10^{26} W
Hydrogen	72%
Helium	25%
Heavier elements (Carbon, nitrogen, Oxygen, neon, silicon, iron, etc.)	3%

Chemical composition

At energies > 15 GeV or distances < 10^{-13} cm: quarks are free particles

Flavor

A property that distinguishes different types of quarks and different kinds of leptons

Maxwell equations

Equations that describe electromagnetic fields

A star of up to $4M_{sun}$ which after the **thermonuclear reaction period** – explodes − the star becomes **a red giant** (**a luminous giant star of low or intermediate mass in a late phase of stellar evolution**) while the core ends up as a white dwarf or neutron star

- **Positronium:** Abound state consisting of an electron and positron.
- **Z bosons:** A neutral boson mediating the neutral current force.

"In science the opinions of a thousand are not worth as much as one tiny spark of reason in an individual man."

GALILEO GALILEI: PHYSICIST, ASTRONOMER, 1610

"Science makes people reach unselfishly for truth and objectivity; it teaches people to accept reality, with wonder and admiration, not to mention the deep awe and delight that the natural order of things brings to the true scientist."

LISE MEITNER: PHYSICIST, 1953

"It is a profound and necessary truth that the deep things in science are not found because they are useful; they are found because it was possible to find them."

J. ROBERT OPPENHEIMER: PHYSICIST, 1953

"Science is a game… In the presentation of a scientific problem, the other player is the good Lord. He has not only set the problem but also has devised the rules of the game – but they are not completely known, half of them are left for you to discover or to deduce."

ERWIN SCHRÖDINGER: PHYSICIST, 1955

"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."

WILLIAM LAWRENCE BRAGG: PHYSICIST, 1957

"No doubt science cannot admit of compromises, and can only bring out the complete truth. Hence there must be controversy, and the strife may be, and sometimes must be, sharp. But must it even then be personal? Does it help science to attack the man as well as the statement?"

RUDOLF VIRCHOW: PATHOLOGIST, 1861

"I strongly believe that fundamental science cannot be driven by instructional, industrial and government or military pressures. This was the reason why I decided, as far as possible, not to accept money from the government."

C. V. RAMAN: PHYSICIST, 1970

"Science is not a heartless pursuit of objective information; it is a creative human activity."

STEPHEN JAY GOULD: PALEONTOLOGIST, 1977

"Science is a self-correcting process. To be accepted, new ideas must survive the most rigorous standards of evidence and scrutiny."

CARL SAGAN: PLANETARY SCIENTIST, 1980

"Science is founded on uncertainty. Each time we learn something new and surprising, the astonishment comes with the realization that we were wrong before… In truth, whenever we discover a new fact it involves the elimination of old ones."

LEWIS THOMAS: PHYSICIAN AND EDUCATOR, 1980

"It is curious how often erroneous theories have had a beneficial effect for particular branches of science."

ERNST MAYR: EVOLUTIONARY BIOLOGIST, 1982

"Nor must we forget that in science there are no final truths."

CLAUDE LÉVI-STRAUSS: ANTHROPOLOGIST, 1990

"Of course, if one ignores contradictory observations, one can claim to have an “elegant” or “robust” theory. But it isn’t science."

HALTON ARP: ASTRONOMER, 1991

"Some people think that science is just all this technology around, but no it’s something much deeper than that. Science, scientific thinking, scientific method is for me the only philosophical construct that the human race has developed to determine what is reliably true."

HARRY KROTO: CHEMIST, 2010

"We sometimes forget about the creative part of science. I think you need time to daydream, to let your imagination take you where it can… I’ve noticed among the creative, successful scientists who’ve really advanced things, that was a part of their life."

ELIZABETH H. BLACKBURN: MOLECULAR BIOLOGIST, 2010

"Science, however, is never conducted as a popularity contest, but instead advances through testable, reproducible, and falsifiable theories."

MICHIO KAKU: PHYSICIST, 2014

Data from Planck

- $H_0 = 67.8 \pm 0.8$ km/s/Mpc
- $\Omega = 0.9995 \pm 0.0034$ (universe is flat)
- Age of the universe: 13.798 ± 0.037 Gyr
- $\Omega_\Lambda = 0.692 \pm 0.010$
- $\Omega_B = 0.048 \pm 0.001$
- $\Omega_{DM} = 0.260 \pm 0.004$

ab-initio calculations → vacuum energy density > 10^{91} erg/cm^3

Inflation → vacuum energy density > 10^{71} erg/cm^3

Today: vacuum energy density ~ 0

The Equation of State of Dark Energy:

$$\text{Pressure} = w \times \text{density}$$

$w = 0$ (Ordinary matter)

$w = \frac{1}{3}$ (Relativistic matter)

String theory predicts → ~10^{500} distinct universes

Gibbs Paradox

In the case of 2 different ideal gases, mixing is accompanied by an entropy increase $\Delta S = 2R\ln 2 = 11.53$ J/K.

In the case of same ideal gases there is no entropy change: $\Delta S = 0$.

where R is the ideal gas constant

Exchange symmetry

The property of nature that observations are unchanged under exchange of identical particles

2 fermions cannot occupy the same quantum state.

Particles that follows Fermi–Dirac statistics and generally possess half odd integer spin

In (3 + 1) **space-time dimensions**, only fermions and bosons exist.

Quantum information

The information of the state of a quantum system

No-communication theorem

Instantaneous sharing of information between two observers is an impossibility

Sterile neutrinos are hypothetical heavier cousins of ordinary neutrinos and would interact with other matter only through the force of gravity – making them essentially impossible to detect.

$$F_G = \frac{GMm}{r^2}$$

especially useful when we plan to put a satellite in orbit or chart the course of the moon

Mathematics reveals its secrets only to those who approach it with pure love, for its own beauty.

– Archimedes

Ginsberg's theorem

(Laws of Thermodynamics in terms of a person playing a game)

- There is a game (consequence of **Zeroth law of thermodynamics**)
- You can't win (consequence of **first law of thermodynamics**)
- You can't break even (consequence of **second law of thermodynamics**)
- You can't quit the game (consequence of **third law of thermodynamics**)

A law predicts what happens and a theory explains why

In 1913: Franck and Hertz independently proved the quantum nature of atomic energy levels.

The day science begins to study non-physical phenomena, it will make more progress in one decade than in all the previous centuries of its existence.

– Nikola Tesla

The controversial Anthropic Principle

↓

The universe can only exist such that **carbon-based life** can arise

Unified field theory

Quantum physics + Albert Einstein's theory of general relativity

1 astronomical unit (AU) = the average distance from the Earth to the Sun

1 AU = 150,000,000 km = 1.5×10^8 km

1light-year = (speed of light) × (1 year)

$$\text{1light-year} = 300{,}000 \text{ km/s} \times \frac{365 \text{ days}}{1 \text{ yr}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{60\text{s}}{1 \text{ min}}$$

1light-year $\approx 10^{13}$ km $\approx 10^5$ AU

Some say the world will end in fire,
Some say in ice.
From what I've tasted of desire
I hold with those who favor fire.
But if it had to perish twice,
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice.

– **Robert Frost**

Normal Matter: ~ 4.4%

- Normal matter inside stars: ~ 0.6%
- Normal matter outside stars: ~ 3.8%

Total mass in dark matter →10x more than in stars

- Ordinary Dark Matter → [Massive Compact Halo Objects]
- Extraordinary Dark Matter → [Weakly Interacting Massive Particles]

"The first stars were most likely quite massive and luminous and their formation was an epochal event that fundamentally changed the universe and its subsequent evolution. These stars altered the dynamics of the cosmos by heating and ionizing the surrounding gases.

The earliest stars also produced and dispersed the first heavy elements, paving the way for the eventual formation of solar systems like our own. And the collapse of some of the first stars may have seeded the growth of supermassive black holes that formed in the hearts of galaxies and became the spectacular power sources of quasars. In short, the earliest stars made possible the emergence of the universe that we see today— everything from galaxies and quasars to planets and people."

Larson & Bromme (2002)

Alexander A. Friedmann (1888 − 1925)

- Soviet mathematician and meteorologist
- Most famous for contributions to cosmology
- First person to mathematically predict an expanding universe (1922)

Why do we need inflation?

Inflation makes the Universe flat, homogeneous and isotropic

We can see just a tiny part of the universe of size $ct = 10^{10}$ light years.

If stars can only fuse elements up to and including iron (Number 26 on the periodic table) then where did all the gold, silver, lead, uranium, etc... Come from?

Nucleosynthesis in Supernovae

The organic molecules needed for life to originate were probably brought to the young Earth by comets or meteorites?

- Alpha rays → penetrate a sheet of paper
- Beta rays → penetrate 3 mm of aluminum
- Gamma rays → penetrate several cm of lead

- Uranium-238 has a half-life of 4.5×10^9 years, and has been used to date the oldest rocks on Earth as about 4 billion years old.

John Dalton [1808]

His ideas account for the law of conservation of mass (atoms are neither created nor destroyed) and the law of constant composition (elements combine in fixed ratios).

Silicon has three stable isotopes

- Silicon -28 [Fractional abundance → 92.21%]
- Silicon -29 [Fractional abundance → 4.70%]
- Silicon -30 [Fractional abundance → 3.09%]

- Photons are not deviated by magnetic and electric fields.
- Photoelectric effect was first experimentally verified by Heinrich Rudolf Hertz in 1887.
- Electrons are ejected immediately. There is no significant delay.
- In no experiment, matter exists both as a particle and as a wave simultaneously. It is either the one or the other aspect i.e. the two aspects are complementary to each other.

$$KE_{max} = h\upsilon - h\upsilon_0$$

If $\upsilon < \upsilon_0$, then KE_{max} is negative, which is not possible. Therefore: for **photoelectric emission** to take place $\upsilon > \upsilon_0$.

$$\lambda = \frac{h}{m_0 v}$$

If the particle is at rest: $v \rightarrow 0$, then the de Broglie wavelength is infinite. Such a wave cannot be visualized.

1 eV = (1.6 x 10^{-19} coulombs) × (1 volt) = 1.6 x 10^{-19} Joules.

Frequency is needed to produce quanta with energies of 1 eV:

$$\upsilon = \frac{E}{h} = \frac{1.6\times10^{-19}}{6.625\times10^{-34}} = 2.4150943396 \times 10^{14}\ \text{Hz}$$

This frequency is in the infrared range, so we could not see these photons with our eyes.

The intensity of an electromagnetic wave is proportional to the square of the amplitude of the electric field of the wave. Thus if the intensity of the light is increased, the amplitude of the electric field in the light is also increased.

Electroweak unification expected at 10^2 GeV

Electroweak + strong unification expected at 10^{16} GeV

Electroweak + strong + gravity unification expected at 10^{19} GeV

E > 10^3 GeV not attainable in modern accelerators

strings + supergravity → superstrings

Grand Unified Theories (GUT) → Theoretical attempt to unify the electroweak and strong interactions.

QCD strength = electroweak coupling for E = 10^{16} GeV

6 quarks + 6 leptons → fundamental particles of matter

- 6 quarks (in 3 colours) → affected by strong force
- 6 leptons → not affected by strong force

Force between quarks due to colour → QCD

Modern particle accelerators

- LINACS
- Synchrotrons
- Storage rings

Cyclotron→ particles move in circular path due to B-field.

- nuclear radius ~ 10^{-14} m
- nuclear density ~ 10^{17} kg/m^3

Thomson atomic model → atom is a heavy sphere of massive positive charges surrounded with light electrons of negative charge.

Mass of the electron:

$$\frac{q}{m_e} = 1.76 \times 10^{11} \text{ C/kg} \quad [\textbf{Thomson}]$$

$$q = 1.6 \times 10^{-19} \text{ C } \textbf{[Millikan]}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

Maxwell, Boltzmann, Gibbs (1850-1900) → mechanics of molecular motion in gases (kinetic theory)

Dimitri Mendeleev (1869) → Listed the chemical elements from the lightest (hydrogen) to the heaviest (uranium) caused elements with similar chemical properties to recur at regular intervals.

Avogadro (1811) → postulated the existence of elementary molecules as the smallest particles that can make up compounds.

Avogadro's Law: "at equal temp and press, equal volumes of gases contain equal numbers of molecules."

Empirical	**Deductive**
↓	↓
Observation and practical application	**Theoretical and mathematical methods**

Ex nihilo is a Latin term that translated means out of nothing. It was an idea presented by theologian and philosopher of Berber origin and the bishop of Hippo Regius in Numidia (**Saint Augustine**) that became set of beliefs held and taught by a Church later on. It is his philosophical rationalization of the way God created everything out of nothing, which interestingly enough can be applied to the big bang as well.

- Before recombination, all of the electrons were free.
- After recombination, the electrons and protons formed atoms.

Collection of universes → **multiverse**

Expanding universe

↓

- In the past, galaxies were closer together.
- In the near future, they will be further apart.

Spherical space	a + b + c > 180	Curvature = positive
Flat space	a + b + c = 180	Curvature = 0
Hyperbolic space	a + b + c < 180	Curvature = negative

In the inflationary model, between 10^{-35} and 10^{-33} seconds, the "**universe**" doubled in size every 10^{-35} seconds. By the end of inflation then, space-time was 10^{50} times bigger than it was before inflation.

I came into the room, which was half dark, and presently spotted Lord Kelvin in the audience and realized that I was in trouble at the last part of my speech dealing with the age of the Earth, where my views conflicted with his. To my relief, Kelvin fell fast asleep, but as I came to the important point, I saw the old bird sit up, open an eye, and cock a baleful glance at me! Then a sudden inspiration came, and I said, "Lord Kelvin had limited the age of the Earth, provided no new source was discovered. That prophetic utterance refers to what we are now considering tonight, radium!" Behold! the old boy beamed upon me.

– Rutherford

- Cosmic photon background temperature = 2.725 K
- Neutrino background temperature = 1.95 K

At low temperature where the neutrinos become non-relativistic:

Neutrinos' thermal energy $\frac{3}{2}k_BT_\nu$ falls below its rest mass energy $m_\nu c^2$

Diffuse supernova neutrino background

Consists of

Neutrinos emitted by all core-collapse supernovae throughout the Universe.

Entropic gravity – theory in modern physics that describes gravity as an entropic force

Dark radiation

Radiation that mediates interactions of dark matter

Photino

Hypothetical superpartner of the photon

Nordtvedt-effect

Massive bodies fall at different rates – depending upon their gravitational self-energy

Massive gravity → Theory of gravity in which the graviton has nonzero mass

Observations of gravitational waves have constrained the Compton wavelength of the graviton to be > 1.6×10^{16} m, which can be interpreted as a bound on the graviton mass < 7.7×10^{-23} eV/c^2.

Unparticle physics

Speculative theory that conjectures a form of matter that cannot be explained in terms of particles

Mirror matter – Hypothetical counterpart to ordinary matter

Dark galaxy – A hypothesized galaxy with no – or very few stars

Self-interacting dark matter – Hypothetical form of dark matter consisting of particles with strong self-interactions

Chameleon particle – Hypothetical scalar particle that couples to matter more weakly than gravity

In 1920, an English astronomer, physicist and mathematician **Arthur Eddington** proposed that stars obtained their energy from nuclear fusion of hydrogen to form helium and raised the possibility that the heavier elements are produced in stars.

Deuterium fusion → A deuterium nucleus and a proton combine to form a helium-3 nucleus

Hydrogen fusion requires much higher temperature and pressure than deuterium fusion

Lithium burning → A nucleosynthetic process in which lithium is depleted in brown dwarfs

Main sequence star	Red giant	Red giant after helium burning begins
Hydrogen burning core	Helium core, no thermonuclear reactions **Hydrogen burning shell**	Helium burning core **Hydrogen burning shell**

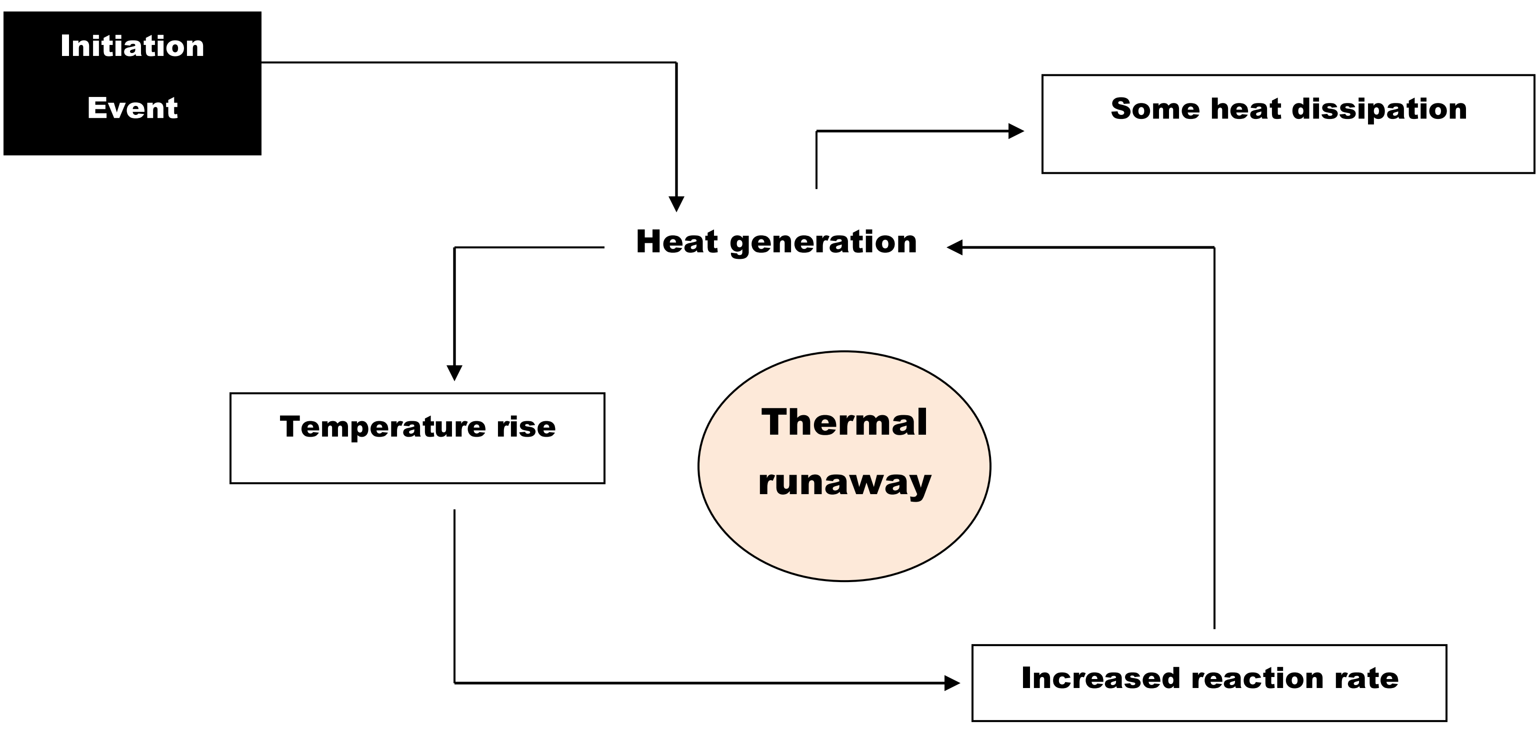
When the core temperature of the star exceed 100 million degrees, the triple alpha process starts where 3 helium nuclei are fused to form carbon and energy as photons.

Horizontal branch star	Asymptotic Giant branch star
Hydrogen burning shell Helium burning core	Hydrogen burning shell Helium burning shell **Carbon/ oxygen core**

- **Photofission** is a process in which a nucleus after absorbing a gamma ray photon undergoes nuclear fission i.e., it splits into two fragments of nearly equal mass.

Pair-instability supernova

When a star is very massive (**130 to 250 solar masses**), the gamma ray photons produced in its core can become so energetic that some of their energy is drained away into production of particle and antiparticle pairs − which temporarily reduces the internal radiation pressure supporting a star's core against gravitational collapse. The resulting drop in radiation pressure causes the star to partially collapse under its own huge gravity. After this violent collapse, runaway thermonuclear reactions ensue and the star explodes.



The different universes− comprising everything that exists: the entirety of space, time, matter, energy, information and the physical laws and constants that describe them − within the multiverse are termed "parallel universes".

The classical ratio between the electromagnetic force and the gravitational force between 2 electrons separated by any given distance r is given by:

$$\frac{F_E}{F_G} = \frac{e^2}{4\pi\varepsilon_0} \times \frac{1}{Gm_e^2} = 2 \times \frac{\text{Classical radius of the electron}}{\text{Schwarzschild radius of the electron}}$$

Gamma ray frequency of 1.24×10^{20} Hz corresponds to a wavelength of 2.4×10^{-12} m. This is around 2000 times larger than a proton.

Totalitarian principle

↓

Everything allowed by the laws of nature must actually exist

Density determines the expansion

Expansion changes the density

Any process which is not forbidden by a conservation law actually does take place

Radiation domination → **Matter domination** → **Dark energy domination**

Dark energy dominates last; it is the dominant component now, and in the infinite future?

Is dark energy mysterious?

Big experimental resources are aimed at measuring its properties better, but they may only prove with slightly better accuracy that it is constant Λ rather than something more exotic.

The classical electron radius is roughly the length scale at which **renormalization** becomes important in quantum electrodynamics.

↓

{ Nature's tendency to sort itself into essentially independent worlds }

Periodic Table

↓

Complex structures in the universe are made by combining simple objects in different ways

We live in a **quantum world**, even if it's not obvious to us

Type of quark	Charge	Spin
u (up)	$+\mathbf{\frac{2}{3}}$	$\frac{1}{2}$
d (down)	$-\mathbf{\frac{1}{3}}$	$\frac{1}{2}$
s (strange)	$-\mathbf{\frac{1}{3}}$	$\frac{1}{2}$
c (charm)	$+\mathbf{\frac{2}{3}}$	$\frac{1}{2}$
b (bottom)	$-\mathbf{\frac{1}{3}}$	$\frac{1}{2}$
t (top)	$+\mathbf{\frac{2}{3}}$	$\frac{1}{2}$

Quantum Electrodynamics (QED)

The oldest, the simplest and the most successful

Early time, High temperature	Expanding Universe →	Later time, low temperature
Dark matter pairs come close enough to interact.		Never close enough to interact

"Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity -- in all this vastness -- there is no hint that help will come from elsewhere to save us from ourselves. It is up to us. It's been said that astronomy is a humbling, and I might add, a character-building experience. To my mind, there is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly and compassionately with one another and to preserve and cherish that pale blue dot, the only home we've ever known."

: Carl Sagan

Life Cycle of a Star

Stellar Nebula → Average star → Red giant → Planetary Nebula → White dwarf

Black hole

Massive star → Red Supergiant → Supernova

Neutron star

Why Do Naked Singularities Develop in Gravitational Collapse?

Albert Einstein first proposed **wormholes** in 1935. He co-wrote a paper with **Nathan Rosen** in which they showed that general relativity allowed for what they called "**bridges**." They theorized that there could be places where space/time is folded that allowed transfer of matter from one point to another in the universe, specifically in black holes.

- **Lorentzian wormholes** (general relativity)
- **Euclidean wormholes** (particle physics)

A **Super giant star** has relatively weak gravity, so emitted photons travel in essentially straight lines.

Falling into a black hole is an infinite voyage?

Space-time near rotating black hole is dragged around in the direction of rotation.

Frame dragging

Near a black hole, time is dilated enough that these virtual particles last longer than $\sqrt{\frac{\hbar G}{c^5}} = 5.391\times10^{-44}$s.

Entropy $\propto$ **number of microstates**

For a black hole, these are the number of ways a quantum black hole could be formed.

Degeneracy pressure: a quantum-mechanical effect that might stop matter from collapsing to form a black hole.

Quantum mechanics is crucial for understanding the large scale geometry of the universe.

Bekenstein bound is an upper limit on the entropy S, or information I, that can be contained within a given finite region of space which has a finite amount of energy—or conversely, the maximal amount of information required to perfectly describe a given physical system down to the quantum level.

$$\boxed{S \leq \frac{2\pi k_B R E}{\hbar c} = \frac{4\pi^2 R E}{\text{second radiation constant}}}$$

where S is the entropy, k_B is Boltzmann's constant, R is the radius of a sphere that can enclose the given system, $E = Mc^2$ is the total mass–energy including any rest masses, ħ is the reduced Planck constant, and c is the speed of light. In informational terms, with $S = k_B \times I \times \ln 2$, the bound is given by:

$$\boxed{I \leq \frac{2\pi R M c}{\hbar \ln 2}}$$

where I is the information expressed in number of bits contained in the quantum states in the sphere.

If a particle of mass m and momentum $p = \frac{h}{\lambda}$ is incident upon an object of size x:

The wave nature of the particle is negligible if λ is much smaller than x.

$$\frac{\lambda}{x} \ll 1$$

$$x\,p \gg h$$

Wave effects negligible

If h⟶ 0: then λ⟶ 0 and the particles have no wave properties

$$\lambda = \frac{h}{p}$$

$$h = \frac{E}{\upsilon} \rightarrow kg\,\frac{m^2}{s}$$

$$L = p \times r \rightarrow kg\,\frac{m^2}{s}$$

Planck's constant has units of angular momentum

The Compton wavelength of the electron:

$$\lambda_C = \frac{h}{m_e c} = 2.426 \text{ pm}$$

is about 20 times smaller than the Bohr radius (53 pm) and about two thousand times the size of a proton (1 fm)

Superposition

↓

Particle's ability to exist across many possible states at the same time

Quantum mechanical entanglement

Two or more particles are linked in such a way that it is impossible for them to be described independently even if separated by a large distance.

Energy density of a collapsing star → Planck energy density

Planck star is formed

The word "pulsar" is a portmanteau of 'pulsating' and 'quasar', and first appeared in print in 1968:

An entirely novel kind of star came to light on Aug. 6 last year and was referred to, by astronomers, as LGM (Little Green Men). Now it is thought to be a novel type between a white dwarf and a neutron [star]. The name Pulsar is likely to be given to it. Dr. A. Hewish told me yesterday: '... I am sure that today every radio telescope is looking at the Pulsars.'

Electron + proton → neutron + neutrino

The minimum kinetic energy of the electrons needed to initiate the above reaction is **0.8 MeV**

$\mathbf{KE_{min}} =$ 0.8MeV

If KE > 0.8MeV:

White dwarf → neutron star

	Type I supernova	Type II supernova
Total energy ejected	10^{42}J	10^{43}J
Peak Luminosity	10^{9} × solar luminosity	10^{8} × solar luminosity
Spectrum of radiation	No hydrogen lines	Strong hydrogen lines
Average mass ejected	0.5 to 2 solar mass	2 to 5 solar mass

$$\Delta s^2 = -c^2\Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

- $\Delta s^2 < 0$ is a timelike interval. Events separated by this interval can be causally related.
- $\Delta s^2 = 0$ is a lightlike interval. Events separated by this interval can be causally related, but only by a light speed signal.
- $\Delta s^2 > 0$ is a spacelike interval. Events separated by this interval cannot be causally related.

```
The sun has T_eff = 5.8 × 10³K

The coolest hydrogen-burning stars have T_eff ≈ 2 × 10³K

The hottest main sequence stars have T_eff ≈ 5 × 10⁴K

The hottest white dwarfs have T_eff ≈ 3 × 10⁵K

The hottest neutron stars have T_eff ≈ 3 × 10⁷K
```

- Conceptual Discoveries → Relativity, Quantum Mechanics, Inflation …
- Phenomenological Discoveries → Dark Matter, CMBR, Extrasolar Planets …

Data + Math → Scientific method

1 Astronomical unit = 1.496×10^{13} cm

1 Parsec = 3.086×10^{18} cm

1 eV = 1.6×10^{-12} erg = 1.6×10^{-19} J

Electromagnetic Radiation

- Discrete (quantum transitions)
- Continuous
  - Thermal (blackbody)
  - Nonthermal (Cherenkov)

Kirchoff's Laws:

- Any hot opaque body produces a continuous spectrum
- A hot transparent gas will produce an emission line spectrum
- A relatively cool transparent gas in front of a source of a continuous spectrum will produce an absorption line spectrum

- Bound → unbound [ionization]
- Unbound → bound [recombination]

- **Blackbody**: Hypothetical object that is a perfect absorber of electromagnetic radiation at all wavelengths.
- Dust [microns] → Pebbles / rocks [cm to m] → Planetesimals [km] → Planets [10^3 km]
- **Three Kinds of Planets**
  - Rocky – Mercury, Venus, Earth, Mars
  - Gas giants – Jupiter, Saturn, Uranus, Neptune
  - Dwarf planets – Pluto, Sedna, Eris, Makemake, Ceres, etc

Oldest moon rocks are 4.4 billion years old

Oldest meteorites are 4.55 billion years old

Planets probably formed ~ 4.6 billion years ago

- **Kelvin-Helmholtz Mechanism:** As a planet cools, it shrinks – the release of the binding energy produces heat that radiates away.

$$\text{Kelvin-Helmholtz time scale} \rightarrow \frac{\text{Total binding energy}}{\text{luminosity}}$$

Low mass planets → low gravity → almost no atmosphere

High mass planets → high gravity → thick atmosphere

- Increasing concentration of the greenhouse gases → Global Warming

The Drake Equation:

$$N = R^* \times f_p \times n_e \times f_L \times f_i \times f_c \times L$$

- N = The number of civilizations in The Milky Way Galaxy whose electromagnetic emissions are detectable
- R^* = The rate of formation of stars suitable for the development of intelligent life
- f_p = The fraction of those stars with planetary systems
- n_e = The number of planets, per solar system, with an environment suitable for life

A description of the same thing in different languages is called a **Duality**.

- f_L = The fraction of suitable planets on which life actually appears
- f_i = The fraction of life bearing planets on which intelligent life emerges
- f_c = The fraction of civilizations that develop a technology that releases detectable signs of their existence into space
- L = The length of time such civilizations release detectable signals

Superposition and quantum mechanical entanglement only exist as long as quantum particles are not observed or measured.

Gravitons are hypothetical particles that are predicted to be the gauge bosons of gravitational fields.

Quantum mechanical entanglement enables

- Particles to affect each other instantaneously across any distance
- Particles to remain "connected" even if they are on opposite sides of the universe.

The **laws of physics** stay the same for all observers that are moving with respect to one another within an inertial frame

Special relativity (which is all about Lorentz symmetry)

Fast moving clocks appear slower, shorter and heavier

The fundamental invariance of **general relativity** which is generically broken under discretization

General relativity (which is all about diffeomorphism symmetry)

Objects moving straight through curved spacetime appear deflected

↓

Gravity

- Suggested in 1956 by Tsung-Dao Lee and Chen Ning Yang.
- Chien-Shiung Wu demonstrates it with cobalt 60, Leon Lederman with accelerator.

The Nobel Prize in Physics 1957 was awarded jointly to Chen Ning Yang and Tsung-Dao Lee "for their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles."

- **Parity symmetry** is violated in the weak interaction.
- **Charge symmetry** is violated in the weak interaction.
- C + P = CP symmetry is not violated in the weak interaction − except in the **kaon system**!
- **Time symmetry** is not violated in the weak interaction.
- C + P + T = CPT symmetry is not violated in the weak interaction.

A symmetry characteristic of a theory in which mathematical changes do not result in physical consequences

Gauge symmetry

A corner stone of particle physics

which is analogous to how we can describe something within one language through different words

Give rise to **gauge fields**. These gauge fields are what describe the fundamental forces of nature.

Quantum field theory → Gauge symmetry → Gauge field → Gauge boson

Quantum electrodynamics → **U(1) Gauge symmetry** → Electromagnetic field → photon

Star loses energy → decrease in gravitational energy (contraction) → but same amount goes into increase in internal energy (heating)

Stars become hotter, because they lose energy!

Interior of a star contains a mixture of ions, electrons, and radiation (photons). For most stars (exception very low mass stars and stellar remnants) the ions and electrons can be treated as an ideal gas and quantum effects can be neglected.

$$\text{Total pressure: } P = [P_i + P_e] + P_{rad}$$

$$\text{Total pressure: } P = P_{gas} + P_{rad}$$

- Pi is the pressure of the ions
- P_e is the electron pressure
- P_{rad} is the radiation pressure

$$\left.\begin{array}{l} P_{gas} = nk_BT \\ \\ P_{rad} = aT^4 \end{array}\right\} \quad \text{Equal when:} \quad T = \sqrt[3]{\frac{nk_B}{a}}$$

where: n is the number density of particles, k_B is Boltzmann's constant, a the radiation constant and T the temperature.

Gas pressure is most important in low mass stars

Radiation pressure is most important in high mass stars

Nuclear fusion in Sun's core

- At low speeds, electromagnetic repulsion prevents the collision of nuclei.
- At high speeds, nuclei come close enough for the strong nuclear force to bind them together.

We have only achieved controlled nuclear fission not controlled nuclear fusion.

↓

It is easier to split than to combine.

Time to get to the nearest star Proxima Centauri

- **Galileo spacecraft (100,000 mph) ~ 44,500 yrs**
- **Voyager spacecraft (30,000 mph) ~ 74,100 yrs**

In beta decay, there is an apparent violation of the law of conservation of angular momentum.

Philipp Lenard's 1902 observations of Photoelectric effect:

- Photons with energy $h\upsilon$ < Work function of the metal liberates no electrons at all.
- Photons with energy $h\upsilon$ > Work function of the metal liberates electrons with **kinetic energy** ($h\upsilon$ − Work function of the metal)
- The kinetic energy of liberated electrons is independent of the intensity of photons **(the photon flux)**. So there will be no change in the kinetic energy even if the intensity of photons is increased.

Particle physics processes

• Absorption	2 particles in, 1 out
• Emission / Decay	1 particle in, 2 out
• Collision / creation • Scattering / annihilation	2 particles in, 2 out

Classical electron radius:

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}$$

$h\upsilon_C = \mathbf{m_e c^2}$

Compton frequency of the electron

Klaus von Klitzing is a German physicist, known for discovery of the integer quantum Hall effect, for which he was awarded the 1985 Nobel Prize in Physics.

$$r_e = \frac{\textbf{Coulomb constant}}{\textbf{von Klitzing constant} \times \text{Compton frequency of the electron}}$$

named in honor of Klaus von Klitzing's discovery of the quantum Hall effect

4 spatial dimensions:

no stable orbits, no stable atoms

- molecule + molecule → new molecule + photon (chemical reaction)
- atom + photon → excited atom (excitation)
- atom + photon → electron + **cation** (ionization; photoelectric emission)
- nucleus + nucleus → new nuclei + photon
- nucleus + nucleus → new nuclei + electron
- nucleus + nucleus → new nuclei + neutrino

Nuclear reaction

- neutron → proton + electron + antineutrino (beta decay)
- photon + photon → electron + positron (pair creation)

If a particle at rest with mass m_0 absorbs a photon of energy $\hbar\omega$, it acquires a kinetic energy = $\hbar\omega$.

$$m_0c^2(\gamma - 1) = \hbar\omega$$

$$\gamma = \frac{\hbar\omega + m_0c^2}{m_0c^2}$$

Lorentz factor

Maxwell's equations → The birth of modern electromagnetism

Heinrich Rudolf Hertz → Established connection between electromagnetism and radiation

Theory of electromagnetism

How matter affects electromagnetic fields and how electromagnetic fields affect matter

Theory of gravity

How matter affects gravitational fields and how gravitational fields affect matter

General relativity

Gravity is a purely geometric effect

associates the force of gravity with the changing geometry of space-time

The strong equivalence principle

The laws of gravitation are independent of velocity and location

$$F = ma \qquad F = \frac{GMm}{r^2}$$

$$a = \frac{GM}{r^2}$$

is mass independent as long as inertial mass = gravitational mass

The Universe is expanding

Distant light is

- **Dimmed**
- **Redshifted**

The idea that the universe began as just a single point, then expanded and stretched to grow as large as it is right now — and it is still stretching.

Evidence for Big Bang:

- Observed galaxy recession
- Existence of Cosmic Microwave Background Radiation
- Correct predictions of big bang nucleosynthesis
- Darkness of night sky
- Distant objects look younger

Evidence that black holes exist

General theory of relativity is correct

- Planes are shorter when they fly.
- Their clocks are slowed by time dilation and look warped from aberration.

Special theory of relativity

Number density of Nucleus = $\rho_N = \frac{N_P + N_n}{V}$

$N_P \rightarrow$ Number of protons

$N_n \rightarrow$ Number of neutrons

$V \rightarrow$ volume of the nucleus = $\frac{4\pi R_0^3 A}{3}$

(R_0 is constant for all nuclei and its value is 1.2×10^{-15}m)

$$\rho_N = \frac{Z+(A-Z)}{\frac{4\pi R_0^3 A}{3}}$$

$$\boxed{\rho_N = \frac{3}{4\pi R_0^3} \rightarrow 137.95 \times 10^{44}\ \mathrm{m}^{-3}}$$

- Nuclear number density is independent of mass number of nucleus.
- It is nearly same for all nuclei.
- It has very high value. Such high densities can be found in white dwarfs.

Neutron $\rightarrow$ proton + electron

$$\frac{1}{2} \rightarrow \frac{1}{2} + \frac{1}{2}$$

The above reaction cannot take place because spin is not conserved.

$$\Delta N = N_P - N_n$$

$$\Delta N = Z - (A - Z)$$

$$\boxed{\Delta N = (2Z - A)}$$

It is convenient to define the proton fraction as:

$$X_p = \frac{N_P}{N_P + N_n} = \frac{Z}{A}$$

$$\boxed{\Delta N = A\,(2X_p - 1)}$$

It is convenient to define the neutron fraction as:

$$X_n = \frac{N_n}{N_P + N_n} = \frac{A - Z}{A}$$

$$Z = A\,(1 - X_n)$$

$$\boxed{\Delta N = A\,(1 - 2X_n)}$$

$$\frac{N_P}{N_n} = \frac{Z}{A-Z}$$

$$r = \frac{Z}{A-Z}$$

$$\boxed{\frac{z}{A} = \frac{r}{1+r}}$$

$$\Delta N = A\left[\frac{2r}{1+r} - 1\right]$$

It is convenient to define the electron fraction (in **neutral atom**) as:

$$X_e = \frac{N_e}{N_P + N_n + N_e} = \frac{Z}{A+Z}$$

$$\boxed{\frac{X_e}{1+X_e} = \frac{Z}{A}}$$

$$X_e\, r = \frac{Z^2}{A^2 - Z^2}$$

$$\boxed{Z = A\sqrt{\frac{X_e r}{1+X_e r}}}$$

A Brief History of Time Travel:

1895: An English writer **Herbert George Wells** publishes science fiction novel "The Time Machine"

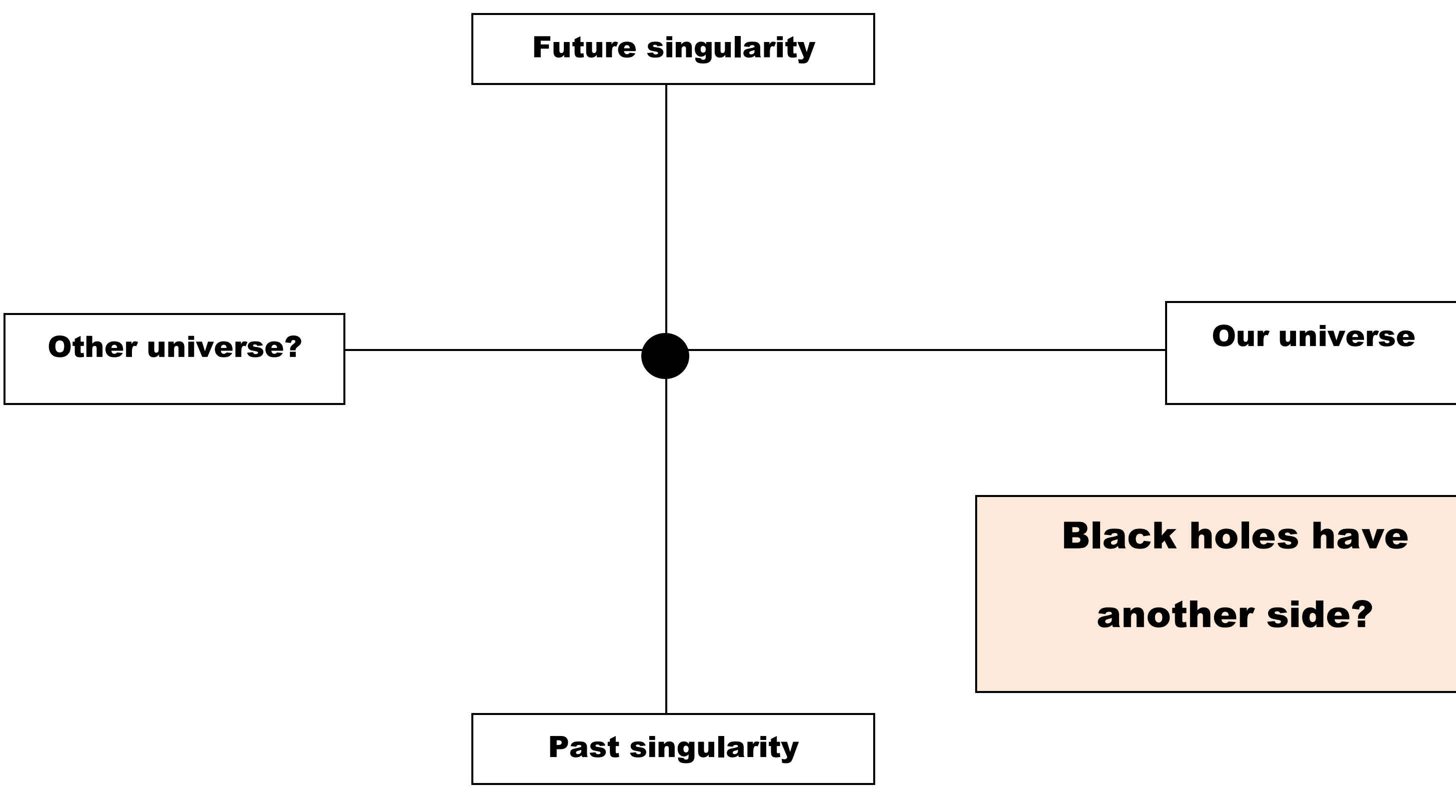
1905: Albert Einstein's special theory of relativity suggested forward time travel possible

1937: A logician, mathematician and philosopher **Kurt Friedrich Gödel** shows that our universe itself could be a time machine

1974: An American mathematical physicist and cosmologist **Frank Jennings Tipler** theorized that vast, spinning cylinder permits time travel

1988: An American theoretical physicist known for his contributions in gravitational physics and astrophysics **Kip Stephen Thorne** suggests using wormholes as a means of time travel

1991: A professor of astrophysical sciences at Princeton University **J. Richard Gott** finds that cosmic strings permit time travel



Black holes have another side?

$k \rightarrow$ curvature or shape of the universe

- Flat universe ($k = 0$)
- Closed or bound universe ($k = +1$)
- Open or unbound universe ($k = -1$)

The highest energy cosmic ray ever detected is estimated to have energy of 3×10^{20}eV which is 8 orders of magnitude below the Planck energy.

- The Planck length $\sqrt{\frac{\hbar G}{c^3}} = 1.616255 \times 10^{-35}$ m is the smallest length scale that we could theoretically probe.
- At about the Planck time $\sqrt{\frac{\hbar G}{c^5}} = 5.39\times10^{-44}$s after the hot big bang, it is thought that gravitation would have separated from the three other fundamental forces of nature (strong, weak and electromagnetic forces)
- At the Planck time, the **mass density of the universe** is thought to have approached the Planck density (5.1550×10^{96} kg/m^3):

$$\underbrace{\frac{M}{V} = \frac{c^5}{\hbar G^2}}$$

$$\boxed{V = \frac{\text{Schwarzschild radius of the universe} \times \text{Planck area}}{2}}$$

- Light always travels in a straight line. This property of light is known as **rectilinear propagation of light**.
- Vision occurs when light reflects from an object and then passes to one's eyes.
- In 1665, an Italian Jesuit priest, mathematician and physicist **Francesco Maria Grimaldi** discovered the phenomenon of diffraction (**the slight bending of light as it passes around the edge of an object**) and pointed out that it resembles the behavior of waves.
- In 1845, an English scientist who contributed to the study of electromagnetism and electrochemistry **"Michael Faraday"** discovered that the plane of polarization of

linearly polarized light is rotated when the light rays travel along the magnetic field direction in the presence of a transparent dielectric − an effect now known as **Faraday Effect or Faraday rotation.**

In March 1832, Faraday left a note in the safe of the Royal Society:

"I am inclined to compare the diffusion of magnetic forces from a magnetic pole to the vibrations upon the surface of disturbed water or those of air in the phenomenon of sound; i.e. I am inclined to think the vibratory theory will apply to these phenomena, as it does to sound and, most probably, to light."

To Ampere, Nov 1845

"I happen to have discovered a direct relation between magnetism and light also Electricity and Light --- and the field it opens is so large & I think rich that I naturally wish to look at it first"

$$\underbrace{E = nh\upsilon}$$

- Energy is quantized.
- Each discrete energy value corresponds to a different quantum state.
- Each quantum state is represented by the **quantum number** "n".

- In 1887 H. Hertz (1857-1894) of Germany was the first person to see the photoelectric effect.
- In 1899, in England, J. J. Thompson demonstrated that ultraviolet light hitting a metal surface caused the ejection of electrons.
- In 1905 Einstein, a young patent clerk in Switzerland explained the phenomenon.
- In 1921 Einstein received the Nobel Prize after Robert Millikan confirmed the work.

- **Letter, Franklin Roosevelt to Robert Oppenheimer thanking the physicist and his colleagues for their ongoing secret atomic research, 29 June 1943**

THE WHITE HOUSE

WASHINGTON

June 29, 1943

SECRET

My dear Dr. Oppenheimer:

I have recently reviewed with Dr. Bush the highly important and secret program of research, development and manufacture with which you are familiar. I was very glad to hear of the excellent work which is being done in a number of places in this country under the immediate supervision of General L.R. Groves and the general direction of the Committee of which Dr. Bush is Chairman. The successful solution of the problem is of the utmost importance to the national safety, and I am confident that the work will be completed in as short a time as possible as the result of the wholehearted cooperation of all concerned.

I am writing to you as the leader of one group which is to play a vital role in the months ahead. I know that you and your colleagues are working on a hazardous matter under unusual circumstances. The fact that the outcome of your labors is of such great significance to the nation requires that this program be even more drastically guarded than other highly secret war development. I have therefore given directions that every precaution be taken to insure the security of your project and feel sure that those in charge will see that these orders are carried out. You are fully aware of the reasons why your endeavors and those of your associates must be circumscribed by very special restrictions. Nevertheless, I wish you would express to the scientists assembled with you my deep appreciation of their willingness to undertake the tasks which lie before them in spite of the dangers and the personal sacrifices. I am sure that we can rely on their continued wholehearted and unselfish labors. Whatever the enemy may be planning, American science will be equal to the challenge. With this thought in mind, I send this note of confidence and appreciation.

Though there are other important groups at work, I am writing only to you as the leader of one which is operating under very special conditions, and to General Groves. While this letter is secret, the contents of it may be disclosed to your associates under pledge of secrecy.

Very Sincerely Yours

Franklin Delano Roosevelt

Dr. J. R. Oppenheimer

Post Office Box 1663

Santa Fe,

New Mexico

```
Niels Bohr talked about the correspondence principle in one of the Silliman Lectures he gave at Yale University between 6 and 13 November 1923. From the correspondence principle, he derived the selection rule that for radiative transitions in atoms, the change in the azimuthal quantum number k must be ±1. Bohr used that result in establishing his electron structures for the elements.
```

Types of Elementary particles

- Fermions → quarks + leptons
- Bosons (force carriers) → photons + gluons + gravitons

Massless → moves at speed of light

High mass → moves at less than speed of light

Particles of the same charge repel each other and particles of different charge attract each other

Invariance → Do not change

$$\textbf{Smallest magnetic charge} = \underbrace{\frac{h}{e} = \frac{eZ_0}{2\alpha} = 4.135\ 66752 \times 10^{-15}\ \text{J/A}}_{\text{suggested by quantum theory}}$$

Changes in magnetic fields produce electric fields

Like poles repel, and unlike poles attract.

The study of moving fields → **field theory**

In **empty space** the electric and the magnetic fields are seen as two faces of the same quantity

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

Light is an electromagnetic wave

The limit energy speed in nature

299 792 458 m/s

Larmor formula:

$$P = \frac{q^2 a^2}{6\pi\varepsilon_0 c^3}$$

The total power radiated by a nonrelativistic point charge as it accelerates − depends on the square of the acceleration and on the square of the charge that is being accelerated

All charged particles have mass

↓

Charges move more slowly than light

I believe there are

15,747,724,136,275,002,577,605,653,961,181,555,468,044,717,914,527,116,709,366,231,425,076,185,631,031,296

protons in the universe and the same number of electrons.

– Arthur Eddington

Moving clocks go slower.

Albert Einstein's Theory of Special Relativity

$v > c \longrightarrow$ not observed

$v > c \rightarrow$ cannot be produced

$v > c \longrightarrow$ cannot even be imagined

The maximum speed = c

$v \leq c$

Principle of nature

maximum force $\longrightarrow$ maximum flow of momentum per unit time $\longrightarrow \dfrac{c^4}{G}$

maximum momentum change per time

Planck mass flow rate $= \dfrac{\text{Planck mass}}{\text{Planck time}} = \dfrac{c^3}{G}$

maximum power $\longrightarrow$ maximum flow of energy per unit time $\longrightarrow \dfrac{c^5}{G}$

maximum energy change per time

$E = Mc^2 \longrightarrow$ Energy of the black hole

$A = 4\pi R_S^2 \longrightarrow$ Surface area of the black hole

$$\frac{E}{A} = \frac{c^2}{4\pi G} \times g$$

$\dfrac{E}{A}$ $\propto$ **Surface gravity of black hole**

The art and science of asking questions is the source of all knowledge.

– Thomas Berger

- **Translation of a machine typed copy of a letter that Wolfgang Pauli sent to a group of physicists**

Dear radioactive ladies and gentlemen,

… I have hit upon a 'desperate remedy' to save… the law of conservation of energy. Namely the possibility that there exists in the nuclei electrically neutral particles, that I call neutrons… I agree that my remedy could seem incredible… but only the one who dare can win…

Unfortunately I cannot appear in person, since I am indispensable at a ball here in Zurich.

Your humble servant

W. Pauli

(December 4, 1930)

230 planetary systems discovered since 1995

- 287 planets total
- 20 multi-planet systems

- Closed geometry → ultimate re-collapse
- Open geometry → eternal expansion
- Flat geometry → perfect balance between

The breakthroughs were made in the 1920's – 1930's

- Quantum Mechanics – discrete energy levels

- Relativity – things are different when you’re really zipping!

Electromagnetic Spectrum:

EM Wave	Range	Source	Use
Radio Wave	A few Hz to 10^9 Hz	Oscillating electronic circuits	Radio and TV broadcasting
Microwave	10^9 Hz to 3×10^{11} Hz	Oscillating electronic circuits	Radar
Infra Red wave	3×10^{11} Hz to 4×10^{14} Hz	Molecules and hot bodies	astronomy
Visible Spectrum	4×10^{14} Hz to 8×10^{14} Hz	Atoms and molecules When electrons are excited	Optics and Optical Instruments
UV Rays	8×10^{14} Hz to 3×10^{17} Hz	Atoms and molecules in electrical discharges and Sun	sterilization
X - Rays	3×10^{17} Hz to 5×10^{19} Hz	Inner or more tightly Bound electrons in atoms	X-ray photography
Gamma Rays	3×10^{18} Hz to 3×10^{22} Hz	Radioactive substances	Information about structure of nuclei

An object sitting still will stay that way, unless acted upon by a force.

Inertia ↔Mass

- **WMAP measurements of CMB (2005)**
  - Strong support for dark energy
  - Strong support for inflation

"The electromagnetic theory of light, as proposed by Faraday, is the same in substance as that which I have begun to develop in this paper, except that in 1846 there were no data to calculate the velocity of propagation. Faraday discovered that when a plane polarized ray transverses a transparent diamagnetic medium in the direction of the lines of magnetic force produced by magnets or currents in the neighborhood, the plane of polarization is caused to rotate."

Maxwell, a publication in 1865

"I think we have now strong reason to believe, whether my theory is a fact or not, that the luminiferous and the electromagnetic medium are one." In other words, light is indeed an electromagnetic undulation-a "ray-vibration," as you had called it in 1846.

Maxwell to Faraday, October 1861

Classical: Energy carried by a light wave is proportional to the square of the Amplitude of wave.

$$E \propto A^2$$

Quantum: Energy carried by a light wave is proportional to the frequency of wave.

$$E \propto \upsilon$$

"New scientific truth usually becomes accepted, not because its opponents become convinced, but because opponents gradually die and because the rising generations are familiar with the new truth at the outset."

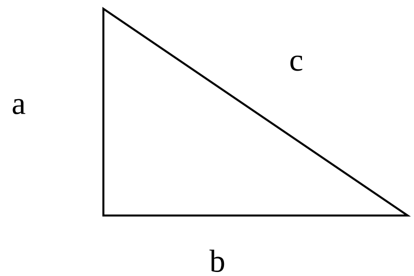
Max Planck, Naturwissenschaften, 33, 230 (1946)

$$\text{strain} \propto \text{stress}$$

$$\text{space-time curvature} \propto \text{mass-energy}$$

The 8 Most Beautiful Mathematical Equations

- 1 = 0.99999999999….
- **Pythagorean Theorem**



$$a^2 + b^2 = c^2$$

- **Euler's Formula**

For any polyhedron that doesn't intersect itself, the

Number of Faces

plus the Number of Vertices (corner points)

minus the Number of Edges

always equals 2

$$\boxed{\mathbf{F + V - E = 2}}$$

- **Time Dilation**

$$\Delta \mathbf{t} = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where:

Δt = time observed in the other reference frame

Δt_0 = time in observers own frame of reference (rest time)

v = the speed of the moving object

c = the speed of light in a vacuum

- **Euler's identity**

$$\boxed{e^{i\pi} + 1 = 0}$$

- **General Relativity**

$$\underbrace{R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu}}_{\text{space-time curvature}} = \underbrace{\frac{8\pi G}{c^4}T_{\mu}}_{\text{stress from stuff in space-time}} - \Lambda g_{\mu\nu}$$

stress from empty

space-time itself

- **E = mc²**

What this equation means is thoroughly world-changing. As Albert Einstein himself put it:

> It followed from the special theory of relativity that mass and energy are both but different manifestations of the same thing — a somewhat unfamiliar conception for the average mind.

- **Calculus**

$$\int_a^b f'(x)dx = f(a) - f(b)$$

Low intensity light beam → less photons

High intensity light beam → more photons

- Photon is emitted when an electron jumps from a higher orbit to a lower orbit and is absorbed when it jumps from a lower to higher orbit.
- The energy of photon emitted or absorbed is given by the difference between the two orbit energies: $h\upsilon = E_2 - E_1$

The basis of Photochemistry and Spectroscopy

Energy levels are quantized.

Light is absorbed and emitted in quantas.

Niels Bohr

Thus light is something like raindrops-each little lump of light is called a photon-and if the light is all one color, all the "raindrops" are the same size.

Richard P. Feynman

Einstein comment on Max Planck:

```
"He was one of the finest people I have ever known . . . but he didn't really understand physics, [because] during the eclipse of 1919 he stayed up all night to see if it would confirm the bending of light by the gravitational field. If he had really understood [the general theory of relativity], he would have gone to bed the way I did."
```

$$\boxed{\text{Strong lensing + Low mass lens} \rightarrow \text{Microlensing}}$$

Gravitational lensing was first proposed by **Soldner** (1801) in context of Newtonian theory. He found a deflection angle

$$\alpha = \frac{2GM}{c^2 r} \quad \text{(For sun gives 0.85 '')}$$

$$Mc^2 = \frac{\text{Planck force}}{2} \times \alpha \times r$$

Einstein derived same result in 1911 using Equivalence principle and Euclidean metric. In 1915 with general relativity, Einstein derived the new result:

$$\alpha = \frac{4GM}{c^2 r} \quad \text{(For sun gives 1.7 '')}$$

$$Mc^2 = \frac{\text{Planck force}}{4} \times \alpha \times r$$

For a start, how is the existence of the other universes to be tested? To be sure, all cosmologists accept that there are some regions of the universe that lie beyond the reach of our telescopes, but somewhere on the slippery slope between that and the idea that there is an infinite number of universes, credibility reaches a limit. As one slips down that slope, more and more must be accepted on faith, and less and less is open to scientific verification. Extreme multiverse explanations are therefore reminiscent of theological discussions. Indeed, invoking an infinity of unseen universes to explain the unusual features of the one we do see is just as ad hoc as invoking an unseen Creator. The multiverse theory may be dressed up in scientific language, but in essence it requires the same leap of faith.

— *Paul Davies,* The New York Times, *"A Brief History of the Multiverse"*

As skeptical as I am, I think the contemplation of the multiverse is an excellent opportunity to reflect on the nature of science and on the ultimate nature of existence: why we are here.... In looking at this concept, we need an open mind, though not too open. It is a delicate path to tread. Parallel universes may or may not exist; the case is unproved. We are going to have to live with that uncertainty. Nothing is wrong with scientifically based philosophical speculation, which is what multiverse proposals are. But we should name it for what it is.

— *George Ellis, Scientific American, "Does the Multiverse Really Exist?"*

[A]n entire ensemble is often much simpler than one of its members. This principle can be stated more formally using the notion of algorithmic information content. The algorithmic information content in a number is, roughly speaking, the length of the shortest computer program that will produce that number as output. For example, consider the set of all integers. Which is simpler, the whole set or just one number? Naively, you might think that a single number is simpler, but the entire set can be generated by quite a trivial computer program, whereas a single number can be hugely long. Therefore, the whole set is actually simpler... (Similarly), the higher-level multiverses are simpler. Going from our universe to the Level I multiverse eliminates the need to specify initial conditions, upgrading to Level II eliminates the need to specify physical constants, and the Level IV multiverse eliminates the need to specify anything at all... A common feature of all four multiverse levels is that the simplest and arguably most elegant theory involves parallel universes by default. To deny the existence of those universes, one needs to complicate the theory by adding experimentally unsupported processes and ad hoc postulates: finite space, wave function collapse and ontological asymmetry. Our judgment therefore comes down to which we find more wasteful and inelegant: many worlds or many words. Perhaps we will gradually get used to the weird ways of our cosmos and find its strangeness to be part of its charm.

— *Max Tegmark*

"Like the moon has a definite position" Einstein said to me last winter, "whether or not we look at the moon, the same must also hold for the atomic objects, as there is no sharp distinction possible between these and macroscopic objects. Observation cannot *create* an element of reality like a position, there must be something contained in the complete description of physical reality which corresponds to the **possibility** of observing a position, already before the observation has been actually made." I hope, that I quoted Einstein correctly; it is always difficult to quote somebody out of memory with whom one does not agree. It is precisely this kind of postulate which I call the ideal of the detached observer.

Letter from Pauli to Niels Bohr, February 15, 1955

What becomes of the energy of a photon after complete emission? Does it spread out in all directions with further propagation in the sense of Huygens' wave theory, so constantly taking up more space, in boundless progressive attenuation? Or does it fly out like a projectile in one direction in the sense of Newton's emanation theory? In the first case, the quantum would no longer be in the position to concentrate energy upon a single point in space in such a way as to release an electron from its atomic bond, and in the second case, the main triumph of the Maxwell theory – the continuity between the static and the dynamic fields and, with it, the complete understanding we have enjoyed, until now, of the fully investigated interference phenomena – would have to be sacrificed, both being very unhappy consequences for today's theoreticians.

Max Planck

Nobel Lecture (June 2, 1920)

Lyman limit → 91.2 nm

It corresponds to the energy required for an electron in the hydrogen atom to escape from the electrostatic potential barrier and jump completely out of the atom, thus creating a hydrogen ion.

Since the second law of thermodynamics states that entropy increases as time flows toward the future ($\frac{dS}{dt} > 0$), in general, the gigantic universe does not show symmetry under time reversal.

Three Failures of Classical Physics

- Blackbody Radiation
- The Photoelectric Effect
- The Hydrogen Atom

Because the orbiting electron in a Hydrogen atom is constantly changing direction, it should emit energy in the form of electromagnetic radiation. As a result, the electron should be continually losing energy. In fact, the electron should lose all of its energy and spiral down into the proton in only about 0.000000000001 second! In other words, atoms should not exist longer than a mere 10^{-12} seconds. **WRONG!!**

Quantum calculus → calculus without limits

$$\boxed{q = e^{ih}}$$

where h stands for Planck's constant while q stands for quantum.

Tolman–Oppenheimer–Volkoff limit (2 to 3 solar masses**)**

A star whose mass exceeds this **limit** cannot be maintained against gravity by degeneracy pressure, and must ultimately collapse to form a black-hole or, possibly, a quark star.

The thermal voltage depends on absolute temperature T as:

$$\boxed{V = \frac{k_B}{e} T = \frac{RT}{F} = \frac{2c\,\phi_0}{c_2} T}$$

where: ϕ_0 denote the Magnetic flux quantum, c the speed of light, c_2 the second radiation constant, R the universal gas constant and F the Faraday constant.

[An] important lesson we learn from the way that pure numbers like *α* define the world is what it really means for worlds to be different. The pure number we call the fine structure constant and denote by *α* is a combination of the electron charge, *e*, the speed of light, *c*, and Planck's constant, *h*. At first we might be tempted to think that a world in which the speed of light was slower would be a different world. But this would be a mistake. If *c*, *h*, and *e* were all changed so that the values they have in metric (or any other) units were different when we looked them up in our tables of physical constants, but the value of *α* remained the same, this new world would be *observationally* *indistinguishable* from our world. The only thing that counts in the definition of worlds are the values of the dimensionless constants of Nature. If all masses were doubled in value [including the Planck mass m_P] you cannot tell because all the pure numbers defined by the ratios of any pair of masses are unchanged.

− George Gamow

Unsolved problem in physics:

Is string theory, superstring theory, or M-theory, or some other variant on this theme, a step on the road to a "theory of everything", or just a blind alley?

Theory of scale relativity = quantum physics + relativity theory.

Electroweak interaction= electromagnetism + weak interaction.

The Einstein–Podolsky–Rosen paradox

↓

Quantum mechanics is not a complete physical theory.

Superfluid vacuum theory → a theoretical approach where the fundamental physical vacuum is viewed as superfluid or as a Bose–Einstein condensate.

Vacuum catastrophe

The disagreement between the observed values of vacuum energy density and theoretical large value of zero-point energy suggested by quantum field theory.

In Einstein's theory, any object that has mass causes a warp in the structure of space and time around it. This warping produces the effect we experience as gravity. Penrose points out those tiny objects, such as dust specks, atoms and electrons, produce space-time warps as well. Ignoring these warps is where most physicists go awry. If a dust speck is in two locations at the same time, each one should create its own distortions in space-time, yielding two superposed gravitational fields. According to Penrose's theory, it takes energy to sustain these dual fields. The stability of a system depends on the amount of energy involved: the higher the energy required to sustain a system, the less stable it is. Over time, an unstable system tends to settle back to its simplest, lowest-energy state: in this case, one object in one location producing one gravitational field. If Penrose is right, gravity yanks objects back into a single location, without any need to invoke observers or parallel universes.

There is no scientific discoverer, no poet, no painter, no musician, who will not tell you that he found ready made his discovery or poem or picture—that it came to him from outside, and that he did not consciously create it from within.

— **William Kingdon Clifford**, from a lecture to the Royal Institution titled "Some of the conditions of mental development"

Bohr radius:

$$a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_0 e^2} = \frac{(\text{Planck charge})^2}{e^2} \times \text{reduced Compton wavelength of electron}$$

- Efficiency coefficient for extinction cross section:

$$Q_{ext} = \frac{\sigma_{ext}}{\pi r^2}$$

- Efficiency coefficient for scattering cross section:

r: **radius of the particle**

$$Q_{sc} = \frac{\sigma_{sc}}{\pi r^2}$$

- Efficiency coefficient for absorption cross section:

$$Q_{abs} = \frac{\sigma_{abs}}{\pi r^2}$$

Fusion in the core:

Inside the core

$$\text{Temperature} \sim 1.5 \times 10^7 \text{ K}$$

- Hydrogen and Helium in the form of **plasma** (positively charged nuclei + free electrons)
- Due to the high temperatures ($k_BT >> mc^2$) electrons are no longer attached to nuclei and positively charged nuclei moving at high speeds.
- The closer nuclei come together. Since like charges repel each other → stronger the repulsive force between them.
- If the distance between nuclei < 10^{-15}m, the strong nuclear force overpowers the electrostatic force of repulsion.
- Fusion of hydrogen and helium nuclei occurs.

If the fusion process speeds up → the more energy would be released and pressure would increase gradually. The increased pressure would cause the core to expand and cool, and the fusion rate would slow down to normal. If the core temperature drops down → the decrease in fusion rate. The pressure would decrease and the core would contract. As the core shrink → the temperature would increase → the fusion rate would return to normal.

Hydrostatic equilibrium keeps the fusion process at a constant rate

Quantum foam

Quantum fluctuation of spacetime on very small scale (**Planck length**).

Principle of locality:

An event at point A cannot cause a result at point B in a time less than $T = \frac{D}{c}$, where D is the distance between the points and c is the speed of light in a vacuum.

There is a most profound and beautiful question associated with the observed coupling constant, e – the amplitude for a real electron to emit or absorb a real photon. It is a simple number that has been experimentally determined to be close to 0.08542455. (My physicist friends won't recognize this number, because they like to remember it as the inverse of its square: about 137.03597 with about an uncertainty of about 2 in the last decimal place. It has been a mystery ever since it was discovered more than fifty years ago, and all good theoretical physicists put this number up on their wall and worry about it.) Immediately you would like to know where this number for a coupling comes from: is it related to pi or perhaps to the base of natural logarithms? Nobody knows. It's one of the greatest damn mysteries of physics: a magic number that comes to us with no understanding by man. You might say the "hand of God" wrote that number, and "we don't know how He pushed his pencil." We know what kind of a dance to do experimentally to measure this number very accurately, but we don't know what kind of dance to do on the computer to make this number come out, without putting it in secretly!

— **Richard P. Feynman (1985). QED: The Strange Theory of Light and Matter**

- At the range of 10^{-15} m, **the strong force** is approximately 137 times as strong as electromagnetism, a million times as strong as the weak interaction, and 10^{38} times as strong as gravitation.

A stationary, asymptotically flat black hole is characterized by its:

- Mass "M"
- Angular momentum "J"
- Electric charge "Q"

After the process:

Star ⟶ black hole

All features of the star has lost classically.

Seager equation:

$$N = N_* \times F_Q \times F_{HZ} \times F_O \times F_L \times F_S$$

where:

- N = the number of planets with detectable signs of life
- N_* = the number of stars observed
- F_Q = the fraction of stars that are quiet
- F_{HZ} = the fraction of stars with rocky planets in the habitable zone
- F_O = the fraction of those planets that can be observed
- F_L = the fraction that have life
- F_S = the fraction on which life produces a detectable signature gas

Ufology ⟶ Study of UFOs

Because:

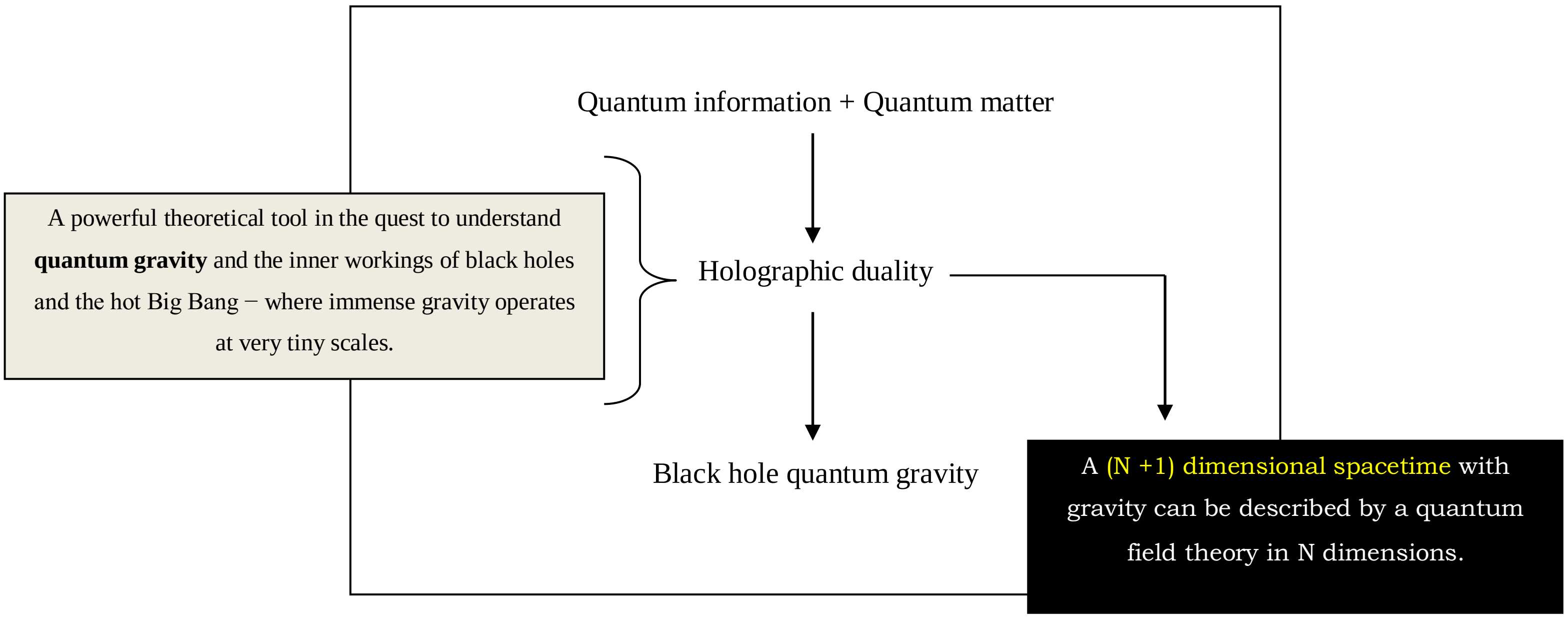
$$T_{BH} = \frac{\hbar c^3}{8\pi GM}$$

T_{BH} decreases as mass M increases, the black hole has a negative specific heat:

$$C = \frac{\partial E}{\partial T} < 0$$

The mystery about α is actually a double mystery. The first mystery – the origin of its numerical value $\alpha \approx \frac{1}{137}$ – has been recognized and discussed for decades. The second mystery – the range of its domain – is generally unrecognized.

*–**M. H. MacGregor** (2007). The Power of Alpha*



The general theory of relativity is what is called **a classical theory**. That is, it does not take into account the fact that particles do not have precisely defined positions and velocities but are "smeared out" over a small region by the uncertainty principle of quantum mechanics that does not allow us to measure simultaneously both the position and the velocity. This does not matter in normal situations, because the radius of curvature of space-time is very large compared to the uncertainty in the position of a particle. However, the singularity theorems indicate that space-time will be highly distorted, with a small radius of curvature at the beginning of the present expansion phase of the universe [or at the center of a black hole]. In this situation, the uncertainty principle will be very important. Thus, general relativity brings about its own downfall by predicting singularities. In order to discuss the beginning of the universe [or the center of a black hole], we need a theory that combines general relativity with quantum mechanics.

—Stephen Hawking

Black holes are macroscopic objects with masses varying from a few solar masses to millions of solar masses. To the extent they may be considered as stationary and isolated, to that extent, they are all, every single one of them, described exactly by the Kerr solution. This is the only instance we have of an exact description of a macroscopic object. Macroscopic objects, as we see them all around us, are governed by a variety of forces, derived from a variety of approximations to a variety of physical theories. In contrast, the only elements in the construction of black holes are our basic concepts of space and time. They are, thus, almost by definition, the most perfect macroscopic objects there are in the universe. And since the general theory of relativity provides a single unique two-parameter family of solutions for their description, they are the simplest objects as well.

– **S. Chandrasekhar**

Of all the entities I have encountered in my life in physics, none approaches the black hole in fascination. And none, I think, is a more important constituent of this universe we call home. The black hole epitomizes the revolution wrought by general relativity. It pushes to an extreme—and therefore tests to the limit—the features of general relativity (the dynamics of curved spacetime) that set it apart from special relativity (the physics of static, "flat" spacetime) and the earlier mechanics of Newton. Spacetime curvature. Geometry as part of physics. Gravitational radiation. All of these things become, with black holes, not tiny corrections to older physics, but the essence of newer physics.

– **John Archibald Wheeler**

The spin parameter of the Kerr Black Hole:

$$\alpha = \frac{cJ}{GM^2}$$

Maximum angular momentum of a Kerr black hole corresponds to a spin parameter $\alpha = 1$

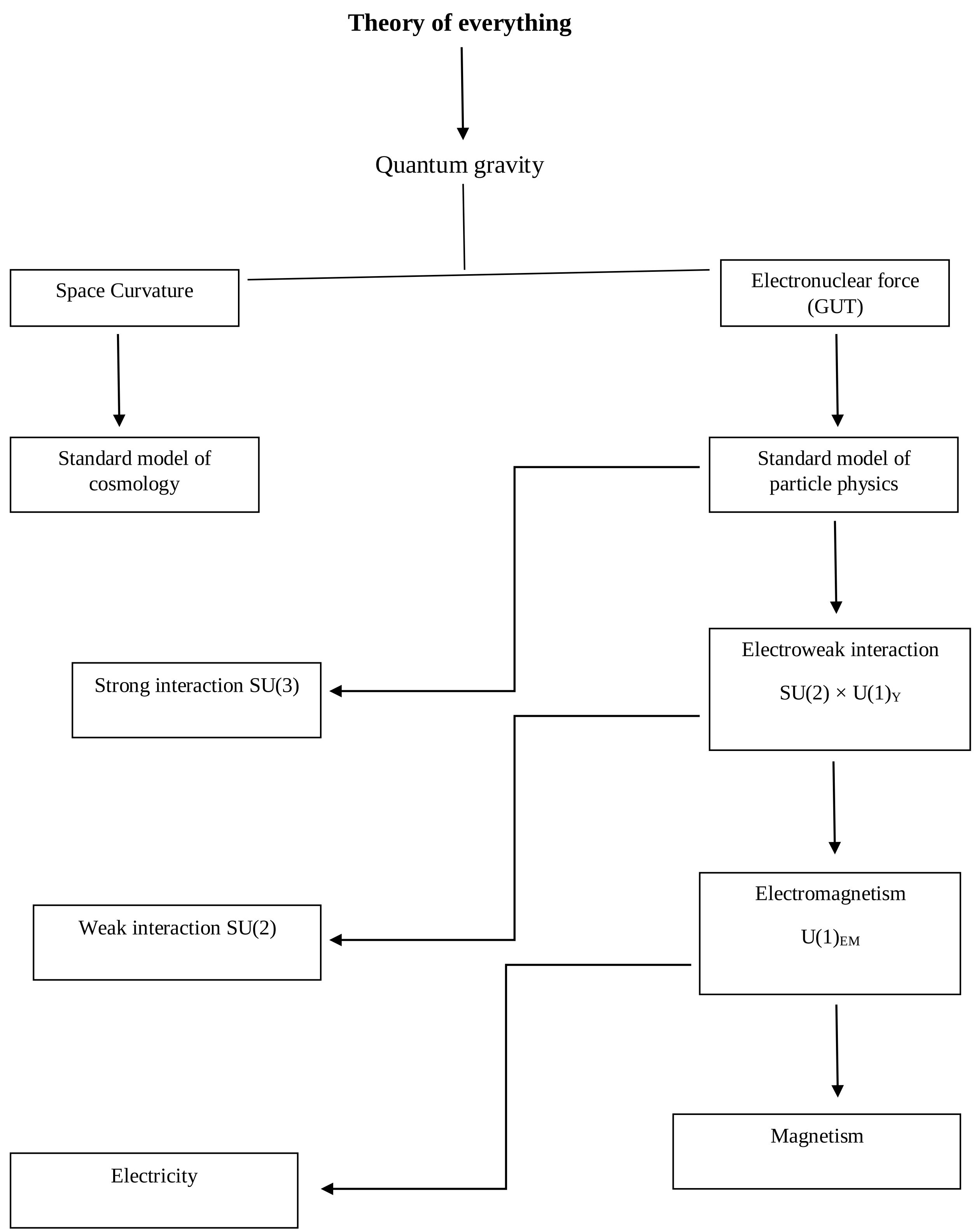
$$\boxed{Mc^2 = \sqrt{\text{Planck power } \times \frac{J}{\alpha}}}$$

If particle A enters the ergosphere of a Kerr black hole, then splits into particles B and C, then the consequence (given the assumptions that conservation of energy still holds and one of the particles is allowed to have negative energy) will be that particle B can exit the ergosphere with more energy than particle A while particle C goes into the black hole, i.e. $E_A = E_B + E_C$ and say $E_C < 0$, then $E_B > E_A$.

Why does the zero-point energy of the vacuum not cause a large cosmological constant?

What cancels it out?

- Special relativity + Quantum mechanics → Relativistic quantum electrodynamics (Very precise and highly successful)
- Quantum mechanics + Gravity → Theories of quantum gravity (Several theories, but no data to test them)
- Electromagnetism + Quantum mechanics + Gravity → The Planck scale of length, time, mass and energy (no data)


Theory of everything
Quantum gravity
Space Curvature
Electronuclear force (GUT)
Standard model of cosmology
Standard model of particle physics
Strong interaction SU(3)
Electroweak interaction
$SU(2) \times U(1)_Y$
Weak interaction SU(2)
Electromagnetism
$U(1)_{EM}$
Magnetism
Electricity

Vacuum genesis → the universe began as a single particle arising from an absolute vacuum, similar to how virtual particles come into existence and then fall back into non-existence.

BKL singularity

$$\overbrace{\text{Solution representing interior geometry of black holes formed by gravitational collapse}}^{\text{BKL singularity}}$$

Speed limit:

- $v < c$ if $m > 0$
- $v = c$ if $m = 0$

The heaviest neutron star detected still (PSR J1614-2230) has a mass of 1.97 ± 0.04 solar masses. This rule out many of the **softer equations of state**.

Innermost stable circular orbit (ISCO):

$$r_{ISCO} = 3 \times \frac{2GM}{c^2}$$

$$r_{ISCO} = \frac{6GM}{c^2}$$

$$Mc^2 = \frac{1}{6} \times \text{Planck force} \times r_{ISCO}$$

The BTZ black hole is an important solution to Einstein field equation in a (2+1) dimensional space with a negative cosmological constant.

Cosmological Constant → Acts like a pressure or "anti-gravity" – causing the expansion to accelerate.

Cold dark matter (CDM) – exotic elementary particles with mass ≥ 10 GeV, only interact via gravity.

Star or Gas cloud in the disc of a **spiral galaxy** will move on nearly circular orbit and is held in its orbit by the mass "M" interior to the orbit.

$$\frac{v^2}{R} = \frac{GM}{R^2}$$

$$\boxed{v = \sqrt{\frac{GM}{R}}}$$

- R → radius of the orbit
- v → orbital speed

$$\boxed{Mc^2 = \text{Planck force} \times \frac{v^2}{c^2} \times R}$$

When the Universe was a few seconds old, at $T=10^{10}$ K, protons and neutrons were in thermal equilibrium, and their ratio was given by the Boltzmann equation:

$$\boxed{\frac{n_n}{n_p} = e^{-\Delta E/k_B T}}$$

- $\Delta E = (m_n - m_p)\, c^2$

Below 10^{10} K, no new neutrons were formed, so that ratio was frozen in. Yet it was too hot for nuclear fusion to happen, so the mix of protons and neutrons was maintained. So for every 1000 protons, there were 223 neutrons.

$$\Delta n = n_n - n_p = n_p\,(e^{-\Delta E/k_B T} - 1)$$

$$n = n_n + n_p = n_p\,(e^{-\Delta E/k_B T} + 1)$$

$$\boxed{\frac{\Delta n}{n} = \frac{(e^{-\Delta E/k_B T} - 1)}{(e^{-\Delta E/k_B T} + 1)}}$$

$$X_n - X_p = \frac{(e^{-\Delta E/k_B T} - 1)}{(e^{-\Delta E/k_B T} + 1)}$$

- $X_p \rightarrow$ proton fraction
- $X_n \rightarrow$ neutron fraction

$$\text{Specific proton charge} = \frac{e}{m_p} = \frac{\text{Faraday constant}}{\text{Molar proton mass}}$$

$$\textbf{Specific positron charge} = \frac{e}{m_e} = \frac{\text{Faraday constant}}{\text{Molar positron mass}} = \text{Josephson constant} \times \text{Quantum of circulation}$$

Cyclotron frequency of the electron:

Faraday constant = 96485.3 C/mol

$$\upsilon_{\text{Cyclotron}} = \frac{eB}{2\pi m_e} = \frac{\text{applied magnetic field}}{2\pi} \times \text{Josephson constant} \times \text{Quantum of circulation}$$

The cyclotron frequency of an electron gyrating in a magnetic field of 1 Tesla is:

$$\upsilon_{\text{Cyclotron}} = \frac{1.6 \times 10^{-19} \times 1}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 28\text{GHz}$$

Geocentric gravitational constant = GM

Heliocentric gravitational constant = GM_{sun}

Art is the tree of life. Science is the tree of death.

– William Blake

Biological evolution

↓

- All living beings are different.
- All living beings compete for the resources they need to survive − air, water, food and space.
- Living beings with an advantage will survive and reproduce.

$$\frac{Gm_p m_e}{r^2} = \frac{m_e v^2}{r}$$

An electron circling a proton due to gravity alone, without electrostatic attraction

$$v^2 = \frac{Gm_p}{r}$$

$$m_e vr = \hbar \text{ or } v^2 = \frac{\hbar^2}{m_e^2 r^2}$$

$$\textbf{Gravitational Bohr radius} = \frac{\hbar^2}{Gm_e^2 m_p}$$

$$\textbf{Bohr radius} = \frac{\hbar}{m_e c\alpha}$$

$$\textbf{Gravitational Bohr radius} = \frac{2 \times (\text{Bohr radius})^2 \alpha^2}{\text{Schwarzschild radius of proton}}$$

Thermodynamics	Horizon mechanics
The temperature is the same across a body at equilibrium	The surface gravity is the same across the horizon
Entropy never decreases	Surface area never decreases (except for black hole radiation)
Temperature = 0 cannot be achieved	Surface gravity = 0 cannot be achieved

$$\underbrace{{}^{27}_{13}\text{Al} + {}^{4}_{2}\alpha \longrightarrow {}^{30}_{15}\text{P} + {}^{1}_{0}\text{n}}_{}$$

α ray transform aluminum into radioactive phosphorus

Equipped with his five senses, man explores the universe around him and calls the adventure Science.

−Edwin Powell Hubble

Margolus–Levitin theorem:

A quantum system of energy E needs at least a time of $\frac{h}{4E}$ to go from one state to an orthogonal state, where h is Planck's constant (6.626×10^{-34} Js)

Hubble–Reynolds law:

$$\boxed{I = \frac{I_0}{(1 + R/R_H)^2}}$$

where I is the surface brightness at radius R, I_0 is the central brightness, and R_H is the radius at which the surface brightness is diminished by a factor of 1/4.

Milgrom's theory:

Test particle moving in a circular orbit in the outskirts of a galaxy disk will have a speed V given by $(a_0GM_{gal})^{1/4}$ where

- M_{gal} is the total mass of the galaxy
- G is the constant of gravitation
- a_0 is Milgrom's constant.

$$\boxed{V \propto M_{gal}^{1/4}}$$

In particle physics, the available energy is the energy in a particle collision available to produce new matter from the kinetic energy of the colliding particles.

In 1898: **Marie and Pierre Curie** introduced the new term "radioactivity" for material which emitted radiation. They discovered that thorium emits "Uranic rays" and also discovered the new elements polonium and radium.

The redshift "**z**" is related to the scale factor "***a***" by:

$$(1 + z) = \frac{a_{now}}{a_{then}}$$

$$(1 + z)^3 = \frac{a_{now}^3}{a_{then}^3}$$

Since the total volume of the universe is proportional to $\boldsymbol{a}^3$, ***a*** being the scale factor of the universe: $(1 + z)^3 = \frac{V_{now}}{V_{then}}$

In 1938: a German-American nuclear physicist **Hans Albrecht Bethe** calculated in detail how nuclear fusion can power the Sun. He proposed a three-step sequence called the proton-proton chain.

The redshift "**z**" is related to the temperature of the CMB "**T**" by:

$$(1 + z) = \frac{T_{then}}{T_{now}}$$

$$(1 + z)^2 \times (1 + z) = \frac{V_{now}}{V_{then}}$$

$$(1 + z) = \sqrt{\frac{V_{now}}{V_{then}} \times \frac{T_{now}}{T_{then}}}$$

With Hubble parameter = 71 km/sec/Mpc,

The critical density = 10^{-26} kg/m^3

A very low density!

Water: 1000 kg/m^3

Air: 1 kg/m^3

Luminous matter is ~1% of total mass

Baryonic matter is ~15% of total mass

85% of universe is non-baryonic dark matter

"This "Hawking temperature" of a black hole and its "**Hawking radiation**" (as they came to be called) were truly radical—perhaps the most radical theoretical physics discovery in the second half of the twentieth century. They opened our eyes to profound connections between general relativity (black holes), thermodynamics (the physics of heat) and quantum physics (the creation of particles where before there were none). For example, they led Stephen to prove that a black hole has entropy, which means that somewhere inside or around the black hole there is enormous randomness. He deduced that the amount of entropy (the logarithm of the hole's amount of randomness) is proportional to the hole's surface area. His formula for the entropy is engraved on Stephen's memorial stone at Gonville and Caius College in Cambridge, where he worked.

For the past forty-five years, Stephen and hundreds of other physicists have struggled to understand the precise nature of a black hole's randomness. It is a question that keeps on generating new insights about the marriage of quantum theory with general relativity—that is, about the ill-understood laws of quantum gravity."

In 1930: an English theoretical physicist **Paul Adrien Maurice Dirac** combined relativity and quantum mechanics with the so-called **Dirac equation** as a consequence. The equation predicted the existence of negative states of electrons and protons – predicting the existence of antimatter.

— **Stephen Hawking, Brief Answers to the Big Questions**

Proton → two up quarks + one down quark

Neutron → two down quarks + one up quark

In 1938: Austrian physicist Lise Meitner and German chemist Otto Hahn bombarded uranium with neutrons and discovered nuclear fission.

$$\boxed{\begin{array}{c} p \equiv uud \\ n \equiv udd \end{array}}$$

Intrinsic energy of proton = Kinetic Energy of quarks + Potential Energy of quarks + intrinsic energy of quarks

Electromagnetic and strong interaction obey C-symmetry but the weak interaction violates C-symmetry

In 1964, Cronin and Fitch performed a beam experiment in which they showed that there was a small CP violation in the kaon decay.

Symmetry	Conservation law
Translation in time	Energy
Translation in space	Momentum
Rotation	Angular momentum
Gauge transformation	Charge

Noether's theorem:

Symmetries ↔ Conservation laws

- $E = i\hbar \frac{\partial}{\partial t}$
- $p = -i\hbar\nabla$

Time-dependent Maxwell equation: $\frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \nabla^2\phi = 0$

$E^2 = p^2c^2 + m_0^2c^4$

$-\hbar^2\frac{\partial^2\phi}{\partial t^2} = -\hbar^2c^2\nabla^2\phi + m_0^2c^4\,\phi$

$$\frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \nabla^2\phi + \frac{m_0^2c^2}{\hbar^2}\phi = 0$$

Thirty-one years ago **Dick Feynman** told me about his 'sum over histories' version of quantum mechanics. 'The electron does anything it likes', he said. 'It just goes in any direction at any speed,. . . however it likes, and then you add up the amplitudes and it gives you the wave function'. I said to him,

'You're crazy'. But he wasn't.

Freeman Dyson 1980

- An electromagnetic decay has a lifetime typically of the order of 10^{-20} seconds.
- Strong decays have lifetimes typically of the order of 10^{-25} seconds
- Weak decays have lifetimes typically of the order of 10^{-10} seconds

CONSERVATION OF ELECTRICAL CHARGE

In any reaction the total charge of all the particles entering the reaction must be the same as the total charge of all the particles after the reaction.

LEPTON CONSERVATION

In any reaction, the total number of particles from each lepton generation must be the same before the reaction as after.

mass of electron neutrino + mass of muon neutrino + mass of tau neutrino ≈ 0.05 − 0.18 eV

CONSERVATION OF BARYON NUMBER

In all reactions the total baryon number of the particles before the reaction must be the same as the total baryon number after the reaction.

If a force involves the exchange of a virtual particle, that particle of energy $\Delta E = mc^2$ can be exchanged if it does not go outside the bounds of the uncertainty principle in the form:

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

$\Delta t \rightarrow$ maximum lifetime of the virtual particle.

$$mc^2 \times \Delta t \geq \frac{\hbar}{2}$$

Since this exchange particle cannot exceed the speed limit of the universe, it cannot travel further than c times that lifetime. The maximum range of the force would then be on the order of

$$\boxed{\text{Range} \approx c \times \Delta t \approx \frac{\hbar}{2mc}}$$

2 Types of dark matter

Hot dark matter

($v \approx c$)

Cold dark matter

($v << c$)

Good evidence for the uniformity of the matter distribution in the early universe is provided by the cosmic background radiation

$$\text{Energy of photon} = mc^2 = \hbar\omega$$

$$E^2 = mc^2 \times \hbar\omega$$

The gravitational radius of the photon:

$$r_s = \frac{2Gm}{c^2} \text{ or } m = \frac{c^2}{2G} \times r_s$$

$$E^2 = \frac{\hbar c^4}{2G} \times r_s \times \omega$$

$$E^2 = \frac{\hbar c^5}{2G} \times r_s \times \frac{2\pi}{\lambda}$$

$$E = \frac{1}{\sqrt{2}} \times \text{Planck energy} \times \sqrt{\text{Schwarzschild radius } \times \text{angular wave number}}$$

The maximum energy possible for the photon is:

$$mc^2 = \sqrt{\frac{\hbar c^5}{2G}} = = 8.61 \times 10^{22} \text{ MeV}$$

This is the Planck energy. The highest energy so far observed for a photon is of order of 10^{13} eV.

Nuclear force vanishes at distance > 2 fm (**short range**)

Nuclear force is strongly attractive at distance ≈ 1 fm

Nuclear force is strongly repulsive at distance < 0.5 fm

Experimental results indicate that nuclear force depends on:

- The distance between interacting nucleons.
- Spins and angular momenta of interacting nucleons.

Liquid-Drop Model

- Nucleons at the surface of the nucleus are surrounded by fewer nucleons and the binding energy is reduced.
- Repulsive force acting between protons reduces the binding energy.
- An asymmetry in number of protons and neutrons reduces the binding energy.

A description of atomic nuclei in which the nucleons (neutrons + protons) behave like the molecules in a drop of liquid.

Quantum electrodynamics: U(1) gauge field + Dirac fields

Electroweak interaction: SU(2) × U(1)

Strong interaction: SU(3)

For a particle of mass m:

$$\text{Reduced Compton wavelength} = \frac{\hbar}{mc}$$

$$\text{Schwarzschild radius} = \frac{2Gm}{c^2}$$

- Schwarzschild radius >> Reduced Compton wavelength

  Classical gravity (quantum effects are not important)

- Schwarzschild radius << Reduced Compton wavelength

  Gravity effect is weak and not important

- Schwarzschild radius ≈ Reduced Compton wavelength

  Quantum gravity effects are important

Planck scale represents the scale at which the quantum effects of gravity become strong.

The electrostatic potential energy between 2 electrons separated by a distance r is:

$$E_P = \frac{e^2}{4\pi\varepsilon_0 r}$$

If we take the **reduced Compton wavelength of the electron** $\frac{\hbar}{m_e c}$ to be the smallest distance between 2 electrons − because this distance can be thought as the fundamental limitation on measuring the positions of an electron − taking quantum mechanics and special relativity into account:

$$\frac{E_P}{m_e c^2} = \textbf{Fine structure constant} = \frac{e^2}{4\pi\varepsilon_0 \hbar c}$$

nucleon – nucleon scattering experiments indicate that the nuclear force is independent of electrical charge

1600s	Sir Isaac Newton unified gravity in space and on earth
1800s	James Clerk Maxwell unified electricity and magnetism
1970s	Sheldon Glashow, Abdus Salam and Steven Weinberg unified electricity and magnetism with weak nuclear force

In 1919: **Ernest Rutherford** produced first nuclear reaction with natural ^4He

$$^{14}N + {}^4He \rightarrow {}^{17}O + p$$

A white hole looks similar to a black hole but instead of sucking matter in, a white hole pushes matter away.

Hubble's Law:

$$\frac{da}{dt} = Ha$$

where: a is the scale factor of the universe.

As space expands,

a increases

↓

The wavelength of light increases

Longer wavelength
Lower frequency
Smaller photon energy

a is proportional to λ

$$\frac{d\lambda}{dt} = H\lambda$$

Since:

$$\lambda = \frac{h}{p}$$

Therefore:

$$\boxed{-\frac{dp}{dt} = Hp}$$

Hubble's Law

Velocity = Hubble constant × Distance

Galaxies furthest from us are moving away at a faster velocity

Galaxies closest to us are moving away at a slower velocity

$$H = 71\,\frac{\text{km/s}}{\text{mpc}} = 2.3 \times 10^{-18} \text{ per second}$$

$$t_H = \frac{1}{2.3\times10^{-18} \text{ per second}}$$

$$t_H = 13.8 \times 10^{9} \text{ years}$$

American astronomer Edwin Powell Hubble is regarded as one of the most important cosmologists of the 20th century and is credited for playing a major role in exploring and establishing the field of extragalactic astronomy and observational cosmology.

NEUTRON STAR ALMOST A BLACK HOLE

Neutron stars are close to being black holes. Their escape speed is about $\frac{1}{3}$ c and their binding energy is about 20% Mc^2. The average density of a neutron star is ~ 10^{15} g cm^{-3}, greater than the density of an atomic nucleus

Unruh temperature:

$$\boxed{T_U = \frac{\hbar a}{2\pi c k_B}}$$

If $a = \sqrt{\frac{c^7}{\hbar G}}$ = Planck acceleration:

$$T_U = \frac{\text{Planck temperature}}{2\pi}$$

Planck temperature is 2π times the Unruh temperature when a → Planck acceleration.

Pair production can be represented by an equation which represents the conservation of total energy (or mass-energy):

$$\boxed{h\upsilon = 2m_e c^2 + KE_1 + KE_2}$$

where h is Planck's constant, υ is the frequency of the photon and the $2m_ec^2$ is the combined rest mass energy of the electron–positron. KE_1 and KE_2 represent the kinetic energy of the electron and positron

If the photon energy hυ were exactly $2m_ec^2$ = 1.02 MeV, the two particles would be created at rest (with zero kinetic energy).

$$h\upsilon = 2m_ec^2$$

$$\frac{hc}{\lambda} = 2m_ec^2$$

$$\boxed{\lambda = \frac{\lambda_C}{2}}$$

Photon – electron interaction

High photon energy

↓

Most energy goes to electron

Low photon energy

↓

Most energy is scattered

If photon wavelength = half the Compton wavelength of the electron:

$$KE_1 + KE_2 = 0$$

If hυ < 1.02 MeV:

No **Pair production**

No direct conversion of radiant energy to matter

Photon scattering

- Compton scattering
- Elastic scattering

Photon Disappearing

- Photoelectric effect
- Pair production
- Photonuclear reaction

Energy density of the Black hole:

$$u_{BH} = \frac{Mc^2}{V} = \frac{3Mc^2}{4\pi R_s^3}$$

$R_s = \frac{2GM}{c^2}$ = Schwarzschild radius of the Black hole.

$$\boxed{u_{BH} = \frac{3c^8}{32\pi G^3 M^2} = \frac{3c^2}{32\pi G} \times \frac{c^6}{G^2 M^2}}$$

Temperature of the Black hole:

$$T = \frac{\hbar c^3}{8\pi GMk_B}$$

$$\frac{c^6}{G^2M^2} = \frac{64\pi^2 k_B^2 T^2}{\hbar^2}$$

$$\boxed{u_{BH} = \frac{24\pi^3 F_{Planck}}{c_2^2} \times T^2}$$

- c_2 → Second radiation constant
- F_{Planck} → Planck force

Tachyon (a particle with imaginary mass $m^2 < 0$ and speed $v > c$), if it exist, could be used to communicate backwards in time. Because time travel is considered to be non-physical, tachyon is believed to be either not to exist or else to be incapable of interacting with normal matter.

Penrose Process → particle splitting inside the ergosphere

Blandford-Znajek Process → Black hole spin twists magnetic field

Reinterpretation principle

A **tachyon** sent back in time can always be reinterpreted as a tachyon traveling forward in time because we cannot distinguish between the emission and absorption of a tachyon.

Cold Big Bang model

The primordial universe was in a very low entropy state near absolute zero

Predicted an absence of acoustic peaks in the cosmic microwave background radiation and was eventually explicitly ruled out by **WMAP** observations.

The gravitational binding energy density of the star:

$$u_B = \frac{U}{V} = \frac{9GM^2}{20\pi R^4}$$

Radiation energy density:

$$u_R = \frac{4\sigma T^4}{c}$$

equal when: $M = \sqrt{\frac{80\pi\sigma}{9Gc}}\, T^2R^2$

"Without doubt, our world will change enormously in the next fifty years. We will find out what happened at the Big Bang. We will come to understand how life began on Earth. We may even discover whether life exists elsewhere in the universe. While the chances of communicating with an intelligent extra-terrestrial species may be slim, the importance of such a discovery means we must not give up trying. We will continue to explore our cosmic habitat, sending robots and humans into space. We cannot continue to look inwards at ourselves on a small and increasingly polluted and overcrowded planet. Through scientific endeavour and technological innovation, we must look outwards to the wider universe, while also striving to fix the problems on Earth. And I am optimistic that we will ultimately create viable habitats for the human race on other planets. We will transcend the Earth and learn to exist in space."

— Stephen Hawking, Brief Answers to the Big Questions

Magnetic fields in sunspots are fairly strong. Suppose same field fills Sun:

$$E_{magnetic} = \text{Volume} \times \text{Magnetic Energy density}$$

$$\boxed{E_{magnetic} = \frac{4\pi R^3}{3} \times \frac{B^2}{2\mu_0} = \frac{2\pi R^3 B^2}{3\mu_0}}$$

Rotation energy of the sun:

$$E_{rotation} = \frac{1}{2} \times I\omega^2 = = \frac{1}{2} \times \frac{2MR^2}{5} \times \omega^2 = \frac{\omega^2 MR^2}{5}$$

$$\boxed{\frac{E_{magnetic}}{E_{rotation}} = \frac{10\pi RB^2}{3\mu_0 M\omega^2}}$$

For prograde rotation:

Number of sidereal days per orbital period = 1 + number of solar days per orbital period

For retrograde rotation:

Number of sidereal days per orbital period = −1 + number of solar days per orbital period

$$\boxed{\text{Nuclear timescale} = \frac{\text{The total nuclear energy resources of a star}}{\text{The rate of energy loss}}}$$

If the Sun were to cease burning nuclear fuel now, it would continue to shine for tens of millions of years.

4 protons → one He^4 nucleus (**an alpha particle**)

The fractional energy change is:

$$\frac{\Delta E}{E} = \frac{4m_p c^2 - m_{He} c^2}{4m_p c^2} \approx 0.007$$

Nuclear time scale (the time required to exhaust all the sun's hydrogen at its current luminosity**):**

$$t_{nuc} \approx \frac{0.007 M_{sun} c^2}{L_{sun}}$$

For the sun, the nuclear time scale is about 10^{10} years.

Based on 2 facts

- ✓ In hydrogen burning about 0.7% of the rest mass is turned into energy.
- ✓ Only 10% of the total mass of the hydrogen in the star is consumed in the main sequence.

$$\frac{\text{Thermal energy}}{\text{Luminosity}}$$

Virial theorem: the thermal energy is half the gravitational potential energy

Kelvin-Helmholtz time scale (thermal timescale**):**

The time it takes a sun to collapse after nuclear burning ceases

$$t_{KH} \approx \frac{GM_{sun}^2}{2R_{sun}L_{sun}}$$

$\approx 3\times10^7$ years (for the Sun)

How long will it take to radiate away a sun's gravitational binding energy?

Dynamical time scale:

$$t_{dyn} \approx \frac{R_{sun}}{v_{esc}}$$

Escape velocity from the surface of the sun: $v_{esc} = \sqrt{\frac{2GM_{sun}}{R_{sun}}}$

$$t_{dyn} \approx \sqrt{\frac{R_{sun}^3}{2GM_{sun}}} = 1100 \text{ seconds}$$

The time scale on which a sun would expand or contract if the balance between pressure gradients and gravity is suddenly disrupted.

$$t_{nuc} \gg t_{KH} \gg t_{dyn}$$

"If you fall towards a black hole feet first, gravity will pull harder on your feet than your head, because they are nearer the black hole. The result is that you will be stretched out lengthwise, and squashed in sideways. If the black hole has a mass of a few times our Sun, you would be torn apart and made into spaghetti before you reached the horizon. However, if you fell into a much larger black hole, with a mass of more than a million times the Sun, the gravitational pull would be the same on the whole of your body and you would reach the horizon without difficulty. So, if you want to explore the inside of a black hole, make sure you choose a big one. There is a black hole with a mass of about four million times that of the Sun at the centre of our Milky Way galaxy."

— Stephen Hawking, Brief Answers to the Big Questions

Eddington luminosity → Maximum luminosity beyond which radiation pressure will overcome gravity

$$L_{Edd} = \frac{4\pi GMcm_p}{\sigma_T}$$

where M is the mass of the star, m_p is the proton mass, G is the gravitational constant, c is the speed of light and σ_T is the Thomson cross section.

Since the dawn of the history of science from Copernicus (who took the details of Ptolemy, and found a way to look at the same construction from a slightly different perspective and discover that the **Earth** is not the center of the universe) and Galileo to the present, we (a hoard of talking monkeys who's consciousness is from a collection of connected neurons − hammering away on typewriters and by pure chance eventually ranging the values for the (fundamental) numbers that would allow the development of any form of intelligent life) have gazed at the stars and attempted to chart the heavens and still discovering the fundamental laws of nature. Beginning at Stonehenge and ending with the current crisis in **String Theory**, the story of this eternal question to uncover the mysteries of the universe describes a narrative that includes some of the greatest discoveries of all time and leading personalities, including Aristotle, Johannes Kepler, and Isaac Newton, and the rise to the modern era of Einstein, Eddington, and **Hawking**.

THE HISTORY OF THE UNIVERSE IN 1000 WORDS OR LESS

- Cosmic Event in which our universe was born.
- Inflation in which the **Grand Unified Force** was separated into the **Four Forces of Nature** as We Now Know Them, and the Universe started to Expand to Many Times Its Original Size in a Very Short Period of Time – Rapid expansion in which the universe cooled, though not Quite as Quickly.
- PARTICLE-ANTIPARTICLE **ANNIHILATION** in which All the Antiparticles in the Universe Annihilated Almost All the Particles, Creating a Universe Made Up of Matter and Photons and no antimatter.
- DEUTERIUM AND HELIUM PRODUCTION in which Many of the Protons and Neutrons in the Early Universe Combined to Form Heavy Hydrogen and Helium.
- **RECOMBINATION** in which Electrons Combined with Hydrogen and Helium Nuclei, Producing Neutral Atoms.
- GALAXY FORMATION in which the Milky Way Galaxy was Formed – **TURBULENT FRAGMENTATION** in which a Giant Cloud of Gas Fragments broke into Smaller

Clouds, which later Became Protostars – MASSIVE STAR FORMATION in which a Massive Star was Formed.

- STELLAR EVOLUTION in which Stars Evolved and Eventually Died– **IRON** PRODUCTION in which Iron was Produced in the Core of a Massive Star, Resulting in a Disaster called **SUPERNOVA** EXPLOSION in Which a Massive Star Ended Its Life by Exploding – STAR FORMATION in which the Sun was Formed.
- PLANETARY DIFFERENTIATION in which the **Planet** Earth was Formed – **VOLATILE GAS EXPULSION** in which the Atmosphere of the Earth was Produced – MOLECULAR REPRODUCTION in which Life on Earth was created.
- **PROTEIN CONSTRUCTION** in which Proteins were built from Amino Acids – FERMENTATION in which Bacteria Obtained Energy from Their Surroundings – CELL DIFFERENTIATION in which **Eukaryotic** Life had a beginning.
- **RESPIRATION** in which Eukaryotes Evolved to Survive in an Atmosphere with Increasing Amounts of Oxygen – **MULTICELLULAR ORGANISMS** CREATION In Which Organisms Composed of Multiple Cells emerged – **SEXUAL REPRODUCTION** in Which a New Form of Reproduction Occurred and with the invention of sex, two organisms exchanged whole paragraphs, pages and books of their DNA helix, producing new varieties for the sieve of natural selection. And the natural selection was a choice of stable forms and a rejection of unstable ones. And the variation within a species occurred randomly, and that the **survival or extinction of each organism** depended upon its ability to adapt to the environment. And organisms that found sex uninteresting quickly became extinct.
- **EVOLUTIONARY DIVERSIFICATION** in which the Diversity of Life Forms on Earth Increased Greatly in a Relatively Short Time – TRILOBITE DOMINATION In Which **Trilobites** (an extremely successful **subphylum** of the arthropods that were at the top of the food chain in Earth's marine ecosystems for about 250 million years) Ruled the Earth.
- **LAND EXPLORATION** In Which Animals First Venture was Onto Land – **COMET** COLLISION in which a Comet smashed the Earth – **DINOSAUR EXTINCTION** In Which the Dinosaurs Died.

- **MAMMAL EXPANSION** in which Many Species of Mammals was developed – **HOMO SAPIENS** MANIFESTATION In Which our caveman ancestors Appeared.
- **LANGUAGE ACQUISITION** in which something called **curiosity** ensued which triggered the breath of perception and our caveman ancestors became conscious of their existence and they learned to talk and they Developed Spoken Language – **GLACIATION** in which a Thousand-Year Ice Age Began.
- INNOVATION in which **Advanced Tools** were Widely made and Used – RELIGION In Which a Diversity of Beliefs emerged – **ANIMAL DOMESTICATION** in which Humans Domesticated Animals.
- **FOOD SURPLUS** PRODUCTION In Which Humans Developed and promoted Agriculture – **INSCRIPTION** In Which Writing was Invented and it allowed the communication of ideas.
- **WARRING NATIONS** In Which Nation Battled Nation for Resources – **EMPIRE CREATION AND DESTRUCTION** In Which the First Empire in Human History Came and went – **CIVILIZATION** In Which Many and Sundry Events Occurred.
- **CONSTITUTION** In Which a Constitution was Written – INDUSTRIALIZATION in Which Automated Manufacturing and Agriculture Revolutionized the World – **WORLD CONFLAGRATIONS** In Which Most of the World was at War.
- **FISSION** EXPLOSIONS In Which Humans Developed **Nuclear Weapons** – ***COMPUTERIZATION*** In Which Computers were Developed.
- **SPACE EXPLORATION** In Which Humans Began to Explore Outer Space – POPULATION EXPLOSION In Which the **Human Population** of the Earth Increased at a Very Rapid Pace.
- **SUPERPOWER CONFRONTATION** In Which Two Powerful Nations Risked it All – **INTERNET EXPANSION** In Which a Network of Computers Developed.
- RESIGNATION In Which One Human **Quitted His Job** – **REUNIFICATION** In Which a Wall went Up and Then Came Down.
- WORLD WIDE WEB CREATION In Which a New Medium was Created – **COMPOSITION** In Which a **Book** was Written – EXTRAPOLATION In Which Future Events were Discussed.

Ever since the beginning of **human civilization**, we have not been in a state of satisfaction to watch things as incoherent and unexplainable. While we have been thinking whether the universe began at the big bang singularity and would come to an end either at the big crunch singularity, we have converted at least a thousand joules of energy in the form of thoughts. This has decreased the disorder of the human brain by about few million units. Thus, in a sense, the evolution of human civilization in understanding the universe has established a small corner of the order in a **human brain**. However, the burning questions still remain unresolved, which set the human race to keep away from such issues. Many **early native postulates** have fallen or are falling aside – and there now alternative substitutes. In short, while we do not have an answer, we now have a whisper of the grandeur of the problem. With our limited brains and tiny knowledge, we cannot hope to have a complete picture of unlimited speculating about the gigantic universe we live in.

In 1911, fresh from completion of his PhD, the young Danish physicist Niels Bohr left Denmark on a foreign scholarship headed for the Cavendish Laboratory in Cambridge to work under J. J. Thomson on the structure of atomic systems. At the time, Bohr began to put forth the idea that since light could no long be treated as continuously propagating waves, but instead as discrete energy packets (as articulated by Planck and Einstein), why should the classical Newtonian mechanics on which Thomson's model was based hold true? It seemed to Bohr that the atomic model should be modified in a similar way. If electromagnetic energy is quantized, i.e. restricted to take on only integer values of $h\upsilon$, where υ is the frequency of light, then it seemed reasonable that the mechanical energy associated with the energy of atomic electrons is also quantized. However, Bohr's still somewhat vague ideas were not well received by Thomson, and Bohr decided to move from Cambridge after his first year to a place where his concepts about quantization of electronic motion in atoms would meet less opposition. He chose the University of Manchester, where the chair of physics was held by Ernest Rutherford. While in Manchester, Bohr learned about the nuclear model of the atom proposed by Rutherford. To overcome the difficulty associated with the classical collapse of the electron into the nucleus, Bohr proposed that the orbiting electron could only exist in certain special states of motion - called stationary states, in which no electromagnetic radiation was emitted. In these states, the angular momentum of the electron L takes on integer values of Planck's constant divided by 2π, denoted by $\hbar = \frac{h}{2\pi}$ (pronounced h-bar). In these stationary states, the electron angular momentum can take on values $\hbar$, $2\hbar$, $3\hbar$... but never non-integer values. This is known as quantization of angular momentum, and was one of Bohr's key hypotheses. Bohr Theory was very successful in predicting and accounting the energies of line spectra of hydrogen i.e. one electron system. It could not explain the line spectra of atoms containing more than one electron. For lack of other theories that can accurately describe a large class of arbitrary elements to must make definite predictions about the results of future observations, we forcibly adore the theories like the big bang, which posits that in the beginning of evolution all the observable galaxies and every speck of energy in the universe was jammed into a very tiny mathematically indefinable entity called the **singularity** (or the primeval atom named by the **Catholic priest Georges Lemaitre,** who was the first to investigate the origin of the universe that we now call the big bang). This extremely dense point exploded with unimaginable force, creating matter and propelling it outward to make the billions of galaxies of our vast universe. It seems to be a good postulate that the anticipation of a mathematically indefinable entity by a scientific theory implies that the theory has ruled out. It would mean that the usual approach of science of building a scientific model could anticipate that the universe must have had a beginning, but that it could not prognosticate how it had a beginning. Between 1920s and 1940s there were several attempts, most notably by the British physicist **Sir Fred Hoyle** (a man who ironically spent almost his entire professional life trying to disprove the big bang theory) and his co-workers: **Hermann Bondi and Thomas Gold**, to avoid the cosmic singularity in terms of an elegant model that supported the idea that as the universe expanded, new matter was continually created to keep the density constant on average. The universe didn't have a beginning and it continues to exist eternally as it is today. This idea was initially given priority, but a mountain of inconsistencies with it began to appear in the mid 1960's when observational discoveries apparently supported the evidence contrary to it. However, Hoyle and his supporters put forward increasingly contrived explanations of the observations. But the final blow to it came with the observational discovery of a faint background of microwaves (whose wavelength was close to the size of water molecules) throughout space in 1965 by Arno Penzias and Robert Wilson, which was the "**the final nail in the coffin of the big bang theory**" i.e., the discovery and confirmation of the cosmic microwave background radiation (which could heat our food stuffs to only about −270 degrees Centigrade — 3 degrees above absolute zero, and not very useful for popping corn) in 1965 secured the Big Bang as the best theory of the origin and evolution of the universe. Though **Hoyle** and **Narlikar** tried desperately, the steady state theory was abandoned.

With many bizarre twists and turns of Humanity's deepest desire for knowledge, super strings − a generalized extension of **string theory** which predicts that all matter consists of tiny vibrating strings and the precise number of dimensions: ten and has a curious history (It was originally invented in the late 1960s in an attempt to find a theory to describe the strong force). The usual three dimensions of space − **length, width, and breadth** − and one of time are extended by six more spatial dimensions − blinked into existence. Although the mathematics of super strings is so complicated that, to date, no one even knows the exact equations of the theory (we know only approximations to these equations, and even the approximate equations are so complicated that they as yet have been only partially solved) − The best choice we have at the moment is the **super strings**, but no one has seen a superstring and it has not been found to agree with experience and moreover there's no direct evidence that it is the correct description of what the universe is. Are there only 4 dimensions or could there be more: **(x, y, z, t) + w, v, …?** Can we experimentally observe evidence of higher dimensions? What are their shapes and sizes? Are they classical or quantum? Are dimensions a fundamental property of the universe or an emergent outcome of chaos by the mere laws of nature (which are shaped by a kind of lens, the interpretive structure of our human brains)? And if they exist, they could provide the key to unlock the deepest secrets of nature and Creation itself? We humans look around and only see four (three spatial dimensions and one time dimension i.e., space has three dimensions, I mean that it takes three numbers − length, breadth and height− to specify a point. And adding time to our description, then space becomes space-time with 4 dimensions) – why 4 dimensions? Where are the other dimensions? Are they rolled the other dimensions up into a space of very small size, something like a **million million million million millionth of an inch** − so small that our most powerful instruments can probe? Up until recently, we have found no evidence for signatures of extra dimensions. No evidence does not mean that extra dimensions do not exist. However, being aware that we live in more dimensions than we see is a great prediction of theoretical physics and also something quite futile even to imagine that we are entering what may be the golden age of cosmology even our best technology cannot resolve their shape.

For n spatial dimensions: The gravitational force between two massive bodies is: $F_G = \frac{GMm}{r^{n-1}}$, where G is the gravitational constant (which was first introduced by **Sir Isaac Newton** (who had strong philosophical ideas and was appointed president of the Royal Society and became the first scientist ever to be knighted.) as part of his popular publication in 1687 "**Philosophiae Naturalis Principia Mathematica**" and was first successfully measured by the English physicist Henry Cavendish), M and m are the masses of the two bodies and r is the distance between them. The electrostatic force between two charges is: $F_E = \frac{Qq}{4\pi\varepsilon_0 r^{n-1}}$, where ε_0 is the absolute permittivity of free space, Q and q are the charges and r is the distance between them. What do we notice about both of these forces? Both of these forces are proportional to $\frac{1}{r^{n-1}}$. So in a 4 dimensional universe (3 spatial dimensions + one time dimension) forces are proportional to $\frac{1}{r^2}$; in the **10 dimensional universe** (9 spatial dimensions + one time dimension) they're proportional to $\frac{1}{r^8}$. Not surprisingly, at present no experiment is smart enough to solve the problem of whether or not the universe exists in 10 dimensions or more (i.e., to prove or disprove both of these forces are proportional to $\frac{1}{r^8}$ or proportional to > $\frac{1}{r^8}$). However, yet mathematically we can imagine many spatial dimensions but the fact that that might be realized in nature is a profound thing. So far, we presume that the universe exists in extra dimensions because the mathematics of superstrings requires the presence of ten distinct dimensions in our universe or because a **standard four dimensional theory** is too small to jam all the forces into one mathematical framework. But what we know about the spatial dimensions we live in is limited by our own abilities to think through many approaches, many of the most satisfying are scientific.

Among many that we can develop, the most well- known, believed theory at the present is the standard four dimensional theory. However, development and change of the **theory always occurs as many questions still remain about our universe we live in**. And if space was 2 dimensional then force of gravitation between two bodies would have been = $\frac{\mathrm{GMm}}{\mathrm{r}}$ (i.e., the force of gravitation between two bodies would have been far greater than its present value). And if the force of gravitation between two bodies would have been far greater than its present value, the rate of emission of gravitational radiation would have been sufficiently high enough to cause the earth to spiral onto the **Sun even before the sun become a black hole** and swallow the earth. While if space was 1 dimensional then force of gravitation between two bodies would have been = GMm (i.e., the force of gravitation between two bodies would have been independent of the distance between them).

The selection principle that we live in a region of the universe that is suitable for intelligent life which is called the **Anthropic principle** (a term coined by astronomer **Brandon Carter** in 1974) would not have seemed to be enough to allow for the development of complicated beings like us. The universe would have been vastly different than it does now and, no doubt, life as we know it would not have existed. And if spacial dimensions would have been > than 3, the force of gravitation between two bodies would have been decreased more rapidly with distance than it does in three dimensions. (In three dimensions, the gravitational force drops to $\frac{1}{4}$ if one doubles the distance. In four dimensions it would drops to $\frac{1}{5}$, in five dimensions to $\frac{1}{6}$, and so on.) The significance of this is that the orbits of planets, like the earth, around the sun would have been unstable to allow for the **existence of any form of life** and there would been no intelligent beings to observe the effectiveness of extra dimensions.

Although the proponents of string theory (which occupies a line in space at each moment of time) predict absolutely everything is built out of strings (which are described as patterns of vibration that have length but no height or width — **like infinitely thin pieces of string**), it could not provide us with an answer of what the string is made up of? And one model of potential multiple universes called the **M Theory** − has eleven dimensions, ten of space and one of time, which we think an explanation of the laws governing our universe that is currently the only viable candidate for a "**theory of everything**": the unified theory that Einstein was looking for, which, if confirmed, would represent the ultimate triumph of human reason− predicts that our universe is not only one giant hologram.

Many theoretical physicists and scientists of a fast developing science have discussed about mass annihilation at different times. Even a level one graduate know that when an electron and a positron approach each other, they annihilate i.e., destroy each other. This process what a quantum physicists call the mass annihilation. During the process their masses are converted into energy in accordance with $\mathbf{E = mc^2}$. The energy thus released manifests **as γ photons**. A positron has the same mass as an electron but an opposite charge equal to +e. The energy released in the form of 2γ photons during the annihilation of a positron and an electron is therefore: $\mathbf{E = 2h\upsilon = 2m_0c^2}$ where m_0 is the rest mass of the electron or positron.

$$2h\upsilon = 2m_0c^2$$

Since $\upsilon = c/\lambda$. Therefore:

$$\lambda = \frac{h}{m_0 c}$$

But $h/m_0c = \lambda_C$ (the Compton wavelength of the electron or positron). Therefore: $\lambda = \lambda_C$ (i.e., wavelength of the resulted gamma photon is = Compton wavelength of the annihilated electron or positron).

$$\lambda_C \rightarrow \frac{h}{m_0 c}$$

Is it a cutoff at which relativistic quantum field theory becomes crucial for its accurate description? The Compton wavelength of the electron or positron characterizes the length scale at which the wave property of an electron or a positron starts to show up. In an interaction that is characterized by a length scale larger than the Compton wavelength, electron or positron behaves classically (i.e., no observation of wave nature). For interactions that occur at a length scale comparable than the Compton wavelength, the wave nature of the electron or positron begins to take over from classical physics.

If a photon streamed freely through a sun, it zips without interruption from the core to the sun's surface in $\frac{R_{sun}}{c} \approx 2$ seconds. This is rather poetic – of course a photon doesn't survive to reach the sun's surface, but is absorbed and re-radiated as a new photon $\approx (\frac{R_{sun}}{\text{mean free path of photon}})^2$ times. Suppose no other forces exist to oppose the collapse of the sun. The radius 'R_{sun}' would collapse under gravity. The radius 'R_{sun}' would shrink to zero after an elapsed "free-fall" time:

$$t_{ff} = \frac{\pi}{\sqrt{8}} \sqrt{\frac{R_{sun}^3}{GM_{sun}}}$$

Evolution of the Universe:

Epoch	**Main event**
Planck	No current theory of physics; quantum gravity
GUT (Grand Unified Theory)	Strong, weak and electromagnetic forces united
Quark	Strong force frozen out. Heavy and light particles all in thermal equilibrium. Electroweak force freezes out at 10^{15}K.
Lepton	Only low-mass particles still in thermal equilibrium; neutrinos decouple at 10^{10}K.
Nuclear	Deuterium and helium formed by fusion of protons and neutrons during first 1000 seconds.
Atomic	Matter begins to dominate; atoms form; electromagnetic radiation decouples.
Galactic	Large-scale structure forms; first stars and quasars shine; galaxies form and grow.
Stellar	Galaxies merge and evolve; star formation peaks. Dark energy begins to dominate.

Extends into the Dark Energy Era

Planck length = $\sqrt{\frac{\hbar G}{c^3}}$

Gravitational limit of quantum theory

Quantum limit of general relativity

Planck mass = $\sqrt{\frac{\hbar c}{G}}$

Upper limit on the mass of elementary particles

Lower limit on the mass of a black hole

Planck temperature = $\frac{m_{Planck} c^2}{k_B}$

Upper limit of temperature

Planck density = $\frac{m_{Planck}}{L^3_{Planck}}$

Limiting density of matter

Laser

↓

Light Amplification through the Stimulated Emission of Radiation

Quantum mechanics is very respectable. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but hardly brings us any closer to the mystery of the old one. In any case, I am convinced that He is not rolling dice.

Albert Einstein Letter to Max Born, 4 December 1926

In the Sun, the nuclear fusion reaction converts hydrogen nuclei into helium nuclei. The fusion reaction is called the **hydrogen – hydrogen cycle** or proton – proton cycle.

proton + proton → deuterium + positron + electron neutrino **(a weak nuclear reaction)**

deuterium + proton → ^{3}He + energy **(a strong nuclear reaction)**

^{3}He + ^{3}He → ^{4}He + 2 protons + energy

If the masses, lifetimes and magnetic moments of matter and antimatter particles would differ, the CPT symmetry would be violated.

About 10^{16} neutrinos pass through our body every second.

quantum electrodynamics	describe the electromagnetic interaction
quantum chromodynamics	describe the strong nuclear interaction
quantum flavordynamics	describe the weak nuclear interaction
Quantum field theory	describe the particle transformations

- the electromagnetic interaction
- the strong nuclear interaction
- the weak nuclear interaction

Involve the Exchange of virtual bosons

In these interactions: energy, momentum, angular momentum, electric charge, colour charge, **CPT parity**, lepton number and baryon number are conserved.

Von Klitzing constant $= \frac{h}{e^2} = \frac{\mu_0 c}{2\alpha}$

Electron-proton mass ratio

↓

Much smaller → No solids

- **vector bosons** — the photon, W and Z bosons, gluons
- **Higgs boson** — the only known fundamental scalar boson
- **graviton** — a hypothetical tensor boson

Baryon number

↓

Much higher → No solar system

Vacuum energy density

↓

Change by 10^{-55} → No flatness

- (3 + 1) dimensions → different → No atoms, no planetary systems
- **No Permutation symmetry** → No matter
- No Lorentz symmetry → No communication possible
- **Different U(1) symmetry** → No Huygens principle
- Different SU (2) symmetry → No radioactivity, no Sun, no life
- Different SU (3) symmetry → No stable quarks and nuclei

Oort cloud object number

↓

Smaller → No comets, no irregular asteroids

Initial cosmic speed

↓

Increase by 0.1% → 1000 times faster cosmic expansion

6 to 8 Generations of Particles	Only helium in nature
Greater than 8 Generations of Particles	No asymptotic freedom and confinement

Neutron-proton mass difference

↓

Smaller than electron mass

↓

Protons would capture electrons, no hydrogen atoms

Galaxy centre distance

↓

Smaller → Irregular planet motion

Like the formation of bubbles of steam in boiling water − Great many **holograms** of possible shapes and inner dimensions were created, started off in every possible way, simply because of an uncaused accident called spontaneous creation. Our universe was one among a zillion of holograms simply happened to have the right properties − with particular values of the physical constants right for stars and galaxies and planetary systems to form and for intelligent beings to emerge due to random physical processes and develop and ask questions, Who or what governs the laws and **constants of physics**? Are such laws the products of chance or a mere cosmic accident or have they been designed? How do the laws and constants of physics relate to the support and development of life forms? Is there any knowable existence beyond the apparently observed dimensions of our existence? However, M theory sounds so bizarre and unrealistic that there is no experiment that can credit its validity. Nature has not been quick to pay us any hints so far. That's the fact of it; grouped together everything we know about the history of the universe is a fascinating topic for study, and trying to understand the meaning of them is one of the key aspects of modern cosmology— which is rather like plumbing, in a way.

And as more space comes into existence, more of the dark energy (an invisible and unexpected cosmological force which was a vanishingly small slice of the pie 13.7 billion years ago, but today it is about three times as much as visible matter and dark matter put together and it eclipses matter and hides in empty space and works for the universe's expansion i.e., **pushes the edges of the universe apart** − a sort of anti-gravity) would appear. Unfortunately, no one at the present time has any understanding of where this "**undetected substance**" comes from or what exactly it is. Is it a **pure cosmological constant** (an arbitrary parameter from general relativity, has been taken to be zero for most of the twentieth century for the simple and adequate reason that this value was consistent with the data) or is it a sign of extra dimensions? What is the cause of the dark energy? Why does it exist at all? Why is it so different from the other energies? Why is the composition of dark energy so large (of about 73% of our universe − we only make up **0.03% of the universe** which include stars orbiting their galaxies much too fast to be held in orbit merely by the gravitational attraction of the observed galactic stars)?

String theory (**a cutting-edge research that has integrated [Einstein's] discoveries into a**

quantum universe with numerous hidden dimensions coiled into the fabric of the cosmos - dimensions whose geometry may well hold the key to some of the most profound questions ever posed) gives us a clue, but there's no definitive answer. Well, all know is that it is a sort of cosmic accelerator pedal or an invisible energy what made the universe bang and if we held it in our hand; we couldn't take hold of it. In fact, it would go right through our fingers, go right through the rock beneath our feet and go all the way to the majestic swirl of the heavenly stars. It would reverse direction and come back from the stately waltz of orbiting binary stars through the intergalactic night all the way to the edge of our feet and go back and forth. How near are we to understand the dark energy? The question lingers, answer complicates and challenges everyone who yearns to resolve. And once we understand the dark energy, can we understand the birth and the death of everything in the **mankind's observable universe**, from a falling apple to the huge furnace (that burns billions of pounds of matter each second and reaches temperatures of tens of millions of degrees at its core) and the earth (standing at the center of the universe, surrounded by eight spheres carrying all the known heavenly bodies) is also an?

Entropy (a thermodynamic quantity -- first introduced by the German physicist **Rudolf Clausius** (1822--1888) − a measure of untidiness in a system and a measure of how much information a system contains) is defined as: **S = k ln {number of states}** which, for N particles of the same type, will be:

$$S = \mathbf{k} \ln \{(\text{no of one-particle states})\ N\}$$

$$S = \mathbf{k}\ N \ln \{\text{a not-too-big number}\}$$

$$S = \mathbf{k}\ N$$

This means: the more particles, the more disorder. The entire universe is getting more disordered and chaotic with time i.e., the entropy of the universe is increasing toward greater disorder. And this observation is elevated to the status of a law, the so called **Second law of thermodynamics** (which was discovered by the great German physicist, **Ludwig Boltzmann** who laid down the second law of thermodynamics, committed suicide in 1906, in part because of the intense ridicule he faced while promoting the concept of atoms) i.e., the universe will tend toward a state of maximum entropy, such as a uniform gas near absolute zero (at this point, the atoms themselves almost come to a halt) and that there is nothing we have to do about it. No matter how advanced our conditions would be right for the generation of thoughts to predict things more or less, even if not in a simplest way, it can never squash the impending threat of the second law of thermodynamics (that will eventually result in the destruction of all intelligent life) nor it can bring us close to the answer of why was the entropy ever low in the first place. This makes cosmology (the study of the universe as a whole, including its birth and perhaps its ultimate fate) a bit more complicated than we would have hoped.

Explaining everything ... is one of the greatest challenges we have ever faced. Hence, it has been an endeavor of science to find a single theory which could explain everything, where every partial theory that we've read so far (in school) is explained as a case of the one cogent theory within some special circumstances. Despite being a mystery skeptic, the **Unified Field Theory** (which **Albert Einstein** sought [but never realized] during the last thirty years of his life and capable of describing nature's forces within a single, all-encompassing, coherent framework) presents an infinite problem. This is embarrassing. Because we now realize before we can work for the theory of everything, we have to work for the ultimate laws of nature. At the present, we’re clueless as to what the ultimate laws of nature really are. Are there new laws beyond the apparently observed dimensions of our universe? **Do all the fundamental laws of nature unify?** At what scale? Ultimately, however, it is likely that answers to these questions in the form of unified field theory may be found over the next few years or by the end of the century we shall know can there really be a complete unified theory that would presumably solve our problems? Or are we just chasing **a mirage**? Is the ultimate unified theory so compelling, that it brings about its own existence? However, if we − a puny and insignificant on the scale of the cosmos − do discover a unified field theory, it should in time be understandable in broad principle by everyone, not just a few people. Then we shall all be able to take part in the discussion of the questions of how and when did the universe begin? Was the universe created? Has this universe been here forever or did it have a beginning at the Big Bang? If the universe was not created, how did it get here? If the Big Bang is the reason there is something rather than nothing, and then before the Big Bang there was NOTHING and then suddenly we got **A HUGE AMOUNT OF ENERGY** where did it come from? What powered the Big Bang? What is the fate of the Universe? Is the universe heading towards a Big Freeze (the end of the universe when it reaches near absolute zero), a Big Rip, a Big Crunch (the final collapse of the universe), or a Big Bounce? Or is it part of an infinitely recurring cyclic model? Is inflation a law of Nature? Why the universe started off very hot and cooled as it expanded? Is the Standard Big Bang Model right? Or is it the satisfactory explanation of the evidence which we have and therefore merits our provisional acceptance? Is our universe finite or infinite in size and content? What lies beyond the existing space and time? What was before the event of creation? Why is the universe so uniform on a large scale (even though uncertainty principle − which fundamentally differentiates quantum from classic reasoning− discovered by the German physicist **Werner Heisenberg** in 1927 − implies that the universe cannot be completely uniform because there are some uncertainties or fluctuations in the positions and velocities of the particles)? Why does it look the same at all points of space and in all directions? In particular, why is the temperature of the cosmic microwave back- ground radiation so nearly the same when we look in different directions? Why are the galaxies distributed in clumps and filaments? When were the first stars formed, and what were they like? Or if string theory (which is part of a grander synthesis: M-theory and have captured the hearts and minds of much of the theoretical physics community while being apparently disconnected from any realistic chance of definitive experimental proof) is right i.e., every particle is a tiny one dimensional vibrating string of **Planck length** (the smallest possible length i.e., Planck time multiplied by the speed of light)?

Why most of the matter in the Universe is dark? **Is anthropic principle a natural coincidence?** If we find the answers to them, it would be the ultimate triumph of human reason i.e., we might hold the key to address the eternal conundrum of some of the most difficult issues in modern physics. Yet those difficult issues are also the most exciting, for those who address big, basic questions: What do we really know about the universe? How do we know it? Where did the universe come from, and where is it going? It would bring to an end a long and glorious lesson in the history of mankind's intellectual struggle to understand the universe. For then we would know whether the laws of physics started off the universe in such an incomprehensible way or not. **Chances are that these questions will be answered** long after we're gone, but there is hope that the beginnings of those answers may come within the next few years, as some aspects of bold scientific theory that attempts to reconcile all the physical properties of our universe into a single unified and coherent mathematical framework begin to enter the realm of theoretical and experimental formulation.

Up until recently, a multitude of revolutions in various domains, from literature to experimental science, has prevailed over established ideas of modern age in a way never seen before. But we do not know about what is the exact mechanism by which an implosion of a dying star becomes a specific kind of explosion called a **supernova**. All that we know is that: When a massive star runs out of nuclear fuel, the gravitational contraction continues increasing the density of matter. And since the internal pressure is proportional to the density of matter, therefore the internal pressure will continually increase with the density of matter. And at a certain point of contraction, internal pressure will be very much greater than gravitational binding pressure and will be **sufficiently high enough to cause the star to explode**, spraying the manufactured elements into space that would flung back into the gas in the galaxy and would provide some of the raw material for the next generation of stars and bodies that now orbit the sun as planets like the Earth. The total energy released would outshine all the other stars in the galaxy, approaching the luminosity of a whole galaxy (will nearly be the order of 10 to the power of 42 Joules). In the aftermath of the supernova, we find a totally **dead star, a neutron star** – a cold star, supported by the exclusion principle repulsion between neutrons – **about the size of Manhattan** (i.e., ten to 50 times the size of our sun).

Why are there atoms, molecules, solar systems, and galaxies? What powered them into existence? How accurate are the physical laws and equations, which control them? Why do the Fundamental Constants of Nature have the precise values they do? The answers have always seemed well beyond the reach of **Dr. Science since the dawn of humanity** − until now (some would claim the answer to these questions is that there is a transcendent God (a cosmic craftsman – a transcendent being than which no being could be more virtuous) who chose to create the universe that way according to some perfect mathematical principle. Then the question merely reflects to that of **who or what created the God**). But the questions are still the picture in the mind of many scientists today who do not spend most of their time worrying about these questions, but almost worry about them some of the time. All that science could say is that: The universe is as it is now. But it could not explain why it was, as it was, just after the Big Bang. **This is a disaster for science**. It would mean that science alone, could not predict how the universe began. Every attempt is made to set up the connection between theoretical predictions and experimental results but some of the experimental results throw cold water on the theoretical predictions.

Back in 1700s, people thought the stars of our galaxy structured the universe, that the galaxy was nearly static, and that the universe was essentially unexpanding with neither a beginning nor an end to time. A situation marked by difficulty with the idea of a static and unchanging universe, was that according to the **Newtonian theory of gravitation**, each star in the universe supposed to be pulled towards every other star with a force that was weaker the less massive the stars and farther they were to each other. It was this force caused all the stars fall together at some point. So how could they remain static? Wouldn't they all collapse in on themselves? A balance of the predominant attractive effect of the stars in the universe was required to keep them at a constant distance from each other. Einstein was aware of this problem. He introduced a term so-called **cosmological constant** in order to hold a static universe in which gravity is a predominant attractive force. This had an effect of a repulsive force, which could balance the predominant attractive force. In this way it was possible to allow a static cosmic solution. Enter the **American astronomer Edwin Hubble**. In 1920s he began to make observations with the hundred inch telescope on Mount Wilson and through detailed measurements of the spectra of stars he found something most peculiar: stars moving away from each other had their spectra shifted toward the red end of the spectrum in proportion to the distance between them (This was a **Doppler effect of light**: Waves of any sort − sound waves, light waves, water waves − emitted at some frequency by a moving object are perceived at a different frequency by a stationary observer. The resulting shift in the spectrum will be towards its red part when the source is moving away and towards the blue part when the source is getting closer). And he also observed that stars were not uniformly distributed throughout space, but were gathered together in vast collections called galaxies and nearly all the galaxies were moving away from us with recessional velocities that were roughly dependent on their distance from us. He reinforced his argument with the formulation of his well- known **Hubble's law**. The observational discovery of the stretching of the space carrying galaxies with it completely shattered the previous image of a static and unchanging cosmos (i.e., the motivation for adding a term to the equations disappeared, and Einstein rejected the cosmological constant a greatest mistake).

We story telling animals (who **TALK ABOUT THE** nature of the universe and discuss such questions as whether it has a beginning or an end) often claim that we know so much more about the universe. But we must beware of overconfidence. We have had false dawns before. At the beginning of this century, for example, it was thought that earth was a perfect sphere, but latter experimental observation of variation of value of **"g"** over the surface of earth confirmed that earth is not a **perfect sphere**. Today there is almost universal agreement that space itself is stretching, carrying galaxies with it, though we are experimentally trying to answer whether cosmic [expansion will] continue forever or slow to a halt, reverse itself [and] lead to a **cosmic implosion**. However, personally, we're sure that the accelerated expansion began with a state of infinite compression and primeval explosion called the hot Big Bang. But will it expand forever or there is a limit beyond which the average matter density exceeds a hundredth of a billionth of a billionth of a billionth (10^{-29}) of a gram per cubic centimeter so-called **critical density** (the density of the universe where the expansion of the universe is poised between eternal expansion and recollapse)... then a large enough gravitational force will permeate the cosmos to halt and reverse the expansion or the expansion and contraction are evenly balanced? We're less sure about that because events cannot be predicted with complete accuracy but that there is always a degree of uncertainty.

The picture of standard model of the Forces of Nature (a sensible and successive quantum-mechanical description developed by **1970s physicists**) is in good agreement with all the observational evidence that we have today and remains consistent with all the measured properties of matter made in our most sophisticated laboratories on Earth and observed in space with our most powerful telescopes. Nevertheless, it leaves a number of important questions unanswered like the unanswered questions given in The **Hitchhiker's Guide to the Galaxy (by Douglas Adams):** Why are the strengths of the fundamental forces (electromagnetism, weak and strong forces, and gravity) are as they are? Why do the force particles have the precise masses they do? Do these forces really become unified at sufficiently high energy? If so how? Are there unobserved fundamental forces that explain other unsolved problems in physics? Why is gravity so weak? May because of hidden extra dimensions? Very likely, we are missing something important that may seem as obvious to us as the earth orbiting the sun – or perhaps as ridiculous as a tower of tortoises. Only time (whatever that may be) will tell.

The theory of evolution (which predicts: that the use of antiviral or antibacterial agents would result in the emergence of resistant strains. This principle is, of course, a mainstay of contemporary medicine and asserts that the **natural selection** is a choice of stable forms and a rejection of unstable ones. And the variation within a species occurs randomly, and that the survival or extinction of each organism depends upon its ability (an internal force or tendency) to adapt to the environment) lined up pictures of apes and humans and claimed that humans evolved from apes (i.e., the chimpanzee and the human share **about 99.5 per cent** of their evolutionary history). This spilled out onto the corridors of the academy and absolutely rocked **Victorian England to the extent that people** just barely raised their voice contradicting the biblical account of creation in the lecture hall rips of the architrave. And despite more than a century of digging straight down and passing through the fossil layers, the fossil record remains maddeningly sparse and provides us with **no evidence that show evolutionary transition development of one species into another species**. However, we are convinced that the theory of evolution, especially the extent to which it’s been believed with blind faith, which may turn to be one of the great fairy tales for adults in the history books of the future. Like raisins in expanding dough, galaxies that are further apart are increasing their separation more than nearer ones. And as a result, the light emitted from distant galaxies and stars is shifted towards the red end of the spectrum. Observations of galaxies indicate that the universe is expanding: the distance D between almost any pair of galaxies is increasing at a rate $V = HD$ − beautifully explained by the Hubble’s law (the law that agrees with Einstein's theory of an expanding universe). However, controversy still remains on the validity of this law. **Andromeda, for example, for which the Hubble relation does not apply**. And quantum theory (The revolutionary theory of the last century clashed with everyday experience which has proved enormously successful, passing with flying colors the many stringent laboratory tests to which it has been subjected for almost a hundred years) predicts that entire space is not continuous and infinite but rather quantized and measured in units of quantity called Planck length (10^{-33} cm – the length scale found at the big bang in which the gravitational force was as strong as the other forces and at this scale, space-time was **"foamy,"** with tiny bubbles and wormholes appearing and disappearing into the vacuum). However, at the present there is no conclusive evidence in favor of quantization of space and time and moreover nobody knows why no spatial or time interval shorter than the Planck values exists?

For length: Planck length (a hundred **billion billion times** [10^{20}] smaller than an atomic nucleus) -1.6×10^{-33} centimeter.

For time: Planck time -5×10^{-44} seconds.

On the other hand, there is no evidence against what the quantum model inform us about the true nature of reality. But in order to unify **Albert Einstein's general relativity** (a theoretical framework for understanding the universe on the largest of scales: the immense expanse of the universe itself and it breaks down at times less than the Planck time and at distances smaller than the Planck length, predicts the existence of **wormhole** − a passageway between two universes – gives us a better way of grasping reality than Newtonian mechanics, because it tells us that there can be black holes, because it tells us there's a Big Bang) with the quantum physics that describe fundamental particles and forces, it is necessary to quantize space and perhaps time as well. And for a universe to be created out of nothing, the positive energy of motion should exactly cancel out the negative energy of gravitational attraction i.e., the net energy of the universe should be = zero. And if that's the case, the spatial curvature of the universe, $\mathbf{\Omega_k}$, should be = 0.0000 (i.e., perfect flatness). But the **Wilkinson Microwave Anisotropy Probe (WMAP)** satellite has established the spatial curvature of the universe, $\mathbf{\Omega_k}$, to be between **− 0.0174** and **+ 0.0051**. Then, how can it cost nothing to create a universe, how can a whole universe be created from nothing? On the other hand, there is a claim that the sum of the energy of matter and of the gravitational energy is equal to zero and hence there is a possibility of a universe appearing from nothing and thus the universe can double the amount of positive matter energy and also double the negative gravitational energy without violation of the conservation of energy. However, **energy of matter + gravitational energy is = zero** is only a claim based on Big Bang implications. No human being can possibly know the precise energy content of the entire universe. In order to verify the claim that the total energy content of the universe is exactly zero, one would have to account for all the forms of energy of matter in the universe, add them together with gravitational energy, and then verify that the sum really is exactly zero. But the attempt to verify that the sum really is exactly zero is not an easy task. We need precision experiments to know for sure.

Gazing at the at the blazing celestial beauty of the night sky and asking a multitude of questions that have puzzled and intrigued humanity since our beginning − **WE'VE DISCOVERED** a lot about our celestial home; however, we still stand at a critical cross road of knowledge where the choice is between spirituality and science to accomplish the hidden truth behind the early evolution of the universe. In order to throw light on a multitude of questions that has so long occupied the mind of scientists and the people who have argued over the years about the nature of reality and whose business it is to ask why, the philosophers: Where did we and the universe come from? Where are we and the universe going? What makes us and the universe exists? Why we born? Why we die? Whether or not the universe had a beginning? If the universe had a beginning, why did it wait an infinite time before it began? What was before the beginning? Is our universe tunneled through the chaos at the Planck time from a prior universe that existed for all previous time? We must either build a sound, balanced, effective and extreme imaginative knowledge beyond our limit. **Many theories were put forth by the scientists** to look into the early evolution of the universe but none of them turned up so far. And if, like me, you have wondered looking at the star, and tried to make sense of what makes it shine the way it is. Did it shine forever or was there a limit beyond which it cannot or may not shine? And, where did the matter that created it all come from? Did the matter have a beginning in time? Or had the matter existed forever and didn’t have a beginning? In other words, what cause made the matter exist? And, what made that cause exist? Some would claim the answer to this question is that matter could have popped into existence 13.9 billion years ago as a result of just the eminent physical laws and constants being there. **Any "meta" or "hyper" laws of physics** that would allow (even in postulate) a matter to pop into existence are completely outside our experience. The eminent laws of physics, as we know them, simply are not applicable here. Invoking the laws of physics doesn’t quite do the trick. And the laws of physics are simply the human-invented ingredients of models that we introduce to describe observations. They are all fictitious, as far as we find a reference frame in which they are observed. The question of matter genesis is clear, and deceptively simple. **It is as old as the question of what was going on before the**

Big Bang. Usually, we tell the story of the matter by starting at the Big Bang and then talking about what happened after. The answer has always seemed well beyond the reach of science. Until now.

Over the decades, there have been several heroic attempts to explain the origin of matter, all of them proven wrong. One was the so-called **Steady State theory**. The idea was that, as the galaxies moved apart from each other; new galaxies would form in the spaces in between, from matter that was spontaneously being created. The matter density of the universe would continue to exist, forever, in more or less the same state as it is today. In a sense disagreement was a credit to the model, every attempt was made to set up the connection between theoretical predictions and experimental results but the Steady State theory was disproved even with limited observational evidence. The theory therefore was abandoned and the idea of spontaneous creation of matter was doomed to fade away into mere shadows. As crazy as it might seem, the matter may have come out of nothing! The meaning of nothing is somewhat ambiguous here. It might be the pre-existing space and time, or it could be nothing at all. After all, no one was around when the matter began, so who can say what really happened? The best that we can do is work out the most vain imaginative and foolish theories, backed up by numerous lines of scientific observations of the universe.

Cats are alive and dead at the same time. But some of the most incredible mysteries of the quantum realm (a jitter in the amorphous haze of the subatomic world) get far less attention than Schrödinger's famous cat. Due to the fuzziness of **quantum theory** (that implies: the cosmos does not have just a single existence or history), and specifically Heisenberg's uncertainty principle (which fundamentally differentiates quantum from classic reasoning − discovered by the German physicist **Werner Heisenberg** in 1927), one can think of the vacuum fluctuations as virtual matter –antimatter pairs that appear together at some time, move apart, then come together and annihilate one another and revert back to energy. Spontaneous births and deaths of roiling frenzy of particles so called virtual matter –antimatter pairs momentarily occurring everywhere, all the time – is the evidence that mass and energy are interconvertible; they are two forms of the same thing. If one argue that matter was a result of such a fluctuation. So then the next question is what cause provided enough energy to make the virtual matter – antimatter pairs materialize in real space. And if we assume some unknown cause has teared the pair apart and boosted the separated **virtual matter –antimatter into the materialized state**. The question then is what created that cause. In other words, what factor created that cause? And what created that factor. Or perhaps, the cause, or the factor that created it, existed forever, and didn't need to be created. The argument leads to a never-ending chain that always leaves us short of the ultimate answer. Unfortunately, **Dr. Science cannot answer these questions**. So, the problem remains. However, quantum origin and separation of the matter still delights theoretical physicists but boggles the mind of mere mortals, is the subject of my thought; have the quantum laws found a genuinely convincing way to explain matter existence apart from divine intervention? If we find the answer to that, it would be the **ultimate triumph of human reason** – for then we would know the ultimate Cause of the Matter. Over the decades, we're trying to understand how the matter began and we're also trying to understand all the other things that go along with it. This is very much the beginning of the story and that story could go in, but I think there could be surprises that no one has even thought of. Something eternal can neither be created nor destroyed. The first law of thermodynamics (a version of the law of conservation of energy, adapted for thermodynamic systems) asserts that matter or energy can neither be created nor destroyed; it can be converted from one form to another.

The overwhelming experience of experimental science (science based on experimental research that plays the role of **testing hypothesis**, typically in controlled laboratory settings) confirms this first law to be a fact. But if the matter prevails in the boundary of understanding in that it neither started nor it ends: it would simply be. What place then for an evidence exposing that we live in a finite expanding universe which has not existed forever, and that all matter was once squeezed into an infinitesimally small volume, which erupted in a cataclysmic explosion which has become known as the Big Bang. However, what we believe about the origin of the matter is not only sketchy, but uncertain and based purely on human perception. There is no reliable and genuine evidence to testify about how the matter began and what may have existed before the beginning of the matter. **The laws of physics tell us that the matter had a beginning**, but they don't answer how it had begun. Mystery is running the universe in a hidden hole and corner, but one day it may wind up the clock work with might and main. The physical science can explain the things after big bang but fails to explain the things before big bang. We know that matter can be created out of energy, and energy can be created out of matter. This doesn't resolve the dilemma because we must also know where the original energy came from.

The electrostatic and gravitational forces according to **Coulomb's and Newton's laws** are both inverse square forces, so if one takes the ratio of the forces, the distances cancel. For the electron and proton, the ratio of the forces is given by the equation: $\frac{F_E}{F_G} = \frac{e^2}{4\pi\varepsilon_0 G m_p m_e}$, where e is the charge = 1.602×10^{-19} Coulombs, G is the gravitational constant, ε_0 is the absolute permittivity of free space = $8.8 \times 10^{-12} \frac{F}{m}$, m_p is the mass of the proton = 1.672×10^{-27} kg and m_e is the mass of the electron = 9.1×10^{-31} kg. Plugging the values we get: $\frac{F_E}{F_G} = 10^{39}$ which means: F_E is > F_G. So, it was argued by a German mathematician, theoretical physicist and philosopher (some say it was **Hermann Weyl**), if the gravitational force between the proton and electron were not much smaller than the electrostatic force between them, then the hydrogen atom would have collapsed to neutron long before there was a chance for stars to form and life to evolve. $F_E > F_G$ must have been numerically **fine-tuned** for the existence of life. Taking $\frac{F_E}{F_G} = 10^{39}$ as an example in most physics literature we will find that gravity is the weakest of all forces, many orders of magnitude weaker than electromagnetism. But this does not make sense any way and it is not true always and in all cases. Note that the ratio $\frac{F_E}{F_G}$ is not a universal constant; it's a number that depends on the particles we use in the calculation. For example: For two particles each of Planck mass (mass on the order of **10 billion billion times** that of a proton) and Planck charge the ratio of the forces is 1 i.e., $\frac{F_E}{F_G} = 1$. Moreover, when the relativistic variation of electron mass with velocity is taken into account then the ratio $\frac{F_E}{F_G}$ becomes velocity dependent.

Does our universe exist inside a black hole of another universe? The question lingers, unanswered until now. Even though the existence of alternative histories with black holes, suggests this might be possible i.e., our universe lies inside a black hole of another universe, we cannot prove or disprove this conjecture any way. Meaning that the event horizon of a black hole is boundary at which nothing inside can escape and then how might one can cross its event boundary and testify whether or not our universe exist inside a black hole of another universe. Thus we cannot answer the central question in cosmology: **Does our universe exist inside a black hole of another universe?** However, the fact that we are simply an advanced breed of talking monkeys surviving on a sumptuous planet, have been reckoning at least from last hundred years − turning unproved belief into unswerving existence through the power of perception and spending our brief time in the sun working at understanding the deepest mysteries of nature by doing repeated calculations and getting some answer that seem very likely makes us feel something very special-- a bit premature to buy tickets to the nearest galaxy to visit the next goldilocks planet or hunt dinosaurs.

The physicist has been spending a month, as he or she does each year, sequestered with colleagues, such as fellow theoretical physicists, to discuss many great mysteries of the cosmos. But despite its simple approximation as a force, and its beautifully subtle description as a property of space-time which in turn can be summarized by Einstein's famous equation, which essentially states: **Matter-energy → curvature of space- time**, we've come to realize over the past century that we still don't know what gravity actually is. It has been a closed book ever since the grand evolution of human understanding and all physicists hang this book up on their wall and distress about it. Unhesitatingly you would yearn to know where this book comes from: is it related to metaphysical science or perhaps to the greatest blast puzzles of physics still to be discovered, like cosmic string and magnetic monopoles? Nobody knows and for the moment, nature has not said yes in any sense. It's one of the **10,000 bits puzzling cosmic story** with a cracking title. You might say the laws of physics designed that book, and we don't know how they designed that book. The elevated design of this book, an extract of which appears in the cosmic art gallery, sets out to the belief that it must have designed as it could not have created out of chaos. In some sense, the origin of the cosmic problem today remains what it was in the time of **Newton** (who not only put forward a theory of how bodies move in space and time, but he also developed the complicated mathematics needed to analyze those motions) – one of the greatest challenges of 21st Century science certainly keep many an aficionado going. Yet, we toasting each other with champagne glasses in laboratories around the world-- have made a bold but brilliant move. In less than a hundred years, we have found a new way to wonder what gravity is. The usual approach of science of constructing a set of rules and equations cannot answer the question of why if you could turn off gravity, space and time would also vanish. In short, we don't have an answer; we now have a whisper of the grandeur of the problem. We don't know exactly how it is intimately related to space and time. It's a mystery that we're going to chip at from quantum theory (the theory developed from **Planck's quantum principle and Heisenberg's uncertainty principle** which deals with phenomena on extremely small scales, such as a millionth of a millionth of an inch). However, when we try to apply quantum theory to gravity, things become more complicated and confusing.

Mankind's deepest desire for scientific intervention introduced a **new idea that of time**. Most of the underlying assumptions of physics are concerned with time. Time may sound like a genre of fiction, but it is a well-defined genuine concept. Some argue that time is not yet discovered by us to be objective features of the mundane world: even without considering time an intrinsic feature of the mundane world, we can see that things in the physical world change, seasons change, people adapt to that drastic changes. The fact that the physical change is an objective feature of the physical world, and time is independent of under whatever circumstances we have named it. Others think time as we comprehend it does not endure beyond the bounds of our physical world. Beyond it, maybe one could run forward in time or just turn around and go back. This could probably mean that one could fall rapidly through their former selves. In a bewildering world, the question of whether the time never begin and has always been ticking, or whether it had a beginning at the big bang, is really a concern for physicists: either science could account for such an inquiry. If we find the answer to it, it would be the ultimate triumph of human justification for our continuing quest. And, our goal of a complete description of the universe we live in is self-justified. The understanding we have today is that time is not an illusion like what age-old philosophers had thought, but rather it is well defined mathematical function of an inevitable methodical framework for systematizing our experiences. If one believed that the time had a beginning, the obvious question was how it had started? The problem of whether or not the time had a beginning was a great concern to the **German Philosopher, Immanuel Kant** (who believed that every human concept is based on observations that are operated on by the mind so that we have no access to a mind- independent reality). He considered the entire human knowledge and came to the conclusion that time is not explored by humans to be objective features of the mundane world domain, but is a part of an inevitable systematic framework for coordinating our experiences. How and when did the time begin? No other scientific question is more fundamental or provokes such spirited debate among physicists. Since the early part of the 1900s, one explanation of the origin and fate of the universe, the Big Bang theory, has dominated the discussion. Although singularity theorem (a theorem showing that a singularity, a point where **general relativity** (a theory which predicts that time would come to an end inside a **black hole – an invisible astrophysical entity** that no one has seen, but scientists have observed gravitational evidence consistent with predictions about it, so most scientists believe it exists) breaks down, must exist under certain circumstances; in particular, that the universe must have started with a singularity) predicted that the time, the space, and the matter or energy itself had a beginning, they didn’t convey how they had a beginning. It would clearly be nice for singularity theorems if they had a beginning, but how can we distinguish whether they had a beginning? In as much as the time had a beginning at the Big Bang it would deepen implication for the role of supreme divine creator (that much of humanity worships as the source of all reality) in the grand design of creation.

But if it persists in the bounds of reason in that it has neither beginning nor end and nothing for a Creator to do. What role could ineffable benevolent creator have in creation? Life could start and new life forms could emerge on their own randomly sustaining themselves by reproducing in the environment fitted for the functional roles they perform. Personally, we're sure that the time began with a hot Big Bang. But will it go on ticking forever? If not, when it will wind up its clockwork of ticking? We’re much less sure about that. However, we are just a willful gene centered breed of talking monkeys on a minor planet of a very average galaxy. But we have found a new way to question ourselves and we have learned to do them. That makes us something very special. Moreover, everything we think we understand about the universe would need to be reassessed. Every high school graduate knows cosmology, the very way we think of things, would be forever altered. The distance to the stars and galaxies and the age of the universe (13.7 billion years − number has now been experimentally determined to within 1% accuracy) would be thrown in doubt. Even the expanding universe theory, the Big Bang theory, and black holes would have to be re- examined. The Big Bang theory of universe assumes the present form of the universe originated from the hot fire ball called singularity and it assumes time did not exist before the Big Bang. But **Erickcek** deduced on the basis of **NASA's, Wilkinson Microwave Anisotropy Probe (WMAP)** that the existence of time and empty space is possible before the Big Bang.

But what would happen if you travel back in time and kill your grandfather before he conceives your father? Would the arrow of time reverse? Because motion makes the clock tick slower, can we travel back in time and kill our grandfather before he conceive our father? If not, why the universe avoids the paradox? **Time Travel − Science Fiction?** Taking the laws of physics and punching them in the stomach and throwing them down the stairs – it's possible for you to break the universal speed limit. It is mind boggling to think about it – you're actually travelling backwards in time. What if you went back in time and prevented big bang from happening? You would prevent yourself from ever having been born! But then if you hadn't been born, you could not have gone back in time to prevent big bang from happening. The concept of time travel may sound something impressive and allow science fiction like possibilities for people who survived from the past, but somewhat it seems to be incredible like seeing **broken tea cups gathering themselves together off** the floor and jumping back on the table promoting cup manufacturers go out of business. However, travelling through time may not be the far-fetched science fiction theory. At the same time, can we open a portal to the past or find a shortcut to the future and master the time itself is still in question and forbidden by the second law of thermodynamics (which states that in any closed system like universe randomness, or entropy, never decreases with time). Of course, we have not seen anyone from the past (or have we?).

We asked how stars are powered and found the answer in the transformations of atomic nuclei. But there are still simple questions that we can ask. And one is: Is our universe merely the by-product of a cosmic accident? If the universe were merely the by-product of a grand accident, then our universe could have been a **conglomeration of objects** each going its own way. But everything we see in the universe obeys rules which are governed by a set of equations, without exception − which give philosophy a lot more attention than science. However, this does not mean that the universe obey rules because it exists in a plan which is created and shaped by a grinding hand.

Maybe the universe is a lucky coincidence of a grand accident emerged with ingredients such as space, time, mass, and energy exist in one-to-one correspondence with the elements of reality, and hence it obeys a set of rational laws without exception. At this moment it seems as though Dr. Science will never be able to raise the curtain on the mystery of creation. Moreover, traditional philosophy is dead, that it has not kept up with modern developments in science, and there is no reason at justifying the grinding hand because **the idea of God is extremely limited** and goes no further than the opening sentence of the classical theology (which has always rejected the idea that God can classified or defined), and much is still in the speculative stage, and we must admit that there are yet no empirical or observational tests that can be used to test the idea of an accidental origin. No evidence. **No scientific observation. Just a speculation**. For those who have lived by their faith in the power of reason, the story may end like a bad dream since free will is just an illusion.

From the Big Bang to the Bodies such as stars or black holes including basic facts such as particle masses and force strengths, the entire universe works because the laws of physics make things happen. But if Meta or hyper laws of physics were whatever produced the universe then what produced those laws. Or perhaps, the laws, or the cause that created them, existed forever, and didn't need to be created. We must admit that there is ignorance on some issues, that is, we **don't have a complete set of laws ….** We are not sure exactly does the existing laws hold everywhere and at all time. Dr. Science gives us a clue, but there's no definitive answer to provide a purely natural, non-causal explanation for the existence of laws of physics and our place in it. So let's just leave it at the hypothetical laws of physics. The question, then, is why are there laws of physics? And we could say, well, that required a biblical deity, who created these laws of physics and the spark that took us from the laws of physics to the notions of time and space. Well, if the laws of physics popped into existence 13.8 billion years ago with divine help whatsoever, like theologians say, why aren't we seeing a at least one evidence of an ineffable creator in our observable universe every now and then? The origin of the Meta or hyper laws of physics remains a mystery for now. However, recent breakthroughs in physics, made possible in part by fantastic revolutionary understanding of the true nature of the mathematical quantities and theories of physics, may suggest an answer that may seem as obvious to us as the earth orbiting the sun – or perhaps as ridiculous as earth is a perfect sphere. We don't know whatever the answer may be because the **Meta or hyper laws of physics** are completely beyond our experience, and beyond our imagination, or our mathematics. This fact leads us to a big mystery and awaits the next generation of high energy experiments, which hope to shed light on the far- reaching answer that might be found in the laws that govern elemental particles.

Who are we? We find that we intelligent apes who have only recently left the trees, live on an fragile planet of a humdrum star by a matter of sheer luck or by divine providence, lost in a galaxy tucked away in some forgotten corner of a universe in which there are far more galaxies than people. Sending the **Beatles song across the Universe** and pointing the telescopes in Deep Space Network towards the **North Star, Polaris**, we seek to find intellectual beings like us outside the sheer number of planets, vast ocean of existence, our solar system, and our own Milky Way galaxy. How awe hunting for them across the empty stretches of the universe would be to acquire a bit of confirmation that either we're alone in this universe or we are not. However, we are not the only life-form in the universe, is reasonable to expect since we have no reason to assume that ours is the only possible form of life. Some sort of life could have happened in a universe of greatly different form, but

Where's the evidence?

The Burden of evidence is only on the people who regard themselves as reliable witnesses that sightings of UFOs are evidence that we are being visited by someone living in another galaxy who are much more advanced enough to spread through some hundred thousand million galaxies and visit the Earth. An alien, like the teapot, is a hypothesis that requires evidence.

The known forces of nature can be divided into four classes:

Gravity: This is the weakest of the four; it acts on everything in the universe as an attraction. And if not for this force, we would go zinging off into outer space and the sun would detonate like trillions upon trillions of hydrogen bombs.

Electromagnetism: This is much stronger than gravity; it acts only on particles with an electric charge, being repulsive between charges of the same sign and attractive between charges of the opposite sign. More than half the gross national product of the earth, representing the accumulated wealth of our planet, depends in some way on the electromagnetic force. It light up the cities of New York, fill the air with music from radios and stereos, entertain all the people in the world with television, reduce housework with electrical appliances, heat their food with microwaves, track their planes and space probes with radar, and electrify their power plants.

Weak nuclear force: This causes radioactivity and plays a vital role in the formation of the elements in stars. And a slightly stronger this force, all the neutrons in the early universe would have decayed, leaving about 100 percent hydrogen, with no deuterium for later use in the synthesizing elements in stars.

Strong nuclear force: This force holds together the protons and neutrons inside the nucleus of an atom. And it is this same force that holds together the quarks to form protons and neutrons. Unleashed in the hydrogen bomb, the strong nuclear force could one day end all life on earth.

The inherent goal of unification is to show that all of these forces are, in fact, manifestations of a single super force. We can't perceive this unity at the low energies of our everyday lives, or even in our most powerful accelerators (capable of accelerating particles nearly up to the speed of light) at Fermi lab or **LHC, the Large Hadron Collider**, at CERN (European Centre for Nuclear Research), in Switzerland. But close to the Big Bang temperatures, at inconceivably high energies…

If the forces unify, the protons − which make up much of the mass of ordinary matter − can be unstable, and eventually decay into lighter particles such as antielectrons. Indeed, several experiments were performed in the **Morton Salt Mine in Ohio** to yield definite evidence of proton decay. But none have succeeded so far. However, the probability of a proton in the universe gaining sufficient energy to decay is so small that one has to wait at least a million million million million million years i.e., longer than the time since the big bang, which is about ten thousand million years.

Relative Strength of the Four Forces

Force: Nuclear
Relative Strength: 10^3

Force: Electromagnetic
Relative Strength: 1

Force: Weak
Relative Strength: 10^{-11}

Force: Gravitational
Relative Strength: 10^{-39}

Proton feel
Nuclear force: Yes
Electromagnetic force: Yes
Weak force: No
Gravitational force: Yes

Neutron feel
Nuclear force: Yes
Electromagnetic force: No
Weak force: No
Gravitational force: Yes

Electron feel

Nuclear force: No

Electromagnetic force: Yes

Weak force: Yes

Gravitational force: Yes

The eminent laws do not tell us why the initial configuration was such as to produce what we observe. For what purpose? Must we turn to the **anthropic principle for an explanation**? Was it all just a lucky chance? That would seem a counsel of despair, a negation of all our hopes of understanding the unfathomable order of the universe. However, this is an extended metaphor for many puzzles in physics uncovered with painstaking labor, and it is especially relevant to particle physics. Still, particle physics remains unfathomable to many people and a bunch of scientists chasing after tiny invisible objects.

If string theory is correct, then every particle is nothing but a vibrating, oscillating, dancing filament named a string. A string does something aside from moving – it oscillates in different ways. Each way represents a particular mode of vibration. Different modes of vibration make the string appear as a dark energy or a cosmic ray, since different modes of vibration are seen as different masses or spins.

If **Higgs theory (which is the last piece of the Standard Model that has still eluded capture – which is one of the theories LHC experimentalists hope to discover and it is the capstone for conventional big bang cosmology --which biblical creationists reject)** is correct, then a new field called the Higgs field which is analogous to the familiar electromagnetic field but with new kinds of properties permits all over the space (considered the origin of mass in Grand Unified Theory – a theory that unifies the weak, strong, and electromagnetic interactions, without gravity). Different masses of the particles are due to the different strengths of interaction of the particle with the Higgs field (more the strength of interaction of the particle with the Higgs field, more the mass of the particle).To make this easier for you, let's say it is cosmic high-fructose corn syrup − the more you go through it, the heavier you get.

Which explanation is right?

Higgs theory runs rampant in the popular media claiming that String Theory Is Not The Only Game In Town. However, by the end of the decade, we will have our first glimpse of the new physics, whatever it well may be

STRING or HIGGS

The new physics will point to even more discoveries at the TeV scale and opens the door beyond the Standard Model and raise new questions like: if the Higgs field generate masses for the W and Z, and for the quarks and leptons − does it generate its own mass and if so how? What is its mass?

Dr. Science remains silent on the profound questions. Ultimately, however, one would hope to find complete, consistent answers that would include all the mathematical techniques as approximations. The quest for such answers is known as the **grand unification** of the two basic partial theories: **the general theory of relativity** (which states that space and time are no longer absolute, no longer a fixed background to events. Instead, they are dynamical quantities that are shaped by the matter and energy in the universe) and quantum mechanics (a theory of the microcosm which has upended many an intuition, but none deeper than this one − developed by 1900 physicists in response to a number of glaring problems that arose when 19th century conceptions of physics were applied to the **microscopic world**, where subatomic particles are held together by particle like forces dancing on the sterile stage of space- time, which is viewed as an empty arena, devoid of any content). Unfortunately, however, these two theories are inconsistent with each other – i.e., **quantum mechanics and general relativity** do not work together. How the ideas of general relativity can be consolidated with those of quantum theory is still a? Until we progress closer toward the laws that govern our universe.

The latest theory of subatomic particles (the quantum theory) gives an estimated value of vacuum energy density that is about 120 orders of magnitude larger than the measured value — claiming our best theory cannot calculate the value of the largest energy source in the entire universe. Dr. Science advances over the wreckage of its theories by continually putting its ideas to experimental test; no matter how beautiful its idea might be; it must be discarded or modified if it is at odds with experiment. It would have been clearly be nice for quantum theory if the value of vacuum energy density were in the order of 10^{96} kg per cubic meter, but the measured value were in the order of 10^{-27} kg per cubic meter. Thus, the best candidate we have at the moment, the quantum theory, brought about its downfall by predicting the value of vacuum energy density that is about 120 orders of magnitude larger than the measured value.

We a lot of exposure with darkness and disbelief and a state of not having an immediate conclusion, and this vulnerability is of great significance, I think. When we don't comprehend the mind of nature, we are in the middle of darkness. When we have an intuitive guess as to what the outcome is; we are unsealed. And when we are fairly damn sure of what the final result is going to be, we are still in **some uncertainty**. And uncertainty being too complex to come about randomly is evidence for human continuing quest for justification. Sometimes, very hard, impossible things just strike and we call them thoughts. In most of the self-reproducing organisms the conditions would not be right for the generation of thoughts to predict things more or less, even if not in a simplest way, only in the few complex organisms like us spontaneous thoughts would generate and what is it that breathes fire into a perception. The human perception is enormous; it's extensive and unlimited, and outrageous that we can ask simple questions. And they are: **What the dark energy is up to?** What it is about? Why this mysterious form of energy permeates all of space blowing the galaxies farther and farther apart? How accurate are the physical laws (which are essentially the same today as they were at the time of **Newton despite the scientific revolutions and paradigm shifts**), which control it? Why it made the universe bang? Unfortunately, the laws that we are using are not able to answer these questions because of the prediction that the universe started off with infinite density at the big bang singularity (where all the known laws would break down). However, if one looks in a commonsense realistic point of view the laws and equations which are considered as inherent ingredients of reality − are simply the man-made ingredients introduced by the rational beings who are free to observe the universe as they want and to draw logical deductions from what they see − to describe the objective features of reality. The scientific data is fallible, changeable, and influenced by scientific understanding is refreshing. Here's an example of what I mean. In most physics textbooks we will read that the strength of the electromagnetic force is measured by the dimensionless parameter $\alpha = \frac{e^2}{4\pi\hbar c\varepsilon_0}$ (where e is the charge = 1.602 × 10 $^{-19}$ Coulombs, ε_0 is the absolute permittivity of free space = 8.8 × 10 $^{-12}$ $\frac{F}{m}$, c is the speed of light in vacuum (an awkward conversion factor for everyday use because it's so big. Light can go all the way around the equator of the Earth in about 0.1 seconds) and ħ is the reduced Planck's constant), called the fine structure constant, which was taught to be constant became variant when the standard model of elementary particles and forces revealed that α actually varies with energy.

$$\text{Quantum field theory} = \{\text{Group theory} + \text{quantum mechanics}\}$$

$$\text{Lim}_{N \to \infty} \text{ Quantum mechanics} = \text{Quantum field theory}$$

The **Quantum theory of electrodynamics** (a relativistic quantum field theory or a quantum field theory – arguably the most precise theory of natural phenomena ever advanced which seems to govern everything small – through which we have been able to solidify the role of photons as the **"smallest possible bundles of light"** and to reveal their interactions with electrically charged particles such as electrons, in a mathematically complete, predictive, and convincing framework) and **General Relativity** (which dominates large things and is now called a classical theory which predicts that the universe started off with infinite density at the big bang singularity) both try to assign mass to the singularity. But according to generally accepted history of the universe, according to what is known as the hot big bang model. At some finite time in the past i.e., between ten and twenty thousand million years ago. At this time, all matter (which is characterized by the physical quantity we define as mass) would have been on top of each other − which is called the singularity, the density would have been **INFINITE**. Under such conditions, all the known laws of science would break down. However, a good mathematical theory can prove anything with that amount of wiggle room, and findings are really determined by nothing except its desire. For all theoreticians and tens of thousands of university graduates at least know, the universe started off with infinite density at the hot big bang singularity with infinitely hot temperatures. And at such high temperatures that are reached in thousands of H-bomb explosions, the strong and weak nuclear forces and the gravity and electromagnetic force were all unified into a single force. What was before the Big Bang? Was the Big Bang created? If the Big Bang was not created, how was this Big Bang accomplished, and what can we learn about the agent and events of creation? Is it the product of chance or was been designed? What is it that blocked the pre-Big Bang view from us? Is Big Bang singularity an impenetrable wall and we cannot, in physics, go beyond it? To answer one question, another question arises. **Erickcek's model** suggests the possibility of existence of space and time before the big bang. But the world famed Big Bang theory abandons the existence of space and time before the big bang. Both the theories are consistent and based upon sophisticated experimental observations and theoretical studies. Truth must be prejudiced with honest scientific inquiry to **illuminate the words of Genesis**. And this is possible only if the modern scientific community would simply open its eyes to the truth.

Do black holes really exist? If they exist, why we haven't observed one hole yet? Can black holes be observed directly, and if so, how? If the production of the tiny black holes is feasible, can particle accelerators, such as the **Large Hadron Collider (LHC) in Switzerland** at the famed **CERN nuclear laboratory** create a micro black hole that will eventually eat the world? If not − if there are no black holes, what are the things we detect ripping gas off the surface of other stars? What is the structure of space-time just outside the black hole? Do their space times have horizons? : are the major questions in theoretical physics today that haunts us. The effort to resolve these complex paradoxes is one of the very few things that lifts human mind a little above the level of farce, and gives it some of the grace of province inspiring new ideas and new experiments.

Since gravity weakens with distance, the earth pulls on your head with less force than it pulls on your feet, which are a meter or two closer to the earth's center. The difference is so tiny we cannot feel it, but an astronaut near the surface of a black hole would be literally torn apart. Most people think of a black hole as a voracious whirlpool in space, sucking down everything around it. But that’s not really true! A black hole is a place where gravity has gotten so strong that even light cannot escape out of its influence.

How a black hole might be formed?

The slightly denser regions of the nearly uniformly distributed atoms (mostly hydrogen) which lack sufficient energy to escape the gravitational attraction of the nearby atoms, would combine together and thus grow even denser, forming giant clouds of gas, which at some point become gravitationally unstable, undergo fragmentation and would break up into smaller clouds that would collapse under their own gravity. As these collapses, the atoms within them collide with one another more and more frequently and at greater and greater speeds – the gas heats up i.e., the temperature of the gas would increase, until eventually it become hot enough to start nuclear fusion reactions. And a consequence of this is that the stars like our sun (which are made up of more than one kind of gas particle) are born to radiate their energy as heat and light.

But the stars with a physical radius smaller than its **Schwarzschild radius** further collapse to produce dark or frozen stars (i.e., the mass of a star is concentrated in a small enough spherical region, so that its mass divided by its radius exceeds a particular critical value, the resulting space-time warp is so radical that anything, including light, that gets too close to the star will be unable to escape its gravitational grip).

And these dark stars are sufficiently massive and compact and possess a strong gravitational field that prevent even light from escaping out its influence: any light emitted from the surface of the star will be dragged back by the star's gravitational attraction before it could get very far. Such stars become black voids in space and were coined in 1969 by **the American scientist John Wheeler "the black holes"** (i.e., black because they cannot emit light and holes because anything getting too close falls into them, never to return). Classically, the gravitational field of the black holes (which seem to be among the most ordered and organized objects in the whole universe) is so strong that they would prevent any information including light from escaping out of their influence i.e., any information is sent down the throat of a black hole or swallowed by a black hole is forever hidden from the outside universe (this goes by the statement that **"black holes have no hair"** — that is, they have lost all information, all hair, except for these three parameters: its mass, spin and charge), and all one could say of the gravitational monster what the poet Dante said of the entrance to Hell: "All hope abandon, ye who enter here." Anything or anyone who falls through the black hole will soon reach the region of infinite density and the end of time. However, only the laws of classical general relativity does not allow anything (not even light) to escape the gravitational grip of the black hole but the inclusion of quantum mechanics modifies this conclusion− quantum fields would scatter off a black hole. Because energy can be created out of nothing, the pair of short-lived virtual particles (one with positive energy and the other with negative energy) appears close to the event horizon of a black hole. The gravitational might of the black hole inject energy into a pair of virtual particles ... that tears them just far enough apart so that one with negative energy gets sucked into the hole even before it can annihilate its partner ... its forsaken partner with positive energy... gets an energy boost from the gravitational force of the black hole ... escape outward to infinity (an abstract mathematical concept that was precisely formulated in the work of **mathematician Georg Cantor** in the late nineteenth century)... where it appear as a real particle (and to an observer at a distance, it will appear to have been emitted from the black hole). **Because E= mc squared (i.e., energy is equivalent to mass)**, a fall of negative energy particle into the black hole therefore reduces its mass with its horizon shrinking in size. As the black hole loses mass, the temperature of the black hole (which depends only on its mass) rises and its rate of emission of particle increases, so it loses mass more and more quickly. We don't know does the emission process continue until the black hole dissipates completely away or does it stop after a finite amount of time leaving black hole remnants.

The attempt to understand the Hawking radiation has a profound impact upon the understanding of the black hole thermodynamics, leading to the description of what the black hole entropic energy is.

Black hole entropic energy = Black hole temperature × Black hole Entropy

This means that the entropic energy makes up half of the mass energy of the black hole. For a black hole of one solar mass ($M = 2 \times 10^{30}$ kg), we get an entropic energy of 9×10^{46} joules – much higher than the thermal entropic energy of the sun.

It is only theoretically possible that black holes with mass M = mass of the electron could be created in high energy collisions. No black holes with mass M = mass of the electron have ever been observed, however – indeed, normally the creation of micro black holes (with mass <= mass of the electron) take place at high energy (i.e., $>10^{28}$ electron volts − roughly greater than million tons of **TNT explosive**), which is a quadrillion times beyond the energy of the LHC. Even if the quantum black holes (with mass <= mass of the electron) are created, they would be extremely difficult to spot - and they are the large emitters of radiation (because $T = \frac{\hbar c^3}{8\pi G M k_B}$) and they shrink and dissipate faster even before they are observed. Though the emission of particles from the primordial black holes is currently the most commonly accepted theory within scientific community, there is some disputation associated with it. There are some issues incompatible with quantum mechanics that it finally results in information being lost, which makes physicists discomfort and this raises a serious problem that strikes at the heart of our understanding of science. However, most physicists admit that black holes must radiate like hot bodies if our ideas about general relativity and quantum mechanics are correct. Thus even though they have not yet managed to find a primordial black hole emitting particles after over two decades of searching. Despite its strong theoretical foundation, the existence of this phenomenon is still in question. Alternately, those who don't believe that black holes themselves exist are similarly unwilling to admit that they emit particles.

In the nuclear reaction mass of reactants is always greater than mass of products. The mass difference is converted to energy, according to the equation which is as famous as the man who wrote it.

For a nuclear reaction: $p + Li_7 \rightarrow \alpha + \alpha + 17.2$ MeV

Mass of reactants:

p = 1.0072764 amu

Li_7 = 7.01600455 amu

Total mass of reactants = 7.01600455 amu + 1.0072764 amu = 8.02328095 amu

Mass of products:

α= 4.0015061amu

Total mass of products = α + α = 2α = 8.0030122 amu

As from above data it is clear that

Total mass of reactants is greater than Total mass of products. The mass difference (8.02328095 amu − 8.0030122 amu = 0.02026875 amu) is converted to energy 18.87 MeV, according to the equation $\mathbf{E = mc^2}$. However, the observed energy is 17.2 MeV.

Expected energy = 18.87 MeV (i.e., 0.02026875 amu × c^2)

Experimentally observed energy = 17.2 MeV

Expected energy is ≠ observed energy

Energy difference = (18.87 − 17.2) MeV =1.67 MeV

Where the energy 1.67 MeV is gone? The question is clear and deceptively simple. But the answer is just being blind to the complexity of reality. Questions are guaranteed in Science; Answers aren't.

If we could peer into the fabric of space- time at the Planck length (the distance where the smoothness of relativity's space-time and the quantum nature of reality begin to rub up against each other), we would see the 4 dimensional fabric of space-time is simply the lowest energy state of the universe. It is neither empty nor uninteresting, and its energy is not necessarily zero (which was discovered by **Richard Dick Feynman**, a colorful character who worked at the California Institute of Technology and played the bongo drums at a strip joint down the road− for which he received Nobel Prize for physics in 1965). Because E = mc squared, one can think that the virtual particle-antiparticle pairs of mass m are continually being created out of energy E of the 4 dimensional fabric of space-time consistent with the **Heisenberg's uncertainty principle of quantum mechanics** (which tells us that from a microscopic vantage point there is a tremendous amount of activity and this activity gets increasingly agitated on ever smaller distance and time scales), and then, they appear together at some time, move apart, then come together and annihilate each other giving energy back to the space-time without violating the law of energy conservation (which has not changed in four hundred years and still appear in **relativity** and **quantum mechanics**). Spontaneous births and deaths of virtual particles so called **quantum fluctuations occurring everywhere**, all the time − is the conclusion that mass and energy are interconvertible; they are two different forms of the same thing. However, spontaneous births and deaths of so called virtual particles can produce some remarkable problem, because infinite number of virtual pairs of mass m can be spontaneously created out of energy E of the 4 dimensional fabric of space-time, does the 4 dimensional fabric of space-time bears an infinite amount of energy, therefore, by Einstein's famous equation $E = mc^2$, does it bears an infinite amount of mass. If so, according to general relativity, the infinite amount of mass would have curved up the universe to infinitely small size. But which obviously has not happened. The word virtual particles literally mean that these particles cannot be observed directly, but their indirect effects can be measured to a remarkable degree of accuracy. Their properties and consequences are well established and well understood consequences of quantum mechanics (which states that the position of a particle is uncertain, and therefore that there is some possibility that a particle will be within an energy barrier rather than outside of it. The process of moving from outside to inside without traversing the distance between is known as **quantum tunneling, and it is very important for the fusion reactions in stars like the Sun**). However, they can be materialized into real particles by several ways. All that one require an energy = energy required to tear the pair apart + energy required to boost the separated virtual particle- antiparticles into real particles (i.e., to bring them from virtual state to the materialize state).

When Einstein was 26 years old, he calculated precisely how energy must change if the relativity principle was correct, and he discovered the relation $E= mc^2$ (which led to the Manhattan Project and ultimately to the bombs that exploded over **Hiroshima and Nagasaki** in 1945). This is now probably the only equation in physics that even people with no background in physics have at least heard of this and are aware of its prodigious influence on the world we live in. And since c is constant (because the maximum distance a light can travel in one second is 3 ×10 to the power of 8 meter), this equation tells us that mass and energy are interconvertible and are two different forms of the same thing and are in fact equivalent. Suppose a mass m is converted into energy E, the resulting energy carries mass = m and moves at the speed of light c. Hence, energy E is defined by E= mc squared. As we know c squared (the speed of light multiplied by itself) is an astronomically large number: 9 × 10 to the power of 16 meters square per second square. So if we convert a small amount of mass, we'll get a tremendous amount of energy. For example, if we convert 1kg of mass, we'll get energy of 9 × 10 to the power of 16 Joules (i.e., the energy more than 1 million times the energy released in a chemical explosion. **Perhaps since c is not just the constant namely the maximum distance**

a light can travel in one second but rather a fundamental feature of the way space and time are married to form space-time. One can think that in the presence of unified space and time, mass and energy are equivalent and interchangeable. But WHY? The question lingers, unanswered. Until now.

However, the equation $E = mc^2$ (where E is energy, m is mass, and c is the speed of light. People often employ this equation to calculate how much energy would be produced if, say, a bit of matter was converted into pure electromagnetic radiation. (**Because the speed of light is a large number, the answer is a lot—the weight of matter converted to energy in the bomb that destroyed the city of Hiroshima was less than one ounce.**) But the equation also tells us that if the energy of an object increases, so does its mass, that is, its resistance to acceleration, or change in speed) has some remarkable consequences (e.g. conversion of less than 1% of 2 pounds of uranium into energy was used in the atomic bomb over Hiroshima and body at rest still contains energy. When a body is moving, it carries an additional energy of motion called kinetic energy. In chemical and nuclear interactions, kinetic energy can be converted into rest energy, which is equivalent to generating mass. Also, the rest energy can be converted into kinetic energy. In that way, chemical and nuclear interactions can generate kinetic energy, which then can be used to run engines or blow things up). Because $E = mc^2$, the energy which a body possess due to its motion will add to its rest mass. This effect is only really significant for bodies moving at speeds close to the speed of light. For example, at 10 percent of the speed of light a body's mass M is only 0.5 percent more than its rest mass m, while at 90 percent of the speed of light it would be more than twice its rest mass. And as an body approaches the speed of light, its mass raise ever more quickly, it acquire infinite mass and since an infinite mass cannot be accelerated any faster by any force, the issue of infinite mass remains an intractable problem. For this reason all the bodies are forever confined by relativity to move at speeds slower than the speed of light. Only tiny packets/particles of light (dubbed "**photons**" by chemist Gilbert Lewis) that have no intrinsic mass can move at the speed of light. There is little disagreement on this point. Now, being more advanced, we do not just consider conclusions like photons have no intrinsic mass. We constantly test them, trying to prove or disprove. So far, relativity has withstood every test. And try as we might, we can measure no mass for the photon. We can just put upper limits on what mass it can have. These upper limits are determined by the sensitivity of the experiment we are using to try to weigh the photon. The last number we can see that a photon, if it has any mass at all, must be less than 4 ×10 to the power of − 48 grams. For comparison, the electron has a mass of 9 × 10 to the power of − 28 grams. Moreover, if the mass of the photon is not considered to zero, then quantum mechanics would be in trouble. And it also an uphill task to conduct an experiment which proves the photon mass to be exactly zero. Tachyons the putative class of hypothetical particles (with negative mass: $\mathbf{m < 0}$) is believed to travel faster than the speed of light. But, the existence of tachyons is still in question and if they exist, how can they be detected is still a? However, on one thing most physicists agree: (Just because we haven't found anything yet that can go faster than light doesn't mean that we won't one day have to eat our words. We should be more open-minded to other possibilities that just may not have occurred to us). Moreover, in expanding space − recession velocity keeps increasing with distance. Beyond a certain distance, known as the Hubble distance, it exceeds the velocity greater than the speed of light in vacuum. But, this is not a violation of relativity, because recession velocity is caused not by motion through space but by the expansion of space.

E= hυ (which implies the energy a photon can have is proportional to its frequency: larger frequency (shorter wavelength) implies larger photon energy and smaller frequency (longer wavelength) implies smaller photon energy) – because h is constant, energy and frequency of the photon are equivalent and are different forms of the same thing. And since h − which is one of the most fundamental numbers in physics, ranking alongside the speed of light c and confines most of these radical departures from life-as- usual to the microscopic realm − is incredibly small (i.e., 6 × 10 to the power of –34 — a decimal point followed by 33 zeros and a 6 — of a joule second), the frequency of the photon is always greater than its energy, so it would not take many quanta to radiate even ten thousand megawatts. And some say the only thing that quantum mechanics (the great intellectual achievement of the first half of this century) has going for it, in fact, is that it is unquestionably correct. Since the Planck's constant is almost infinitesimally small, quantum mechanics is for little things. Suppose this number would have been too long to keep writing down i.e., h would have been = 6.625×10 to the power of 34 Js, then quantum mechanical effects would have been noticeable for macroscopic objects. For example, the De Broglie wavelength of a 100 kg man walking at 1 m/s would have

been = $\frac{h}{mv}$ = (6.625 ×10 ^{34} Js) / (100kg) (1m/s) = 6.625 × 10 to the power of 32 m (very large to be noticeable).

Are Neutrinos Massless? If not they could contribute significantly to the mass of the universe? Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one hundred-thousandth that of an electron. The work on atomic science in the first thirty five years of this century took our understanding down to lengths of a millionth of a millimeter. Then we discovered that protons and neutrons are made of even smaller particles called quarks (which were named by the Caltech physicist **Murray Gell-Mann**, who won the **Nobel Prize in 1969** for his work on them). We might indeed expect to find several new layers of structure more basic than the quarks and leptons that we now regard as elemental particles. Are there elementary particles that have not yet been observed, and, if so, which ones are they and what are their properties? What lies beyond the quarks and the leptons? If we find answers to them, then the entire picture of particle physics would be quite different.

Experimental evidence supporting the **Watson and Crick model** was published in a series of five articles in the same issue of Nature – caused an explosion in biochemistry and transformed the science. Of these, Franklin and Gosling's paper was the first publication of their own x-ray diffraction data and original analysis method that partially supported the Watson and Crick model; this issue also contained an article on DNA (a main family of polynucleotides in living cells) structure by **Maurice Wilkins and two of his colleagues, whose analysis supported their double-helix molecular model of DNA**. In 1962, after **Franklin's death**, Watson, Crick, and Wilkins jointly received the Nobel Prize in Physiology or Medicine. From each gene's point of view, the 'background' genes are those with which it shares bodies in its journey down the generations. DNA (**deoxyribonucleic acid**) – which is known to occur in the chromosomes of all cells (whose coded characters spell out specific instructions for building willow trees that will shed a new generation of downy seeds). Most forms of life including vertebrates, reptiles, Craniates or suckling pigs, chimps and dogs and crocodiles and bats and cockroaches and humans and worms and dandelions, carry the amazing complexity of the information within the some kind of replicator—molecules called DNA in each cell of their body, that a live reading of that code at a rate of one letter per second would take thirty-one years, even if reading continued day and night. Just as protein molecules are chains of amino acids, so DNA molecules are chains of nucleotides. Linking the two chains in the DNA, are pairs of nucleic acids (**purines + pyrimidines**). There are four types of nucleic acid, adenine "A", cytosine "C", guanine "G", and thiamine "T." An adenine (**purine**) on one chain is always matched with a thiamine (**pyrimidine**) on the other chain, and a guanine (**purine**) with a cytosine (**pyrimidine**). Thus DNA exhibits all the properties of genetic material, such as replication, mutation and recombination. Hence, it is called the molecule of life. We need DNA to create enzymes in the cell, but we need enzymes to unzip the DNA. Which came first, proteins or protein synthesis? If proteins are needed to make proteins, how did the whole thing get started? We need precision genetic experiments to know for sure.

A theory is a good theory if it satisfies one requirement. It must make definite predictions about the results of future observations. Basically, all scientific theories are scientific statements that predict, explain, and perhaps describe the basic features of reality. Despite having received some great deal, discrepancies frequently lead to doubt and discomfort. For example, the most precise estimate of sun's age is around 10 million years, based on linear density model. But geologists have the evidence that the formation of the rocks, and the fossils in them, would have taken hundreds or thousands of millions of years. This is far longer than the age of the Earth, predicted by linear density model. Hence the earth existed even before the birth of the sun! Which is absolutely has no sense. The linear density model therefore fails to account for the age of the sun. Any physical theory is always provisional, in the sense that it is only a hypothesis: it can be disproved by finding even a single observation that disagrees with the predictions of the theory. Towards the end of the nineteenth century, physicists thought they were close to a complete understanding of the universe. They believed that entire universe was filled by a **hypothetical medium called the ether.** As a material medium is required for the propagation of waves, it was believed that light waves propagate through ether as the pressure waves propagate through air. Soon, however, inconsistencies with the idea of ether begin to appear. Yet a series of experiments failed to support this idea. The most careful and accurate experiments were carried out by two Americans: **Albert Michelson and Edward Morley** (who showed that light always traveled at a speed of one hundred and eighty six thousand miles a second (no matter where it came from) and disproved **Michell and Laplace's idea** of light as consisting of particles, rather like cannon balls, that could be slowed down by gravity, and made to fall back on the star) at the Case School of Applied Science in Cleveland, Ohio, in 1887 − which proved to be a serve blow to the existence of ether. All the known subatomic particles in the universe belong to one of two groups, Fermions or bosons. Fermions are particles with integer spin ½ and they make up ordinary matter. Their ground state energies are negative. Bosons are particles (whose ground state energies are positive) with integer spin 0, 1, 2 and they act as the force carriers between fermions (For example: The electromagnetic force of attraction between electron and a proton is pictured as being caused by the exchange of large numbers of virtual massless bosons of spin 1, called photons).

Positive ground state energy of bosons plus negative ground state energy of fermions = 0

But Why? May be because to eliminate the biggest infinity in supergravity theory (the theory which introduced a superpartner to the conjectured subatomic particle with spin 2 that is the quanta of gravity "the graviton" (called the **gravitino, meaning "little graviton," with spin** $\frac{3}{2}$) – that even inspired one of the most brilliant theoretical physicists since Einstein “Stephen Hawking” to speak of "the end of theoretical physics" being in sight when he gave his inaugural lecture upon taking the **Lucasian Chair of Mathematics at Cambridge** University, the same chair once held by **Isaac Newton** – a person who developed the theory of mechanics, which gave us the classical laws governing machines which in turn, greatly accelerated the Industrial Revolution, which unleashed political forces that eventually overthrew the feudal dynasties of Europe)?

There is strong evidence ... that the universe is permeated with dark matter approximately six times as much as normal visible matter (i.e. invisible matter became apparent in 1933 by Swiss **astronomer Fritz Zwicky** – which can be considered to have energy, too, because $E = mc^2$ – exist in a huge halo around galaxies and does not participate in the processes of nuclear fusion that powers stars, does not give off light and does not interact with light but bend starlight due to its gravity, somewhat similar to the way glass bends light). Although we live in a dark matter dominated universe (i.e., dark matter, according to the latest data, makes up 23 percent of the total matter/energy content of the universe) experiments to detect dark matter in the laboratory have been exceedingly difficult to perform because dark matter particles such as the neutralino, which represent higher vibrations of the superstring – interact so weakly with ordinary matter. Although dark matter was discovered almost a century ago, it is still a mystery shining on library shelves that everyone yearns to resolve.

Opening up the splendor of the immense heavens for the first time to serious scientific investigation. On the short time scale of our lives, not surprisingly, we underwent many transformations in our slow, painful evolution, an evolution often overshadowed by religious dogma and superstition to seek the answer to the question from the beginnings of our understanding. No progress was made in any scientific explanations because the experimental data were non-existent and there were no theoretical foundations that could be applied. In the latter half of the 20th century, there were several attempts such as quantum mechanics (the theory of subatomic physics and is one of the most successful theories of all time which is based on three principles: (1) **energy is found in discrete packets called quanta**; (2) matter is based on point particles but the probability of finding them is given by a wave, which obeys the Schrödinger wave equation; (3) a measurement is necessary to collapse the wave and determine the final state of an object), the "**big bang**," probability theory, the general relativity (a theoretical framework of geometry which has been verified experimentally to better than 99.7 percent accuracy and predicts that the curvature of space-time gives the illusion that there is a force of attraction called gravity) to adjust to ensure agreement with experimental measurements and answer the questions that have so long occupied the mind of philosophers (from **Aristotle to Kant**) and scientists. However, we must admit that there is ignorance on some issues, for example, "*we don't have a complete theory of universe which could form a framework for stitching these insights together into a seamless whole – capable of describing all phenomena…. We are not sure exactly how universe happened*." However, the generally accepted history of the universe, according to what is so-called the big bang theory (proposed by a Belgian priest, **Georges Lemaître, who learned of Einstein's theory** and was fascinated by the idea that the theory logically led to a universe that was expanding and therefore had a beginning) has completely changed the discussion of the origin of the universe from almost pure speculation to an observational subject. In such model one finds that our universe started with an explosion. This was not any ordinary explosion as might occur today, which would have a point of origin (center) and would spread out from that point. The explosion occurred simultaneously everywhere, filling all space with infinite heat and energy. At this time, order and structure were just beginning to emerge – the universe was hotter and denser than anything we can imagine (at such temperatures and densities (of about a trillion trillion trillion trillion trillion trillion (1 with 72 zeros after it) tons per cubic inch) gravity and quantum mechanics were no longer treated as two separate entities as they were in point-particle quantum field theory, the four known forces were unified as one unified super force) and was very rapidly expanding much faster than the speed of light (this did not violate Einstein's dictum that nothing can travel faster than light, because it was empty space that was expanding) and cooling in a way consistent with **Einstein field equations**. As the universe was expanding, the temperature was decreasing. Since the temperature was decreasing, the universe was cooling and its curvature energy was converted into matter like a formless water vapor freezes into snowflakes whose unique patterns arise from a combination of symmetry and randomness. Approximately 10^{-37} seconds into the expansion, a phase transition caused a cosmic inflation, during which the universe underwent an incredible amount of superliminal expansion and grew exponentially by a factor e^{3Ht} (where H was a constant called **Hubble parameter** and t was the time) – just as the prices grew by a factor of ten million in a period of 18 months in Germany after the First World War and it doubled in size every tiny fraction of a second – just as prices double every year in certain countries. After inflation stopped, the universe was not in a de Sitter phase and its rate of expansion was no longer proportional to its volume since H was no longer constant. At that time, the entire universe had grown by an unimaginable factor of 10^{50} and consisted of a hot plasma "**soup**" of high energetic quarks as well as leptons (a group of particles which interacted with each other by exchanging new particles called the W and Z bosons as well as photons). And quarks and gluons were "**deconfined**" and free to move over distances much larger than the hadron size (>>1 fm) in a soup called quark gluon plasma (QGP). There were a number of different varieties of quarks: there were six "**flavors**," which we now call up, down, strange, charmed, bottom, and top. And among the leptons the electron was a stable object and muon (that had mass 207 times larger than electron and now belongs to the second redundant generation of particles found in the **Standard Model**) and the tauon (that had mass 3,490 times the mass of the electron) were allowed to decay into other particles. And associated to each charged lepton, there were three distinct kinds of ghostly particles called neutrinos (the most mysterious of subatomic particles, are difficult to detect because they rarely interact with other forms of matter. Although they can easily pass through a planet or solid walls, they seldom leave a trace of their existence. Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one- hundred-thousandth that of an electron):

- the electron neutrino (which was predicted in the early 1930s by Wolfgang Pauli and discovered by **Frederick Reines and Clyde Cowan** in mid-1950s)
- the muon neutrino (which was discovered by physicists when studying the cosmic rays in late 1930s)
- the tauon neutrino (a heavier cousin of the electron neutrino)

Temperatures were so high that these quarks and leptons were moving around so fast that they escaped any attraction toward each other due to nuclear or electromagnetic forces. However, they possessed so much energy that whenever they collided, particle – antiparticle pairs of all kinds were being continuously created and destroyed in collisions. And the uncertainty in the position of the particle times the uncertainty in its velocity times the mass of the particle was never smaller than a certain quantity, which was known as Planck's constant. Similarly, $\Delta E \times \Delta t$ was $\leq \frac{h}{4\pi}$ (where h was a quantity called **Planck's constant** and $\pi = 3.14159\ldots$ was the familiar ratio of the circumference of a circle to its diameter). Hence the **Heisenberg's uncertainty principle** (which captures the heart of quantum mechanics – i.e. features normally thought of as being so basic as to be beyond question (e.g. that objects have definite positions and speeds and that they have definite energies at definite moments) are now seen as mere artifacts of Planck's constant being so tiny on the scales of the everyday world) was a fundamental, inescapable property of the universe. At some point an unknown reaction led to a very small excess of quarks and leptons over antiquarks and antileptons — of the order of one part in 30 million. This resulted in the predominance of matter over antimatter in the universe. The universe continued to decrease in density and fall in temperature, hence the typical energy of each particle was decreased in inverse proportion to the size of the universe (since the average energy – or speed – of the particles was simply a measure of the temperature of the universe). The symmetry (a central part of the theory [and] its experimental confirmation would be a compelling, albeit circumstantial, piece of evidence for strings) however, was unstable and, as the universe cooled, a process called spontaneous symmetry breaking phase transitions placed the fundamental forces of physics and the parameters of elementary particles into their present form. After about 10^{-11} seconds, the picture becomes less speculative, since particle energies drop to values that can be attained in particle physics experiments. At about 10^{-6} seconds, there was a continuous exchange of smallest constituents of the strong force called gluons between the quarks and this resulted in a force that pulled the quarks to form little wisps of matter which obeys the strong interactions and makes up only a tiny fraction of the matter in the universe and is dwarfed by dark matter called the baryons (protons – a positively charged particles very similar to the neutrons, which accounts for roughly half the particles in the nucleus of most atoms − and neutrons – a neutral subatomic particles which, along with the protons, makes up the nuclei of atoms – belonged to the class baryons) as well as other particles. The small excess of quarks over antiquarks led to a small excess of baryons over antibaryons. The proton was composed of two up quarks and one down quark and the neutron was composed of two down quarks and one up quark. And other particles contained other quarks (strange, charmed, bottom, and top), but these all had a much greater mass and decayed very rapidly into protons and neutrons. The charge on the up quark was = $+\frac{2}{3}$ e and the charge on the down quark was = $-\frac{1}{3}$ e. The other quarks possessed charges of $+\frac{2}{3}$ e or $-\frac{1}{3}$ e. The charges of the quarks added up in the combination that composed the proton but cancelled out in the combination that composed the neutron i.e.,

$$\text{Proton charge was} = (\tfrac{2}{3}\text{ e}) + (\tfrac{2}{3}\text{ e}) + (-\tfrac{1}{3}\text{ e}) = \text{e}$$
$$\text{Neutron charge was} = (\tfrac{2}{3}\text{ e}) + (-\tfrac{1}{3}\text{ e}) + (-\tfrac{1}{3}\text{ e}) = 0$$

And the force that confined the rest mass energy of the proton or the neutron to its radius was so strong that it is now proved very difficult if not impossible to obtain an isolated quark. As we try to pull them out of the proton or neutron it gets more and more difficult. Even stranger is the suggestion that the harder and harder if we could drag a quark out of a proton this force gets bigger and bigger – rather like the force in a spring as it is stretched causing the quark to snap back immediately to its original position. This **property of confinement** prevented one from observing an isolated quark (and the question of whether it makes sense to say quarks really exist if we can never isolate one was a controversial issue in the years after the quark model was first proposed). However, now it has been revealed that experiments with large particle accelerators indicate that at high energies the strong force becomes much weaker, and one can observe an isolated quark. In fact, the standard model (one of the most successful physical theories of all time and since it fails to account for gravity (and seems so ugly), theoretical physicists feel it cannot be the final theory) in its current form requires that the quarks not be free. The observation of a free quark would falsify that **aspect of the standard model**, although nicely confirm the quark idea itself and fits all the experimental data concerning particle physics without exception. Each quark possessed baryon number = $\frac{1}{3}$: the total baryon number of the proton or the neutron was the sum of the baryon numbers of the quarks from which it was composed. And the electrons and neutrinos contained no quarks; they were themselves truly fundamental particles. And since there were no electrically charged particles lighter than an electron and a proton, the electrons and protons were prevented from decaying into lighter particles – such as photons (that carried zero mass, zero charge, a definite energy $E = pc$ and a momentum $p = mc$) and less massive neutrinos (with very little mass, no electric charge, and no radius — and, adding insult to injury, no strong force acted on it). And a free neutron being heavier than the proton **was not prevented from decaying into a proton** (plus an electron and an antineutrino). The temperature was now no longer high enough to create new proton–antiproton pairs, so a mass annihilation immediately followed, leaving just one in 10^{10} of the original protons and neutrons, and none of their antiparticles (i.e., antiparticle was sort of the reverse of matter particle. The counterparts of electrons were positrons (positively charged), and the counterparts of protons were antiprotons (negatively charged). Even neutrons had an antiparticle: antineutrons. A similar process happened at about 1 second for electrons and positrons (positron: the antiparticle of an electron with exactly the same mass as an electron but its electric charge is +1e). After these annihilations, the remaining protons, neutrons and electrons were no longer **moving relativistically and the energy density of the universe** was dominated by photons − (what are sometimes referred to as the messenger particles for the electromagnetic force) − with a minor contribution from neutrinos. The density of the universe was about 4×10^{9} times the density of water and much hotter than the center of even the hottest star – no ordinary components of matter as we know them – molecules, atoms, nuclei – could hold together at this temperature. And the total positive charge due to protons plus the total negative charge due to electrons in the universe was = 0 (Just what it was if electromagnetism would not dominate over gravity and for the universe to remain electrically neutral).

And a few minutes into the expansion, when the temperature was about a billion (one thousand million; 10 to the power of 9) kelvin and the density was about that of air, protons and neutrons no longer had sufficient energy to escape the attraction of the strong nuclear force and they started to combine together to produce the universe's deuterium and helium nuclei in a process **called Big Bang nucleosynthesis**. And most of the protons remained uncombined as hydrogen nuclei. And inside the tiny core of an atom, consisting of protons and neutrons, which was roughly 10 −13 cm across or roughly an angstrom, a proton was never permanently a proton and also a neutron was never permanently a neutron. They kept on changing into each other. A neutron emitted a π **meson** (a particle predicted by Hideki Yukawa (for which he was awarded the Nobel Prize in physics in 1949) – composed of a quark and antiquark, which is unstable because the quark and antiquark can annihilate each other, producing electrons and other particles) and became proton and a proton absorbed a π meson and became a neutron. That is, the exchange force resulted due to the absorption and emission of π mesons kept the protons and neutrons bound in the nucleus. And the time in which the absorption and emission of π mesons took place was so small that π mesons were not detected. And a property of the strong force called asymptotic freedom caused it to become weaker at short distances. Hence, although quarks were bound in nuclei by the strong force, they moved within nuclei almost as if they felt no force at all.

Within only a few hours of the big bang, the Big Bang nucleosynthesis stopped. And after that, for the next million years or so, the universe just continued expanding, without anything much happening. Eventually, once the temperature had dropped to a few thousand degrees, there was a continuous exchange of virtual photons between the nuclei and the electrons. And the exchange was good enough to produce — what else? — A force (proportional to a quantity called their charge and inversely proportional to the square of the distance between them). And that force pulled the electrons towards the nuclei to form neutral atoms (the basic unit of ordinary matter, made up of a tiny nucleus (consisting of protons and neutrons) surrounded by orbiting electrons). And these atoms reflected, absorbed, and scattered light and the resulted light was red shifted by the expansion of the universe towards the microwave region of the electromagnetic spectrum. And there was cosmic microwave background radiation (which, through the last 15 billion years of cosmic expansion, has now cooled to a mere handful of degrees above absolute zero (–273ºC − the lowest possible temperature, at which substances contain no heat energy and all vibrations stop—almost: **the water molecules are as fixed in their equilibrium positions as quantum uncertainty allows**) and today, scientists measure tiny deviations within this background radiation to provide evidence for inflation or other theories).

The irregularities in the universe meant that some regions of the nearly uniformly distributed atoms had slightly higher density than others. The gravitational attraction of the extra density slowed the expansion of the region, and eventually caused the region to collapse to form galaxies and stars. And the nuclear reactions in the stars transformed hydrogen to helium (composed of two protons and two neutrons and **symbolized by** $_2\mathbf{He}^4$, highly stable—as predicted by the rules of quantum mechanics) to carbon (with their self- bonding properties, provide the immense variety for the complex cellular machinery— no other element offers a comparable range of possibilities) with the release of an enormous amount of energy via Einstein's equation $E = mc^2$. This was the energy that lighted up the stars. And the process continued converting the carbon to oxygen to silicon to iron. And the nuclear reaction ceased at iron. And the star experienced several chemical changes in its innermost core and these changes required huge amount of energy which was supplied by the severe gravitational contraction. And as a result the central region of the star collapsed to form a neutron star. And the outer region of the star got blown off in a tremendous explosion called a supernova, which outshone an entire galaxy of 100 billion stars, spraying the manufactured elements into space. And these elements provided some of the raw material for the generation of cloud of rotating gas which went to form the sun and a small amount of the heavier elements collected together to form the asteroids, stars, comets, and the bodies that now orbit the sun as planets like the Earth and their presence caused the fabric of space around them to warp (more massive the bodies, the greater the distortion it caused in the surrounding space).

The earth was initially very hot and without an atmosphere. In the course of time the planet earth produced volcanoes and the volcanoes emitted water vapor, carbon dioxide and other gases. And there was an atmosphere. This early atmosphere contained no oxygen, but a lot of other gases and among them some were poisonous, such as hydrogen sulfide (the gas that gives rotten eggs their smell). And the sunlight dissociated water vapor and there was oxygen. And carbon dioxide in excess heated the earth and balance was needed. So carbon dioxide dissolved to form carbonic acid and carbonic acid on rocks produced limestone and subducted limestone fed volcanoes that released more carbon dioxide. And there was high temperature and high temperature meant more evaporation and dissolved more carbon dioxide. And as the carbon dioxide turned into limestone, the temperature began to fall. And a consequence of this was that most of the water vapor condensed and formed the oceans. And the low temperature meant less evaporation and carbon dioxide began to build up in the atmosphere. And the cycle went on for billions of years. And after the few **billion years, volcanoes ceased to exist**. And the molten earth cooled, forming a hardened, outer crust. And the earth's atmosphere consisted of nitrogen, oxygen, carbon dioxide, plus other miscellaneous gases (hydrogen sulfide, methane, water vapor, and ammonia). And then a continuous electric current through the atmosphere simulated lightning storms. And some of the gases came to be arranged in the form of more complex organic molecules such as **simple amino acids (the basic chemical subunit of proteins, when, when linked together, formed proteins)** and carbohydrates (which were very simple sugars). And the water vapor in the atmosphere probably caused millions of seconds of torrential rains, during which the organic molecules reached the earth. And it took two and a half billion years for an ooze of organic molecules to react and built earliest cells as a result of chance combinations of atoms into large structures called macromolecules and then advance to a wide variety of one – celled organisms, and another billion years to evolve through a highly sophisticated form of life to primitive mammals endowed with two elements: genes (a set of instructions that tell them how to sustain and multiply themselves), and metabolism (a mechanism to carry out the instructions). But then evolution seemed to have speeded up. It only took about a hundred million years to develop from the early mammals (the highest class of animals, including the ordinary hairy quadrupeds, the whales and Mammoths , and characterized by the production of living young which are nourished after birth by milk from the teats (**MAMMAE, MAMMARY GLANDS**) of the mother) to Homosapiens. This picture of a universe that started off very hot and cooled as it expanded (like when things are compressed they heat up ... and, when things ... expand ... they cool down) is in agreement with all the observational evidence which we have today (and it explains **Olbers' paradox**: The paradox that asks why the night sky is black. If the universe is infinite and uniform, then we must receive light from an infinite number of stars, and hence the sky must be white, which violates observation). Nevertheless, it leaves a number of important questions unanswered:

Why the universe started off very hot i.e., why it violently emerged from a state of infinite compression? Why is the universe the same everywhere i.e., looks the same from every point (homogeneous) and looks the same in every direction (isotropic)? If the cosmic inflation made the universe flat, homogeneous and isotropic, then what is the hypothetical field that powered the inflation? What are the details of this inflation?

Much is explained by protons and electrons. But there remains the neutrino…

$\approx 10^{9}$ neutrinos / proton. What is their physical picture in the universe?

What is our physical place in the universe?
Present 13.8 billion years after the Big Bang
We can only see the surface of the sky where light was scattered.

The big bang theory, on its own, cannot explain these features or answer these questions because of its prediction that the universe started off with infinite density at the big bang singularity. At the singularity (a state of infinite gravity), all the known physical laws of cosmology would break down: one couldn't predict what would come out of the infinitely dense Planck-sized nugget called the **singularity**. The search for the origin and fate of the universe (which is determined by whether the Omega (Ω_0) density parameter is less than, equal to or greater than 1) is a distinctly human drama, one that has stretched the mind and enriched the spirit. We (a species ruled by all sorts of closer, warmer, ambitions and perceptions) are all, each in our own way, seekers of an absolute limit of scientific explanation (that may never be achieved) and we each long for an answer to why we exist... as our future descendants marvels at our new view of the universe ... we are... contributing our wrong to the human letter reaching for the stars. In the millennia of Homo sapiens evolution, we have found it something quite . . . puzzling. Even that great Jewish scientist Albert Einstein (**who freed us from the superstition of the past and interpreted the constancy of the speed of light as a universal principle of nature that contradicted Newtonian theory**) sustained a mystical outlook on the universe that was, he said, constantly renewed from the wonder and humility that filled him when he gazed at the universe. I wonder, can our finite minds ever truly understand such things as mysticism and infinity?

Undisturbed space + rigid mass was = distorted space

$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

$G_{\alpha\beta}$ → curvature of space

$T_{\alpha\beta}$ → distribution of mass/ energy

$\frac{8\pi G}{c^4}$ → Constant

But WHY? Maybe because matter and energy warp time and cause the time dimension to mix with the space?

The universe is a pretty big place seems like an awful waste of space.

- Nearest star: 4.22 light years.
- Nearest galaxy: 2.44 million light years.

- Galaxies within our horizon are now 40 billion light years away.
- Universe beyond horizon: 10 to the 10 to the 100 times bigger.

The Goldilocks Planet is not all that well suited for human life.

- 2/3 salt water unfit for drinking.
- Humans are restricted only to surface.
- Atmosphere does not block harmful ultraviolet radiation which causes skin cancer and other genetic disorders.
- Natural calamities like floods, earthquakes, famine and droughts, diseases like cancer, AIDS, kill millions millions of people yearly.

Only two photons of every billion emitted by sun are used to warm the Earth surface, the rest radiating uselessly into space. And lack of oxygen and cosmic microwave background radiation (which is well characterized by a (2.728 ± 0.002) Kelvin black body spectrum over more than three decades in frequency) prevents humans from spending years in outer space.

The fine tuning coincidences are updated and refurbished and have been somewhat misleadingly categorized under the designation **anthropic principle**, a term coined by astronomer **Brandon Carter in 1974** – which states that the physical properties of the universe are as they are because they permit the emergence of life. This teleological principle tries to explain why some physical properties of matter seem so fine-tuned as to permit the existence of life -- and are widely claimed to provide prima facie evidence for purposeful design—a design with life and perhaps humanity in mind. However, fine tuning coincidences are only needed to fill in the details of evidence for the existence of insulated interpositions of Divine power. If the universe were congenial to human life, then we would expect it to be easy for humanlike life to develop and survive throughout the vast stretches of the universe (an intricately complex place). We must admit that much of what we believe, including our fundamental coincidences about the universe is a blind leap of faith. We, after all, carbon-based biological systems operating a billion times slower than computer chips made of silicon, can carry the implications of the illusion of intelligent design about as far as we can imagine we could go -- classifying as an argument from design is the contemporary claim that the laws and constants of physics are "fine-tuned" so that the universe is able to contain life – which is commonly -- have been publicized in the popular print media, featured in television specials on PBS and BBC, and disseminated through a wide variety of popular and scholarly books, including entries from prestigious academic publishing houses such as Oxford and Cambridge University Presses -- but misleading. Furthermore, blind faith can justify anything and we have no reason to conclude that earthlike planets and sunlike stars and life itself are far too complex to have arisen by coincidence or could not have had a purely accidental origin because astrobiologists have now demonstrated that captured material from a comet -- analyzed immediately after striking Earth so that effects of contamination by earthly matter are minimal-- possessed lysine, an amino acid, in the sample, suggesting that the evolution of life on Earth had only begun after accidental jump-start from space i.e., the first ingredients of life accidently came from space after Earth formed.

LONG STANDING QUESTIONS

- Are there undiscovered principles of nature: new symmetries, new physical laws?

- How can we solve the mystery of dark energy? Are dark energy and the Higgs field related?

- What are neutrinos telling us? Is dark matter is made up of weakly interacting massive particles (something like heavy versions of the neutrinos)?

- What is dark matter? How can we make it in the laboratory?

- Why are there so many kinds of particles? Why the Higgs exists and who its cosmological cousins are?

- Which particles are travelers in extra dimensions, and what are their locations within them? Is our Universe part of a Multiverse?

- How did the universe come to be? What happened to the antimatter? What do we learn about the early Universe from experiments at the LHC? Can precise measures of the distribution of galaxies and DM unveil the nature of DM/DE?

- Why there is missing energy from a weakly interacting heavy particle? Is the direct discovery of the effects of extra dimensions or a new source of matter- antimatter asymmetry possible? An all- embracing theory of physics that unifies quantum mechanics (which applies to the very small: atoms, subatomic particles and the forces between them) and general relativity (which applies to the very large: stars, galaxies and gravity, the driving force of the cosmos) would solve the problem of describing everything in the universe from the big bang to subatomic particles? Our leading candidate for a theory of everything is known as M-theory. It grew from a merger of the two seemingly different approaches: 11-dimensional supergravity and 10-dimensional superstring theory. Could this be the final theory of everything? What do observations of galaxies at early times tell us about how galaxies were made?

Mapping the dark universe

PROFILING THE INVISIBLE

Is Cosmology about to SNAP?

Or does it explain everything about the universe?

To answer these most challenging questions about the nature of the universe and led down open doors into new insights and findings, all the approaches must converge. Results from accelerator experiments at LHC must agree with most powerful and insightful astrophysical observations and results from sophisticated data. However, the experiments necessary to go beyond the existing knowledge of standard physics are rapidly becoming prohibitively expensive and time consuming and the macroscopic experiments are difficult to perform in the laboratory as subatomic reactions at the incredible energy scale of 10^9 GeV -- which is far beyond the range of our largest particle accelerators and it is the biggest embarrassment in all of modern physics and if you listen closely, you can almost hear the dreams of physicists everywhere being shattered.

DECODING THE UNIVERSE SINCE 1905

Atom → nucleus → proton →

quark So, particle physics

finished……

Or is it not?

If it is not, then what completes the particle physics?

"What we know is a drop, what we don't know is an ocean."

− Isaac Newton

"If the whole universe has no meaning, we should never have found out that it has no meaning: just as, if there were no light in the universe and therefore no creatures with eyes, we should never know it was dark. Dark would be without meaning."

— C.S. Lewis

Visible light can be split into its components by a prism

Why we haven't found signs of aliens yet?

Perhaps they are content to stay at home

Perhaps it takes longer

Perhaps it has happened but we are not aware of it

Because:

$$\text{Apparent brightness} \propto \frac{\text{Luminosity}}{(\text{distance})^2}$$

The farther away an object is the fainter it appears.

Universality of Physical Laws

The same physical laws apply everywhere in the universe

Nebulae

Emission nebula → formed of ionized gases that emit light of various wavelengths

Absorption nebulae → mass of interstellar gas and dust that absorbs most or all of the light from the stars behind it

Reflection nebulae → clouds of interstellar dust which reflect the light of a nearby star

Planetary nebula → formed by matter ejected by red giant stars

Supernova remnants → remains from violent explosion of a star, often leaves neutron star (**pulsar**)

Spiral nebula → a galaxy having a spiral structure

Synchrotron Radiation

Magnetic fields bend the paths of charged particles → acceleration → radiation

Interstellar medium	**Intergalactic medium**	**Intercluster medium**
Gas resides between stars within a galaxy	Gas resides between galaxies within the cluster	Gas resides between galactic clusters

The cosmological constant is not zero. The vacuum energy of the universe speeds up the cosmic expansion. This vacuum energy is termed Dark Energy

Urey-Miller Experiment

H_2O (water) + CH_4 (methane) + NH_3 (ammonia) + CO_2 (carbon dioxide) + electric spark

↓

Amino acids – the basic building blocks of life

- **SETI** → search for extraterrestrial intelligence
- **CETI** → communication with extraterrestrial intelligence

Landauer limit:

Minimum possible amount of energy required to erase one bit of information

$$E = \ln 2\, k_B T$$

where k_B is the Boltzmann constant (approximately 1.38×10^{-23} J/K), T is the temperature of the heat sink in Kelvins, and ln2 is the natural logarithm of 2 (approximately 0.69315).

Chandrasekhar limit

Maximum mass of a stable white dwarf star

$$M_{limit} = \frac{\omega_3^0 \sqrt{3\pi}}{2} \frac{M_{Planck}^3}{m_p^2 \mu_e^2} = 1.4 \text{ Solar mass}$$

where:

- ħ is the reduced Planck constant
- c is the speed of light
- G is the gravitational constant
- μ_e is the average molecular weight per electron, which depends upon the chemical composition of the star.
- m_p is the mass of the proton.
- $\omega_3^0 \approx 2.018236$.

Modern Physics

- **Electrons in an atom exist in certain allowed energy states.**
- **When an electron makes a transition from a higher energy level to a lower energy level, radiation is emitted. The energy of the emitted radiation is determined by the difference in the energies of the two atomic energy levels:**

$$\boxed{\Delta E = E_2 - E_1 = h\upsilon}$$

where: E_1 and E_2 are the energies of the levels involved in transition, h is Planck's constant and υ is the frequency of the emitted.

The atomic electron emits a photon when it makes a transition from a higher energy level to a lower energy level giving rise to emission spectrum

The atomic electron absorbs a photon when it makes a transition from a lower energy level to a higher energy level giving rise to absorption spectrum

No 2 elements have the same type of emission spectra because each one of them has a characteristic set of allowed energy levels.

Red shift	**Blue shift**
If the star is moving away from the Earth, the wavelength is shifted towards longer wavelength	If the star is moving towards the Earth, the wavelength is shifted towards shorter wavelength

Hot light source → **Cloud of gas** $\xrightarrow{\text{Spectroscope}}$ **Continuous spectrum with dark lines**

Hot light source → Spectroscope → **Continuous spectrum**

Cloud of gas → Spectroscope → **Bright-line spectrum**

Graph in which the intrinsic brightness of stars are plotted against their temperatures

Hertzsprung–Russell diagram provides information about:

- **Size of stars**
- **Luminosity of stars**
- **Mass of stars**
- **Spectral type of stars**
- **Absolute magnitude of stars**

50 to 80% of the mass of a typical star is made of hydrogen.

Luminosity class	
Ia	Bright supergiant **(β Orionis)**
Ib	Supergiant **(Polaris)**
II	Bright giant **(ε Canis Majoris)**
III	Giant **(α Aurigae)**
IV	Subgiant **(α Aquilae)**
V	Main-sequence star **(Sun)**

Spectro-luminosity classification

Schönberg-Chandrasekhar limit → $\frac{M_{core}}{M} = 0.37 \frac{\mu_{env}^2}{\mu_{core}^2}$

- M_{core} → mass of the core.
- M →mass of the whole star.
- μ_{core} → mean molecular mass of the core.
- μ_{env} → mean molecular mass of the envelope.

Above **Schönberg-Chandrasekhar limit**, star core begins to contract rapidly. Contraction heats core, sets up temperature gradients, makes core radiate.

According to the Bekenstein bound, the entropy of a black hole is proportional to the number of Planck areas that it would take to cover the black hole's event horizon.

Correspondence principle:

For large orbits and for large energies, quantum calculations agree with classical calculations.

The magnitude of Earth's gravitomagnetic field at its equator is:

$$B = \frac{2\pi GM}{5Rc^2T}$$

- M is the mass
- R is the radius
- T is the rotational period.

Baryon asymmetry parameter:

$$\eta = \frac{n_B - \bar{n}_B}{n_\gamma}$$

- n_B = number density of Baryons
- $\bar{n}_B$ = number density of Antibaryons
- n_γ = number density of cosmic background radiation photons

Unsolved problem in physics:

Why is the strong nuclear interaction force CP-invariant?

The most underrated puzzle in all of physics

The **Standard Model** is inherently an incomplete theory.

Does not explain the strong **CP problem**, neutrino oscillations, matter–antimatter asymmetry, and the nature of dark matter and dark energy.

Dynamic equilibrium

The energy radiated by a star is equal to the energy supplied from its core

Photospheric granulation of the Sun is caused due to convective transport of energy in which the hot matter comes out to the solar surface from layers below the surface.

The gravitational binding energy of a star of mass M and radius R:

$$E_B = -\frac{3GM^2}{5R}$$

This means that during the formation of a star, an energy equal to $\frac{3GM^2}{5R}$ is released.

The **Solar energy** would last only for about 10^7 yrs if $\frac{3GM^2}{5R}$ was its only source. But, the results obtained on the basis of method of dating rocks and minerals using radioactive isotopes of different types of meteorites, deep terrestrial oceanic sediments and lunar rocks suggest an age of $\approx 5 \times 10^9$ years for the Sun. Thus, the **gravitational potential energy** cannot be the source for the total power output of the Sun radiated to space.

Classically, the temperature required to provide sufficient energy to two nuclei so that they overcome Coulombic barrier is much higher than the core temperature of the Sun ($\approx 1.5 \times 10^7$ K). Thus, classical physics is inadequate to explain the possibility of nuclear fusion reactions in stars.

10 dimensions	used to describe superstring theory
11 dimensions	used to describe supergravity and M-theory

Lorenz number:

$$L = \frac{\pi^2 k_B^2}{3e^2} = \frac{\pi c_1 R_K}{6c_2^2}$$

- c_1 : first radiation constant
- c_2 : second radiation constant
- R_K : von Klitzing constant

At Planck energy:

$$\sqrt{\frac{\hbar c^5}{G}} = 1.22 \times 10^{19}\ \text{GeV}$$

Quantum effects of gravity become strong

The ultra-high-energy cosmic ray observed in 1991 had a measured energy of about 50 J, equivalent to about $2.5\times10^{-8}\sqrt{\frac{\hbar c^5}{G}}$.

Unsolved problem in physics:

Can we measure the neutrino masses? Do neutrinos follow Dirac or Majorana statistics?

The Sun has mass 1.99×10^{33} g and radius 6.96×10^{10} cm.

$$\frac{2GM}{c^2 r} = 4.24 \times 10^{-6}$$

$$\frac{2GM}{c^2 r} << 1$$

1 pc = 3.262 ly = 2.06×10^5AU = 3.084×10^{16}m

The light gathering power of a telescope refers to its ability to collect light from an object.

General relativity → **Very important** in

- The study of collapsed stars
- The study of the entire universe

1 solar radius = 7×10^8 m

1 solar mass = 2×10^{30} kg

1 solar luminosity = 4×10^{26} W.

Optical depth describes how much absorption occurs when light travels through an absorbing object

- If the optical depth >> 1, then the object is optically thick
- If the optical depth << 1, then the object is optically thin

A smaller apparent magnitude means a brighter star.

Parallax is the apparent change in the position of an object due to a change in the location of the observer.

"No one shall expel us from the paradise which Cantor has created for us.

{Expressing the importance of Georg Cantor's set theory in the development of mathematics.}"

― David Hilbert

- **Gravitational lensing:** The big galaxy cluster at the center of the image acts like the lens of a telescope. Any light from a distant object would converge as it passes around the galaxy. When we gaze at the distant galaxy, we see a ring like pattern called Einstein ring, an optical illusion caused by general relativity.
- **Newton rings** is a phenomenon in which an interference pattern is created by the reflection of light between two surfaces — a spherical surface and an adjacent flat surface. It is named after Isaac Newton, who first studied them in 1717.

There seem good reasons for believing that radio-activity is due to changes going on within the atoms of the radio-active substances. If this is so then we must face the problem of the constitution of the atom, and see if we can imagine a model which has in it the potentiality of explaining the remarkable properties shown by radioactive substances.

– J. J. Thomson (1904)

It could be that I've perhaps found out a little bit about the structure of atoms. ... If I'm right, it would not be an indication of the nature of a possibility [marginal note in the original: "i.e., impossibility"] (like J. J. Thomson's theory) but perhaps a little piece of reality.

– N. Bohr (1912)

"If the whole universe has no meaning, we should never have found out that it has no meaning: just as, if there were no light in the universe and therefore no creatures with eyes, we should never know it was dark. Dark would be without meaning."

— C.S. Lewis

"What we know is a drop, what we don't know is an ocean."

: Isaac Newton

- **Grand Challenges in Global Health**

To improve childhood vaccines:

- Create effective single-dose vaccines that can be used soon after birth;
- Prepare vaccines that do not require refrigeration;
- Develop needle-free delivery systems for vaccines.

To create new vaccines:

- Devise reliable tests in model systems to evaluate live attenuated vaccines;
- Solve how to design antigens for effective, protective immunity;
- Learn which immunological responses provide protective immunity.

To control insects that transmits agents of disease:

- Develop a genetic strategy to deplete or incapacitate a disease-transmitting insect population;
- Develop a chemical strategy to deplete or incapacitate a disease-transmitting insect population.

To improve nutrition to promote health:

- Create a full range of optimal bioavailable nutrients in a single staple plant species.

To improve drug treatment of infectious diseases:

- Discover drugs and delivery systems that minimize the likelihood of drug-resistant microorganisms.

To cure latent and chronic infections:

- Create therapies that can cure latent infections;
- Create immunological methods that can cure chronic infections.

To measure disease and health status accurately and economically in poor countries:

- Develop technologies that permit quantitative assessment of population health status;
- Develop technologies that allow assessment of individuals for multiple conditions or pathogens at point-of-care.

Famous Scientists Who Changed the World

[1] Sir Isaac Newton

Birth: Dec. 25, 1642 [Jan. 4, 1643, New Style], Woolsthorpe, Lincolnshire, England

Death: March 20 [March 31], 1727, London

Known for: the Newtonian Revolution

"Gravity explains the motions of the planets, but it cannot explain who sets the planets in motion."

— *Isaac Newton*

William Stukely, who was a good friend of Newton's, wrote about Newton's Discovery in his ' **Memoirs of Sir Isaac Newton's life** ' in 1752.

He wrote:

' After dinner, the weather being warm, we went into the garden, and drank tea under the shade of some apple trees…he told me, he was just in the same situation as when formally, the notation of gravitation came to his mind.

"Why should that apple always descend perpendicularly to the ground," thought he to himself. '

- **Letter from Sir Isaac Newton to Richard Bentley (**one of the great figures in the history of classical scholarship**)**

As to your first query, it seems to me that if the matter of our sun and planets and all the matter of the universe were evenly scattered throughout all the heavens, and every particle had an innate gravity toward all the rest, and the whole space throughout which this matter was scattered was but finite, the matter on the outside of this space would, by its gravity, tend toward all the matter on the inside and, by consequence, fall down into the middle of the whole space and there compose one great spherical mass. But if the matter was evenly disposed throughout an infinite space, it could never convene into one mass; but some of it would convene into one mass and some into another, so as to make an infinite number of great masses, scattered at great distances from one to another throughout all that infinite space. And thus might the sun and fixed stars be formed, supposing the matter were of a lucid nature.

But how the matter should divide itself into two sorts, and that part of it which is to compose a shining body should fall down into one mass and make a sun and the rest which is t to compose an opaque body should coalesce, not into one great body, like the shining matter, but into many little ones; or if the sun at first were an opaque body like the planets or the planets lucid bodies like the sun, how he alone should be changed into a shining body whilst all they continue opaque, or all they be changed into opaque ones whilst he remains unchanged, I do not think explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary Agent.

− December 10, 1692

But you argue, in the next paragraph of your letter, that every particle of matter in an infinite space has an infinite quantity of matter on all sides, and, by consequence, an infinite attraction every way, and therefore must rest in equili- brio, because all infinites are equal. Yet you suspect a paralogism in this argument; and I conceive the paralogism lies in the position, that all infinites are equal. The generality of mankind consider infinites no other ways than indefinitely; and in this sense they say all infinites are equal; though they would speak more truly if they should say, they are neither equal nor unequal, nor have any certain difference or proportion one to another. In this sense, therefore, no conclusions can be drawn from them about the equality, proportions, or differences of things; and they that attempt to do it usually fall into paralogisms.

So, when men argue against the infinite divisibility of magnitude, by saying, that if an inch may be divided into an infinite number of parts, the sum of those parts will be an inch; and if a foot may be divided into an infinite number of parts, the sum of those parts must be a foot; and therefore, since all infinites are equal, those sums must be equal, that is, an inch equal to a foot. The falseness of the conclusion shews an error in the premises; and the error lies in the position, that all infinites are equal.

− January 17, 1693

[2] Albert Einstein

Birth: March 14, 1879, Ulm, Wurttemberg, Germany

Death: April 18, 1955, Princeton, N.J., U.S.

Known for: **The 1905 Annus mirabilis papers**

- **On a Heuristic Point of View Concerning the Production and Transformation of Light** − which introduced the theory of the photon or light quantum.
- **On the movement of small particles suspended in stationary liquids required by the molecular-kinetic theory of heat**, related to Brownian movement, which provided sufficient arguments to leave the atomic theory of matter definitively settled.
- **On the electrodynamics of moving bodies** − where he established the basis for the special theory of relativity.
- **Does the inertia of a body depend on its energy content?** − In which he devised the formula which would later come to be written as $E = mc^2$.

"The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science."

— Albert Einstein

- **Einstein letter to Professor G. Gamow (in August 4, 1946), with a comment handwritten by Gamow at the bottom**

Dear Dr. Gamow

After receiving your manuscript I read it immediately and then forwarded it to Dr. Spitzer. I am convinced that the abundance of elements as function of the atomic weight is a highly important starting point for cosmogonic speculations. The idea that the whole expansion process started with a neutron gas seems to be quite natural too. The explanation of the abundance curve by formation of the heavier elements in making use of the known facts of probability coefficients seems to me pretty convincing. Your remarks concerning the formation of the big units (nebulae) I am not able to judge for lack of special knowledge.

Thanking you for your kindness, I am

yours sincerely,

Albert Einstein

(*Of course, the old man agrees with almost anything nowadays*.)

− Comment handwritten by Gamow

- **Einstein's Letter to Mathematician David Hilbert**

When Marie Curie was denied a seat in the French Academy of Sciences and Einstein sent a letter of support, he also wrote a sensitive note to Hilbert seeking to put disagreements behind and to rekindle their friendship. It says:

There was a moment in which something like as irritation came between us, the origin of which I no longer want to analyze. I have fought against the bitterness which it provoked in me, and have succeeded completely in doing so. I again think of you with unclouded friendship, and I ask you to do the same for me. It is really a pity if companions such as we are, who have managed to forge a path aside from the pettiness of this world, could find anything other than joy in each other's company.

- **The Einstein-Szilard Letter – 1939**

Sir:

Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable — through the work of Joliot in France as well as Fermi and Szilard in America — that it may become possible to set up a nuclear chain reaction in a large mass of uranium by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain — that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States.

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,

Albert Einstein

- **Letter from Albert Einstein to Chaim Weizmann**

Dear Mr. Weizmann,

I have read with great satisfaction that the Palestinian Jewry has made you head of the new state. This is at least a partial reparation for the ungrateful attitude they have shown towards you and your great accomplishments. One still cannot say that the powerful men of this earth mean well with us. The game the English play with us is miserable, and the American attitude appears ambivalent.

However, I am confident that our people will overcome this last scare and that you will live to experience the satisfaction of having created a happy Jewish community.

With heartfelt greetings and best wishes,

Your A. Einstein

- **A letter from Albert Einstein to his daughter: on The Universal Force of Love**

"When I proposed the theory of relativity, very few understood me, and what I will reveal now to transmit to mankind will also collide with the misunderstanding and prejudice in the world.

I ask you to guard the letters as long as necessary, years, decades, until society is advanced enough to accept what I will explain below.

There is an extremely powerful force that, so far, science has not found a formal explanation to. It is a force that includes and governs all others, and is even behind any phenomenon operating in the universe and has not yet been identified by us. This universal force is LOVE.

When scientists looked for a unified theory of the universe they forgot the most powerful unseen force. Love is Light, that enlightens those who give and receive it. Love is gravity, because it makes some people feel attracted to others. Love is power, because it multiplies the best we have, and allows humanity not to be extinguished in their blind selfishness. Love unfolds and reveals. For love we live and die. Love is God and God is Love.

This force explains everything and gives meaning to life. This is the variable that we have ignored for too long, maybe because we are afraid of love because it is the only energy in the universe that man has not learned to drive at will.

To give visibility to love, I made a simple substitution in my most famous equation. If instead of $\mathbf{E = mc^2}$, we accept that the energy to heal the world can be obtained through love multiplied by the speed of light squared, we arrive at the conclusion that love is the most powerful force there is, because it has no limits.

After the failure of humanity in the use and control of the other forces of the universe that have turned against us, it is urgent that we nourish ourselves with another kind of energy…

If we want our species to survive, if we are to find meaning in life, if we want to save the world and every sentient being that inhabits it, love is the one and only answer.

Perhaps we are not yet ready to make a bomb of love, a device powerful enough to entirely destroy the hate, selfishness and greed that devastate the planet.

However, each individual carries within them a small but powerful generator of love whose energy is waiting to be released.

When we learn to give and receive this universal energy, dear Lieserl, we will have affirmed that love conquers all, is able to transcend everything and anything, because love is the quintessence of life.

I deeply regret not having been able to express what is in my heart, which has quietly beaten for you all my life. Maybe it's too late to apologize, but as time is relative, I need to tell you that I love you and thanks to you I have reached the ultimate answer! ".

Your father,

Albert Einstein

- ### Letter from Albert Einstein to the Jewish philosopher Eric B. Gutkind

The word God is for me nothing more than the expression and product of human weaknesses, the Bible a collection of honorable, but still primitive legends which are nevertheless pretty childish. No interpretation no matter how subtle can (for me) change this. These subtilised interpretations are highly manifold according to their nature and have almost nothing to do with the original text. For me the Jewish religion like all other religions is an incarnation of the most childish superstitions. And the Jewish people to whom I gladly belong and with whose mentality I have a deep affinity have no different quality for me than all other people. As far as my experience goes, they are also no better than other human groups, although they are protected from the worst cancers by a lack of power. Otherwise I cannot see anything 'chosen' about them.

In general I find it painful that you claim a privileged position and try to defend it by two walls of pride, an external one as a man and an internal one as a Jew. As a man you claim, so to speak, a dispensation from causality otherwise accepted, as a Jew the privilege of monotheism. But a limited causality is no longer a causality at all, as our wonderful Spinoza recognized with all incision, probably as the first one. And the animistic interpretations of the religions of nature are in principle not annulled by monopolization. With such walls we can only attain a certain self-deception, but our moral efforts are not furthered by them. On the contrary.

Now that I have quite openly stated our differences in intellectual convictions it is still clear to me that we are quite close to each other in essential things, i.e; in our evaluations of human behavior. What separates us are only intellectual 'props' and 'rationalization' in Freud's language. Therefore I think that we would understand each other quite well if we talked about concrete things.

With friendly thanks and best wishes,

Yours, A. Einstein

- ### Do Scientists Pray? Einstein Answers a Little Girl's Question about Science vs. Religion

The Riverside Church

January 19, 1936

My dear Dr. Einstein,

We have brought up the question: Do scientists pray? in our Sunday school class. It began by asking whether we could believe in both science and religion. We are writing to scientists and other important men, to try and have our own question answered.

We will feel greatly honored if you will answer our question: Do scientists pray, and what do they pray for? We are in the sixth grade, Miss Ellis's class.

Respectfully yours,

Phyllis

Einstein's reply:

January 24, 1936

Dear Phyllis,

I will attempt to reply to your question as simply as I can. Here is my answer:

Scientists believe that every occurrence, including the affairs of human beings, is due to the laws of nature. Therefore a scientist cannot be inclined to believe that the course of events can be influenced by prayer, that is, by a supernaturally manifested wish.

However, we must concede that our actual knowledge of these forces is imperfect, so that in the end the belief in the existence of a final, ultimate spirit rests on a kind of faith. Such belief remains widespread even with the current achievements in science.

But also, everyone who is seriously involved in the pursuit of science becomes convinced that some spirit is manifest in the laws of the universe, one that is vastly superior to that of man. In this way the pursuit of science leads to a religious feeling of a special sort, which is surely quite different from the religiosity of someone more naive.

With cordial greetings,

your A. Einstein

- ### Russell-Einstein Manifesto

5 April, 1955.

41, Queen's Road,

Richmond, Surrey.

Dear Einstein,

I have been turning over in my mind, and discussing with various people, the best steps for giving effect to the feeling against war among the great majority of men of science. I think the first step should be a statement by men of the highest eminence, communists and anti-Communists, Western and Eastern, about the disasters to be expected in a war. I enclose a draft of such a statement, and I very much hope that you will be willing to sign it. I enclose also a list of those whom I am asking to sign. If sufficient signatures are obtained, I think the next step should be an international scientific congress which should be invited by the signatories to pass a resolution on the lines of the draft resolution which I enclose. I hope that in this way both Governments and public opinion can be made aware of the seriousness of the situation.

On the whole, I have thought that it was better at this stage to approach only men of science and not men in other fields, such as Arnold Toynbee whom you mentioned. Scientists have, and feel that they have, a special responsibility, since their work has unintentionally caused our present dangers. Moreover, widening the field would make it very much more difficult to steer clear of politics.

Yours sincerely,

(Signed, 'Bertrand Russell')

In response, Einstein was brief:

Dear Bertrand Russell,

Thank you for your letter of April 5. I am gladly willing to sign your excellent statement. I also agree with your choice of the prospective signers.

With kind regards,

A. Einstein.

[3] Niels Bohr

Birth: Oct. 7, 1885, Copenhagen, Denmark

Death: Nov. 18, 1962, Copenhagen

Known for: the Atom

"Everything we call real is made of things that cannot be regarded as real."

— Niels Bohr

- **Draft of letter from Bohr to Heisenberg, never sent**

In the handwriting of Niels Bohr's assistant, Aage Petersen.

Undated, but written after the first publication, in 1957, of the Danish translation of Robert Jungk, Heller als Tausend Sonnen, the first edition of Jungk's book to contain Heisenberg's letter

Dear Heisenberg,

I have seen a book, "Stærkere end tusind sole" ["**Brighter than a thousand suns**"] by Robert Jungk, recently published in Danish, and I think that I owe it to you to tell you that I am greatly amazed to see how much your memory has deceived you in your letter to the author of the book, excerpts of which are printed in the Danish edition [1957].

Personally, I remember every word of our conversations, which took place on a background of extreme sorrow and tension for us here in Denmark. In particular, it made a strong impression both on Margrethe and me, and on everyone at the Institute that the two of you spoke to, that you and Weizsäcker expressed your definite conviction that Germany would win and that it was therefore quite foolish for us to maintain the hope of a different outcome of the war and to be reticent as regards all German offers of cooperation. I also remember quite clearly our conversation in my room at the Institute, where in vague terms you spoke in a manner that could only give me the firm impression that, under your leadership, everything was being done in Germany to develop atomic weapons and that you said that there was no need to talk about details since you were completely familiar with them and had spent the past two years working more or less exclusively on such preparations. I listened to this without speaking since [a] great matter for mankind was at issue in which, despite our personal friendship, we had to be regarded as representatives of two sides engaged in mortal combat. That my silence and gravity, as you write in the letter, could be taken as an expression of shock at your reports that it was possible to make an atomic bomb is a quite peculiar misunderstanding, which must be due to the great tension in your own mind. From the day three years earlier when I realized that slow neutrons could only cause fission in Uranium 235 and not 238, it was of course obvious to me that a bomb with certain effect could be produced by separating the uraniums. In June 1939 I had even given a public lecture in Birmingham about uranium fission, where I talked about the effects of such a bomb but of course added that the technical preparations would be so large that one did not know how soon they could be overcome. If anything in my behaviour could be interpreted as shock, it did not derive from such reports but rather from the news, as I had to understand it, that Germany was participating vigorously in a race to be the first with atomic weapons.

Besides, at the time I knew nothing about how far one had already come in England and America, which I learned only the following year when I was able to go to England after being informed that the German occupation force in Denmark had made preparations for my arrest.

All this is of course just a rendition of what I remember clearly from our conversations, which subsequently were naturally the subject of thorough discussions at the Institute and with other trusted friends in Denmark. It is quite another matter that, at that time and ever since, I have always had the definite impression that you and Weizsäcker had arranged the symposium at the German Institute, in which I did not take part myself as a matter of principle, and the visit to us in order to assure yourselves that we suffered no harm and to try in every way to help us in our dangerous situation.

This letter is essentially just between the two of us, but because of the stir the book has already caused in **Danish newspapers**, I have thought it appropriate to relate the contents of the letter in confidence to the head of the Danish Foreign Office and to Ambassador Duckwitz.

[4] Charles Darwin

Birth: Feb. 12, 1809, Shrewsbury, Shropshire, England

Death: April 19, 1882, Downe, Kent

Known for: Evolution

"If I had my life to live over again, I would have made a rule to read some poetry and listen to some music at least once every week."

— Charles Darwin

- **Darwin-Hooker Letter**

"At last gleams of light have come, & I am almost convinced (quite contrary to opinion I started with) that species are not (it is like confessing a murder) immutable."

Charles Darwin to Joseph Dalton Hooker, 11 January 1844

- **A letter to Charles Darwin from Jerry Coyne**

My Dear Mr. Darwin,

Happy 200th birthday! I hope you are as well as can expected for someone who has been dead for nearly 130 years. I suppose that your final book, the one about earthworms, has a special significance for you these days. Are the worms of Westminster Abbey superior to the ones you studied so carefully in the grounds of your home at Downe in Kent? They've certainly mulched some distinguished people over the years!

But enough of the personal questions: let me introduce myself. I am one of thousands – maybe tens of thousands – of professional biologists who work full time on your scientific legacy. You'll be happy to know that Britain remains a powerhouse in what we nowadays call evolutionary biology, and your ideas now have wide currency across the entire planet. I work in Chicago, in the United States of America. But even the French have finally reluctantly relinquished their embrace of Jean-Baptiste Lamarck, whose misguided evolutionary ideas you did so much to discredit.

Your Origin of Species turns 150 this year. I just re-read it in your honour and must say that, though you did not always have the snappiest turn of phrase, it really is a wonderfully comprehensive and insightful work. It is remarkable, considering what you did not know when you wrote it, how robust the book has proved over the years. The findings of modern biology, many of them inconceivable to you as you beavered away in your Down House study, have provided ever more evidence in support of your ideas, and none that contradicts them. We have learned a huge amount in the past 150 years, but nearly all of it still fits comfortably into the framework you outlined in The Origin. Take DNA, for example. This is what we call the hereditary material that is passed down from generation to generation. You knew nothing about it – remember how you wished you understood more about how heredity works? Now we have full DNA sequences from dozens of species, each one a string of billions of the four DNA letters — A, T, G and C — each a different chemical compound. What do we find when we compare these sequences, say between a mouse and a human? We see the DNA equivalent of the anatomical similarities – as mammals – that you noted mice and humans share because they are descended from a common ancestor, an early mammal. Strings of As, Gs, Cs, and Ts tell precisely the same evolutionary story as traits like lactation and warm-bloodedness. It is absolutely marvelous that your 150 year old insight on common ancestry should be so relevant to the very latest discoveries of the new field we call molecular biology.

In The Origin, you gave very little evidence for evolution from the fossil record, wringing your hands instead about the incompleteness of the geological record. But since then, the labors of fossil-hunters throughout the world have turned up plenty of evidence of evolutionary change, and many amazing "transitional" forms that connect major groups of animals, proving your idea of common ancestry. You predicted that these forms would exist; we have found them. These include fossils that show transitions between mammals and reptiles, fish and amphibians, and even dinosaurs with feathers—the ancestors of birds! Just in the past few years, paleontologists have unearthed an astonishing fossil, called Tiktaalik, that is intermediate between fish and amphibians. It has the flat head and neck of an amphibian, but a fishy tail and body, while its fins are sturdy, easily able, with slight modification, to give them a leg up when they left the water. The fossil record has given us a direct glimpse of an event of great moment in the history of the planet: the colonization of land by vertebrates. And we have evidence just as convincing for the recolonization of the sea by mammals: the group that gave rise to whales. In The Origin, you were correct in suggesting that whales arose from land animals, but you got it wrong on one point. You thought they may have come from carnivores like bears, but we now know this is not true. Instead, the ancestral whale came from a small hooved animal rather like a deer. And in the last thirty years we have discovered a whole series of intermediate fossils spanning the gap from those ancient deer to modern whales, showing them losing their hind legs, evolving flippers, and moving their breathing hole to the top of their head. Both Tiktaalik and these ancestral whales put paid to the objection, which you yourself encountered, that no transitional form between land and water could possibly have existed.

Perhaps the most remarkable set of intermediate fossils, however, come from an evolutionary transition rather closer to home. In 1871, you more predicted that, since humans seem most related to African great apes, gorillas and chimpanzees, we would find human fossils on that continent. And now we have them—in profusion! It turns out that our lineage separated from that of chimpanzees, our closest living relatives, nearly 7 million years ago, and we have a superb series of fossils documenting our transition from early apelike creatures to more modern human forms. Our own species has become an exemplar of evolution. And we know even more: evidence from our hereditary DNA material has told us that all modern humans came from a relatively recent migration event—about 100,000 years ago—when our ancestors left Africa and spread throughout the world.

The idea you were proudest of was natural selection. That too has had a good 150 years, holding up well as the main cause of evolution and the only known cause of adaptation. Perhaps the most dramatic modern example involves bacteria that are now known to cause disease, including the scarlet fever that was such a plague upon your family. Chemists have developed drugs to cure diseases like this, but now, as you might well predict, the microbes are becoming resistant to those drugs—precisely in accord with the principles of natural selection—for the most drug-resistant microbes are the ones that survive to breed. There are hundreds of other cases. One that will especially please you is the observation of natural selection in the Galápagos finches you collected in the Beagle voyage—now called "Darwin's finches" in your honor. A few decades ago, zoologists observed a great drought on the islands that reduced the number of small seeds available for the birds to eat. And, just as predicted, natural selection caused the evolution of larger-beaked birds within only a few years. These examples would surely be a centerpiece of The Origin were you to rewrite it today.

All told, the resilience of your ideas is remarkable. But that is not to say that you got everything right. On The Origin of Species was, admit it, a misnomer. You described correctly how a single species changes through time, but you came a cropper trying to explain how one species splits into two. Speciation is a significant problem, because it underpins the branching process that has yielded the tree of life – that extraordinary vision you bequeathed us of the natural world as one vast genealogy. Speciation is the key to understanding how, starting with the very first species on earth, evolution has resulted in the 50 million species that are thought to inhabit our planet today.

You once called speciation the "mystery of mysteries," but it’s a lot less mysterious these days. We recognize now that species are separated one from another by barriers to reproduction. That is, we recognize different species, like humans and chimpanzees, because they cannot successfully interbreed. To modern evolutionary biologists, studying "the origin of species" means studying how these barriers to reproduction arise. And now that we have a concrete phenomenon to investigate, we are making remarkable progress in understanding the genetic details of how one species splits into two. This is in fact the problem to which I’ve devoted my entire career

I wish I could end this letter by telling you that your theory of evolution has achieved universal acceptance. As you well knew, evolution has proved a bitter pill for religious people to swallow. For example, a large proportion of the American public, despite access to education, clings to a belief in the literal truth of Genesis. You will find this hard to believe, but more Americans believe in the existence of heavenly angels than accept the fact of evolution. Unfortunately, I must often put aside my research to fight the attempts of these "creationists" to have their Biblical views taught in the public schools. Humans have evolved extraordinary intellectual abilities, but sadly these are not always given a free rein by their owners. But this probably won't surprise you – remember the Bishop of Oxford and his attempt to put your friend Thomas H. Huxley in his place?

You wrote in your introduction to The Origin of Species that

> "No one can feel more sensible than I do of the necessity of hereafter publishing in detail all the facts, with references, on which my conclusions have been grounded; and I hope in a future work to do this."

It seems that, distracted by other projects, you never got around to it, but my own effort along these lines is represented in a book (which I enclose) called Why Evolution is True. It goes further to describe the evidence supporting you than a letter this size ever could, but it's just one book at just one moment in the history of biology. When I myself am as long gone as you are, somebody else will certainly need to write an update, for the facts supporting your theories continue to roll in, and I wager they will continue to do so.

So, rest in peace, Mr. Darwin, and here's hoping that the next hundred years will see a steady evolution of rationality in a troubled world.

Your most humble servant,

Jerry Coyne

[5] Louis Pasteur

Birth: Dec. 27, 1822, Dole, France

Sept. 28, 1895, Saint-Cloud, near Paris

Known for: the Germ Theory of Disease

"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."

— *Louis Pasteur*

[6] Sigmund Freud

Birth: May 6, 1856, Freiberg, Moravia, Austrian Empire [now Příbor, Czech Republic]

Death: Sept. 23, 1939, London, England

Known for: Psychology of the Unconscious

"Religion is an attempt to get control over the sensory world, in which we are placed, by means of the wish-world, which we have developed inside us as a result of biological and psychological necessities. But it cannot achieve its end. Its doctrines carry with them the stamp of the times in which they originated, the ignorant childhood days of the human race. Its consolations deserve no trust. Experience teaches us that the world is not a nursery. The ethical commands, to which religion seeks to lend its weight, require some other foundations instead, for human society cannot do without them, and it is dangerous to link up obedience to them with religious belief. If one attempts to assign to religion its place in man's evolution, it seems not so much to be a lasting acquisition, as a parallel to the neurosis which the civilized individual must pass through on his way from childhood to maturity."

— *Sigmund Freud*

[7] Galileo Galilei

Birth: Feb. 15, 1564, Pisa [Italy]

Death: Jan. 8, 1642, Arcetri, near Florence

Known for: the New Science

"In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual."

— Galileo Galilei

[8] Antoine-Lau rent Lavoisier

Birth: Aug. 26, 1743, Paris, France

Death: May 8, 1794, Paris

Known for: the Revolution in Chemistry

"In nature nothing is created, nothing is lost, everything changes."

— Antoine-Laurent de Lavoisier

[9] Johannes Kepler

Birth: Dec. 27, 1571, Weil der Stadt, Wurttemberg [Germany]

Death: Nov. 15, 1630, Regensburg

Known for: Motion of the Planets

*"Geometry has two great treasures; one is the Theorem of **Pythagoras**; the other, the division of a line into extreme and mean ratio. The first we may compare to a measure of gold; the second we may name a precious jewel."*

— Johannes Kepler

[10] Nicolaus Copernicus

Birth: Feb. 19, 1473, Toruń, Poland

Death: May 24, 1543, Frauenburg, East Prussia [now Frombork, Poland]

Known for: the Heliocentric Universe

"To know that we know what we know, and to know that we do not know what we do not know, that is true knowledge."

— Nicolaus Copernicus

[11] Michael Faraday

Birth: Sept. 22, 1791, Newington, Surrey, England

Death: Aug. 25, 1867, Hampton Court

Known for: the Classical Field Theory

"Nothing is too wonderful to be true if it be consistent with the laws of nature."

— Michael Faraday

- **Observations on the Filth of the Thames a letter to the Editor of the Times of London (July 7, 1855) by Professor Michael Faraday**

SIR,

I traversed this day by steam-boat the space between London and Hangerford Bridges between half-past one and two o'clock; it was low water, and I think the tide must have been near the turn. The appearance and the smell of the water forced themselves at once on my attention. The whole of the river was an opaque pale brown fluid. In order to test the degree of opacity, I tore up some white cards into pieces, moistened them so as to make them sink easily below the surface, and then dropped some of these pieces into the water at every pier the boat came to; before they had sunk an inch below the surface they were indistinguishable, though the sun shone brightly at the time; and when the pieces fell edgeways the lower part was hidden from sight before the upper part was under water. This happened at St. Paul's Wharf, Blackfriars Bridge, Temple Wharf, Southwark Bridge, and Hungerford; and I have no doubt would have occurred further up and down the river. Near the bridges the feculence rolled up in clouds so dense that they were visible at the surface, even in water of this kind.

The smell was very bad, and common to the whole of the water; it was the same as that which now comes up from the gully-holes in the streets; the whole river was for the time a real sewer. Having just returned from out of the country air, I was, perhaps, more affected by it than others; but I do not think I could have gone on to Lambeth or Chelsea, and I was glad to enter the streets for an atmosphere which, except near the sink-holes, I found much sweeter than that on the river.

I have thought it a duty to record these facts, that they may be brought to the attention of those who exercise power or have responsibility in relation to the condition of our river; there s nothing figurative in the words I have employed, or any approach to exaggeration; they are the simple truth. If there be sufficient authority to remove a putrescent pond from the neighbourhood of a few simple dwellings, surely the river which flows for so many miles through London ought not to be allowed to become a fermenting sewer. The condition in which I saw the Thames may perhaps be considered as exceptional, but it ought to be an impossible state, instead of which I fear it is rapidly becoming the general condition. If we neglect this subject, we cannot expect to do so with impunity; nor ought we to be surprised if, ere many years are over, a hot season give us sad proof of the folly of our carelessness.

I am, Sir,

Your obedient servant,

M. FARADAY.

Royal Institution, July 7

[12] James Clerk Maxwell

Birth: June 13, 1831, Edinburgh, Scotland

Death: Nov. 5, 1879, Cambridge, Cambridgeshire, England

Known for: the Electromagnetic Field

> *"Thoroughly conscious ignorance is the prelude to every real advance in science."*
>
> *— James Clerk Maxwell*

- **Maxwell Letter to R. B. Litchfield**

5 February 1858, from The Life of James Clerk Maxwell, Campbell and Garnett, pp.306-6

With respect to the " material sciences," they appear to me to be the appointed road to all scientific truth, whether metaphysical, mental, or social. The knowledge which exists in these subjects derives a great part of its value from ideas suggested by analogies from the material sciences, and the remaining part, though valuable and important to mankind, is not scientific but aphoristic. The chief philosophical value of physics is that it gives the mind something distinct to lay hold of, which, if you don't, Nature at once tells you you are wrong. Now, every stage of this conquest of truth leaves a more or less presentable trace on the memory, so that materials are furnished here more than anywhere else for investigation of the great question, "How does Knowledge come?"

I have observed that the practical cultivators of science (e.g., Sir J. Herschel, Faraday, Ampere, Oersted, Newton, Young), although differing excessively in turn of mind, have all a distinctness and a freedom from the tyranny of words in dealing with questions of Order, Law, etc., which pure speculators and literary men never attain.

Now, I am going to put down something on my own authority, which you must not take for more than it is worth. There are certain men who write books, who assume that, whatever things are orderly, certain, and capable of being accurately predicted by men of experience, belong to one category; and whatever things are the result of conscious action, whatever are capricious, contingent, and cannot be foreseen, belong to another category.

All the time I have lived and thought, I have seen more and more reason to disagree with this opinion, and to hold that all want of order, caprice, and unaccountableness results from interference with liberty, which would, if unimpeded, result in order, certainty, and trustworthiness (certainty of success of predicting). Remember I do not say that caprice and order are not the result of free will (so called), only I say that there is a liberty which is not disorder, and that this is by no means less free than the other, but more.

In the next place, there are various states of mind, and schools of philosophy corresponding to various stages in the evolution of the idea of liberty.

In one phase, human actions are the resultant (by parallelogram of forces) of the various attractions of surrounding things, modified in some degree by internal states, regarding which all that is to be said is that they are subjectively capricious, objectively the "RESULT OF LAW," — that is, the wilfulness of our wills feels to us like liberty, being in reality necessity.

In another phase, the wilfulness is seen to be anything but free will, since it is merely a submission to the strongest attraction, after the fashion of material things. So some say that a man's will is the root of all evil in him, and that he should mortify it out till nothing of himself remains, and the man and his selfishness disappear together. So said Buddha (see Max Muller), and many Christians have and thought nearly the same thing.

Nevertheless there is another phase still, in which appears a possibility of the exact contrary to the first state, namely, an abandonment of wilfulness without extinction of will, but rather by means of a great development of will, whereby, instead of being consciously free and really in subjection to unknown laws, it becomes consciously acting by law, and really free from the interference of unrecognised laws.

There is a screed of metaphysics. I don't suppose that is what you wanted. I have no nostrum that is exactly what you want. Every man must brew his own, or at least fill his own glass for himself, but I greatly desire to hear some more from you, just to get into rapport.

[13] Claude Bernard

Birth: July 12, 1813, Saint-Julien

Death: February. 10, 1878, Paris

Known for: the Founding of Modern Physiology

"Man can learn nothing except by going from the known to the unknown."

— Claude Bernard

[14] Franz Boas

Birth: July 9, 1858, Minden, Westphalia, Germany

Death: December 21, 1942, New York, U.S

Known for: Modern Anthropology

"The passion for seeking the truth for truth's sake...can be kept alive only if we continue to seek the truth for truth's sake."

— Franz Boas

[15] Werner Heisenberg

Birth: December, 1901, Würzburg, Bavaria, German Empire

Death: 1 February 1976, Munich, Bavaria, West Germany

Known for: Quantum Theory

"What we observe is not nature itself, but nature exposed to our method of questioning."

— Werner Heisenberg

[16] Linus Pauling

Birth: Feb. 28, 1901, Portland, Ore., U.S.

Death: Aug. 19, 1994, Big Sur, California

Known for: Twentieth-Century Chemistry

"The best way to get a good idea is to have a lot of ideas."

— Linus Pauling

- **Letter from Linus Pauling to President Kennedy**

1 March 1962 Night Letters Durham, NC

President John F. Kennedy, White House:

Are you going to give an order that will cause you to go down in history as one of the most immoral men of all time and one of the greatest enemies of the human race? In a letter to the New York Times, I state that nuclear tests duplicating the Soviet 1961 tests would seriously damage over 20 million unborn children, including those caused to have gross physical or mental defect and also the still births and embryonic, neonatal and childhood deaths from the radioactive fission products and carbon 14. Are you going to be guilty of this monstrous immorality, matching that of the Soviet leaders, for the political purpose of increasing the still imposing lead of the United States over the Soviet Union in nuclear weapons technology?

(Signed) Linus Pauling

[17] Erwin Schrodinger

Birth: Aug. 12, 1887, Vienna, Austria

Death: Jan. 4, 1961, Vienna

Known for: Wave Mechanics

"The scientist only imposes two things, namely truth and sincerity, imposes them upon himself and upon other scientists."

— *Erwin Schrödinger*

[18] John James Audubon

Birth: April 26, 1785, Les Cayes, Saint-Domingue, West Indies [now in Haiti]

Death: Jan. 27, 1851, New York, N.Y., U.S.

Known for: drawings and paintings of North American birds

"The woods would be very silent if no birds sang except those who sang the best."

— *John James Audubon*

[19] Ernest Rutherford

Birth: Aug. 30, 1871, Spring Grove, N.Z.

Death: Oct. 19, 1937, Cambridge, Cambridgeshire, England

Known for: the Structure of the Atom

"All science is either physics or stamp collecting."

— *Ernest Rutherford*

[20] Paul Adrien Maurice Dirac

Birth: Aug. 8, 1902, Bristol, Gloucestershire, England

Death: Oct. 20, 1984, Tallahassee, Florida, USA

Known for: Quantum Electrodynamics

"A theory with mathematical beauty is more likely to be correct than an ugly one that fits some experimental data. God is a mathematician of a very high order, and He used very advanced mathematics in constructing the universe."

— Paul A. M. Dirac

[21] Andreas Vesalius

Birth: Dec. 1514, Brussels [now in Belgium]

Death: June 1564, island of Zacynthus, Republic of Venice [now in Greece]

Known for: the New Anatomy

"I am not accustomed to saying anything with certainty after only one or two observations."

— Andreas Vesalius

[22] Tycho Brahe

Birth: Dec. 14, 1546, Knudstrup, Scania, Denmark

Death: Oct. 24, 1601, Prague

Known for: the New Astronomy

"Let me not seem to have lived in vain."

— Tycho Brahe

[23] Comte de Buffon

Birth: September 07, 1707, Montbard, Burgundy, France

Death: April 16, 1788, Paris, France

Known for: l'Histoire Naturelle

"Genius is nothing but a great aptitude for patience."

— Comte Georges-Louis Leclerc de Buffon

[24] Ludwig Boltzmann

Birth: February 20, 1844, Vienna, Austrian Empire (present-day Austria)

Death: September 5, 1906, Tybein near Trieste, Austria-Hungary [present-day Duino, Italy]

Known for: Thermodynamics

"Available energy is the main object at stake in the struggle for existence and the evolution of the world."

— Ludwig Boltzmann

- Tragic deaths in science: Ludwig Boltzmann — a mind in disorder. Can a life be summed up by

$$S = \boldsymbol{\kappa} \cdot \log W?$$

  The equation is the slightly geeky inscription on the tombstone of Ludwig Boltzmann, Austrian physicist and pioneer of statistical mechanics.

[25] Max Planck

Birth: April 23, 1858, Kiel, Schleswig [Germany]

Death: Oct. 4, 1947, Göttingen, West Germany

Known for: the Quanta

"Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are a part of the mystery that we are trying to solve."

— Max Planck

- Sadly Planck life was filled with tragedy in the years following his remarkable initiation of the study of **quantum mechanics.**

- ### Max Planck Letter to Hitler

"My Führer!

I am most deeply shaken by the message that my son Erwin has been sentenced to death by the People's Court.

The acknowledgement for my achievements in service of our fatherland, which you, my Führer, have expressed towards me in repeated and most honouring way, makes me confident that you will lend your ear to an imploring 87-year old.

As the gratitude of the German people for my life's work, which has become an everlasting intellectual wealth of Germany, I am pleading for my son's life.

Max Planck"

[26] Marie Curie

Birth: Nov. 7, 1867, Warsaw, Poland, Russian Empire

Death: July 4, 1934, near Sallanches, France

Known for: Radioactivity

"Be less curious about people and more curious about ideas."

— Marie Curie

- Marie Curie was the first woman to win a Nobel Prize, in Physics, and with her later win, in Chemistry, she became the first person to claim Nobel honors twice.

[27] Sir William Herschel

Birth: Nov. 15, 1738, Hanover, Germany

Death: Aug. 25, 1822, Slough, Buckinghamshire, England

Known for: Sidereal astronomy

"An object is frequently not seen from not knowing how to see it, rather than from any deficit in the organ of vision. I will instruct you how to see them..."

— William Herschel

[28] Charles Lyell

Birth: Nov. 14, 1797, Kinnordy, Forfarshire, Scotland

Death: Feb. 22, 1875, London, England

Known for: Modern Geology

"Geology is intimately related to almost all the physical sciences, as history is to the moral. An"

— Charles Lyell

[29] Pierre Simon de Laplace

Birth: March 23, 1749, Beaumount-en-Auge, Normandy, France

Death: March 5, 1827, Paris

Known for: Black hole, nebular hypothesis of the origin of the solar system

"Your Excellency, I have no need of this hypothesis."

— Pierre Laplace

[30] Edwin Powell Hubble

Birth: Nov. 20, 1889, Marshfield, Mo., U.S.

Death: Sept. 28, 1953, San Marino, California

Known for: Extragalactic astronomy

"Science is the one human activity that is truly progressive. The body of positive knowledge is transmitted from generation to generation."

— Edwin Powell Hubble

[31] Joseph J. Thomson

Birth: December 18, 1856, Cheetham Hill, Manchester, Lancashire, England, United Kingdom

Death: August 30, 1940, Cambridge, Cambridgeshire, England, UK

Known for: the Discovery of the Electron

"His work was so great that it cannot be compassed in a few words. His death is one of the greatest losses ever to occur to British science.

{Describing Ernest Rutherford upon his death at age 66. Thomson, then 80 years old, was once his teacher.}"

— Joseph John Thomson

[32] Max Born

Birth: December 11, 1882, Breslau, German Empire

Death: January 5, 1970, Göttingen, West Germany

Known for: Quantum Mechanics

"The belief that there is only one truth and that oneself is in possession of it seems to me the root of all the evil that is in the world"

— Max Born

[33] Francis Harry Compton Crick

Birth: June 8, 1916, Northampton, Northamptonshire, England

Death: July 28, 2004, San Diego, Calif., U.S.

Known for: Molecular Biology

"Biologists must constantly keep in mind that what they see was not designed, but rather evolved."

— Francis Crick

[34] Enrico Fermi

Birth: Sept. 29, 1901, Rome, Italy

Death: Nov. 28, 1954, Chicago, Ill., U.S.

Known for: Statistical mechanics

"Whatever Nature has in store for mankind, unpleasant as it may be, men must accept, for ignorance is never better than knowledge."

— Enrico Fermi

[35] Leonard Euler

Birth: April 15, 1707, Basel, Switzerland

Death: September 18, 1783, Saint Petersburg, Russian Empire

Known for: Eighteenth-Century Mathematics

"Logic is the foundation of the certainty of all the knowledge we acquire."

— Leonhard Euler

[36] Justus Liebig

Birth: May 12, 1803, Darmstadt, Grand Duchy of Hesse

Death: April 18, 1873, Munich, German Empire

Known for: Nineteenth-Century Chemistry

"From one sublime genius—NEWTON—more light has proceeded than the labour of a thousand years preceding had been able to produce."

— Justus Liebig

[37] Arthur Stanley Eddington

Birth: December 28, 1882, Kendal, Westmorland, England

Death: November 22, 1944, Cambridge, Cambridgeshire, England

Known for: Modern astronomy

"An ocean traveler has even more vividly the impression that the ocean is made of waves than that it is made of water."

— Arthur S. Eddington

[38] William Harvey

Birth: April 1, 1578, Folkestone, Kent, England

Death: June 3, 1657, London

Known for: Circulation of the Blood

"Doctrine once sown strikes deep its root, and respect for antiquity influences all men."

— William Harvey

[39] Marcello Malpighi

Birth: 1628

Death: 1694

Known for: Microscopic Anatomy

"For Nature is accustomed to rehearse with certain large, perhaps baser, and all classes of wild (animals), and to place in the imperfect the rudiments of the perfect animals."

— Marcello Malpighi

[40] Christiaan Huygens

Birth: 1629

Death: 1695

Known for: the Wave Theory of Light

"The world is my country, science is my religion."

— Christiaan Huygens

[41] Johann Carl Friedrich Gauss

Birth: April 30, 1777, Brunswick, Duchy of Brunswick-Wolfenbüttel, Holy Roman Empire

Death: February 23, 1855, Göttingen, Kingdom of Hanover

Known for: Number theory, algebra, statistics, analysis, differential geometry, geodesy, geophysics, mechanics, electrostatics, astronomy, matrix theory and optics

"Astronomy and Pure Mathematics are the magnetic poles toward which the compass of my mind ever turns."

— Carl Friedrich Gauss

[42] Albrecht von Haller

Birth: October 16, 1708, Bern, Swiss Confederacy

Death: December 12, 1777, Bern, Swiss Confederacy

Known for: Eighteenth-Century Medicine

"Nature never jests."

— Albrecht von Haller

[43] Friedrich August Kekule von Stradonitz

Birth: September 7, 1829, Darmstadt, Grand Duchy of Hesse

Death: July 13, 1896, Bonn, German Empire

Known for: Theory of chemical structure, tetravalence of carbon, structure of benzene

"Let us learn to dream, gentlemen, then perhaps we shall find the truth."

— *August Kekule*

[44] Robert Koch

Birth: Dec. 11, 1843, Clausthal, Hannover [now Clausthal-Zellerfeld, Germany]

Death: May 27, 1910, Baden-Baden, Germany

Known for: Bacteriology

"The day will come when man will have to fight noise as inexorably as cholera and the plague."

— *Robert Koch*

[45] Murray Gell-Mann

Birth: September 15, 1929, Manhattan, New York City, United States

Known for: Gell-Mann and Low theorem, Elementary particles, quarks, Gell-Mann matrices

"Think how hard physics would be if particles could think."

— Murray Gell-Mann

[46] Hermann Emil Louis Fischer

Birth: October 09, 1852, Euskirchen, Rhine Province

Death: July 15, 1919, Berlin, Germany

Known for: Organic Chemistry

"To use a picture, I will say that enzyme and glucoside must join one another as lock and key, in order to be able to exert a chemical effect."

— Hermann Emil Fischer

[47] Dmitri Mendeleev

Birth: Jan. 27 [Feb. 8, New Style], 1834, Tobolsk, Siberia, Russian Empire

Death: Jan. 20 [Feb. 2], 1907, St. Petersburg, Russia

Known for: the Periodic Table of Elements

"Work, look for peace and calm in work; you will find it nowhere else."

— Dmitri Mendeleev

[48] Sheldon Glashow

Birth: December 5, 1932, New York City, New York, USA

Known for: Electroweak theory & Georgi–Glashow model

"Some astrophysicists have convinced themselves that the fifth significant figure of the fine structure constant has changed over the past ten billion years."

— Sheldon L. Glashow

[49] James Dewey Watson

Birth: April 6, 1928, Chicago, Illinois, U.S

Known for: the Structure of DNA

"Today, the theory of evolution is an accepted fact for everyone but a fundamentalist minority, whose objections are based not on reasoning but on doctrinaire adherence to religious principles."

— James D. Watson

- **Letter from James Watson to Max DelbrÃžck. March 12, 1953**

March 12, 1953

Dear Max

Thank you very much for your recent letters. We were quite interested in your account of the Pauling Seminar. The day following the arrival of your letter, I received a note from Pauling, mentioning that their model had been revised, and indicating interest in our model. We shall thus have to write him in the near future as to what we are doing. Until now we preferred not to write him since we did not want to commit ourselves until we were completely sure that all of the Van der Waals contacts were correct and that all aspects of our structure were stereochemically feasible. I believe now that we have made sure that our structure can be built and today we are laboriously calculating out exact atomic coordinates.

Our model (a joint project of Francis Crick and myself) bears no relationship to either the original or the revised Pauling-Corey-Schomaker models. It is a strange model and embodies several unusual features. However since DNA is an unusual substance, we are not hesitant in being bold. The main features of the model are (1) The basic structure is helical - it consists of two intertwining helices - the core of the helix is occupied by the purine and pyrimidine bases - the phosphates groups are on the outside. (2) The helices are not identical but complementary so that if one helix contains a purine base, the other helix contains a pyrimidine - this feature is a result of our attempt to make the residues equivalent and at the same time put the purines and pyrimidine bases in the center. The pairing of the purine with pyramidines is very exact and dictated by their desire to form hydrogen bonds - Adenine will pair with Thymine while Guanine will always pair with Cytosine. For example [diagrams of base pairing] Thymine with Adenine, Cytosine with Guanine.

While my diagram is crude, in fact these pairs form 2 very nice hydrogen bonds in which all of the angles are exactly right. This pairing is based on the effective existence of only one out of the two possible tautomeric forms - in all cases we prefer the keto form over the enol[,] the amino over the imino. This is definitely an assumption but Jerry Donohue and Bill Cochran tell us that for all organic molecules so far examined, the keto and amino forms are present in preference to the enol and imino possibilities.

The model has been derived almost entirely from stereochemical considerations with the only x-ray consideration being the spacing between the pair of bases 3.4 A which was originally found by Astbury. It tends to build itself with approximately 10 residues per tern in 34 A. The screw is right handed.

The x-ray pattern approximately agreed with the model, but since the photographs available to us are poor and meagre (we have no prototypes of our own and like Pauling must use Astbury's photographs) this agreement in no way constitutes a proof of our model. We are certainly a long way from proving its correctness. To do this we must obtain collaboration from the group at Kings College London who possess very excellent photographs of a crystalline phase in addition to rather good photographs of a paracrystalline phase. Our model has been made in reference to the paracrystalline form, and as yet we have no clear idea as to how these helices pack together to form the crystalline phase.

In the next day or so Crick and I shall send a note to Nature proposing our structure as a possible model, at the same time emphasizing its provisional nature and the lack of proof in its favor. Even if wrong I believe it to be interesting since it promises a concrete example of a structure composed of complementary chains. If by chance, it is right then

I suspect we may be making a slight dent into the manner in which DNA can reproduce itself. For these reasons (in addition to many others) I prefer this type of model over Pauling's which if true would tell us next to nothing about [the] manner of DNA reproduction.

I shall write you in a day or so about the recombination paper. Yesterday I received a very interesting note from Bill Hayes. I believe he is sending you a copy.

I have met Alfred Tissieus recently. He seems very nice. He speaks fondly of Pasadena and I suspect has not yet become accustomed to being a Fellow of Kings.

My regards to Mary

Jim

P.S. We would prefer your not mentioning this letter to Pauling. When our letter to Nature is completed we shall send him a copy. We should like to send him coordinates.

[50] John Bardeen

Birth: May 23, 1908, Madison, Wisconsin, U.S

Death: Jan. 30, 1991, Boston, Massachusetts, U.S

Known for: Superconductivity and BCS theory

"Science is a field which grows continuously with ever expanding frontiers. Further, it is truly international in scope. Any particular advance has been preceded by the contributions of those from many lands who have set firm foundations for further developments. The Nobel awards should be regarded as giving recognition to this general scientific progress as well as to the individuals involved.

Further, science is a collaborative effort. The combined results of several people working together is often much more effective than could be that of an individual scientist working alone."

— John Bardeen

[51] John von Neumann

Birth: December 28, 1903, Budapest, Austria-Hungary

Death: February 8, 1957, Walter Reed General Hospital Washington, D.C.

Known for: the Modern Computer

"Young man, in mathematics you don't understand things. You just get used to them."

— John von Neumann

[52] Richard P. Feynman

Birth: May 11, 1918, New York, N.Y., U.S.

Death: Feb. 15, 1988, Los Angeles, California

Known for: Quantum Electrodynamics

"Study hard what interests you the most in the most undisciplined, irreverent and original manner possible."

— Richard Feynman

- **Feynman's letter to an old pupil of his - on the worthwhile of 'humble' research**

27 October 1964

Mr. David Eisenman

Harvard University

Adams C-56

Cambridge 38, Massachusetts

Dear Mr. Eisenman:

Thank you for your interesting letter describing that wonderful phenomenon. I guess your "zero" is displaced outward but the inner nerve connections are as usual, so you have to "converge" to see parallel. Half way through your letter, I though, "poor guy", but on reading of the manifold advantages that your singular ability has for your [sic], I am going back to the bathroom mirror and practice harder this time, again and again, to see if I can do it too. Evidently you are a genetically advantageous mutation, and we can guess now where the evolution of the human race is headed.

Sincerely,

[signed]

Richard P. Feynman

[53] Alfred Lothar Wegener

Birth: Nov. 1, 1880, Berlin, Germany

Death: Nov. 1930, Greenland

Known for: Continental Drift

"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. ... It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw."

— *Alfred Wegener*

[54] Stephen W. Hawking

Birth: Jan. 8, 1942, Oxford, Oxfordshire, England

Known for: Quantum Cosmology

"Intelligence is the ability to adapt to change."

— *Stephen Hawking*

- Stephen Hawking was born on the 300th death anniversary of Galileo Galilei, and died on the 139th birth anniversary of Albert Einstein.

- **Memories of my father - Lucy Hawking**

On the bleak greyness of a Cambridge spring day, we set off in a cortège of black cars towards Great St Mary's Church, the university church where distinguished academics by tradition have their funeral services. Out of term, the streets seemed muted. Cambridge looked empty, not even a wandering tourist in sight. The only spikes of colour came from the blue flashing lights of the police motorcycle outriders, guarding the hearse with my father's coffin in it, stopping the sparse traffic as we went.

And then we turned left. And saw the crowds, massed along one of the most recognisable streets in the world, King's Parade, the heart of Cambridge itself. I have never seen so many people so silent. With banners, flags, cameras and mobile phones held aloft, the huge numbers of people lining the streets stood in quiet respect as the head porter of Gonville and Caius, my father's Cambridge college, dressed ceremonially in his bowler hat and carrying an ebony cane, walked solemnly along the street to meet the hearse and walk it to the church.

My aunt squeezed my hand as we both burst into tears. "He would have loved this," she whispered to me. Since my father died, there has been so much he would have loved, so much I wish he could have known. I wish he could have seen the extraordinary outpouring of affection towards him, coming from all around the world. I wish he could have known how dearly loved and respected he was by millions of people he had never met. I wish he had known he would be interred in Westminster Abbey, between two of his scientific heroes, Isaac Newton and Charles Darwin, and that as he was laid to rest in the earth his voice would be beamed by a radio telescope towards a black hole.

But he would also have wondered what all the fuss was about. He was a surprisingly modest man who, while adoring the limelight, seemed baffled by his own fame. One phrase in this book jumped off the page at me as summing up his attitude to himself: "if I have made a contribution." He is the only person who would have added the "if" to that sentence. I think everyone else felt pretty sure he had. And what a contribution it is. Both in the overarching grandeur of his work in cosmology, exploring the structure and origins of the universe itself and in his completely human bravery and humour in the face of his challenges. He found a way to reach beyond the limits of knowledge while surpassing the limits of endurance at the same time. I believe it was this combination which made him so iconic yet also so reachable, so accessible. He suffered but he persevered. It was effortful for him to communicate—but he made that effort, constantly adapting his equipment as he further lost mobility. He selected his words precisely so that they would have maximum impact when spoken in that flat electronic voice which became so oddly expressive when used by him. When he spoke, people listened, whether it was his views on the NHS or on the expansion of the universe, never losing an opportunity to include a joke, delivered in the most deadpan fashion but with a knowing twinkle in his eyes.

My father was also a family man, a fact lost on most people until the film The Theory of Everything came out in 2014. It certainly was not usual, in the 1970s, to find a disabled person who had a spouse and children of his own nor one with such a strong sense of autonomy and independence. As a small child, I intensely disliked the way strangers felt free to stare at us, sometimes with open mouths, as my father piloted his wheelchair at insane speeds through Cambridge, accompanied by two mop-haired blond children, often running alongside while trying to eat an ice cream. I thought it was incredibly rude. I used to try to stare back but I don't think my indignation ever hit the target, especially not from a childish face smeared with melted lolly.

It wasn't, by any stretch of the imagination, a normal childhood. I knew that—and yet at the same time I didn’t. I thought it was perfectly normal to ask grown-ups lots of challenging questions because this is what we did at home. It was only when I allegedly reduced a vicar to tears with my close examination of his proof of the existence of God that it started to dawn on me that this was unexpected. As a child, I didn’t think of myself as the questioning type — I believed that was my elder brother, who in the manner of elder brothers outsmarted me at every turn (and indeed still does). I remember one family holiday—which, like so many family holidays, mysteriously coincided with an overseas physics conference. My brother and I attended some of the lectures — presumably to give my mother a break from her wraparound caring duties. In those days, physics lectures were not popular and definitely not for kids. I sat there, doodling on my notepad, but my brother put his skinny littleboy arm in the air and asked a question of the distinguished academic presenter while my father glowed with pride. I am often asked, "What is it like to be Stephen Hawking's daughter?" and inevitably, there is no brief answer that fits the bill. I can say that the highs were very high, the lows were profound and that in between existed a place which we used to call "normal — for us," an acceptance as adults that what we found normal wouldn't count as such for anyone else. As time dulls the raw grief, I have reflected that it could take me forever to process our experiences. In a way, I'm not even sure I want to. Sometimes, I just want to hold on to the last words my father said to me, that I had been a lovely daughter and that I should be unafraid. I will never be as brave as him — I'm not by nature a particularly courageous person — but he showed me that I could try. And that trying might turn out to be the most important part of courage.

My father never gave up, he never shied away from the fight. At the age of seventy-five, completely paralysed and able to move only a few facial muscles, he still got up every day, put on a suit and went to work. He had stuff to do and was not going to let a few trivialities get in his way. But I have to say, had he known about the police motorcycle outriders who were present at his funeral, he would have requested them each day to navigate him through the morning traffic from his home in Cambridge to his office.

Happily, he did know about this book. It was one of the projects he worked on in what would turn out to be his last year on Earth. His idea was to bring his contemporary writings together into one volume. Like so many things that have happened since he died, I wish he could have seen the final version. I think he would have been very proud of this book and even he might have had to admit, in the end, that he had made a contribution after all.

Lucy Hawking

July 2018

[55] Antonie van Leeuwenhoek

Birth: Oct. 24, 1632, Delft, Neth.

Death: Aug. 26, 1723, Delft

Known for: the Simple Microscope

"My determination is not to remain stubbornly with my ideas but I'll leave them and go over to others as soon as I am shown plausible reason which I can grasp. This is the more true since I have no other purpose than to place truth before my eyes so far as it is in my power to embrace it; and to use the little talent I have received to draw the world away from its old heathenish superstitions and to go over to the truth and to stick to it."

— *Antony Van Leeuwenhoek*

[56] Max von Laue

Birth: Oct. 09, 1879, Pfaffendorf, Kingdom of Prussia, German Empire

Death: April 24, 1960, West Berlin

Known for: X-ray Crystallography

"For in 1900 all electromagnetic radiation of longer wavelengths was already known at least to the extent that one could not seek in it the more striking characteristics of X-rays such as, for example, the strong penetrating power."

—Max von Laue

[57] Gustav Kirchhoff

Birth: March 12, 1824, Königsberg, Kingdom of Prussia [present-day Russia]

Death: October 17, 1887, Berlin, Prussia, German Empire [present-day Germany]

Known for: Kirchhoff's circuit laws, Kirchhoff's laws of spectroscopy, Kirchhoff's law of thermochemistry and Kirchhoff's law of thermal radiation

"Look here, I have succeeded at last in fetching some gold from the sun.

{After his banker questioned the value of investigating gold in the Fraunhofer lines of the sun and Kirchhoff handing him over a medal he was awarded for his investigations.}"

— Gustav Kirchhoff

[58] Hans Bethe

Birth: July 2, 1906, Strassburg, Ger. [now Strasbourg, France]

Death: March 6, 2005, Ithaca, N.Y., U.S.

Known for: the Energy of the Sun

"We need science education to produce scientists, but we need it equally to create literacy in the public. Man has a fundamental urge to comprehend the world about him, and science gives today the only world picture which we can consider as valid. It gives an understanding of the inside of the atom and of the whole universe, or the peculiar properties of the chemical

substances and of the manner in which genes duplicate in biology. An educated layman can, of course, not contribute to science, but can enjoy and participate in many scientific discoveries which as constantly made. Such participation was quite common in the 19th century, but has unhappily declined. Literacy in science will enrich a person's life."

— Hans A. Bethe

[59] Euclid

Known for: the Foundations of Mathematics

"The laws of nature are but the mathematical thoughts of God."

— Euclid

[60] Gregor Mendel

Birth: July 22, 1822, Heinzendorf, Austria [now Hynčice, Czech Rep.]

Death: Jan. 6, 1884, Brünn, Austria-Hungary [now Brno, Czech Rep.]

Known for: the Laws of Inheritance

"I am convinced that it will not be long before the whole world acknowledges the results of my work."

— Gregor Mendel

[61] Heike Kamerlingh Onnes

Birth: September 21, 1853, Groningen, Netherlands

Death: February 21, 1926, Leiden, Netherlands

Known for: Superconductivity, Onnes-effect and Virial Equation of State

"The experiment left no doubt that, as far as accuracy of measurement went, the resistance disappeared. At the same time, however, something unexpected occurred. The disappearance did not take place gradually but abruptly. From 1/500 the resistance at 4.2K, it could be established that the resistance had become less than a thousand-millionth part of that at normal temperature. Thus the mercury at 4.2K has entered a new state, which, owing to its particular electrical properties, can be called the state of superconductivity."

— Heike Kamerlingh Onnes

[62] Thomas Hunt Morgan

Birth: September 25, 1866, Lexington, Kentucky

Death: December 04, 1945, Pasadena, California

Known for: the Chromosomal Theory of Heredity

"Except for the rare cases of plastid inheritance, the inheritance of all known cofactors can be sufficiently accounted for by the presence of genes in the chromosomes. In a word the cytoplasm may be ignored genetically."

— Thomas Hunt Morgan

[63] Hermann von Helmholtz

Birth: August 31, 1821, Potsdam, Kingdom of Prussia

Death: September 08, 1894, Charlottenburg, German Empire

Known for: the Rise of German Science

"What the recent physiology of the senses has shown by the way of experience is what Kant had tried to show for the representations of the human mind in general when he laid out the participation of the particular, built-in rules of the mind, the organization of the mind as it were, in our representations."

— Hermann von Helmholtz

[64] Paul Ehrlich

Birth: March 14, 1854, Strehlen, Lower Silesia, German Kingdom of Prussia

Death: August 20, 1915, Bad Homburg, Hesse, Germany

Known for: Chemotherapy

"Few problems are less recognized, but more important than, the accelerating disappearance of the earth's biological resources. In pushing other species to extinction, humanity is busy sawing off the limb on which it is perched."

— Paul Ehrlich

[65] Ernst Walter Mayr

Birth: July 05, 1904, Kempten, Germany

Death: February 03, 2005, Bedford, Massachusetts, United States

Known for: Evolutionary Theory

"According to the concept of transformational evolution, first clearly articulated by Lamarck, evolution consists of the gradual transformation of organisms from one condition of existence to another."

— Ernst Mayr

[66] Theodosius Grygorovych Dobzhansky

Birth: January 25, 1900, Nemyriv, Russian Empire

Death: December 18, 1975, San Jacinto, California, United States

Known for: the Modern Synthesis

"Nothing in biology makes sense except in the light of evolution."

— Theodosius Dobzhansky

[67] Max Delbruck

Birth: September 04, 1906, Berlin, German Empire

Death: March 9, 1981, Pasadena, California, United States

Known for: the Bacteriophage

"The scientist has in common with the artist only this: that he can find no better retreat from the world than his work and no stronger link with the world than his work."

— Max Delbruck

[68] Charles Scott Sherrington

Birth: November 27, 1857, Islington, Middlesex, England

Death: March 04, 1952, Eastbourne, Sussex, England

Known for: Neurophysiology

"Swiftly the brain becomes an enchanted loom, where millions of flashing shuttles weave a dissolving pattern-always a meaningful pattern-though never an abiding one."

— Charles Sherrington

[69] Jean Baptiste Lamarck

Birth: August 01, 1744, Bazentin, Picardy, France

Death: December 18, 1829, Paris, France

Known for: the Foundations of Biology

"It is not enough to discover and prove a useful truth previously unknown, but that it is necessary also to be able to propagate it and get it recognized."

— Jean-Baptiste Lamarck

[70] William Bayliss

Birth: May 2, 1860, Wednesbury, Staffordshire, England

Death: August 27, 1924, London, England

Known for: Modern Physiology

"But at the same time, there must never be the least hesitation in giving up a position the moment it is shown to be untenable. It is not going too far to say that the greatness of a scientific investigator does not rest on the fact of his having never made a mistake, but rather on his readiness to admit that he has done so, whenever the contrary evidence is cogent enough."

— William Bayliss

[71] John Dalton

Birth: Sept. 5 or 6, 1766, Eaglesfield, Cumberland, England

Death: July 27, 1844, Manchester

Known for: the Theory of the Atom

It's the right idea, but not the right time.

— John Dalton

[72] Frederick Sanger

Birth: August 13, 1918, Rendcomb, Gloucestershire, England

Death: November 19, 2013, Cambridge, Cambridgeshire, England

Known for: the Genetic Code

"A DNA sequence for the genome of bacteriophage ΦX174 of approximately 5,375 nucleotides has been determined using the rapid and simple 'plus and minus' method. The sequence identifies many of the features responsible for the production of the proteins of the nine known genes of the

organism, including initiation and termination sites for the proteins and RNAs. Two pairs of genes are coded by the same region of DNA using different reading frames."

— Frederick Sanger

[73] Louis Victor de Broglie

Birth: August 15, 1892, Dieppe, France

Death: March 19, 1987, Louveciennes, France

Known for: Wave/Particle Duality

"After long reflection in solitude and meditation, I suddenly had the idea, during the year 1923, that the discovery made by Einstein in 1905 should be generalised by extending it to all material particles and notably to electrons."

— Louis de Broglie

[74] Carl Linnaeus

Birth: May 23, 1707, Råshult, Stenbrohult parish (now within Älmhult Municipality), Sweden

Death: January 10, 1778, Hammarby (estate), Danmark parish (outside Uppsala), Sweden

Known for: the Binomial Nomenclature

"When all the thoughts are concerning one thing and the person loses interest in other things, the melancholy begins."

— Carl Linnaeus

[75] J. Robert Oppenheimer

Birth: April 22, 1904, New York, N.Y., U.S.

Death: Feb. 18, 1967, Princeton, N.J.

Known for: the Atomic Era

"The optimist thinks this is the best of all possible worlds. The pessimist fears it is true."

— J. Robert Oppenheimer

[76] Sir Alexander Fleming

Birth: Aug. 6, 1881, Lochfield Farm, Darvel, Ayrshire, Scotland

Death: March 11, 1955, London, England

Known for: Penicillin

"One sometimes finds what one is not looking for."

— Alexander Fleming

[77] Jonas Edward Salk

Birth: October 28, 1914, New York

Death: June 23, 1995, La Jolla, California, United States

Known for: Vaccination

"There is hope in dreams, imagination, and in the courage of those who wish to make those dreams a reality."

— *Jonas Salk*

[78] Robert Boyle

Birth: Jan. 25, 1627, Lismore Castle, County Waterford, Ireland

Death: Dec. 31, 1691, London, England

Known for: Boyle's law

"Those distinct substances, which concretes generally either afford, or are made up of, may, without very much inconvenience, be called the elements or principles of them."

— *Robert Boyle*

[79] Francis Galton

Birth: Feb. 16, 1822, near Sparkbrook, Birmingham, Warwickshire, England

Death: Jan. 17, 1911, Grayshott House, Haslemere, Surrey

Known for: Eugenics

"Men who leave their mark on the world are very often those who, being gifted and full of nervous power, are at the same time haunted and driven by a dominant idea, and are therefore within a measurable distance of insanity."

— *Francis Galton*

[80] Joseph Priestley

Birth: March 13, 1733, Birstall Fieldhead, near Leeds, Yorkshire [now West Yorkshire], England

Death: Feb. 6, 1804, Northumberland, Pa., U.S.

Known for: Discovery of oxygen

"We should like to have some towering geniuses, to reveal us to ourselves in color and fire, but of course they would have to fit into the pattern of our society and be able to take orders from sound administrative types."

— Joseph Priestley

[81] Hippocrates

Known for: Medicine

"Let food be thy medicine and medicine be thy food."

— Hippocrates

[82] Pythagoras

Known for: Pythagorean Theorem

"Educate the children and it won't be necessary to punish the men."

— Pythagoras

"There is geometry in the humming of the strings. There is music in the spacing of the spheres."

— Pythagoras

[83] Benjamin Franklin

Birth: January 17, 1706, Boston, Massachusetts Bay, British America

Death: April 17, 1790, Philadelphia, Pennsylvania, U.S.

Known for: Electricity

"In wine there is wisdom, in beer there is Freedom, in water there is bacteria."

— Benjamin Franklin

[84] Leonardo da Vinci

Birth: April 15, 1452, Anchiano, near Vinci, Republic of Florence [now in Italy]

Death: May 2, 1519, Cloux [now Clos-Luce], France

Known for: Mechanics and Cosmology

"Painting is poetry that is seen rather than felt, and poetry is painting that is felt rather than seen."

— Leonardo da Vinci

- **Leonardo da Vinci Letter to Ludovico Sforza**

My Most Illustrious Lord,

Having now sufficiently seen and considered the achievements of all those who count themselves masters and artificers of instruments of war, and having noted that the invention and performance of the said instruments is in no way different from that in common usage, I shall endeavour, while intending no discredit to anyone else, to make myself understood to Your Excellency for the purpose of unfolding to you my secrets, and thereafter offering them at your complete disposal, and when the time is right bringing into effective operation all those things which are in part briefly listed below:

I have plans for very light, strong and easily portable bridges with which to pursue and, on some occasions, flee the enemy, and others, sturdy and indestructible either by fire or in battle, easy and convenient to lift and place in position. Also means of burning and destroying those of the enemy.

I know how, in the course of the siege of a terrain, to remove water from the moats and how to make an infinite number of bridges, mantlets and scaling ladders and other instruments necessary to such an enterprise.

Also, if one cannot, when besieging a terrain, proceed by bombardment either because of the height of the glacis or the strength of its situation and location, I have methods for destroying every fortress or other stranglehold unless it has been founded upon a rock or so forth.

I have also types of cannon, most convenient and easily portable, with which to hurl small stones almost like a hail-storm; and the smoke from the cannon will instil a great fear in the enemy on account of the grave damage and confusion.

Also, I have means of arriving at a designated spot through mines and secret winding passages constructed completely without noise, even if it should be necessary to pass underneath moats or any river.

Also, I will make covered vehicles, safe and unassailable, which will penetrate the enemy and their artillery, and there is no host of armed men so great that they would not break through it. And behind these the infantry will be able to follow, quite uninjured and unimpeded.

Also, should the need arise, I will make cannon, mortar and light ordnance of very beautiful and functional design that are quite out of the ordinary.

Where the use of cannon is impracticable, I will assemble catapults, mangonels, trebuckets and other instruments of wonderful efficiency not in general use. In short, as the variety of circumstances dictate, I will make an infinite number of items for attack and defence.

And should a sea battle be occasioned, I have examples of many instruments which are highly suitable either in attack or defence, and craft which will resist the fire of all the heaviest cannon and powder and smoke.

In time of peace I believe I can give as complete satisfaction as any other in the field of architecture, and the construction of both public and private buildings, and in conducting water from one place to another.

Also I can execute sculpture in marble, bronze and clay. Likewise in painting, I can do everything possible as well as any other, whosoever he may be.

Moreover, work could be undertaken on the bronze horse which will be to the immortal glory and eternal honour of the auspicious memory of His Lordship your father, and of the illustrious house of Sforza.

And if any of the above-mentioned things seem impossible or impracticable to anyone, I am most readily disposed to demonstrate them in your park or in whatsoever place shall please Your Excellency, to whom I commend myself with all possible humility.

[85] Ptolemy

Known for: Greco-Roman science

"I know that I am mortal by nature, and ephemeral; but when I trace at my pleasure the windings to and fro of the heavenly bodies I no longer touch the earth with my feet: I stand in the presence of Zeus himself and take my fill of ambrosia."

— *Ptolemy*

[86] Joseph-Louis Gay-Lussac

Birth: Dec. 6, 1778, Saint-Léonard-de-Noblat, France

Death: May 9, 1850, Paris

Known for: Behavior of gases

"In the natural sciences, and particularly in chemistry, generalities must come after the detailed knowledge of each fact and not before it."

— Joseph-Louis Gay-Lussac

[87] Archimedes

Known for: the Beginning of Science

"Give me a place to stand and I will move the earth."

— Archimedes

[88] Sir Fred Hoyle

Birth: June 24, 1915, Bingley, Yorkshire [now West Yorkshire], England

Death: Aug. 20, 2001, Bournemouth, Dorset

Known for: Stellar nucleosynthesis

"Space isn't remote at all. It's only an hour's drive away if your car could go straight upwards."

— Fred Hoyle

- Fred Hoyle Dies at 86; Opposed 'Big Bang' but Named It

[89] Norman Ernest Borlaug

Birth: March 25, 1914, Cresco, Iowa, U.S.

Known for: Green revolution

"You can't build a peaceful world on empty stomachs and human misery."

— Dr. Norman Ernest Borlaug

[90] Amedeo Avogadro

Birth: Aug. 9, 1776, Turin, in the Kingdom of Sardinia and Piedmont

Death: July 9, 1856, Turin, Italy

Known for: Molecular Hypothesis of Combining Gases

"We suppose ... that the constituent molecules of any simple gas whatever (i.e., the molecules which are at such a distance from each other that they cannot exercise their mutual action) are not formed of a solitary elementary molecule, but are made up of a certain number of these molecules united by attraction to form a single one."

— Count of Quaregna Amedeo Avogadro

[91] Luis W. Alvarez

Birth: June 13, 1911, San Francisco, Calif., U.S.

Death: Sept. 1, 1988, Berkeley, California

Known for: discovery of many resonance particles (subatomic particles having extremely short lifetimes and occurring only in high-energy nuclear collisions)

*"Around the lab I heard that publicity was measured in an absolute unit, the "kan". That unit was too large for ordinary application and a practical unit one one-thousandth of the size served in its place, the "**millikan**"."*

— Luis W. Alvarez

[92] George Gamow

Birth: March 4, 1904, Odessa, Russian Empire [now in Ukraine]

Death: Aug. 19, 1968, Boulder, Colo., U.S.

Known for: Big Bang Hypothesis

"It took less than an hour to make the atoms, a few hundred million years to make the stars and planets, but five billion years to make man!"

— George Gamow

- **Letter from George Gamow to Linus Pauling. October 22, 1953**

Oct 22d 1953

Dear Pauling,

I am playing with complex organic molecules (what I never did before!), am getting some amusing results, and would like to hear your opinion about it.

Ever since I read the article of Watson and Crick last June, I was trying to figure out how a long number written in a four digital system (i.e. nucleic acid molecule) can determine (uniquely) a correspondingly long word based on 20-letter-alphabet (i.e. an enzyme molecule). Along the lines of key & lock ideas, one could think about different amino acids as fitting into quadrangular loops formed by four bases in the DNA chain. But there are only five different types of such loops ie such as [diagram of types], etc.

For a while I have thought that things can be helped by permitting 1-4 (excited) and 3-2 (excited) bonds since, indeed, this would lead to twenty different types of loops. But it would lead to a complete breakup of the original W&C model of replication process and is apparently inacceptable.

1-Adenine, 2-Thymine

3-Guanine, 4-Cytosine.

It just occurred to me today that another way of getting 20 different loops would be the use of triangular combinations with three arbitrary bases at vertices: [drawing of triangular combinations] etc.

$$\frac{4 \times 5 \times 6}{1 \times 2 \times 3} = 20.$$

And, indeed, the W&C model permits such shapes because of helical nature of DNA. On the surface of a cylinder the bases will form a system of rombs with three independent and one dependent and one dependent vertices. A, B, and C can be any of the four bases, while D is determined completely by B (D=2 if B=1, ect) [drawing of cylinder]

Thus, there are 20 different types of such rombs, and I wonder [whether] the 20 amino acids "vital for life" are just those which would fit into these 20 different "locks". What do you think about it? It would be wonderful if it could be true!

The shape of these loops should also explain the fact that only L-amino acids could be used for building of proteins by DNA.

Yours

Geo Gamow

[93] Francis Collins

Birth: April 14, 1950, Staunton, Va., U.S.

Known for: Human Genome Project

"Yeah, it's true we're all dealt a set of cards. But it's also true that it's up to us to figure out how to play the hand."

— Francis S. Collins

[94] Albert Abraham Michelson

Birth: Dec. 19, 1852, Strelno, Prussia [now Strzelno, Pol.]

Death: May 9, 1931, Pasadena, Calif., U.S.

Known for: Establishment of the speed of light as a fundamental Constant

"The velocity of light is one of the most important of the fundamental constants of Nature. Its measurement by Foucault and Fizeau gave as the result a speed greater in air than in water, thus deciding in favor of the undulatory and against the corpuscular theory. Again, the comparison of the electrostatic and the electromagnetic units gives as an experimental result a value remarkably close to the velocity of light–a result which justified Maxwell in concluding that light is the propagation of an electromagnetic disturbance. Finally, the principle of relativity gives the velocity of light a still greater importance, since one of its fundamental postulates is the constancy of this velocity under all possible conditions."

— A.A. Michelson

[95] Rachel Carson

Birth: May 27, 1907, Springdale, Pa., U.S.

Death: April 14, 1964, Silver Spring, Md.

Known for: Environmental pollution and the natural history of the sea

"In nature nothing exists alone."

— Rachel Carson

[96] Joseph Lister

Birth: April 5, 1827, Upton, Essex, England

Death: Feb. 10, 1912, Walmer, Kent

Known for: antiseptic medicine

"But when it has been shown by the researches of Pasteur that the septic property of the atmosphere depended not on the oxygen, or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured part might be avoided without excluding the air, by applying as a dressing some material capable of destroying the life of the floating particles. Upon this principle I have based a practice."

— Joseph Lister

[97] Louis Agassiz

Birth: May 28, 1807, Motier, Switz.

Death: Dec. 14, 1873, Cambridge, Mass., U.S.

Known for: Natural science

"Every great scientific truth goes through three stages. First, people say it conflicts with the Bible. Next they say it has been discovered before. Lastly they say they always believed it."

— Louis Agassiz

[98] André-Marie Ampère

Birth: Jan. 22, 1775, Lyon, France

Death: June 10, 1836, Marseille

Known for: Electrodynamics

"The future science of government should be called 'la cybernétique' (1843)

{Coining the French word to mean 'the art of governing,' from the Greek (Kybernetes = navigator or steersman), subsequently adopted as cybernetics by Norbert Wiener for the field of control and communication theory.}"

— André-Marie Ampère

[99] Paracelsus

Birth: Nov. 11 or Dec. 17, 1493, Einsiedeln, Switzerland

Death: Sept. 24, 1541, Salzburg, Archbishopric of Salzburg [now in Austria]

Known for: Der grossen Wundartzney ("**Great Surgery Book**")

"All things are poisons, for there is nothing without poisonous qualities. It is only the dose which makes a thing poison."

— Paracelsus

[100] Edward O. Wilson

Birth: April 15, 1452, Anchiano, near Vinci, Republic of Florence [now in Italy]

Death: June 10, 1929, Birmingham, Ala., U.S.

Known for: Sociobiology

"Destroying rainforest for economic gain is like burning a Renaissance painting to cook a meal."

— E.O. Wilson

Cosmology→ the study of the universe

How big is it?

How old is it?

How will it end?

Electricity + magnetism → electromagnetism

Speed of electromagnetic wave → speed of light

- **Evidence for special relativity**

  - Mass increase $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

    The experiments of Kaufmann and Bucherer

  - Time dilation $t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

The long-lived muon (2 μs to 22 μs)

- Invariance of the speed of light
- Particle experiments at the LHC

Maximum velocity = 0.999c

Mass increase

Particle creation via $E=MC^2$

The principle of equivalence → Equivalence of gravity and acceleration

- **Evidence for GR**

  - The perihelion of Mercury
  - The bending of starlight by the sun
  - Gravitational redshift

```
If redshifts are velocities, and if effect is non-local
Hubble's law = expansion of space? (Edd., de Sitter)
```

- **Expanding universe**

  - Einstein → Basic framework for theory
  - Friedman → Expanding universe (theoretical)
  - Hubble, Slipher → Recession of the galaxies (observed)
  - Lemaitre → Observation + theory

- **Nikola Tesla's Letter To His Mother**

My dear mother, I feel sad and dreary when I think of you. I don't know how, but I feel that you are not well.I wish I could be beside you now mother, to bring you a glass of water. All these years that I had spent in the service of mankind brought me nothing but insults and humiliation. This morning I woke up early, just before the dawn, because I had heard something that I have been hearing through my dreams for quite some time now. I heard this voice that sang some beautiful chant, lament or even prayer in Moorish. When I came to my senses I realized that this voice came from everywhere and it was impossible to determine whether it was from within. I am afraid of loosing my mind. I cannot confide this to Doctor Lionel because I don't trust him anymore. I heard that he visited Mr. Edison two weeks ago...

Again my thoughts are of you, Mother, and again I feel that same restlessness and sorrow. I will write to the Patent office to speed up the realization of my public experiment for one week. I have to go back home, to my homeland, to You. I know now for sure that you are not well because once again I have heard that lamenting voice, but this time I was wide awake. I still haven't lost my sense.

I didn't write to the Patent office, one of their agents came and I told him about my intentions in person. He said he was sorry, but the dates could not be changed because all the congressmen have already determined them. I went down to the Waterfalls and told the boys to prepare the turbines and wait for my call tomorrow.

I have decided to provide the mankind with the gift it deserves and to return to Europe, to You, Mother. Governments here are the same as the ones back home. I have realized now, at the very end, that the mankind depends on governments and the individual cannot change the world on himself. But that strange voice still bothers me. I know it is connected to You, my experiment, with something transcendental...

Dear Mother, I leave for Yugoslavia tomorrow. Miss Nora went to the Port and bought me the ticket for Lisbon. From there I will go by train to Zurich, and then straight home. It will take me approximately ten days, no more than two weeks, to get home.

Today I have entered the Congressional office building and at the middle of the congressional session asked for couple of minutes of their time. They weren't very happy about it but they let me. I asked for the telephone to call the laboratory at Niagara falls. The boys over there activated the turbines and the Congress hall was lit up with my power, ten times stronger than the regular one, as I promised it would. I didn't care about their reactions at all. I instantly left the hall, because I didn't do all this for them , but for the mankind. In that very moment, when I was looking at the lightning bulb to shine with "my" wireless electricity, I realized that I wasn't the maker of all this.

I felt that someone or something was carrying it from Niagara falls to the Congress hall and that the law I thought I "invented" actually always existed. I was just the vessel blessed with inspiration to formulate and explain it to the mankind. Instead of triumph and happiness, some empty sorrow emerged. I realized that I had missed something big in my life. As If I had left something unrecognized completely. Some formula was within the grasp of my understanding and I have failed or didn't want to clarify it. That has to be connected to that Moorish lament, I am sure of it now...

This letter will never get to you, Mother. I don't know why I write it to you when you cannot read it...rest in peace Mother and please forgive me for choosing paths that had lead me away from you. I cannot even be there for your funeral. I read the telegram that informed me of your death and despise people who weren't ready to understand two years ago that electricity can be transferred without wires. Now, they have seen it but they won't use it for centuries to come because someone burned my downtown laboratory to the ground, with all of my formulas and writings in it. They suspect of Mr. Edison. I became so indifferent, I cannot even recognize myself. I would maybe feel sad before but not any more because I am now sure that someone is keeping "my" patents under control, that "my" discovery isn't "mine" at all and finally, that mankind was not ready for it. I know that someone is overseeing everything and has a plan of their own, which is probably why I am indifferent.

My ship for Lisbon leaves at 11 o'clock. The car is waiting outside.

I will lay this letter on your grave, when I arrive at our village's graveyard. I believe in something that I have never believed at. I believe that I am still a part of you, and that my life is not over for good. I now feel sorry for avoiding Turks because they sang similar laments I heard before dawns. I now realize that they knew about this things a lot more than I ever did.

All those years spent in science were in vain. Please mother, pray for me over there if you can, sing the Moorish lament for the lost soul of your poor ignorant son...

My mother forgave me for taking my paths from Thee, so I can not come to the funeral. Pray there, for me, Mother, if you can.

This is the last letter by the famous Serbian scientist Nikola Tesla to his mother, Djuka.

PHYSICS GLOSSARY

- **Absolute zero:** The lowest possible temperature T, at which substances contain no heat energy Q.
- **Acceleration:** The rate at which the speed of an object is changing and it is given by the equation:

$$a = \frac{dv}{dt}$$

- **Anthropic principle:** We see the universe the way it is because if it were different we would not be here to observe it through a gigantic telescopes pointing deep into the immense sky – merely stating that the constants of nature must be tuned to allow for intelligence (otherwise we would not be here). Some believe that this is the sign of a cosmic creator. Others believe that this is a sign of the multiverse.
- **Antiparticle:** Each type of matter particle has a corresponding antiparticle – first predicted to exist by *P. A. M. Dirac*. When a particle collides with its antiparticle, they annihilate, leaving only pure energy in the form of discrete bundle (or quantum) of electromagnetic (or light) energy called photons.
- **Atom:** The basic unit of ordinary matter, made up of a tiny nucleus (consisting of positively charged protons and electrically neutral neutrons – which obey the strong interactions) surrounded by orbiting negatively charged weakly interacting particles called the electrons.
- **Big Bang:** The singularity at the beginning of the universe. The titanic explosion that created the universe, sending the galaxies hurtling in all directions. When the universe was created, the temperature was extremely hot, and the density of material was enormous i.e., infinite. The big bang took place 13.7 billion years ago, according to the WMAP satellite. The afterglow of the big bang is seen today as the cosmic background microwave radiation (of temperature 2.7 degrees above absolute zero). There are three experimental "proofs" of the big bang: the redshift of the galaxies, the cosmic background microwave radiation, and nucleosynthesis of the elements.
    - The observation of red shift is a key piece of evidence for the Big Bang theory about the origin of the Universe.
    - The other key piece of evidence for the Big Bang theory is cosmic microwave background radiation {CMB − A fossil from the early universe! − Released when atoms formed (300,000 year)}.

```
As the Universe cooled:
▪ Quarks condensed out
▪ Protons and neutrons condensed
▪ Atomic nuclei formed
▪ Electrons condensed onto nuclei to form neutral atoms

CMB looks completely uniform; 2.7 degrees above absolute zero.
Perfect blackbody spectrum
Radiation too uniform?
Perturbations < 1 in 10^5?

The Universe has expanded 1000 times since this light began its journey in the 3000°K
plasma
380,000 years old, Universe 1000 times smaller than today
3,000 degrees Kelvin cooler than sun's surface
```

- **Big crunch:** The singularity at the end of the universe i.e., The final collapse of the universe. If the density of matter is large enough (Omega – The parameter that measures the average density of matter in the universe – being larger than 1), then there is enough matter in the universe to reverse the original expansion and cause the universe to recollapse. Temperatures rise to infinity at the instant of the big crunch.
- **Big freeze:** The end of the universe when it reaches near absolute zero. The big freeze is probably the final state of our universe, because the sum of Omega and Lambda is believed to be 1.0, and hence the universe is in a state of inflation. There is not enough matter and energy to reverse the original expansion of the universe, so it will probably expand forever.
- **Big Bang nucleosynthesis:** The production of deuterium, Helium-3 and Helium-4 (the latter to about 25% mass fraction) in the first 500 to 1000 sec of the early universe. These light isotopes, plus measurable amounts of lithium-7 and trace amounts of elements B, Be, are the result of non-equilibrium nuclear

reactions as the universe cooled to about 10 to the power of 8 K. Heavier isotopes were produced in stellar nucleosynthesis.

- **Black hole:** A region of space-time from which nothing, not even light, can escape, because gravity is so strong and escape velocity equals the speed of light. Because the speed of light is the ultimate velocity in the universe, this means that nothing can escape a black hole, once an object has crossed the event horizon. Black holes can be of various sizes. Galactic black holes, lurking in the center of galaxies and quasars, can weight millions to billions of solar masses. Stellar black holes are the remnant of a dying star, perhaps originally up to forty times the mass of our Sun. Both of these black holes have been identified with our instruments. Mini–black holes may also exist, as predicted by theory, but they have not yet been seen in the laboratory conditions.
- **Black Hole Escape Velocity:** It is widely held by astrophysicists and astronomers that a black hole has an escape velocity c (or c, the speed of light in Vacuum). **Chandrasekhar** [Nobel laureate] remarked,

> "Let me be more precise as to what one means by a black hole. One says that a black hole is formed when the gravitational forces on the surface become so strong that light cannot escape from it. ... A trapped surface is one from which light cannot escape to infinity."

According to **Hawking**,

> "Eventually when a star has shrunk to a certain critical radius, the gravitational field at the surface becomes so strong that the light cones are bent inward so much that the light can no longer escape. According to the theory of relativity, nothing can travel faster than light. Thus, if light cannot escape, neither can anything else. Everything is dragged back by the gravitational field. So one has a set of events, a region of space-time from which it is not possible to escape to reach a distant observer. Its boundary is called the event horizon. It coincides with the paths of the light rays that just fail to escape from the black hole."

A neutron star has a radius of about ten miles, only a few times the critical radius at which a star becomes a black hole.

> "I had already discussed with Roger Penrose the idea of defining a black hole as a set of events from which it is not possible to escape to a large distance. It means that the boundary of the black hole, the event horizon, is formed by rays of light that just fail to get away from the black hole. Instead, they stay forever hovering on the edge of the black hole."

However, according to the alleged properties of a black hole, nothing at all can even leave the black hole. In the very same paper Chandrasekhar made the following quite typical contradictory assertion:

> "The problem we now consider is that of the gravitational collapse of a body to a volume so small that a trapped surface forms around it; as we have stated, from such a surface no light can emerge."

Hughes reiterates,

> "Things can go into the horizon (from r > 2M to r < 2M), but they cannot get out; once inside, all causal trajectories (time-like or null) take us inexorably into the classical singularity at r = 0."

The defining property of black holes is their event horizon. Rather than a true surface, black holes have a 'one-way membrane' through which stuff can go in but cannot come out.

Taylor and Wheeler assert,

```
"... Einstein predicts that nothing, not even light, can be successfully launched outward from the horizon ... and that light launched outward EXACTLY at the horizon will never increase its radial position by so much as a millimeter."
```

- **Zero point Energy:** an intrinsic and unavoidable part of quantum physics. The ZPE has been studied, both theoretically and experimentally, since the discovery of quantum mechanics in the 1920s and there can be no doubt that the ZPE is a real physical effect.
- **Casimir effect:** The attractive pressure between two flat, parallel metal plates placed very near to each other in a vacuum. The pressure is due to a reduction in the usual number of virtual particles in the space between the plates. This tiny effect has been measured in the laboratory. The Casimir effect may be used as the energy to drive a time machine or wormhole, if its energy is large enough.
- **Chandrasekhar limit:** The maximum possible mass of a stable cold star (i.e., 1.4 solar masses), above which it must collapse into a black hole.

```
A Horrific Humiliation and Sense of Betrayal | Eddington and Chandrasekhar

[1] Sir Arthur Stanley Eddington
Birth:  [28 December 1882] Kendal, Westmorland, England, United Kingdom
Death: [22 November 1944] (aged 61) Cambridge, Cambridgeshire, England, United Kingdom
Known for:
▪ Eddington approximation
▪ Eddington experiment
▪ Eddington limit
▪ Eddington number
▪ Eddington valve
▪ Eddington–Dirac number
▪ Eddington–Finkelstein coordinates
```

[2] **Subrahmanyan Chandrasekhar**

Birth: [19 October 1910] Lahore, Punjab, British India (present-day Punjab, Pakistan)

Death: [21 August 1995] (aged 84) Chicago, Illinois, U.S.

Known for:

- Chandrasekhar limit
- Chandrasekhar number
- Chandrasekhar friction
- Chandrasekhar–Kendall function
- Chandrasekhar's H-function
- Emden–Chandrasekhar equation
- Chandrasekhar–Page equations
- Chandrasekhar tensor
- Chandrasekhar virial equations
- Batchelor–Chandrasekhar equation
- Schönberg–Chandrasekhar limit
- Chandrasekhar's white dwarf equation
- Chandrasekhar polarization
- Chandrasekhar's X- and Y-function

This story dates back to 1930s when India was ruled or administered by the United Kingdom and its predecessor states. Just a few years ago, the Nobel Prize in Physics was awarded to the first Asian Sir Chandrasekhara Venkata Raman for his work on the scattering of light and for the discovery of the effect named after him. In this uncertain time when India was suffering under colonial rule of the British Raj, there was one Lahore-born, Presidency College-educated student who was dreaming of bringing the second Nobel Prize to his country and he was none other than Nephew of the Indian physicist Chandrasekhara Venkata Raman: Subrahmanyan Chandrasekhar.

Applied mathematician and astrophysicist Subrahmanyan Chandrasekhar completed his university education at Presidency College [Madras] graduating with a Bachelor of

Science degree in physics and to pursue his Master's Chandra went to Britain as he was awarded a Government of India scholarship to study at Cambridge as a member of Trinity College.

While on the voyage to Cambridge in 1930, Chandra worked on one of his most significant discoveries called **Chandrasekhar's limit**. He applied Albert Einstein's theory of relativity to the processes inside a star. His calculations suggested that once a stellar star had burned up all its energy (exhibiting a corresponding mass m given by its energy E divided by the speed of light squared) it would collapse to a point of infinite density where gravity is so strong that nothing—no particles or even electromagnetic radiation such as light—can escape from it.

Since he was born in an open minded Tamil Iyer family, to Sita Balakrishnan (1891–1931) and Chandrasekhara Subrahmanya Ayyar (1885–1960) who was stationed in Lahore as Deputy Auditor General of the Northwestern Railways at the time of Chandrasekhar's birth, He assumed the community there would welcome him and his contribution to the structure and evolution of stars with open arms. But the reality was far from what he had thought – his theories were overlooked because of his race. The scientific community in Britain ignored him and his work on the white dwarfs and black holes as a result of which he went into a deep mood disorder. He had lost all feeling of trust.

Then came an English astronomer, physicist, and mathematician "Sir Arthur Stanley Eddington". For those who don't know about Eddington, he was the

- Philosopher of science
- Populariser of science
- One who conducted an expedition to observe the solar eclipse of 29 May 1919 that provided one of the earliest confirmations of Albert Einstein's general theory of relativity, and he became known for his popular expositions and interpretations of the theory.

The legendary astrophysicist Arthur Stanley Eddington started meeting Chandra frequently. Chandra and Eddington were almost in daily contact about their research.

Subrahmanyan Chandrasekhar felt motivated that a man of Eddinton's reputation is helping him out. Arthur Eddington was also working on the similar subject and he encouraged Chandrasekhar to pursue the detailed calculations and produce his results at the Royal Astronomical Society meeting on 11 January 1935, in England to which Chandrasekhar agreed.

But, on January 10, he came to know that Eddington too had a lecture after him that too on the same topic. He was puzzled, but thought no more about it. On the day of the conference, all the leading figures in astrophysics were at the Royal Astronomical Society. Chandra delivered his paper, showing a graph that made it transparently clear that the maximum mass at which a star near the end of its life cycle can become a white dwarf and above which the star will collapse to form a neutron star or black hole: a stellar mass equal to about 1.4 solar masses. Triumphantly he sat down, assuming that Eddington would support his conclusions. But to his horror, Eddington – a supercilious man – claimed that there was no such thing as Chandra's relativistic degeneracy; arguing that Chandra's theory was mere mathematical game-playing – with no basis in reality, he used the full force of his famed oratorical skills to demolish the young researcher's calculations and theory. Eddington's arguments were unfounded and highly dubious; but the weight of his reputation was such that no one dared to disagree with him. Chandra was not even given the opportunity to reply to this confrontation. The next speaker was called.

This controversy rumbled and preoccupied scientific journals for several years. Chandra and Eddington came across each other in many conferences and it was Sir Arthur Eddington, who was always favored and at a talk at Harvard, Eddington termed Chandra's notions a "stellar buffoonery".

But years later, in one meeting it was proved that it was Chandrasekhar’s calculations that were correct. On that day, they both had a brief meeting. "I am sorry if I hurt you," Eddington said to Chandra. Chandra asked whether he had changed his mind. "No,"

```
Eddington responded. "What are you sorry about then?" Chandra replied and brusquely walked away.

Chandrasekhar was awarded the 1983 Nobel Prize for Physics with William A. Fowler for "... theoretical studies of the physical processes of importance to the structure and evolution of the stars". On several occasions he admitted that Eddington's behavior was indeed racially motivated.
```

- **Conservation of energy:** The law of science that states that energy (or its equivalent in mass) can neither be created nor destroyed i.e., they never change with time. For example, the conservation of matter and energy posits that the total amount of matter and energy in the universe is a constant.
- **Coordinates:** Numbers that specify the position of a point in a 4 dimensional space-time.
- **Cosmological constant:** A mathematical parameter (which measures the amount of dark energy in the universe) introduced by Albert Einstein to give space-time an inbuilt tendency to expand. At present, the data supports density parameter + cosmological constant = 1, which fits the prediction of inflation for a flat universe. Cosmological constant, which was once thought to be zero, is now known to determine the ultimate destiny of the universe.
- **Cosmology:** The study of the universe as a whole.

```
One coulomb of charge is that charge which when placed at rest in vacuum at a distance of one meter from an equal and similar stationary charge repels it and is repelled by it with a force of 9 x 10^9 Newton.
```

- **COBE:** The Cosmic Observer Background Explorer satellite.
- **Dark matter:** Invisible Matter usually found in a huge halo around galaxies, clusters, and possibly between clusters, that cannot be observed directly but can be detected by its gravitational effect and they does not interact with light. As much as 90 percent of the mass of the universe may be in the form of dark matter and

they makes up 23 percent of the total matter/energy content of the universe. According to string theory, dark matter may be made of subatomic particles, such as the neutralino, which represent higher vibrations of the superstring.

- **Duality:** A correspondence between apparently different theories that lead to the same physical results.
- **Einstein-Rosen bridge:** A thin tube of space-time linking two black holes.
- **Electric charge:** A property of a particle by which it may repel (or attract) other particles that have a charge of similar (or opposite) sign.
- **Electromagnetic force:** The force of electricity and magnetism that arises between particles with electric charge; the second strongest of the four fundamental forces –which obeys Maxwell's equations.
- **Electron:** A negatively charged subatomic particle with negative electric charge that orbits the nucleus of an atom and determines the chemical properties of the atom.
- **Electroweak unification energy:** The energy (around 100 GeV) above which the distinction between the electromagnetic force and the weak force disappears.
- **Elementary particle:** A particle that, it is believed fundamental building block of Nature, cannot be subdivided and are not composed of other simpler particles.
- **Event:** A point in space-time, specified by its time and place.
- **Event horizon:** The boundary of a black hole. The point of no return, often called the horizon.
- **Electromagnetic wave:** A wave in which electric and magnetic fields are perpendicular to each other and also perpendicular to the direction of propagation of wave.
- **Exclusion principle:** The idea that two identical spin-1/2 particles cannot have (within the limits set by the uncertainty principle) both the same position and the same velocity. This means that two electrons cannot occupy precisely the same point with the same properties, so that there is a net force pushing the electrons apart (in addition to electrostatic repulsion).
- **Electric Current:**

If the rate of flow of charge is steady: $I = \frac{q}{t}$

If the rate of flow of charge varies with time: $I = \frac{dq}{dt}$

Ohm's Law → Resistance = $\frac{\text{potential difference}}{\text{Current}}$

- **Field:** Something that exists throughout 4 dimensional fabric of space -time, as opposed to a particle that exists at only one point at a time.
- **Frequency:** For a wave, the number of complete cycles per second.
- **Fermi Level:** The highest energy level in the conduction band occupied by electrons in a crystal at absolute zero temperature. The energy corresponding to this energy level is called Fermi energy.
- **Gamma rays:** Electromagnetic rays of very short wavelength, produced in radio-active decay or by collisions of elementary particles.
- **General relativity:** Einstein's theory of gravity based on the idea that the laws of science should be the same for all observers, no matter how they are moving. It explains the force of gravity in terms of the curvature of a four dimensional space-time; so that the curvature of space-time gives the illusion that there is a force of attraction called gravity. It has been verified experimentally to better than 99.7 percent accuracy and predicts the existence of black holes and the expanding universe. The theory, however, break down at the center of a black hole or the instant of creation, where the theory predicts nonsense. To explain these phenomena, one must resort to a theory of subatomic physics.
- **Geodesic:** The shortest (or longest) path between two points.
- **Grand unification energy:** The energy above which, it is believed, the electromagnetic force, weak force, and strong force become indistinguishable from each other.
- **Grand unified theory (GUT):** A theory which unifies the electromagnetic, strong, and weak forces (but not gravity). The proton is not stable in these theories and can decay into positrons. GUT theories are inherently unstable (unless one adds super symmetry). GUT theories also lack gravity. (Adding gravity to GUT theories makes them diverge with infinities.)
- **Imaginary time:** Time measured using imaginary numbers.
- **Inflation:** The theory which states that the universe underwent an incredible amount of superliminal expansion at the instant of its birth i.e., A distance of one nanometer was enlarged to a quarter of a billion light-years.
- **Hyperspace:** Dimensions higher than four.

Like the Moon, Mercury has no atmosphere and its surface is full of craters.

A day on Mars is 24 hours 40 minutes and a year lasts for 1.88 Earth years

Venus is covered by a thick cloud mainly consisting of Sulphuric acid droplets.

Most of the mass of the solar system is contained in the Sun.

Total angular momentum of all the planets is more than the angular momentum of the Sun.

Nebular hypothesis

Our solar system is formed due to gravitational contraction of the rotating interstellar cloud called the solar nebula

Because the Sun and the planets are formed from the same rotating nebula:

The direction of rotation of the Sun and the directions of revolution of most of the planets are the same.

Extra-solar planets: Planets exist outside the solar system

The formation of a planet involves 3 phases:

1. Formation of a minute planet.
2. Formation of a small celestial object that is the size of a moon or a bit bigger.
3. Stabilization of the planet.

- **Light cone:** A surface in space-time that marks out the possible directions for light rays passing through a given event.
- **Light year:** The distance light travels in one year, or approximately 5.88 trillion miles (9.46 trillion kilometers).
- **LIGO:** The Laser Interferometry Gravitational-Wave Observatory, based in Washington state and Louisiana,which is the world's largest gravity wave detector.
- **LISA:** The Laser Interferometry Space Antenna- which is a series of three space satellites using laser beams to measure gravity waves. It is sensitive enough to confirm or disprove the inflationary theory and possibly even string theory.
- **Magnetic field:** The field responsible for magnetic forces, now incorporated along with the electric field, into the electromagnetic field.
- **Muon:** A subatomic particle identical to the electron but with a much larger mass. It belongs to the second redundant generation of particles found in the Standard Model.
- **Mass:** The quantity of matter in a body; its inertia, or resistance to acceleration.
- **Microwave background radiation:** The remnant radiation (with a temperature of about 2.7 degrees K) from the glowing of the hot early universe (big bang), now so greatly red-shifted that it appears not as light but as microwaves (radio waves with a wavelength of a few centimeters). Tiny deviations in this background radiation give scientists valuable data that can verify or rule out many cosmological theories.
- **Naked singularity:** A space-time singularity not surrounded by a black hole.
- **Neutrino:** An extremely light (possibly massless) subatomic particle that react very weakly with other particles and may penetrate several light-years of lead without ever interacting with anything and is affected only by the weak force and gravity.
- **Neutron:** A neutral subatomic particle, very similar to the proton, which accounts for roughly half the particles in an atomic nucleus. Neutron left alone for 15 minutes will decay into electron, proton, neutrino (very light, chargeless lepton).
- **Neutron star:** A cold collapsed star consisting of a solid mass of neutrons — which is usually about 10 to 15 miles across — supported by the exclusion principle repulsion between neutrons. If the mass of the neutron stars exceeds (3- 4 solar masses) i.e., if the number of neutrons becomes $\geq 5.9 \times 10^{57}$, then the

degenerate neutron pressure will not be large enough to overcome the gravitational contraction and the star collapses into the next stage called black holes.

- **No boundary condition:** The idea that the universe is finite but has no boundary (rooted in the Euclidean formalism) to account for the initial conditions in the big bang.
- **Nuclear fusion:** The process by which two nuclei collide and coalesce to form a single, heavier nucleus.
- **Nucleus:** The tiny core of an atom, which is roughly 10 to the power of -13 cm across, consisting only of protons and neutrons, held together by the strong force.
- **Particle accelerator:** A machine — based in Geneva, Switzerland — that, using electromagnets, can accelerate moving charged particles, giving them more energy.
- **Phase:** For a wave, the position in its cycle at a specified time: a measure of whether it is at a crest, a trough, or somewhere in between.
- **Photon sphere:** An area or region of space where gravity is so strong that photons are forced to travel in orbits. Because r = $\frac{3GM}{c^2}$ — photon spheres can only exist in the space surrounding an extremely compact object (a black hole or possibly an "**ultracompact**" neutron star).
- **Photon:** A quantum of light (which was first proposed by Einstein to explain the photoelectric effect—that is, the fact that shining light on a metal results in the ejection of electrons).
- **Planck's quantum principle:** The idea that light (or any other classical waves) can be emitted or absorbed only in discrete quanta, whose energy E is proportional to their wavelength λ (i.e., E = $\frac{hc}{\lambda}$).
- **Positron:** The (positively charged) antiparticle of the electron.
- **Primordial black hole:** A black hole created in the very early universe.
- **Negative energy:** Energy that is less than zero.
- **Proton:** A positively charged subatomic particle, very similar to the neutron, that accounts for roughly half the particles in the nucleus of most atoms. They are stable, but Grand Unification theory predicts that they may decay over a long period of time.
- **Pulsar:** A rotating neutron star that emits regular pulses of radio waves.
- **Quantum:** The indivisible unit in which waves may be emitted or absorbed.

The nuclear forces account for the attractive force between:

- a proton and a neutron
- 2 protons
- 2 neutrons

Bohr Correspondence principle

For large orbits and for large energies, quantum calculations must agree with classical calculations.

Semi-classical physics → a theory in which one part of a system is described quantum mechanically whereas the other is treated classically.

Condition

Einstein's special theory of relativity → classical mechanics	velocities are very small compared to the speed of light
Einstein's General theory of relativity → Newtonian gravity	weak gravitational fields
Statistical mechanics → thermodynamics	the number of particles is large
Laplace's theory of celestial mechanics →Kepler's theory of celestial mechanics	interplanetary interactions are ignored

Electrons can exist in states of positive energy as well as negative energy states:

$$E = \pm\sqrt{m_0^2c^4 + p^2c^2}$$

- The positive root permits the total energy "E" of an electron to have any value from m_0c^2 to $+\infty$
- The negative root permits the total energy "E" of an electron to have any value from $-\infty$ to $-m_0c^2$

As momentum increases

The formation of a non-radioactive element from a radioactive element constitute

Disintegration Series	Parent Element	Last Stable element
Thorium Series	$_{90}Th^{232}$	$_{82}Pb^{208}$
Neptunium Series	$_{93}Np^{237}$	$_{83}Bi^{209}$
Uranium Series	$_{92}U^{238}$	$_{82}Pb^{206}$
Actinium Series	$_{92}U^{235}$	$_{82}Pb^{207}$

The naturally occurring radioactive elements conform to 4 radioactive series

- **Quark:** A subatomic particle that makes up the proton and neutron and feels the strong force. Three quarks make up a proton or neutron, and a quark and antiquark pair makes up a meson.
- **Quantum chromodynamics (QCD):** The theory that describes the interactions of quarks and gluons.
- **Quantum mechanics:** The theory developed from wave equations, Planck's quantum principle and Heisenberg's uncertainty principle. No deviation from quantum mechanics has ever been found in the laboratory. Its most advanced version today is called quantum field theory, which combines special relativity and quantum mechanics. A fully quantum mechanical theory of gravity, however, is exceedingly difficult.

```
According to Quantum Mechanical Laws, the energies of electrons in a free atom cannot have arbitrary values but only some definite (quantized) values.
```

- **Quasar:** Quasi-stellar object. They are huge galaxies that were formed shortly after the gigantic explosion called the big bang.
- **Quantum foam:** Tiny, foam like distortions of 4 dimensional fabric of space-time at the level of the Planck length.
- **Radioactivity:** The spontaneous breakdown of one type of atomic nucleus into another.
- **Red shift:** The reddening or decrease in frequency of light from a star that is moving away from us, due to the Doppler effect.
    - Light from far away has more time to stretch
    - Light from nearby sources gets stretched less
    - Longer wavelength → redder light → far away light more red shifted
    - **Hubble's Expansion Law** → The farther away the galaxy, the bigger the redshift.
- **Refraction:**
  - Fact #1 → As light goes from one medium to another, the velocity CHANGES!
  - Fact #2 → As light goes from one medium to another, the path CHANGES!
- **Singularity:** A point in space-time at which the space-time curvature becomes infinite – which represent a breakdown of general relativity, forcing the introduction of a quantum theory of gravity.

The notable consequences of the Heisenberg's **uncertainty principle:**

- The path of a particle is not defined in **quantum physics** (the study of matter and energy at the most fundamental level).
- Electrons do not exist inside the nucleus of the atom.
- **Atomic oscillators** possess a certain amount of energy, known as the zero-point energy, even at absolute zero temperature.

Length Contraction:

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

For v = 0.9c:

$$L = 0.44L_0.$$

That is the measured length is less than half of the proper length. If $v << c$, then L and L_0 are nearly equal. At low velocities, relativity approaches classical mechanics — our everyday experiences have negligible relativistic effects.

An inertial frame is a frame of reference in which Newtonian first law holds well.

The Galilean principle of relativity:

If two cars are moving at the same speed in the same direction, then a passenger in either car will not be able to notice that either car is moving.

- The **special theory of relativity** deals with observations made in inertial frames.
- The **general theory of relativity** deals with observations made in non-inertial frames.

The negative outcome of the Michelson–Morley experiment (1887)

↓

The aether did not exist

The relativity of simultaneity

↓

2 events are defined to be simultaneous if an observer measures them as occurring at the same time. They are not necessarily simultaneous to all observers — **simultaneity** is not absolute.

- **Singularity theorem:** A theorem that states that the universe must have started with a singularity.
- **Space-time:** The four-dimensional space whose points are events.
- **Spatial dimension:** Any of the three dimensions that are space like – that is, any except the time dimension.
- **Special relativity:** Einstein's 1905 theory based on the idea that the laws of science should be the same for all observers, no matter how they are moving, in the absence of gravitational phenomena. Consequences include: time slows down, mass increases, and distances shrink the faster you move. Also, matter and energy are related via $E = mc^2 = \frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}}$. One consequence of special relativity is the atomic bomb.
- **Spectrum:** The different colors or component frequencies that make up a wave. By analyzing the spectrum of starlight, one can determine that stars are mainly made of hydrogen and helium.
- **Spin:** An internal property of elementary particles.
- **Stationary state:** One that is not changing with time.
- **Supernova:** An exploding star. They are so energetic that they can sometimes outshine a galaxy.
- **String theory:** A theory of physics based on tiny vibrating strings, such that each particle is described as a wave on a string. It is the only theory that can combine gravity with the quantum theory, making it the leading candidate for a theory of everything.
- **Strong force:** The strongest of the four fundamental forces, with the shortest range of all. It holds the quarks together within protons and neutrons, and holds the protons and neutrons together to form atoms.
- **Steady state theory:** The theory which states that the universe had no beginning but constantly generates new matter as it expands, keeping the same density.
- **Uncertainty principle:** The principle, formulated by Heisenberg, that one can never be exactly sure of both the position and the velocity of a particle; the more accurately one knows the one, the less accurately one can know the other.

$$\Delta x \times \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

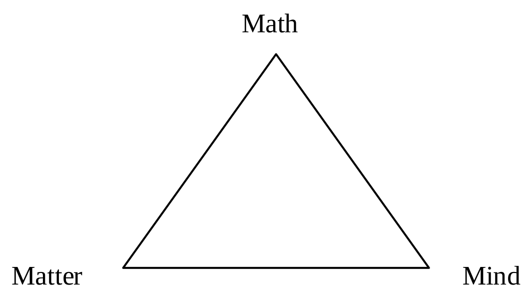
- **Virtual particle:** In quantum mechanics, a particle that briefly dart in and out of the vacuum but can never be directly detected, but whose existence does have measurable effects. They violate known conservation laws but only for a short period of time, via the uncertainty principle.
- **Wave / particle duality:** The concept in quantum mechanics that there is no distinction between waves and particles; particles may sometimes behave like waves, and waves like particles.
- **Wavelength:** For a wave, the distance between two adjacent troughs or two adjacent crests.
- **Weak force:** The second weakest of the four fundamental forces – which is carried by the W^{-} and Z^{-}bosons − that makes possible nuclear decay. It affects all matter particles, but not force carrying particles.
- **Weight:** The force exerted on a body by a gravitational field. It is proportional to, but not the same as, its mass.
- **White dwarf:** A stable cold star consisting of lower elements such as oxygen, lithium, carbon, and so forth, supported by the exclusion principle repulsion between electrons.
- **Wormhole:** A passageway between two universes or a thin tube of space-time connecting distant regions of the universe. Wormholes might also link to parallel or baby universes and could provide the possibility of time travel.

Telescopes make small, far objects appear larger.

Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the characters in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these one is wandering in a dark labyrinth.

– Galileo Galilei 1623

- **External Reality Hypothesis (ERH):** There exists an external physical reality completely independent of us human beings.
- **Mathematical Universe Hypothesis (MUH):** External physical reality is a mathematical structure.
- **Penrose's Bermuda triangle**



If we assume the satellite to go around the planet of mass M in a circular orbit of radius r with speed v, then the force balance equation is:

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$2\left(\frac{mv^2}{2}\right) - \frac{GMm}{r} = 0$$

The gravitational potential energy of the system (the Satellite and the planet) is:

$$E_G = -\frac{GMm}{r}$$

whereas the kinetic energy of the system is:

$$E_K = \frac{mv^2}{2}$$

$$2E_K + E_G = 0$$

This is the **virial theorem** for a satellite going around the Planet.

The size of the only star in our solar system is so big that it can contain the Earth as well as the orbit of the Moon

A Van Allen radiation belt is a zone of energetic charged particles– most of which originate from the upper atmosphere of the Sun– that are captured by and held around a earth by earth's magnetosphere.

Magnetohydrodynamics

The study of the motion of conducting fluid in the presence of magnetic field

$$\text{Magnetic Reynolds number} \propto \frac{\text{induction of a magnetic field by the motion of a conducting fluid}}{\text{magnetic diffusion}}$$

>>1: the magnetic field is frozen in the fluid. In other words, the magnetic flux is transported along with the fluid motion.

An Alfven wave is a wave that occurs in a plasma – resulting from the interaction of the magnetic fields and electric currents within it – causing an oscillation of the ions in the plasma.

A Swedish electrical engineer **Hannes Alfven** wrote in a letter to the prestigious journal **Nature** in 1942:

"If a conducting liquid is placed in a constant magnetic field, every motion of the liquid gives rise to an E.M.F. which produces electric currents. Owing to the magnetic field, these currents give mechanical forces which change the state of motion of the liquid. Thus a kind of combined electromagnetic-hydrodynamic wave is produced."

Alfven wave initiated the field of **Magnetohydrodynamics** which subsequently earned Alfven the 1970 Nobel Prize in Physics.

The speed of this wave is proportional to $\frac{\text{magnetic field strength}}{\sqrt{\text{density of the plasma}}}$

0 = dQ = dU + PdV

where: dQ is the total heat which is assumed to be constant, dU is the internal energy of the matter and radiation in the universe, P is the pressure and V the volume.

$$-\frac{dU}{dt} = P \times \frac{dV}{dt}$$

Hubble's Law:

$$\frac{da}{dt} = Ha$$

where a the scale factor of the universe is proportional to $\sqrt[3]{V}$, V being the volume of the universe.

$$\frac{dV}{dt} = 3HV$$

The **internal energy density** of the matter and radiation in the universe:

$$u = \frac{U}{V}$$

$$\frac{dV}{dt}u + \frac{du}{dt}V = \frac{dU}{dt}$$

$$3HVu + \frac{du}{dt}V = -P \times \frac{dV}{dt}$$

$$3HU + \frac{du}{dt}V = -3HPV$$

$$-\frac{du}{dt} = \frac{3H(U+PV)}{V}$$

Enthalpy = U + PV

$$-\frac{du}{dt} = 3H \times \text{Enthalpy density}$$

If U >> PV:

$$-\frac{du}{dt} = 3Hu$$

If U << PV:

$$-\frac{du}{dt} = 3HP$$

In a radiation-dominated universe: $a \propto (\text{time})^{1/2}$

In a matter-dominated universe: $a \propto (\text{time})^{2/3}$

Ultra-high-energy cosmic ray

Cosmic-ray particle with a kinetic energy greater than 10^{18} eV

$$\rho_{vac} = \rho_{\Lambda} \equiv \frac{\Lambda}{8\pi G}$$

vacuum energy and cosmological constant are interchangeable

Consists of a quark and an antiquark and is therefore a meson

$$\pi^0 \longrightarrow \gamma + \gamma$$

Intrinsic energy of π^0 = energy of 2 γ photons

$$m_{\pi^0}c^2 = 2h\upsilon = \frac{2hc}{\lambda}$$

$\lambda = 2 \times$ Compton wavelength of π^0

Greisen–Zatsepin–Kuzmin limit

A theoretical upper limit on the energy of cosmic ray protons traveling from other galaxies through the intergalactic medium to our galaxy

5×10^{19} eV or about 8 joules (the energy of a proton travelling at ≈ 99.99999999999999999998% the speed of light)

- **HZE ions – High-energy, heavy ions of cosmic origin**
- **Oh-My-God particle – Ultra-high-energy cosmic ray detected in 1991**

Auger Effect

The ejection of an electron from an atom as a result of the de-excitation of an excited electron within the atom

- **Photoelectric Effect** → The phenomenon of emission of electrons from metal surfaces exposed to light energy of suitable frequency. Non metals also show photoelectric effect. Liquids and gases also show this effect but to limited extent.
- **Dual Nature of Radiation and Matter** → In no experiment, matter exists both as a particle and as a wave simultaneously. It is either the one or the other aspect i.e. the two aspects are complementary to each other.
- **Mass Defect** → The difference between the rest mass of the nucleus and the sum of the masses of the nucleons composing a nucleus.

$$\text{Binding Energy} = \text{Mass Defect} \times c^2$$

$$\text{Binding Energy per Nucleon} = \frac{\text{Binding Energy}}{\text{Total number of nucleons}}$$

- **Soddy 's Displacement Law:**

$${}_{Z}Y^{A} \xrightarrow{\alpha} {}_{Z-2}Y^{A-4}$$

$${}_{Z}Y^{A} \xrightarrow{\beta} {}_{Z+1}Y^{A}$$

$${}_{Z}Y^{A} \xrightarrow{\gamma} {}_{Z}Y^{A}$$

- 1 curie = 3.7×10^{10} disintegrations / second
- 1 rutherford = 10^{6} disintegrations / second
- 1 becquerel = 1 disintegration / second

Bose-Einstein condensate

Was first predicted by Satyendra Nath Bose and Albert Einstein in the 1920s

A fifth state of matter created when particles called bosons are cooled to near absolute zero

- **Energy Source of Sun** → Proton – Proton Cycle
- **Energy Source of Star** → Carbon **-** Nitrogen Cycle
- G was first measured in 1798by a wealthy English aristocrat, **Cavendish**. It was a very expensive experiment—the apparatus was ten feet high, in its own constructed room. He measured a 10^{-7} Newton attraction between lead balls.

Kepler's First Law → Each planet moves in an elliptical orbit.

Kepler's Second Law → As the planet moves, a line from the planet to the center of the Sun sweeps out equal areas in equal times.

Kepler's Third Law → The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

- The Zeroth Law of Thermodynamics states that if A is in thermal equilibrium with B, and B is with C, then A will be with C.
- The First Law of Thermodynamics → In any process, total energy is always conserved.
- The Second Law of Thermodynamics → Heat energy will never flow by itself from a cold body to a hot body.

Thermonuclear fusion reaction in the sun's center:

4 protons (mass = 4.029) → ^{4}He nucleus (mass = 4.0015) + 2 neutrinos, photons (light)

The twin paradox:

- one twin (age 30) sets off in rocket at high speed, returns to earth after long trip
- if v = 0.6c, 30 years will pass on earth while only 24 will pass in high speed rocket
- twin returns at age 54 to find sibling 60 years old

- Mass is not conserved.
- Energy is conserved, but only if we account for changing masses.

$E = mc^2$ extensively confirmed:

- nuclear power/bombs
- sun's energy conversion mechanism
- bread-and-butter of particle accelerators

Chandrasekhar friction

(Drag produced by gravitational interaction with surrounding objects)

Gravity → Geometrical Distortions

Chandler wobble

The change in the spin of Earth on its axis which was predicted by Sir Isaac Newton and Euler and confirmed much later by Seth Carlo Chandler in 1891

Freeman's law: All spiral galaxies have the same central surface brightness

DGP gravity

Alternative theory of gravity addressing "dark energy"

Forbush decrease

(Decrease in cosmic rays after a coronal mass ejection)

Kappa mechanism

Stellar instability caused by opacity increasing with temperature

- Among Newton's many accomplishments were the description of gravity and the development of calculus.
- After developing the first telescope useful for astronomical research, the ground breaking Italian physicist, mathematician, astronomer, and philosopher **Galilei Galileo** discovered the four moons of Jupiter.

Antoine-Laurent de Lavoisier (1743 − 1794)

↓

French chemist who was considered the **father of modern chemistry** but lost his life in the French revolution.

"Matter, though divisible in an extreme degree, is nevertheless not infinitely divisible. That is, there must be some point beyond which we cannot go in the division of matter. ... I have chosen the word "atom" to signify these ultimate particles."

John Dalton

Maxwell's equations demonstrate that electricity, magnetism and light are all manifestations of the electromagnetic field.

Svante Arrhenius

The first person to predict anthropomorphic global warming.

Humanity stands ... before a great problem of finding new raw materials and new sources of energy that shall never become exhausted. In the meantime we must not waste what we have, but must leave as much as possible for coming generations.

−Arrhenius

Lise Meitner (1878 −1968)

Austrian-born Swedish nuclear physicist. Born in Vienna, she worked with radiochemist, Otto Hahn. They discovered the element protactinium and studied the effects of neutron bombardment on uranium. After leaving Nazi Germany in 1938, she continued her work at the Nobel Physical Institute in Stockholm. Lise and her nephew **Otto Frisch**, realized that the uranium nucleus had been split. They called the process "fission." During the war, she refused to work on the atomic bomb.

Alfred Wegener (1880 −1930)

The German meteorologist and geophysicist who developed the theory of continental drift, plate tectonics, and Pangea

Wallace Hume Carothers (1896 – 1937) was an **American chemist**, inventor and the leader of organic chemistry at DuPont and was credited with the invention of nylon and helped lay the groundwork for Neoprene. Carothers had been troubled by periods of mental depression since his youth. Despite his success with nylon, he felt that he had not accomplished much and had run out of ideas. His unhappiness was compounded by the death of his sister, Isobel, and in 1937 he committed suicide. As Nobel prizes are not granted posthumously, the suicide eliminated the high probability of a Nobel Prize for Carothers.

Rachel Louise Carson (1907 – 1964)

Her book, "**Silent Spring**" significantly contributed to the launching of the environmental movement.

Dame Jane Morris Goodall, is a British primatologist, ethologist, anthropologist, and UN Messenger of Peace. Born in 1934 in London, Jane Goodall set out to Tanzania to study wild chimpanzees by sitting amongst them, bypassing more rigid procedures and uncovering discoveries about primate behavior that have continued to shape scientific discourse. She is a highly respected member of the world scientific community and is a staunch advocate of ecological preservation.

Science

- Understanding how nature and the physical world work.
- Concisely explains an action or group of actions.
- Supported by **considerable evidence-never yet disproven**

Quarks → Come in three colours

Leptons, other Gauge Bosons − γ, $W^{\pm}$, Z^0 → Don't carry colour

Up quark has charge $+\frac{2}{3}$

Down quark has charge $-\frac{1}{3}$

Quarks have spin $\frac{1}{2}$

Proton = uud

Neutron = udd

Science = A Process for Change!

- Discovery
- Experiment/Observation
- Hypothesis
- Prediction
- Test
- Theory

Earth mass is < 0.0003% of solar system mass

The moon is 385,000 km away

The sun is 1.5×10^{11} m away

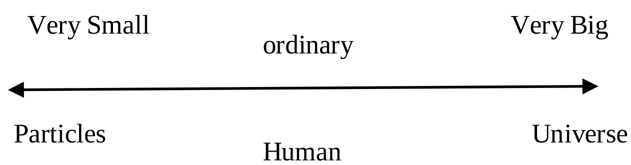
Pluto: 6×10^{12} m away

Andromeda Galaxy – 2.2 million light years away

Most distant galaxies (Older than Earth/Sun; 90% of Universe age) – 12.5 billion light years away

The Distribution of Galaxies → Large Scale Structure

10,000 galaxies would fit across a typical void



Stars → less than 1% of critical density

Ordinary Baryonic Matter → at most 5% of critical density

4.6 % Baryonic Matter stuff on periodic table.

Most gravitating matter is dark (non-baryonic).

Most of the energy density in Universe isn't mass at all!

total = baryons + dark matter + dark energy

Expansion is accelerating

There's not enough matter to stop the expansion

Based on CMB structure scale:

Universe is flat

Brahmanda Purana

Golden womb, the Hiranyagarbha or Brahmanda, the **Cosmic Egg**

The golden fetus or embryo that floating in a dark void – contracted and gave birth to the universe

Atomist Universe

All of reality and all the objects in the universe are made up of a combination of very small, indivisible and indestructible building blocks known as atoms and an infinite void (which is empty space).

Aristotelian cosmology

The earth is the center of the universe, and all the planets, stars, sun and all heavenly bodies revolve around the earth

Copernican Universe

The sun is at the centre of the solar system, with the planets (including the earth) orbiting it.

After the Big Bang explosion, the Universe experienced a period of exponential inflation. Then it slowed down, and the energy converted into matter and radiation.

$$\text{Packing Fraction} = \frac{\text{Isotopic atomic mass} - \text{Mass number}}{\text{Mass number}} \times 10^4$$

Positive value of Packing fraction is unstable undergoes fission and fusion process.

- ^{1}H (+ve packing fraction) undergoes fusion.
- ^{235}U (+ve packing fraction) undergoes fission.

Virial theorem:

$$2K + U = 0$$

where K is the kinetic energy of the gas molecules and U is the gravitational potential energy of the cloud of gas.

$$\boxed{K = -\frac{U}{2}}$$

$$U = -\frac{3GM^2}{5R}$$

$$K = \frac{3}{2} N k_B T$$

where N is the number of molecules, k_B is Boltzmann's constant and T is the temperature.

If $\frac{3}{2} N k_B T > -\frac{3GM^2}{5R}$:

Kinetic (thermal) energy wins over gravity: expansion

If $\frac{3}{2}\mathrm{N}k_{\mathrm{B}}\mathrm{T} < -\frac{3\mathrm{GM}^2}{5\mathrm{R}}$:

Gravity wins: collapse!

If $\frac{3}{2}\mathrm{N}k_{\mathrm{B}}\mathrm{T} = -\frac{3\mathrm{GM}^2}{5\mathrm{R}}$:

The system is in virial equilibrium

- Rayleigh scattering (particle size is small compared to wavelength of light)
- Mie scattering (particle about the same size as wavelength of light, valid only for spheres)
- Geometric scattering (particle size much larger than wavelength of light)

In order to produce the energy, the Sun needs to fuse 4×10^{38} protons into helium-4 every second.

Large mass → Giant Elliptical

Smaller mass → Dwarf Galaxy

Smallest that collapse → globular clusters

Tiny regions stable: can't form stars.

CLEAN

(Algorithm to extract usable images from interferometry-produced images)

A copper atom with all of its electrons weighs slightly less than a copper nucleus and its electrons weighed separately.

Cosmic inflation

Addresses the flatness problem: the question of why the universe shows so little curvature

Rapid expansion of the very early universe by 78 orders-of-magnitude within its first 10^{-32} seconds of existence.

Urca process

A reaction by which a neutrino is emitted from a baryon

Oort Cloud	Cloud of comets and minor planets that are inferred to revolve around the Sun at distances ranging from 0.03 to 3.2 light-years
Planck length $\sqrt{\frac{\hbar G}{c^3}}$	The length scale below which space as we know it ceases to exist and becomes **quantum foam** The quantum fluctuation of spacetime on very small scales due to quantum mechanics **Fireball** An extremely bright meteor
Thorne-Żytkow objects	Giant stars that have a neutron star core with an extended hydrogen-rich envelope
Apastron	The point of maximum separation between the two stars in a **binary star system** A system of 2 stars that revolve around a common center of gravity
Christian Doppler 19th century Austrian physicist who discovered the variation in the wavelength of waves caused by motion of the wave source.	**One bar = 0.987 atmospheres** **Double Asteroid:** 2 asteroids that revolve around each other and are held together by the gravity between them
Steady State Theory	Matter must be continually created to maintain the constant density of the universe. Numerous observations have discredited the theory.
NBODY	Code to carry out N-body simulations for stellar dynamics − developed by a research scientist at the Institute of Astronomy at the University of Cambridge (**Sverre Johannes Aarseth**)
Cosmogony: The study of celestial systems including the Solar System, stars, galaxies and galactic clusters. **Cosmology:** A branch of science that deals with the study of the origin, structure and nature of the universe.	
Extragalactic	Outside or beyond our own galaxy **Extraterrestrial:** from outside the earth or its atmosphere
Abell Catalog	Catalogue of Rich Clusters of Galaxies assembled over 1950s-1980s

Greenhouse Effect

An increase in temperature caused when gases in Earth's atmosphere trap the Sun's heat

The heavy isotope of hydrogen (deuterium) was discovered by Harold Clayton Urey and his coworkers in 1931 by spectrographic methods. This however was predicted by Ernest Rutherford in 1920.

Rutherford model:

- All the mass and the positive charge in an atom is concentrated in a tiny nucleus of radius of the order of a few fermi (1 fm = 10^{-15}m)
- Negatively charged electrons reside outside the nucleus

Used up in doing work against the forces which bind the nucleons together

When **deuterium** is bombarded by a **2.223 MeV** gamma ray photon, it breaks up into a proton and a neutron

When **deuterium** is bombarded by a gamma ray photon of energy > **2.223 MeV**, the extra energy goes to provide kinetic energy to liberated nucleons.

The more tightly bound a nucleus is, the stronger the nuclear forces that hold it together and the greater the binding energy **($BE = \Delta mc^2$)** required to pull it apart.

Yukawa's theory	A fundamental theory of nuclear forces involving the exchange of massive charged particles (**having a mass about 200 times that of an electron**) between neutrons and protons.
Galilean Moons	The 4 largest moons of Jupiter: • Io • Europa • Ganymede • Callisto First observed by Italian astronomer **Galileo Galilei** in December 1609 or January 1610, and recognized by him as satellites of Jupiter in March 1610.

Hypergalaxy

A system that consists of a dominant spiral galaxy that is surrounded by a cloud of smaller satellite galaxies which are often elliptical

Inferior Planet

A planet that orbits between the Earth and the Sun. Mercury and Venus are the only two inferior planets in our solar system.

Interplanetary Magnetic Field	The magnetic field carried along with the solar wind
Interstellar Medium	The gas and dust that exist in the space between the star systems in a galaxy
Iron Meteorite	A meteorite that is composed mainly of iron mixed with smaller amounts of nickel

1 Kiloparsec = 1000 parsecs

Karl Guthe Jansky was an American physicist and radio engineer who in August 1931 first discovered radio waves emitted from the Milky Way. He is considered one of the founding figures of radio astronomy.

A lunar month is equal to 29 days 12 hours 44 minutes

Meteor Shower

An event where a large number of Meteors enter the Earth's atmosphere from one point in space at nearly the same time

Meteors become **meteorites** if they reach the Earth's surface.

Open clusters

- Loosely bound groups of a few tens to a few hundred stars
- Found in spiral and irregular galaxies

Planemo: A large planet or planetary body that does not orbit a star.

Solar prominence

An explosion of hot gas that erupts from the Sun's surface

Protoplanetary disk

A rotating ring-shaped accumulation of dense gas surrounding a young newly formed star

- **Homogeneous:** the same at all locations
- **Isotropic:** the same in all directions.

Quasi-Stellar Object	A star-like object with a large redshift that gives off a strong source of radio waves
nanowatt	one billion'th of a watt
Baryon acoustic oscillations	A pattern of wrinkles in the density distribution of the clusters of galaxies spread across the Universe

Frozen relics left over from the pre-decoupling universe

Nature of dark energy?
Scalar fields, cosmological constant, GR wrong or needs modification …

1 micron: 0.000001 meters

1 Joule: 10,000,000 ergs

There exist only two types of charges, namely positive and negative.

Like charges repel and unlike charges attract each other.

Coulomb's Law → Force between two point electric charges

Strictly speaking, Coulomb's law applies to stationary point charges.

QCD vs. QED

- **QED** → Quantum theory of electromagnetic interactions mediated by exchange of photons

QCD → Quantum theory of strong interactions mediated by exchange of gluons between quarks

```
Galileo: No preferred observer cannot detect constant uniform motion by physical experiment.
Michelson, Morley, de Sitter: Speed of light – same to all observers, independent of motion of the observer or the source.
```

"Henceforth space by itself, and time by itself, is doomed to fade away into mere shadows, and only a kind of union of the two will preserve independence."

– **Hermann Minkowski, 1908**

- When there is matter in a small region of space, the **Ricci tensor** will be non-zero there. But Ricci is zero in a vacuum.

Black Holes

- 1783: John Michell
- 1796: Pierre Laplace
- 1916: Karl Schwarzschild
- 1930: Subrahmanyan Chandrasekhar
- 1939: J. Robert Oppenheimer
- 1968: John Wheeler
- **1930: Einstein still tried to prove they don't exist!**

Hawking, Penrose, ...

Tidal heating

The generation of heat due to friction produced by the strong tidal forces exerted by a very massive parent body on a body moving about it in an elliptical orbit

Gravitational waves → extremely weak

- Stringent verification of General Relativity
- Direct evidence of black holes

Almost no satellites are launched into **retrograde orbit** because the quantity of fuel required to launch them is much greater than for a **prograde orbit**

An orbit in which the satellite travels in the same direction as the planet's rotation

The everlasting goals of particle physics

- What are the fundamental building blocks of Nature?
- What are the interactions between them?
- Where does the mass of the particles originate?
- What is the structure of space and time?
- What is dark matter? Or even dark energy?
- Why is antimatter different from matter?

A tide is a distortion in the shape of one body induced by the gravitational pull of another nearby object.

How large is the Universe

What is its origin – its fate?

What is the human place in it?

What is the universe made of?

What holds the universe together?

Where did we come from?

Trans-Neptunian Object

↓

Any minor planet or dwarf planet in the Solar System that orbit the Sun at a distance beyond the orbit of the planet Neptune.

Particle physics is a modern name for centuries old effort to understand the laws of Nature

E. Witten (String Theorist)

Retrograde Orbit

The orbit of a satellite where the satellite travels in a direction opposite to that direction of the planet's rotation

General Relativity

$\downarrow$

Provides the theoretical framework for the development of cosmological models

Early Dating of Earth's Age

- 1921: H.N. Russell: 4×10^9 yrs is maximum age of Earth's crust via radioactive dating of Thorium and Uranium
- 1929: Rutherford: 3.4×10^9 yrs via U-235 and U-238
- 1930s: 2 to 3×10^9 yrs is accepted age of Earth using radioactive dating techniques

Generally,

$$\boxed{\rho \sim R^{-3(w+1)}}$$

Matter dominated ($w = 0$):

$$\rho \sim R^{-3}$$

Radiation dominated ($w = \frac{1}{3}$):

$$\rho \sim R^{-4}$$

Dark Energy ($w = -1$):

$$\rho = \textbf{\textit{constant}}$$

If $\rho_\Lambda > 0$, then

$$[\frac{dR}{dt} = HR] > 0$$

Universe expands forever

Umbra

The area of total darkness in the shadow caused by an eclipse

If $\rho_\Lambda < 0$:

Things get more complicated

Cosmological Brightness Dimming

Loss of brightness due to Cosmic Expansion

If $[\frac{dR}{dt} = HR] < 0$ → Collapse is inevitable

A star is called a **variable star** if its apparent brightness as seen from Earth changes over time.

Hubble distance = $\frac{c}{H}$

Hubble time = $\frac{1}{H}$

Luminosity measures what is emitted.

Brightness measures what is received.

X-ray Astronomy	An observational branch of astronomy that studies celestial objects by the X-rays they emit.
X-ray Star	A STAR that gives off X-rays as a major portion of its radiation.

X-ray Binary Stars

A **special class of binary stars** – made up of a normal star and a collapsed star (a white dwarf, neutron star or a black hole)

When electrons slow down in the electric fields of other electrons or protons they emit gamma-rays called **Bremsstrahlung radiation**.

"It is a glorious feeling to discover the unity of a set of phenomena that seem at first to be completely separate…"

— Albert Einstein

Quantum mechanics **Absolute Time**	**General Relativity** **Dynamical Time**

Problem of time?

Quantum mechanics and general relativity have different concepts of time. Unifying both theories leads to the so-called "**problem of time**".

"If you expect science to give all the answers to the wonderful questions about what we are, where we're going, what the meaning of the universe is... you could easily become disillusioned and look for a mystic answer... [W]e're exploring, trying to find out as much as we can about the world. People [ask], "Are you looking for the ultimate physics laws?" No, I'm not. I'm just looking to find out more about the world. If it turns out there is an ultimate law which explains everything, so be it; that would be very nice to discover. If it turns out it's like an onion, with millions of layers... then that's the way it is. But whatever way it comes out, it's nature, and she's going to come out the way she is! Therefore we shouldn't pre-decide what it is we're going to find, except to try to find out more. If you think that you are going to get an answer to some deep philosophical question, you may be wrong - it may be that you can't get an answer to that particular problem by finding out more about the character of nature. But I don't look at it like that; my interest in science is to find out more about the world, and the more I find out, the better."

— Richard P. Feynman

- Matter bends the fabric of space and time. The distortion of the space-time affects the path of light.
- The warp and twist of space-time near the earth. The Moon follows this warp of space-time as it orbits Earth.
- Captured material from a comet possessed lysine, an amino acid, in the sample, suggesting that the evolution of life on Earth had only begun after a jump-start from space.
- Albert Michelson (the first American to receive the Nobel Prize for physics) who disproved the existence of Aether

We Humans, a curious beings developed from the Darwin's principle of natural selection, are accustomed into an inquisition. The question is not 'do we know everything from the triumph of the Higgs boson to the underlying discomfort of ultimate question of life, the universe, and everything?' or it is 'do we know enough?' But how the creative principle resides in mathematics? There's something very mathematical about our gigantic Cosmos, and that the more carefully we look, the more equations are built into nature: From basic arithmetic to the calculation of rocket trajectories, math provides a good understanding of the equations that govern the world around us. Our universe isn't just described by math, but that universe is a "grand book" written in the language of mathematics. We find it very appropriate that mathematics has played a striking role in our growing understanding of the events around us, and of our own existence.

"But the creative principle resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed."

— Albert Einstein

⇨ **Newton's laws of motion** tie into almost everything we see in everyday life.

- **Law 1 (law of inertia):** An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
- **Law 2:** Force equals mass times acceleration (**F = ma**).
- **Law 3:** For every action, there is an equal and opposite reaction.

⇨ As a remarkable consequence of the **uncertainty principle of quantum mechanics** (which implies that certain pairs of quantities, such as the energy and time, cannot both be predicted with complete accuracy), the empty space is filled with what is called vacuum energy.

Because $E=MC^2$:

- Mass is just energy in disguise.
- A small amount of mass can equal a large amount of energy.

If the mass of the star < 1.4 solar masses

- Electrons prevent further collapse.
- The core will thus continue to collapse and form a **white dwarf**.

If the mass of the star > 1.4 solar masses but mass < 3 solar masses

- Electrons + protons combine to form neutrons.
- Neutrons prevent further collapse.
- The core will thus continue to collapse and form a **neutron star**.

If the mass of the star > 3 solar masses

- Gravity wins! Nothing prevents collapse.
- The core will thus continue to collapse and form a black hole.

*Any object with a physical radius smaller than its **Schwarzschild radius** will be a black hole.*

Raman Effect	When a light traverses a transparent liquid or gas a small fraction of the light scatters.
Closed Space	A space of finite volume without a boundary.
Sunyaev Zel'dovich Effect	Low energy Cosmic Microwave photons amplified and scattered by interactions with higher energy electrons of hot gas of galaxies and clusters
Superluminal	Faster than the speed of light **(Forbidden by Special Relativity)**

- **Stokes-Raman scattering:** When the light loses energy to the molecule (redshift)
- **Anti-Stokes-Raman scattering:** When the light gains energy (blueshift)

Spectral line Redshift → radiation losing energy in a linear fashion while traveling for millions to billions of years through space and having experienced thousands to trillions of particle interactions with matter (plasma, gas and dust) along the way.

Tolman test

If the Universe is expanding, the surface brightness of galaxies should decrease rapidly with redshift.

An axion is a hypothetical elementary particle of zero electrical charge postulated by the Peccei–Quinn theory in 1977 to resolve the strong CP problem in quantum chromodynamics.

CERN

The European Organization for Nuclear Research – headquartered in Geneva – established in 1954 and is a research firm dedicated to high-energy physics.

All the laws of physics that we know, breaks down –

- Below this time: (**Planck Time**)
- Below this length: (**Planck Length**)
- Above this temperature: (**Planck Temperature**)

Density parameter (Ω): The ratio of the total amount of matter in the universe divided by the minimum amount of matter needed to cause the **big crunch**.

- **Ω < 1:** the Universe will continue to expand forever.
- **Ω > 1:** the Universe will eventually halt its expansion and recollapse.
- **Ω = 1:** the Universe contains enough matter to halt the expansion but not enough to recollapse it.

If a black hole has a mass less than the **Planck mass**, its quantum mechanical size could be outside its event horizon. This wouldn't make sense, **Planck mass** is the smallest possible black hole.

Absolute zero: (–273ºC) − the lowest possible temperature, at which substances contain no heat energy and all vibrations stop — almost.

⇨ If the two quarks would have occupied precisely the same point with the same properties, they would not have stayed in the same position for long. And quarks would have not formed separate, **well-defined protons and neutrons**. And nor would these, together with electrons have formed separate, well-defined atoms. And the world would have collapsed before it ever reached its present size.

- When 2 similar waves are added, the resultant wave is bigger (**constructive interference**).

- When 2 dissimilar waves are added, they cancel each other out (**destructive interference**).

The different frequencies of light appear as different colors.

Proton charge + Electron charge = 0

Just what it is if **electromagnetism** would not dominate over **gravity** and for the universe to remain electrically neutral.

- It's not their energy; it's their zero rest mass that makes **photons** to travel at the speed of light.
- Just like a dozen is 12 things, a mole is simply **Avogadro's number of particles**.

Undisturbed space + rigid mass = distorted space.

3 dimensions of space + one dimension of time = **single four-dimensional continuum** (space-time).

Since **h** − which is one of the most **fundamental numbers in physics**, ranking alongside the speed of light "**c**" and confined most of these radical departures from life-as-usual to the microscopic realm − is incredibly small (i.e., **6 × 10 to the power of – 34** − a decimal point followed by 33 zeros and a 6 − of a joule second), the frequency of the photon is always greater than its energy, so it do not take many quanta to radiate even ten thousand megawatts.

What is GRAVITY?

- **Newtonian view:** Force tells mass how to accelerate. Accelerated mass tells what gravity is.

- **Einsteinian view:** Mass tells space how to curve. Curved space tells what gravity is.

All objects emit **electromagnetic radiation** according to their temperature. Colder objects emit waves with very low frequency (such as **radio or microwaves**), while hot objects emit visible light or even **ultraviolet** and higher frequencies.

- Longer half-life of nucleus → **Slow Radioactive Decay**.
- **Shorter half-life of nucleus** → Fast Radioactive Decay.

".. Physics at the atomic and subatomic level ..."

… Weird things are possible:

- Energy is quantized ($\mathbf{E = nh\upsilon}$).
- Momentum is quantized ($\mathbf{L = n\hbar}$).
- Charge is quantized ($\mathbf{Q = ne}$).

Because

$$E = h\upsilon, \qquad c = \lambda\upsilon, \qquad E = \frac{hc}{\lambda} = pc$$

$$\lambda = \frac{h}{p}$$

Every particle or quantum entity may be partly described in terms not only of particles, but also of waves.

The Thermodynamic Laws think big: they dictate energy behavior…

- **1 Law:** Energy is conserved; its form can be converted.
- **2 Law:** Energies can flow, equilibrate.
- **3 Law:** "Driving force" for equilibration uniquely defined.

- **0 Law:** Thermal equilibrium is transitive.

The Life of a Star:

"More mass

More pressure and temperature

Faster Fusion

Shorter life"

"Less mass

Less pressure and temperature

Slower Fusion

Longer life"

String Theory (A theory that tries to adjust / harmonize / reconcile **General Relativity** and **Quantum mechanics**):

- Different vibrations → Different particles.
- String combinations → Particle interactions.

The universe is made of

- 21% Dark Matter.
- 74% Dark Energy.
- 4% Normal Matter.

MATTER UNDER EXTREME CONDITIONS

$$\text{Nuclei} + \text{heat} + \text{pressure} \rightarrow \text{quark-gluon plasma}$$

- **Hydrogen atom:** Diameter about a Billionth of an inch.
- **Electron:** Diameter at least 1000 times smaller than that of proton.
- **Proton:** Diameter about 60,000 times smaller than H atom.
- **Probability distribution** is the only way to locate an electron in an atom.

The Gas laws deal with how gases behave with respect to pressure, volume, temperature …

- **Boyle's law:**

Volume and pressure are inversely proportional.

- **Charles' law:**

Volume is proportional to temperature.

- **Pressure law:**

Pressure is proportional to temperature.

All three combined:

$$\frac{PV}{T} = \text{constant}$$

n → number of neutrons

p → number of protons

- **If (n / p) ≈1 (atomic number between 1 and 20):**

Nucleus has equal number of protons and neutrons to become stable.

- **If (n / p) >1 (atomic number between 20 and 83):**

Number of protons increase and repulsion between them also increases. To balance this force number of neutrons also increases.

- **If (n / p) >1 (atomic number > 83):**

Nucleus having atomic number higher than 83 has great number of protons and repulsion force between protons. Since the amount of force is too high, number of neutrons cannot balance them and nucleus stays unstable. Thus, we can say that nuclei having atomic number greater than 83 generally undergo **transmutation**, **alpha decay** or **beta decay**.

- Weak nuclear forces + **Maxwell equations** → Electro weak theory.
- Electro weak theory + Quantum Chromodynamics (**QCD**) → Standard Model of particle physics.
- **Standard Model** of particle physics → explains everything except **gravity**.

4 NUMBERS describe the characteristics of electrons and their orbitals:

- **Principal quantum number:** a number that describes the average distance of the orbital from the nucleus and the energy of the electron in an atom.
- **Angular momentum quantum number:** a number that describes the shape of the orbital.
- **Magnetic quantum number:** a number that describes how the various orbitals are oriented in space.
- **Spin quantum number:** a number that describes the direction the electron is spinning in a magnetic field — either clockwise or counterclockwise.

The square of the periods of the planets (**the times for them to complete one orbit**) is proportional to the cubes of their average distance from the Sun. A consequence of this is that the

inner planets move rapidly in their orbits. Venus, Earth and Mars move progressively less rapidly about the Sun. And the **outer planets**, such as Jupiter and Saturn, move stately and slow.

Wavelength of UV radiation < Wavelength of IR radiation < Wavelength of microwave radiation

- Molecule dissociates (when it absorbs UV radiation).
- Molecule vibrates (when it absorbs IR radiation).
- Molecule rotates (when it absorbs microwave radiation).

⇨ If the expansion of space had overwhelmed the pull of gravity in the beginning − stars, galaxies and humans would never have been able to form. If, on the other hand, gravity had been 5% stronger− stars and galaxies might have formed, but they would have quickly collapsed in on themselves and each other to form a sphere of roughly infinite density.

Neutrons have a mass of 939.56 MeV.

If the mass of a neutron was a seventh of a percent more than it is, stars like most of those we can see would not have existed. If the neutron mass was 0.085% less than it is, the Universe would have been full of neutrons and nothing else.

If we cut the surface of a sphere up into faces, edges and vertices, and let F be the number of faces, E the number of edges and V the number of vertices, we will always get:

$$\mathbf{V - E + F = 2}.$$

Fibonacci numbers − 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144...

- Each number is the sum of the previous two.

- The ratio between the numbers = 1.618034 (**golden ratio**).
- From **pinecones to the Hurricane Sandy**, Fibonacci reflects various patterns found in nature.

The paths of anything you throw have the same shape, called an **upside-down parabola**.

When we observe how objects move around in **gravitationally curved trajectories** in space, we discover another recurring shape: **the ellipse**.

All material particles have properties such as charge and spin.

Space itself has properties such as dimensions.

- These properties are purely mathematical.

Equations aren't the only hints of mathematics that are built into nature: **there are also numbers involving not only motion and gravity**, but also areas as disparate as classical physics, quantum mechanics, and astronomy.

Strong force → force that is responsible for binding together the fundamental particles of matter to form larger particles.

- **If stronger:** No hydrogen would have formed; atomic nuclei for most life-essential elements would have been unstable; thus, there would have been no life chemistry.
- **If weaker:** No elements heavier than hydrogen would have formed: again, no life chemistry.

Weak force → force that is responsible for the radioactive decay of atoms.

- **If stronger:** Too much hydrogen would have been converted to helium in the big bang; hence, stars would have converted too much matter into heavy elements making life chemistry impossible.
- **If weaker:** Too little helium would have been produced from big bang; hence, stars would have converted too little matter into heavy elements making life chemistry impossible.

Electromagnetic force → force that is responsible for most of the interactions we see in our environment today.

- **If stronger:** Chemical bonding would have been disrupted; elements more massive than boron would have been unstable to fission.
- **If weaker:** Chemical bonding would have been insufficient for life chemistry.

c = 299,792,458 meters per second − serves as the single limiting velocity in the universe, being an upper bound to the propagation speed of signals and to the speeds of all material particles.

Ratio of electromagnetic force to gravitational force

- **If larger:** All stars would have been at least 40% more massive than the sun; hence, stellar burning would have been too brief and too uneven for life support.
- **If smaller:** All stars would have been at least 20% less massive than the sun, thus incapable of producing heavier elements.

Ratio of electron to proton mass

- **If larger or smaller:** Chemical bonding would have been insufficient for life chemistry.

Mass of the neutrino

- **If smaller:** Galaxy clusters, galaxies, and stars would have not formed.
- **If greater:** Galaxy clusters and galaxies would have been too dense.

Ratio of exotic matter to ordinary matter

- **If larger:** the universe would have collapsed before the formation of solar-type stars.
- **If smaller:** no galaxies would have formed.

Number of effective dimensions in the early universe

- **If larger or smaller:** Quantum mechanics, gravity, and relativity could not have coexisted; thus, life would have been impossible.

Entropy level of the universe

- **If larger:** Stars would have not formed within proto-galaxies.
- **If smaller:** No proto-galaxies would have formed.

Polarity of the water molecule

- **If greater:** Heat of fusion and vaporization would have been too high for life.
- **If smaller:** Heat of fusion and vaporization would have been too low for life; liquid water would not have worked as a solvent for life chemistry; ice would not have floated, and a runaway freeze-up would have resulted.

From the properties of subatomic particles and the **realm of quantum physics to the formation of a giant mathematical object** (**universe**), math proves unquestionably effective in describing and predicting their physical reality.

However, a question that lies at the intersection of philosophy and science arises: **Is Math the Language of the Universe?**

"Gravity pulls everything in, but a force called dark energy tries to push it all back together again. And the ultimate fate of the universe relies on which force will win the desire to succeed."

− S.W. Hawking

"Since the mathematicians have invaded the theory of relativity I do not understand it myself anymore."

− Albert Einstein

The physicist Leo Szilard once announced to his friend Hans Bethe that he was thinking of keeping a diary: "I don't intend to publish. I am merely going to record the facts for the information of God."

"Don't you think God knows the facts?" Bethe asked.

"Yes," said Szilard.

"He knows the facts, but He does not know this version of the facts."

− Hans Christian von Baeyer, Taming the Atom

- Kuiper belt – a region of the Solar System extending from the orbit of Neptune (at 30 AU) to approximately 50 AU from the Sun (consists mainly of small bodies or remnants from the Solar System's formation).
- Newton rings is a phenomenon in which an interference pattern is created by the reflection of light between two surfaces — a spherical surface and an adjacent flat surface. It is named after Isaac Newton, who first studied them in 1717.

"In life, everything is relative - except Einstein's theory."

– **Leonid S. Sukhorukov**

Extinction

The disappearance of electromagnetic photons due to absorption or scattering by dust, gas or plasma between stars or galaxies

"Slower" recession velocity → smaller Hubble Constant → Older Universe

"The area formula for the entropy — or number of internal states — of a black hole suggests that information about what falls into a black hole may be stored like that on a record, and played back as the black hole evaporates."

$$S_{BH} = \frac{Ak_B c^3}{4\hbar G}$$

– S.W. Hawking

"Euclid taught me that without assumptions there is no proof. Therefore, in any argument, examine the assumptions"

– **Eric Temple Bell**

- When we place two long parallel uncharged plates close to each other, virtual particles outside the plates exerts more pressure than the virtual particles inside the plates, and hence the plates are attracted to each other, which we call the "**Casimir effect**."

Plasma Models

Cosmic Models where plasma and electromagnetic forces dominate the largest scale Universe dynamics rather than gravity.

Nebulae

A cloud of intergalactic or interstellar gas

Consider an electron moving in a circular orbit of radius **r**. Let the total magnetic flux through the orbit is ϕ and the flux density is **B**. The magnetic field lines being perpendicular to the plane of the orbit. The flux ϕ is incased at the rate of $\frac{d\phi}{dt}$. As a consequence, the *e.m.f.* **E** induced in the orbit is given by: $E = \frac{d\phi}{dt}$. The work done on the electron in one revolution is given by **eE**. This must be equal to the tangential force **F** acting on the electron times the original path length **2πr**.

Therefore: Work done = eE = F × 2πr.

$$\boxed{F = \frac{eE}{2\pi r} = \frac{e}{2\pi r} \times \frac{d\phi}{dt}}$$

The inward radial force on the electron is Bev which, for a circular orbit of given radius r, equals the electron mass m times $\frac{v^2}{r}$.

$$Bev = \frac{mv^2}{r} \longrightarrow p = Be\,r$$ where p is the momentum of the electron.

$$\underbrace{\frac{dp}{dt} = er\frac{dB}{dt}}$$

$$F = er\frac{dB}{dt} \longrightarrow \underbrace{\frac{e}{2\pi r} \times \frac{d\phi}{dt} = er\frac{dB}{dt}}$$

$$d\phi = 2\pi r^2\, dB$$

Since: $p = \frac{h}{\lambda}$. Therefore:

$$-\frac{d\lambda}{dt} = \frac{er}{h} \times \lambda^2 \times \frac{dB}{dt}$$

$$-\frac{d\lambda}{dB} = \frac{h}{B^2 er}$$

$$-\frac{d\lambda}{d\phi} = \frac{\hbar}{B^2 er^3}$$

We are certainly a long way from understanding all the details of the universe:

Is it sensible to talk about the universe before the big bang?

Do the laws of quantum theory work in the context of the moment of creation?

"So Einstein was wrong when he said, "God does not play dice." Consideration of black holes suggests, not only that God does play dice, but that he sometimes confuses us by throwing them where they can't be seen."

— Stephen Hawking

Ferromagnet

$\overbrace{\hphantom{xxxxxxxxxxxxxxxxxx}}$

An object which exhibits the property of ferromagnetism

What is time?

Answers ?

Thermal bubble nucleation

$\overbrace{\hphantom{xxxxxxxxxxxxxxxxxx}}$

The process during which the superheated liquid molecules overcome the energy barrier to become vapor

```
Feynman diagrams are often used to represent different aspects of the processes that go on when particles interact via the fundamental forces. They were originally designed as a way of showing how the various mathematical terms in a calculation linked together
```

The Fermi National Accelerator Laboratory

$\downarrow$

United States Department of Energy laboratory **(Located near Chicago)** focuses on high-energy physics.

The time that the black hole takes to dissipate is:

$$t_{ev} = \frac{480c^2V}{\hbar G} = 480 \times \frac{V}{\text{Planck volume}} \times \text{Planck time}$$

If V = Planck volume:

$$\boxed{t_{ev} = 480 \times \text{Planck time}}$$

The lifetime of a one solar mass (2×10^{30} kg) **black hole** is as more than 57 orders of magnitude longer than the current age of the universe. But that does not take into account the fact that such a black hole is colder than the cosmic microwave background radiation bathing it. Therefore, whatever little energy it radiates, it actually receives more in the form of heat from the cosmos. So rather than shrinking, it would continue to grow. Indeed, any black hole with a mass greater than about 0.75% of the Earth's mass is colder than the cosmic background, and thus its mass increases for now. As the universe expands and cools, however, eventually the black hole may begin to lose mass-energy through Hawking radiation.

The Hall of Shame: How Bad Science can cause Real Harm in Real Life

There are no qualms in accepting the fact that − in the past − things were different from what they are now. Even though science transformed extensively from our personal laptops, tablets, and phones to behind-the-scenes technology, it is yet a continuing effort to discover and increase human knowledge and understanding. Science is ubiquitous and has made very rapid progress and completely transformed outwardly the manner of our living — allowing us to develop new technologies, solve practical problems, and make informed decisions — both individually and collectively. In its pursuit of excellence, it has lead to pollution, environmental crisis, greater violence, sorrow, tension, new pathogenic diseases, chemical and biological war to name a few. On the one hand, Science (a system of acquiring knowledge based on scientific method and research) has been a boon to mankind and on the other hand, it has also proved to be a cause of great distress or annoyance.

> "Although Nature needs thousands or millions of years to create a new species, man needs only a few dozen years to destroy one."
>
> **: Victor Scheffer**

We humans, who began as a mineral and then emerged into plant life and into the animal state and then to being aggressive mortal beings who fought a survival struggle in caveman days, to get more food, territory or partner with whom to reproduce, now are glued to the TV set, marveling at the adventures of science and their dazzling array of **futuristic technology** from **teleportation** to **telekinesis**: rocket ships, fax machines, supercomputers, a worldwide communications network, gas-powered automobiles and high-speed elevated trains. The science has opened up an entirely new world for us. And our lives have become easier and more comfortable. With the help of science we have estimated about 8,000 **chemotherapeutic exogenous non-nutritive chemical substances** which when taken in the solid form by the mouth enter the digestive tract and there they are transformed into a solution and passed on to the liver where they are chemically altered and finally released into the blood stream. And through blood they reach the site of action and binds reversibly to the target cell surface receptors to produce their pharmacological effect. And after their

pharmacological effect they slowly detaches from the **receptor**. And then they are sent to the liver. And there they are transformed into a more water soluble compound called **metabolite** and released from the body through urine, sweat, saliva, and excretory products. However, the long term use of chemotherapeutic drugs for diseases like cancer, diabetes leads to side effects. And the **side effects** — including nausea, loss of hair, loss of strength, permanent organ damage to the heart, lung, liver, kidneys, or reproductive system etc. — are so severe that some patients rather die of disease than subjecting themselves to this torture.

And smallpox (an acute contagious disease caused by the **variola virus**, a member of the **orthopoxvirus family**) was a leading cause of death in **18th century**, and the inexorable spread of the disease reliably recorded the death rate of some hundred thousand people. And the death toll surpassed 5000 people a day. Yet **Edward Jenner, an English physician**, noticed something special occurring in his small village. People who were exposed to cowpox did not get smallpox when they were exposed to the disease. Concluding that cowpox could save people from smallpox, Edward purposely infected a young boy who lived in his village first with **cowpox, then with smallpox**. Fortunately, **Edward's hypothesis** worked well. He had successfully demonstrated the world’s first vaccine and eradicated the disease. And vaccines which once saved humanity from the smallpox (which was a leading cause of death in 18th-century England), now have associated with the outbreaks of diseases like **pertussis** (whooping cough) which have begun showing up in the United States in the past forty years.

TOP 5 DRUGS WITH REPORTED SIDE EFFECTS
(Withdrawn from market in September 2004)

⇨ **Drug:** Byetta

Used for: Type 2 diabetes

Side effect: Increase of blood glucose level

⇨ **Drug:** Humira

Used for: Rheumatoid arthritis

Side effect: Injection site pain

⇨ **Drug:** Chantix

Used for: Smoking cessation

Side effect: Nausea

⇨ **Drug:** Tysabri

Used for: Multiple sclerosis

Side effect: Fatigue

⇨ **Drug:** Vioxx*

Used for: Arthritis

Side effect: Heart attack

In 1930s, **Paul Hermann Muller** a research chemist at the **firm of Geigy in Basel**, with the help of science introduced the first modern insecticide (DDT: **dichloro diphenyl trichloroethane**) and it won him the 1948 Nobel Prize in Physiology and Medicine for its credit of saving thousands of human lives in World War II by killing typhus- carrying lice and malaria-carrying mosquitoes, dramatically reducing **Malaria and Yellow Fever** around the world. But in the late 1960s DDT which was a world saver was no longer in public favor – it was blamed moderately **hazardous and carcinogenic**. And most applications of DDT were banned in the U.S. and many other countries. However, DDT is still legally manufactured in the U.S., but only sold to foreign countries. At a time when **Napoleon was almost disturbing whole of Europe** due to his aggressive policies and designs and most of the world was at war – the science gave birth to the many inventions which took place in the field of textile industry and due to invention of steam engine and development of means of transportation and communication. Though it gave birth in England, yet its inventions spread all over the world in a reasonably period. And **rapid industrialization** was a consequence of new inventions and demand for expansion of large industrial cities led to the large scale exploitation of agricultural land. And socio-economic growth was peaking, as industries were booming, and agricultural lands were decreasing, as the world enjoyed the fruits of the rapid industrialization. As a result of this, the world's population was growing at an exponential rate and the world's food supply was not in the pace of the population's increase. And this resulted in widespread famine in many parts of the world, such as England, and as starvation was rampant. In that time line, science suppressed that situation by producing more ammonia through the Haber Bosch Process (**more ammonia**, more fertilizers. **more fertilizers**, more food production). But at the same time, science which solved the world's hunger problems also led to the production of megatons of TNT (**trinitrotoluene**) and other explosives which were dropped on all the cities leading to the death of some hundred million people.

Rapid industrialization which once raised the **economic and living standard of the people** has now become a major global issue. The full impact of an industrial fuel economy has led to the **global warming** (i.e., the increase of Earth's average surface temperature due to effect of too much carbon dioxide emissions from industrial centers which acts as a **blanket, trap heat and warm the planet**). And as a result, **Greenland's ice shelves** have started to shrink permanently, disrupting the world's weather by altering the flow of ocean and air currents around the planet. And violent swings in the climate have started to appear in the form of floods, droughts, snow storms and hurricanes.

And industries are the main sources of sulfur dioxide emission and automobiles for nitrogen oxides. And the oxides of nitrogen and sulfur combine with the **moisture in the atmosphere to form acids**. And these acids reach the Earth as rain, snow, or fog and react with minerals in the soil and release deadly toxins and affect a variety of plants and animals on the earth. And these acids damage buildings, historic monuments, and statues, especially those made of rocks, such as limestone and marble, that contain large amounts of calcium carbonate. For example, acid rain has reacted with the marble (**calcium carbonate**) of **Taj Mahal** (an ivory-white marble mausoleum on the south bank of the **Yamuna river in the Indian city of Agra**) causing immense damage to this wonderful structure (i.e., Taj is changing color).

And science once introduced refrigerators for prolonging storage of food but now refrigerators are the active sources of **chlorofluorocarbons (CFC)** which interact with the **UV light** during which chlorine is separated. And this chlorine in turn destroys a significant amount of the ozone in the high atmosphere admitting an intense dose of **harmful ultraviolet radiation**. And the increased ultraviolet flux produces the related health effects of skin cancer, cataracts, and immune suppression and produces a permanent change in the nucleotide sequence and lead to changes in the molecules the cell produce, which modify and ultimately affect the process of photosynthesis and destroy green plants. And the **massive extinction of green plants** may lead to famine and immense death of all living species including man.

Fertilizers which once provided a sufficient amount of the essential nitrates to plants to synthesize chlorophyll and increase crop growth to feed the growing population and satisfy the demand for food, has now blamed for causing **hypertrophication** i.e., fertilizers left unused in soil are carried away by rain water into lakes and rivers, and then to coastal estuaries and bays. And the overload of fertilizers induces explosive growth of **algal blooms**, which prevents light from getting into the water and thereby preventing the aquatic plants from photosynthesizing, a process which provides oxygen in the water to animals that need it, like fish and crabs. So, in addition to the **lack of oxygen from photosynthesis**, when algal blooms die they decompose and they are acted upon by **microorganisms**. And this decomposition process consumes oxygen, which reduces the concentration of dissolved oxygen. And the depleted oxygen levels in turn lead to fish kills and a range of other effects promoting the loss of species biodiversity. And the large scale exploitation of forests for industrialization and residential purposes has not only led to the loss of biodiversity but has led the diseases like **AIDS (Acquired immunodeficiency syndrome caused by a virus called HIV (Human immunodeficiency virus)** which alters the immune system, making victim much more vulnerable to infections and diseases) to transmit from forests to cities.

At the dawn of the early century, the entire world was thoroughly wedded to fossil fuels in the form of oil, natural gas, and coal to satisfy the demand for energy. And as a result, **fossil fuels were becoming increasingly rare** and were slowly dooming to extinction. In that period, science (**upon the work of Curie and Einstein**) introduced nuclear fission reaction (the process by which a heavy nucleus breaks down into two or more smaller nuclei, releasing energy. For example: if we hit a **uranium-235** nucleus with a neutron, it split into a krypton nucleus, a barium nucleus, three neutrons, and energy) as an alternate to the world's energy supply and therefore prevented the world economy from coming to a grinding halt. But at the same time science introduced **nuclear fission reaction** to produce thousands of nuclear weapons, which were dropped on all the cities in World War II amounted to some two million tons, **two megatons, of TNT**, which flattened heavily reinforced buildings many kilometers away, the firestorm, the gamma rays and the thermal neutrons, which effectively fried the people. A school girl who survived the nuclear attack on Hiroshima, the event that ended the Second World War, wrote this first-hand account:

"Through a darkness like the bottom of hell, I could hear the voices of the other students calling for their mothers. And at the base of the bridge, inside a big cistern that had been dug out there, was a mother weeping, holding above her head a naked baby that was burned red all over its body. And another mother was crying and sobbing as she gave her burned breast to her baby. In the cistern the students stood with only their heads above the water, and their two hands, which they clasped as they imploringly cried and screamed, calling for their parents. But every single person who passed was wounded, all of them, and there was no one, there was no one to turn to for help. And the singed hair on the heads of the people was frizzled and whitish and covered with dust. They did not appear to be human, not creatures of this world."

Nuclear breakthroughs have now turned out to be the biggest existential threat to human survival. Nuclear waste is banking up at every single nuclear site. And as a result, every nation is suffering from a massive case of nuclear constipation (that Causes **Intractable Chronic Constipation** in Children).

Ninety-one percent of world adults and 60 percent of teens own this device that has revolutionized the most indispensable accessories of professional and social life. Science once introduced this device for wireless communication but now they are pointed to as a possible cause of everything from infertility to cancer to other health issues. And in a study conducted at the University of London, researchers sampled 390 cell phones to measure for levels of **pathogenic bacteria**. The results of the study showed that 92 percent of the cell phones sampled had heavily colonized by high quantities of various types of disease-prone bacteria with high resistances to commonly used antibiotics (**around 25,000 bacteria per square inch**) and the results concluded that their ability to transmit diseases of which the mobile phones are no exception. The fluoridation of water at optimal levels has been shown to be highly beneficial to the development of tooth enamel and prevention of dental cavities since the late 1800s. And studies showed that children who drink water fluoridated at optimal levels can experience **20 to 40 per cent less tooth decay**. But now fluoridation of water has termed to cause lower IQ, memory loss, cancer, kidney stones & kidney failures – faster than any other chemical.

Science once introduced irradiation to prevent food poisoning by destroying molds, bacteria (such as one – celled animal 'Amoeba ' – that have as much information in their DNA as **1,000 Encyclopedia Britannicas** – which is almost unbelievably minute form of life which, after being cut into six separate parts, is able to produce six complete bodies to carry on as though nothing had happened), **yeast and virus** (the smallest living things which cannot reproduce itself unaided and therefore it is lifeless in the true sense. But when placed in the plasma of a living cell and, in forty eight minutes it can reproduce itself four hundred times) and control microbial infestation. But now it has been blamed to cause the loss of nutrients, for example vitamin E levels can be reduced by 25% after irradiation and vitamin C by 5-10% and damage food by breaking up molecules and creating free radicals. And these **free radicals combine with existing chemicals (like preservatives) in the food to produce deadly toxins**. This has caused some food manufacturers to limit or avoid the process and bills have even been introduced to ban irradiated foods in public cafeterias or to require irradiated food to carry sensational warning labels. And the rapid advancement of science combined with human aggression and aim for global supremacy has led even the smaller nations to weaponize anthrax spores and other viruses for maximum death and destruction. And thus the entire planet is gripped with fear that one day a terrorist group may pay to gain access to **weaponized H5N1 flu** and other viruses. And the rapid development of nuclear technology has led to the banking up of nuclear waste at every single nuclear site. And as a result, every nation is suffering from a massive case of nuclear constipation. And the enormous automation, capacity of artificial intelligence and their ability to interact like humans has caused the humans to be replaced by artificial intelligence. But now artificial intelligence is taking off on its own, and re-designing itself at an ever increasing rate. And this has turned out to be the biggest existential threat to human survival (i.e., one day artificial intelligence may plan for a war against humanity). Highly **toxic gases, poisons, defoliants, and every technological state are planning for it to disable or destroy people or their domestic animals**, to damage their crops, and/or to deteriorate their supplies, threaten every citizen, not just of a nation, but of the world

"The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom."

— Isaac Asimov

Good and Bad Effects of Chemistry:

What is Chemistry?

Chemistry (a creative discipline chiefly concerned with the **study of matter:** its structure, composition, properties, and reactivity through chemical reactions) is important because everything you do like cooking, fermentation, glass making, and **metallurgy** is chemistry! Even our Human body is made of chemical elements.

⇨ **Element:**

Oxygen

Percent by Mass:

65

⇨ **Element:**

Carbon

Percent by Mass:

18

⇨ **Element:**

Hydrogen

Percent by Mass:

10

⇨ **Element:**

Nitrogen

Percent by Mass:

3

⇨ **Element:**

Calcium

Percent by Mass:

1.5

⇨ **Element:**

Phosphorus

Percent by Mass:

1.2

⇨ **Element:**

Potassium

Percent by Mass:

0.2

⇨ **Element:**

Sulfur

Percent by Mass:

0.2

⇨ **Element:**

Chlorine

Percent by Mass:

0.2

⇨ **Element:**

Sodium

Percent by Mass:

0.1

⇨ **Element:**

Magnesium

Percent by Mass:

0.05

⇨ **Elements:**

Iron, Cobalt, Copper, Zinc, Iodine

Percent by Mass:

Trace

⇨ **Elements:**

Selenium, Fluorine

Percent by Mass:

Minute amounts

Chemical reactions (**an integral part of technology and indeed of life itself that involves a rearrangement of the constituent atoms of the reactants to create one or more different substances — the products**) occur when you breathe, eat, or just sit there burning fuels, smelting iron, making liquid crystals and semiconductors, brewing beer, and making wine and cheese. All matter is made of chemical elements, so the importance of chemistry is that it's the study of everything — is part of everything in our lives.

Good Effects:

- Helps mankind develop food preservatives that are widely used in the food industry to preserve the natural **characteristics of food and to fight food spoilage** caused by bacteria, molds, fungus, and yeast.
- Helps mankind develop fuels that we use today as dense repositories of energy that are consumed to provide energy services such as heating, transportation and electrical generation.
- Helps mankind enclose the **design, development, and synthesis of pharmaceutical drugs** that prolong our life and help us fight diseases.
- Helps mankind develop cosmetics that we use today to enhance or alter the appearance of the face or fragrance and texture of the body.
- Helps mankind develop pesticides that are widely used in agriculture for the protection of crops from disease, insects, rodents and regulating plant growth and killing weeds.
- Helps mankind develop fertilizers that enhance the natural fertility of the soil and improve growth and productiveness of crops.
- Helps mankind analyze the **non-biological trace evidence** that is brought in from crime scenes and reach a conclusion based on tests run on that piece of evidence.
- Helps mankind devise new ways to make the manufacturing of the products (from fireworks to explosions) easier and more cost effective.

- Helps mankind develop safety strategies for handling dangerous materials, and supervise the manufacture of nearly every product (from pharmaceuticals to fuels and computer components) we use.
- Helps mankind to remove valuable metals from an ore and refine the extracted raw metals into a purer form.

Bad effects:

- Accidents or incorrect use of household cleaning products may cause immediate health effects, such as skin or eye irritation or burns, or may influence children's gut bacteria and cause obesity.
- **Chemistry is at the heart of environmental issues.** Chemical pesticides are known to pollute the environment as they can work their way into the food chain and accumulate or persist in the environment for many years.
- **Maleic Hydrazide** is generally added to potatoes to keep them from sprouting. It is a known chemical inhibitor and can even lead to cancer in the long run.
- Plastic cannot biodegrade. **Toxic chemicals** leach out of plastic water bottles, bags and straws make their way into our bodies and cause a variety of health issues that result cancer, reproductive issues, immune system suppression and problems with childhood development.
- Chemicals that are widely used in **cosmetics and personal care products** can cause changes in women's reproductive hormones and harm women's fertility or even cause breast cancer.
- Chemical waste is a usually a byproduct of a large scale factories and laboratories that — if improperly managed or disposed of — may pose **substantial hazards to human health** and the environment.
- The excessive use of fertilizers can destroy soil nutrients like sodium, potassium, nitrogen and creates imbalances in soil fertility and **result in failure of crops in agriculture** and can pollute groundwater.

"If you wish to make an apple pie from scratch, you must first invent the universe."

— Carl Sagan

More extended use of **digital technologies**

More sedentary lifestyle

- obesity
- cardiovascular disease
- type 2 diabetes
- premature death
- eye and ear problems

Stunt the imagination in children

Transportation → Pollution

Increased threat of global climate change, degradation of water resources, noise and habitat loss and fragmentation and pose a threat to the very existence of the flora and fauna.

Bhopal Gas Tragedy: The world's worst industrial disaster which killed twenty five thousand people and affected more than five lakh people with breathlessness, failing eyesight, painful stomachs, missing limbs, angry skins.

Svante Arrhenius, **the Man Who Foresaw Climate Change** − estimated that "Doubling the level of CO_2 in the Earth's atmosphere would raise the mean global temperature by several degrees."

Burning of fossil fuels → Emission of SO_2 and NO

↓ combine with water and oxygen in the atmosphere

sulphuric, nitric and nitrous acids

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$$

"Warming of the climate system is unequivocal,

human influence on the climate system is clear …"

− **The Intergovernmental Panel on Climate Change, January, 2014, Press Release**

Increase in extreme weather since 1970s

90% contribution from global warming

More rain in some places, less in others

"Scientific prayer makes God a celestial lab rat, leading to bad science and worse religion."

— Michael Shermer

Use of computers, tablets and cell phones

↓

- blurred vision
- dry eyes
- headaches
- neck and shoulder pain

Symptoms of **nutrient** deficiency → Stunted growth and death of plant tissue

↓ To overcome this

Development of crop plants that intake high nutrient from the soil

↓

High intake of nutrients → soil less fertile

Modification of genes $\xrightarrow{\text{Human-controlled process}}$ Ruin the natural balance of species and lead to the extinction of certain species

(Selective cross breeding)

From self-driving cars to industrial robots, all complex real world problems are being solved with applications of intelligence (AI). Artificial intelligence (AI) is progressing rapidly and makes it possible for machines to think like humans and mimic their actions − adjust to new inputs and perform human-like tasks by processing large amounts of data and recognizing patterns in the data. While science fiction often renders AI as robots (a machine − especially one programmable by a computer − capable of carrying out a complex series of actions without conscious thought or attention) with human-like characteristics, AI can encompass anything from missile guidance to tumor detection to face recognition.

The applications for artificial intelligence are countless and **John McCarthy**, who coined the term in 1956, defines it as: "the science and engineering of making intelligent machines." The study and design of intelligent agents − where an intelligent agent is a system that becomes aware or conscious of its environment and takes actions which maximizes its chances of success − can be applied to many sectors and industries including computer science, psychology, philosophy, neuroscience, cognitive science, linguistics, operations research, economics, control theory, probability, optimization, and logic. The simulation of human intelligence in machines is being tested and used in the maintenance or improvement of health industry for dosing drugs and different treatment in patients, and for surgical procedures in the hospital operating room.

A property of machines: the intelligence that the system demonstrates − today is properly known as Weak Artificial intelligence, in that it is designed to perform a narrow task (such as web searches, control systems, scheduling, data mining, logistics, speech recognition, facial recognition and many others). However, the long-term goal of many technical researchers is to create Strong Artificial intelligence. While Weak Artificial intelligence may outperform humans at whatever its specific task is, like playing games or solving mathematical problems, Strong Artificial intelligence would outsmart humans at nearly every cognitive task.

In little over a decade, Artificial intelligence (a wide-ranging tool that enables people to rethink how we integrate information, analyze data, and use the resulting insights to improve decision making) has made leaps and bounds. Every single day, a new thousand word post showcase the most recent advancement in Artificial intelligence. Being Artificial intelligence has made remarkable breakthroughs, and many scientists dream of creating the Master Algorithm proposed by Pedro Domingos -- which can solve all problems envisioned by humans -- failure is at the core of human advancement-- notable failures are emerging. From self-driving car accidents to Face ID hacks, AI didn't have a perfect year.

The Most Significant Failures When Al Turned Rogue, Causing Disastrous Results:

- **1959:** AI designed to be a General Problem Solver failed to solve real world problems.
- **1982:** Software designed to make discoveries, discovered how to cheat instead.
- **1983:** Nuclear attack early warning system falsely claimed that an attack is taking place.
- **2010:** Complex AI stock trading software caused a trillion dollar flash crash.
- **2011:** E-Assistant told to "call me an ambulance" began to refer to the user as Ambulance.
- **2013:** Object recognition neural networks saw phantom objects in particular noise images.
- **2015:** An automated email reply generator created inappropriate responses, such as writing "I love you" to a business colleague.
- **2015:** A robot for grabbing auto parts grabbed and killed a man.
- **2015:** Image tagging software classified black people as gorillas.
- **2015:** Medical AI classified patients with asthma as having a lower risk of dying of pneumonia.
- **2015:** Adult content filtering software failed to remove inappropriate content, exposing children to violent and sexual content.
- **2016:** AI designed to predict recidivism acted racist.
- **2016:** An AI agent exploited a reward signal to win a game without actually completing the game.
- **2016:** Video game NPCs (non-player characters, or any character that is not controlled by a human player) designed unauthorized super weapons.
- **2016:** AI judged a beauty contest and rated dark-skinned contestants lower.

- **2016:** A mall security robot collided with and injured a child.
- **2016:** The AI "Alpha Go" lost to a human in a world-championship-level game of "Go."
- **2016:** A self-driving car had a deadly accident.
- **2017:** Google Translate shows gender bias in Turkish-English translations.
- **2017:** Facebook chat bots shut down after developing their own language.
- **2017:** Autonomous van in accident on its first day.
- **2017:** Google Allo suggested man in turban emoji as response to a gun emoji.
- **2017:** Face ID beat by a mask.
- **2017:** AI misses the mark with Kentucky Derby predictions.
- **2017:** Google Home Minis spied on their owners.
- **2017:** Google Home outage causes near 100% failure rate.
- **2017:** Facebook allowed ads to be targeted to "Jew Haters".
- **2018:** Chinese billionaire's face identified as jaywalker.
- **2018:** Uber self-driving car kills a pedestrian.
- **2018:** Amazon AI recruiting tool is gender biased.
- **2018:** Google Photo confuses skier and mountain.
- **2018:** LG robot Cloi gets stagefright at its unveiling.
- **2018:** IBM Watson comes up short in healthcare.

While these are only a few instances of failures that have been observed so far, they are pieces of evidence to the fact that Artificial intelligence (the simulation of human intelligence processes by machines, especially computer systems) has the potential to develop a will of its own that may be in conflict with members of the human race. This is definitely a warning about the potential dangers of Artificial intelligence which should be addressed while exploring its potential interests.

> "I believe there is no deep difference between what can be achieved by a biological brain and what can be achieved by a computer. It therefore follows that computers can, in theory, emulate human intelligence — and exceed it."
>
> – Stephen Hawking.

Artificial intelligence in general, context remains a challenge. Despite Its Many Failures, why is artificial intelligence important?

- Artificial intelligence automates repetitive learning and discovery through data.
- Artificial intelligence analyzes more and deeper data.
- Artificial intelligence adds intelligence to existing products.
- Artificial intelligence adapts through progressive learning algorithms to let the data do the programming.
- Artificial intelligence gets the most out of data.
- Artificial intelligence achieves unbelievable accuracy through deep neural networks – which was previously impossible. For example, your interactions with Amazon Alexa, Google Search and Google Photos are all based on deep learning – and they keep getting more precise the more we use them.

The threat of AI-charged job loss is spreading (AI and automation will eliminate the most mundane tasks). No matter what industry you're in, AI-powered bots (which can answer common questions and point users to FAQs and knowledge base articles) and software are taking a crack at it. Artificial intelligence seems to be ringing the death sound of a bell for all manner of jobs, tasks, chores and activities. From hospitality, to customer service, to home assistants, no job feels safe. Naturally, this has made people worried about the future. But is Artificial intelligence ready to take over our jobs, or even likely to do so ever? Prevalent AI- charged failures would suggest not.

Chernobyl nuclear reactor explosion in Ukraine in 1986 caused more than 6000 people develop thyroid cancer, according to an investigation by the UN.

Grotthuss-Draper law

Only that light which is absorbed by a chemical substance can bring about a photochemical reaction

Einstein law of photochemical equivalence

↓

For every quantum of radiation that is absorbed, one molecule of the chemical substance reacts

These experiments show that the uranium radiation is complex, and that there are present at least two distinct types of radiation — one that is very readily absorbed, which will be termed for convenience the α radiation, and the other of a more penetrative character, which will be termed the β radiation.

− Ernest Rutherford

Rate of photochemical reaction = $I_{absorbed} \times \phi$

$$\varphi = \frac{\text{number of molecules reacted}}{\text{number of photons absorbed}}$$

The **rate of photochemical reaction** is directly proportional to the product of the absorbed light intensity and the quantum yield of the reaction.

The interacting boson model

↓

A model in **nuclear physics** in which protons or neutrons pair up − essentially acting as a single particle with boson properties with integral spin of 0, 2 or 4.

CAM (crassulacean acid metabolism)

CO_2 is converted to an inorganic acid (**malate**) during the night and released back into the plant as CO_2 during the day

Explosive fusion → light elements

Neutron capture → heavy elements

Slow neutron capture within stars will not synthesize elements heavier than iron

meson	quark-antiquark pair
hadron	quark triplet
tetraquark	two quarks-two antiquarks
pentaquark	four quarks and one antiquark

Quantum Flavordynamics

↓

The theory describing the behavior and effects of weak interaction

A weakless universe is a hypothetical universe that contains no weak interactions

Electromagnetic (charge)	**Strong** (color)	**Weak** (Flavor)
Interaction mediated by photons	Interaction mediated by gluons	Interaction mediated by W and Z particles

Quantum geometrodynamics

The mathematical model that describe gravity on the particle level

The universe doesn't allow perfection.

— Stephen Hawking

String theory = The standard model + quantum gravity

Loop quantum gravity = general relativity + quantum mechanics

quantity = numerical value × unit

"I have a friend who's an artist and has sometimes taken a view which I don't agree with very well. He'll hold up a flower and say "look how beautiful it is," and I'll agree. Then he says "I as an artist can see how beautiful this is but you as a scientist take this all apart and it becomes a dull thing," and I think that he's kind of nutty. First of all, the beauty that he sees is available to other people and to me too, I believe. Although I may not be quite as refined aesthetically as he is ... I can appreciate the beauty of a flower. At the same time, I see much more about the flower than he sees. I could imagine the cells in there, the complicated actions inside, which also have a beauty. I mean it's not just beauty at this dimension, at one centimeter; there's also beauty at smaller dimensions, the inner structure, also the processes. The fact that the colors in the flower evolved in order to attract insects to pollinate it is interesting; it means that insects can see the color. It adds a question: does this aesthetic sense also exist in the lower forms? Why is it aesthetic? All kinds of interesting questions which the science knowledge only adds to the excitement, the mystery and the awe of a flower. It only adds. I don't understand how it subtracts."

— Richard P. Feynman

Cyclotron

A machine that accelerates charged particles or ions to high energies.

When a particle of e and speed v moves in a field of B, the Lorentz force in the circular orbit, evB, provides the necessary centripetal acceleration to maintain the circular motion:

$F = evB = \frac{m_0 v^2}{r}$ (where r is the radius of the orbit) $\longrightarrow$ $\boxed{v = \frac{eBr}{m_0}}$

The maximum kinetic energy of the particle when it reaches the outer most (largest) radius (r) of the cyclotron is given by: $KE_{max} = \frac{m_0 v^2}{2} = \frac{e^2B^2r^2}{2m_0}$.

The orbital frequency can be calculated from the expression: $\upsilon = \frac{v}{2\pi r} = \frac{eB}{2\pi m_0}$

- Cyclotron cannot accelerate electrons because electrons are of very small mass.
- A cyclotron cannot be used to accelerate neutral particles.
- Cyclotron cannot accelerate positively charged particles with large mass due to the relativistic effect.

For **relativistic particles**, the orbital frequency can be calculated from the expression:

$$\upsilon = \frac{eB}{2\pi m} \quad \text{where } m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

When a proton of energy E_{lab} strikes a stationary proton of mass m_p, the centre of mass energy in the reaction is given by: $E_{cm} = \sqrt{2m_pc^2E_{lab}}$

Thus when a 30 GeV proton hits a stationary target, available energy for the reaction in the centre of mass is about 7.6GeV only.

"The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science."

— Albert Einstein

A protein in solution exists in two forms: bound and unbound. Depending on a specific protein's affinity for ligand, a proportion of the protein may become bound to ligands, with the remainder being unbound. If the protein ligand binding is reversible, then a chemical equilibrium will exist between the bound and unbound states, such that:

P (protein) + L (ligand) ⇌ PL (protein - ligand complex)

The dissociation constant for this reaction is,

$$\mathbf{K} = \frac{[\mathbf{P}]\,[\mathbf{L}]}{[\mathbf{PL}]}$$

In this equation $[P] = [P]_T - [PL]$ and $[L] = [L]_T - [PL]$ where $[P]_T$ and $[L]_T$ are the initial total concentrations of the protein and ligand, respectively. The dissociation constant K is a useful way to present the affinity of a protein for its ligand. This is because the number K quickly tells us the concentration of protein that is required to yield a significant amount of interaction with the target ligand. Specifically, when protein concentration equals K, the 50% of the target ligand will exist in the protein ligand complex and 50% of the ligand will remain in the free form [L]. (This holds true under conditions where protein is present in excess relative to ligand). Typically, proteins must display a $\mathbf{K \leq 1 \times 10^{-6}\ M}$ for the interaction with their target ligand. When considering the K for proteins, smaller numbers mean better binding. The higher the K value the protein does not bind well to the ligand.

CASE 1:

Using the equilibrium relationship K [PL] = [L] [P] and substituting,

$[L]_T - [PL]$ for [L]

$[P]_T - [PL]$ for [P] Gives:

$$K\,[PL] = \{[L]_T - [PL]\}\,\{[P]_T - [PL]\}$$

$$K\,[PL] = [L]_T\,[P]_T - [PL]\,[L]_T - [PL]\,[P]_T + [PL]^2$$

Dividing throughout by [PL] gives:

$$K = \{\frac{[L]_T[P]_T}{[PL]}\} - [L]_T - [P]_T + [PL]$$

But

$$[P]_T = [PL] + [P]$$

And, therefore,

$$K = \{\frac{[L]_T[P]_T}{[PL]}\} - [L]_T - [P]$$

$$K = [L]_T(\{\frac{[P]_T}{[PL]}\} - 1) - [P]$$

From this it follows that

$$K + [P] = \frac{\mathbf{[P]\ [L]_T}}{\mathbf{[PL]}}$$

Rearranging

$$\mathbf{[PL]} = \frac{\mathbf{[P]\ [L]_T}}{\mathbf{K + [P]}} \quad \dots (1)$$

DISCUSSION

This defines a rectangular hyperbola with several important regional properties:

- **Saturation:** when [P] >> K, [PL] asymptotically approaches $[L]_T$.
- **Half-saturation:** when [P] = K, [PL] = $\frac{[L]_T}{2}$ − in other word, the dissociation constant is equal to the (free) protein concentration needed to ensure that 50% of the ligand will be bounded.
- Linearity: when [P] << K, [PL] is ~ proportional to [P] with slope = $\frac{[L]_T}{K}$.

CASE 2:

Using the equilibrium relationship K [PL] = [L] [P] and substituting,

$[P]_T - [P]$ for [PL]

$[L]_T - [PL]$ for [L]

$[P]_T - [PL]$ for [P] Gives:

$$K\{[P]_T - [P]\} = \{[L]_T - [PL]\}\{[P]_T - [PL]\}$$

$$K\,[P]_T - K\,[P] = [L]_T\,[P]_T - [PL]\,[L]_T - [PL]\,[P]_T + [PL]^2$$

Rearranging

$$K\,[P]_T - [L]_T\,[P]_T + [PL]\,[P]_T = -\,[PL]\,[L]_T + [PL]^2 + K\,[P]$$

$$[P]_T\,\{K - [L]_T + [PL]\} = [PL]\,\{-[L]_T + [PL]\} + K\,[P]$$

Further, if we substitute

$$[L]_T = [PL] + [L]$$

Then we get

$$[P]_T\,\{K - [PL] - [L] + [PL]\} = [PL]\,\{-[PL] - [L] + [PL]\} + K\,[P]$$

$$[P]_T\,\{K - [L]\} = -\,[PL]\,[L] + K\,[P]$$

Which is the same as:

$$[P]_T\,\{K - [L]\} = K\,[P] - [PL]\,[L]$$

$$K - [L] = K\,\{\frac{[P]}{[P]_T}\} - \{\frac{[PL]}{[P]_T}\}\,[L]$$

Labeling $\frac{[P]}{[P]_T}$ as F_{FP} (fraction of free protein) and $\frac{[PL]}{[P]_T}$ as F_{BP} (fraction of bound protein) then above expression turn into

$$K - [L] = K\,F_{FP} - F_{BP}\,[L] \qquad \ldots (2)$$

DISCUSSION

- If $F_{FP} = F_{BP} = 1$, then the LHS = RHS, and the Eq. (2) is true.
- If $F_{FP} = F_{BP} \neq 1$, then the LHS $\neq$ RHS, and the Eq. (2) is invalid.

Let us now check the validity of the condition

"$F_{FP} = F_{BP} = 1$"

As per the **protein conservation law**,

$$[P]_T = [PL] + [P]$$

From this it follows that

$$1 = F_{BP} + F_{FP}$$

If we assume $F_{BP} = F_{FP} = 1$, we get:

$$1 = 2$$

The condition $F_{FP} = F_{BP} = 1$ cannot be achieved, since $1 \neq 2$.

In fact, the only way it can happen that K – [L] = K – [L] is if both $F_{FP} = F_{BP} = 1$. Since $F_{FP} = F_{BP} \neq 1$, Eq. (2) does not therefore hold well.

CASE NOTES

CASE 1

If we substitute

$[L]_T$ – [PL] for [L] and $[P]_T$ – [PL] for [P], then equilibrium relationship

K [PL] = [L] [P] becomes

K [PL] = ($[L]_T$ – [PL]) ($[P]_T$ – [PL])

From this it follows that

$$\mathbf{[PL] = \frac{[P]\,[L]_T}{K + [P]}}$$

CASE 2

If we substitute

$[L]_T$ – [PL] for [L],

$[P]_T$ – [PL] for [P] and $[P]_T$ – [P] for [PL], then equilibrium relationship

K [PL] = [L] [P] becomes

K ($[P]_T$ – [P]) = ($[L]_T$ – [PL]) ($[P]_T$ – [PL])

From this it follows that

K – [L] = K F_{FP} – F_{BP} [L] (wrong result)

CONCLUSION

Substitution for ' [PL] ' along with the substitutions for ' [L] ' and ' [P] ' should be avoided in order to prevent the occurrence of wrong result.

H I region

A region of interstellar hydrogen that is in the form of neutral, unionized atoms.

H II region

A region of interstellar hydrogen that is in the form of ionized atoms.

Tides are the rise and fall of sea level that is caused by the gravitational pull of the moon and the sun.

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

The Universe underwent a period of expansion immediately after the **Big Bang** that saw its volume expanded by a factor of 10^{26}

This allows the temporary creation of a particle of mass m, where $\Delta E = mc^2$. The larger the mass and the greater the ΔE, the shorter is the time it can exist.

Millisecond Pulsar

A pulsar with a rotational period less than about 10 milliseconds

Population I: Stars rich in atoms heavier than helium

Population II: Stars poor in atoms heavier than helium

- **Spectral Sequence:** The arrangement of a star's position in the temperature classification system (O, B, A, F, G, K, M), ranging from hot to cool.
- **Starburst galaxies:** galaxies that are observed to be forming stars at an unusually fast rate (about 10^3 times greater than in a normal galaxy).
- **Nematic liquid crystal:** a phase of matter which exhibits properties somewhere between those exhibited by a liquid and solid crystal.

Liquid drop model

- **The surface energy of the nucleus:**

$$E_S = \sigma \times 4\pi R^2 = 4\pi\sigma\, R_0^2 A^{2/3}$$

- **The Coulomb energy of the nucleus:**

$$E_C = \frac{3Z^2e^2}{5R} = \frac{3Z^2e^2}{5R_0A^{1/3}}$$

Nuclei are assumed to behave in a similar way to a liquid

- $R_0 = 1.2 \times 10^{-15}$m
- σ = surface tension
- A = atomic mass number
- Z = atomic number
- e = electronic charge

Liquid drop model

- Fails to explain the spin of nuclei
- Fails to explain the extra stability of certain nuclei where the number of protons or neutrons in the nucleus are $\underbrace{2, 8, 20, 28, 50, 82 \text{ or } 126}_{\text{Magic numbers}}$

Magic numbers

A barycenter is the common center mass around which a solar system orbits.

During an equinox, Planet Earth experiences an even 12 hours of daytime and 12 hours of nighttime.

Gamma-ray burst

Short-lived bursts of gamma-ray light

Immensely energetic explosion in the universe that emits more energy in 10 seconds than the sun will emit in its lifetime.

A meteor is a space rock that vaporizes when entering the Earth's atmosphere. It is often called "shooting star" and provide a beautiful glowing tail as it enter the Earth's atmosphere.

Neutron stars can exist in 2 states

- **Pulsar** − which emits a narrow electromagnetic radiation beam.
- **Magnetar** − which has an extremely powerful magnetic field ($\sim 10^9$ to 10^{11} T) that has the force to distort atoms.

Stars with an abundance of metals are said to have high metallicity

Dark nebula

(Coalsack Nebula)

A cool cloud of dust and gas that

- Does not emit light in visible region of spectrum so appears dark
- Block out light from stars that are behind it.

Helium flash

The explosive ignition of helium fusion in the core of a giant star

Interferometry: Technique that extract information from interference

- **Pre-main sequence stars:** Stars not still hot enough in their cores for hydrogen fusion to begin.
- **Supernova remnant:** The debris left by a supernova.

Zero Age Main Sequence (ZAMS)

The lower, left edge of the main sequence on the Hertzsprung-Russell Diagram representing a locus of stars just beginning their lives by burning hydrogen in its core through fusion reactions.

Abiogenesis

The natural process by which life has arisen from non-living matter

- **Alpha Particle:** A particle of 2 protons and 2 neutrons (essentially a helium nucleus) that is emitted by an unstable radioactive nucleus during radioactive decay.

Complementarity

The wave-particle duality of light – where light can either behave as a particle or as a wave – but not simultaneously as both

2 particles such as a pair of photons or electrons become entangled – if they remain connected even when separated by vast distances

Oscillating Universe: A cosmological model, in which the universe undergoes a potentially endless series of oscillations, each beginning with a Big Bang and ending with a Big Crunch.

Exogenesis

Life originated elsewhere in the universe and was spread to Earth

Parallel Universes: A hypothetical set of multiple possible universes (including our own) which exist in parallel with each other.

Planck Temperature

The temperature of the universe at one Planck Time after the Big Bang

1.41×10^{32}K

Charles Darwin's theory of primordial soup

Earth's original blend of gases produced a broth of organic molecules when exposed to light and heat, eventually forming the building blocks for the evolution of life in amino acids

Panspermia

Life is originated in space, in spatial ices, and continuously distributed to the planets by meteorites, comets or asteroids.

In an 1871 letter to a friend, Charles Darwin wrote:

"It is often said that all the conditions for the first production of a living organism are now present, which could ever have been present.— But if (& oh what a big if) we could conceive in some warm little pond with all sorts of ammonia & phosphoric salts,—light, heat, electricity &c present, that a protein compound was chemically formed, ready to undergo still more complex changes, at the present day such matter wd be instantly devoured, or absorbed, which would not have been the case before living creatures were formed."

One cannot distinguish a state of rest from a state of constant velocity

There is no absolute and well-defined state of rest

General theory of relativity

The Big Bang started with a singularity and there is a singularity at the center of a black hole

Distant active galactic nucleus

A compact region at the center of a galaxy which has a much higher than normal luminosity

Quarks are the only elementary particles in the standard model of particle physics to experience all 4 fundamental forces of nature and they have the properties of electric charge, color charge, spin and mass.

Cosmography	The branch of astronomy that maps and describes the main features of the universe.
Cosmotheism	The concept that the universe and God are identical.
Cosmozoism	The concept of the cosmos as alive.
Geocentricism	The concept that the earth is the center of the universe.
Heliocentricism	The concept that the sun is the center of the universe.
Pancosmism	The philosophical doctrine that the material universe is all that exists.
Spencerianism	The mechanistic evolution of the universe from relative simplicity to relative complexity.
Teleologism	Explanation by reference to some purpose, end, goal or function.
Universology	A science covering the whole ground of philosophy, of the sciences in their general aspects, and of social policy, or the collective life of the human world.
Nebular hypothesis	The theory that the solar system evolved from a hot gaseous nebula.
Planetesimals hypothesis	The theory that the solar system was formed by the gravitational accumulation of Planetesimals.
ylem	The hypothetical initial substance of the universe from which all the elements are supposed to have derived. → **Originally thought as composed of neutrons at high temperature and density.**
Cosmic consistency Launched on June 30, 2001 and named in honor of the late David Wilkinson of Princeton University	**(Wilkinson Microwave Anisotropy Probe data + other precision cosmological observations)** pointing to a unified model that can predict key parameters such as: the age and shape of the Universe, the era for first star light, the Hubble constant, and the matter and energy content in the Universe.
Cosmic horizon	The limit of the observable universe
Decoupling	A period 380,000 years after the Big Bang Photons separated from matter and propagated freely.
Zero Kelvin (−273.15 degrees Celsius)	The complete absence of heat

Universe: The totality of all that physically exists

The 4 fundamental forces — gravity, electromagnetic, weak and strong — are thought to be unified at a tiny fraction of a second (5.4×10^{-43} seconds).

A set of **fundamental invariant quantities** that describes the strengths of all the interactions and the physical properties of all the particles observed in nature and appearing in the basic theoretical equations of physics

"It Takes Fundamental Constants To Give Us Our Universe, But They Still Don't Give Everything."

The speed of light (**c**) **(ultimate speed limit)** **186,000 miles per second**	The conversion factor between the time dimension and the three space dimensions in our 4 dimensional space-time If particles with intrinsic mass exceed the speed of light, then c loses its special status, giving rise to a host of other problems elsewhere in the world of physics, where c has been used in calculations, such as the equation in Albert Einstein's theory of special relativity that expresses the equivalence of mass and energy: **$E=mc^2$**
Planck's constant (**h**) {tells about the behavior of the particles and the waves on the atomic scale}	One of the smallest constants used in quantum mechanics that sets the scale for quantum phenomena **($6.626\ 070\ 15 \times 10^{-34}$ J Hz^{-1})**

Planck's constant defines the amount of energy that a electromagnetic radiation photon can carry – according to the frequency of the electromagnetic wave in which it travels

Newtonian gravitational constant (**G**) The basis of our understanding of **non-relativistic gravity**	One of the earliest fundamental constants that defines the strength of gravitational force

The constant relating the force of gravitational attraction between two objects to the product of their masses and the inverse square of the distance between them in Sir Isaac Newton's universal law of gravitation:

$$F = \frac{Gm_1m_2}{r^2}$$

6.673×10^{-11} N m^2 kg^{-2}

The **Boltzmann constant** (k_B) relates temperature to energy. It is a fundamental constant of physics occurring in nearly every statistical formulation of both classical and quantum physics. It is named after Austrian physicist and philosopher **Ludwig Boltzmann**, one of the pioneers of statistical mechanics.

The idea of Quantum foam was devised by John Wheeler in 1955

PLANCK FORCE:

The amount of force required to accelerate one Planck mass by one Planck acceleration:

Planck force = Planck mass × Planck acceleration

$$\frac{c^4}{G} = \underbrace{\sqrt{\frac{\hbar c}{G}} \times \sqrt{\frac{c^7}{\hbar G}}}$$

$$\boxed{\mathbf{F_{Planck} = 1.2103 \times 10^{44}\ N}}$$

The maximum force value that can be observed in nature

appears in the Albert Einsteinian field equations describing the properties of a gravitational field surrounding any given mass:

$$\underbrace{\textbf{Einstein tensor} = 8\pi \times \frac{\text{energy–momentum tensor}}{\text{Planck force}}}$$

The Planck force describes how much or how easily space-time is curved by a given amount of mass-energy.

The amount of energy possessed by a Schwarzschild Black Hole is equal to its mass multiplied by the square of the speed of light: $E = Mc^2$, where: c is not just the constant namely the maximum distance a light can travel in one second in vacuum but rather a fundamental feature of the way space and time are unified to form space-time.

$$E = \frac{F_{Planck}}{2} \times r_S$$

This means: Half of the Planck force is responsible for confining the energy $E = Mc^2$ of the Black Hole to a distance $r_S = \frac{2GM}{c^2}$.

The value of h is about 0.6 trillionths of a trillionth of a billionth of 1 joule-second.

Any object with a physical radius < $\frac{2GM}{c^2}$ will be a Black Hole.

$\Delta p \, \Delta x \geq \frac{\hbar}{2}$	$\Delta E \, \Delta t \geq \frac{\hbar}{2}$
Planck momentum × Planck length = $\hbar$	Planck energy × Planck time = $\hbar$

The Planck time is the time it takes for light to traverse a Planck length.

The Planck mass is so large because the gravitational force in this universe is very weak

The **Planck mass** is approximately the mass of a black hole where quantum and gravitational effects are at the same scale: where its reduced Compton wavelength and half of its Schwarzschild radius are approximately the same.

If $\sqrt{\frac{\hbar c^5}{G}}$ is confined to the volume of a cube of size $\sqrt{\frac{\hbar G}{c^3}}$ it will form a black hole. In fact, this is thought to be the smallest possible mass limit for a black hole and at

Distance = $\sqrt{\frac{\hbar G}{c^3}}$

Time = $\sqrt{\frac{\hbar G}{c^5}}$

Energy = $\sqrt{\frac{\hbar c^5}{G}}$

it is thought that quantum gravitational effects will be very significant.

- Space-time would become chaotic quantum foam. Matter and antimatter would be constantly created and destroyed.
- Space-time would become quantized (which would cause violations of Lorentz invariance).

at

The attempt to understand the Hawking radiation has a profound impact upon the understanding of the Black Hole thermodynamics, leading to the description of what the black hole entropic energy is:

Black Hole Entropic Energy = Black Hole Temperature × Black Hole Entropy

$$E_S = T_{BH} \times S_{BH} = \frac{Mc^2}{2}$$

This means that the entropic energy makes up half of the mass energy of the Black Hole. For a Black Hole of one solar mass (M☺ $= 2 \times 10^{30}$ kg), we get an entropic energy of 9×10^{46} joules – much higher than the thermal entropic energy of the sun. Given that power emitted in Hawking radiation is the rate of energy loss of the black hole: $P = -\frac{dMc^2}{dt} = 2 \times -\frac{dE_S}{dt}$. The more power a black hole radiates per second, the more entropic energy being lost in Hawking radiation. However, the entropic energy of the black hole of one solar mass is about 9×10^{46} joules of which only 4.502×10^{-29} joules per second is lost in Hawking radiation.

$$E_S = \frac{F_{Planck}}{4} \times r_S$$

This means: $\frac{1}{4}$ th of the Planck force is responsible for confining the entropic energy $E_S = (T_{BH} \times S_{BH})$ of the Black Hole to a distance $r_S = \frac{2GM}{c^2}$. A photon sphere or photon ring is an area or region of space where gravity is so strong that photons are forced to travel in orbits. The radius of the photon sphere for a Schwarzschild Black Hole: $r = \frac{3GM}{c^2}$**.** This equation entails that photon spheres can only exist in the space surrounding an extremely compact object (a Black Hole or possibly an "**ultracompact**" neutron star).

E = hʋ

The first "**quantum**" expression in history – stated by Max Planck in 1900

$$E = \frac{F_{Planck}}{3} \times r$$

This means: $\frac{1}{3}$ rd of the Planck force times the radius of the photon sphere equals the amount of energy possessed by a Schwarzschild Black Hole.

Radiation Constants:

"Nature shows us only the tail of the lion. But there is no doubt in my mind that the lion belongs with it even if he cannot reveal himself to the eye all at once because of his huge dimension. We see him only the way a louse sitting upon him would." **— Albert Einstein**

Fundamental physical constants characterizing black body radiation. The first radiation constant is $c_1 = 2\pi hc^2 = 3.7417749 \times 10^{-16}$ Wm^2, the second is $c_2 = \frac{hc}{k_B} = 1.438769 \times 10^{-2}$ mK, where: h is the Planck constant c is the speed of light in vacuum and k_B the Boltzmann constant.

Radiation

$$\underbrace{\text{Heat flows through space by means of electromagnetic waves}}_{\text{Radiation}}$$

$$\frac{(\text{elementary charge})^2}{(\text{Planck charge})^2} = \frac{1}{4} Z_0 G_0$$

elementary charge $= \frac{\text{Planck charge}}{2}\sqrt{Z_0 G_0}$

Fine structure constant:

{ **Sommerfeld's constant** }

$$\alpha = \frac{e^2}{4\pi\varepsilon_0 \hbar c} = \frac{1}{4} Z_0 G_0$$

$$\alpha = \frac{1}{4} \times \text{impedance of free space} \times \text{conductance quantum} = 0.0072973525693$$

expresses the strength of the electromagnetic interaction between elementary charged particles.

$$\frac{(\text{elementary charge})^2}{(\text{Planck charge})^2}$$

If $\frac{e^2}{4\pi\varepsilon_0 \hbar c}$ were greater than 0.1, stellar fusion would be impossible and no place in the cosmos would be warm enough for carbon-based life as we know it.

When I die my first question to the Devil will be: What is the meaning of the fine structure constant?

— Wolfgang Pauli

Planck units

The ultra-high-energy cosmic ray observed in 1991 had a measured energy of about $2.5\times10^{-8}\sqrt{\frac{\hbar c^5}{G}}$

Planck mass	$m_{Planck} = \sqrt{\frac{\hbar c}{G}} = 2.176434 \times 10^{-8}$ kg
Planck length	$L_{Planck} = \sqrt{\frac{\hbar G}{c^3}} = 1.616255 \times 10^{-35}$ m At which all the fundamental forces are unified.
Planck time	$t_{Planck} = \sqrt{\frac{\hbar G}{c^5}} = 5.391247 \times 10^{-44}$ s **Quantum effects of gravity** dominate physical interactions at this time interval.
Planck temperature	$T_{Planck} = \sqrt{\frac{\hbar c^5}{Gk_B^2}} = 1.416784 \times 10^{32}$ K At this temperature, the wavelength of emitted **thermal radiation** reaches the **Planck length.**
Planck charge	$q_{Planck} = \sqrt{4\pi\varepsilon_0 \hbar c} = 1.875546 \times 10^{-18}$ C $\approx 11.7e$
Planck area	$L_{Planck}^2 = \frac{\hbar G}{c^3} = 2.6121 \times 10^{-70}$ m^2
Planck volume	$L_{Planck}^3 = \sqrt{\frac{\hbar^3 G^3}{c^9}} = 4.2217 \times 10^{-105}$ m^3
Planck momentum	$m_{Planck}c = \frac{\hbar}{L_{Planck}} = \sqrt{\frac{\hbar c^3}{G}} = 6.5249$ kg-m/s
Planck energy	$m_{Planck}c^2 = \frac{\hbar}{t_{Planck}} = \sqrt{\frac{\hbar c^5}{G}} = 1.9561 \times 10^9$ J At which quantum effects of gravity become strong.
Planck force	$\frac{m_{Planck}c^2}{L_{Planck}} = \frac{\hbar}{L_{Planck}\, t_{Planck}} = \frac{c^4}{G} = 1.2103 \times 10^{44}$ N • It is the gravitational attractive force of two bodies of **one Planck mass** each that are held **one Planck length** apart • It is the electrostatic attractive or repulsive force of **two Planck units of charges** that are held **one Planck length** apart.

Events happening at the Planck scale are undetectable with current scientific technology

Planck power	$\frac{m_{Planck}c^2}{t_{Planck}} = \frac{\hbar}{t^2_{Planck}} = \frac{c^5}{G} = 3.628 \times 10^{52}$ W
Planck density	$\frac{m_{Planck}}{L^3_{Planck}} = \frac{c^5}{\hbar G^2} = 5.1550 \times 10^{96}$ kg/m^3
Planck acceleration	$\frac{c}{t_{Planck}} = \sqrt{\frac{c^7}{\hbar G}} = 5.5608 \times 10^{51}$ m/s^2
Planck frequency	$\frac{1}{t_{Planck}} = \sqrt{\frac{c^5}{\hbar G}} = 1.8549 \times 10^{43}$ s^{-1}
Planck current	$\frac{q_{Planck}}{t_{Planck}} = \sqrt{\frac{4\pi\varepsilon_0 c^6}{G}} = 3.479 \times 10^{25}$ A
Planck voltage	$\frac{m_{Planck}c^2}{q_{Planck}} = \sqrt{\frac{c^4}{4\pi\varepsilon_0 G}} = 1.43 \times 10^{27}$ V

The density at which the Universe can no longer be described without quantum gravity

For energies approaching or exceeding $\sqrt{\frac{\hbar c^5}{G}} = 1.22 \times 10^{19}\ \text{GeV}$, gravity is problematic and cannot be integrated with quantum mechanics. A new theory of quantum gravity is necessary. Approaches to this problem include:

- **String theory** (point-like particles are replaced by one-dimensional infinitesimal vibrating strings − smaller than atoms, electrons or quarks)
- **M-theory** (The Mother of all theories or Mystery − an 11 dimensional theory in which the weak and strong forces and gravity are unified and to which all the string theories belong)

A theory that extends general theory of relativity by quantizing spacetime—predicts that black holes evolve into white holes

- **Loop quantum gravity** (a theory of quantum gravity which aims to merge quantum mechanics and general theory of relativity)
- **Non-commutative geometry** (a branch of mathematics concerned with a geometric approach to noncommutative algebra)
- **Causal set theory** (an approach to quantum gravity that tries to replace the continuum spacetime structure of general relativity with the spacetime that has the property of discreteness and **causality**)

- The study of how things influence one other
- The study of how causes lead to effects

The idea of quantum foam arises out of Albert Einstein's idea that gravity is caused by the warping and curving of spacetime

Martin Bojowald

A German physicist who developed the application of loop quantum gravity to cosmology

The incorporation of a standard model into the framework of the quantum gravity

Loop Quantum Gravity **(quantized space and time)**	**String Theory**
Does not attempt to unify fundamental interactions	Attempts to unify all four fundamental interactions
Approaches the quantum gravity assuming the aspects of general relativity	Approaches the quantum gravity assuming the aspects of quantum theory
Does not require a super-symmetry	

Grand unification theory

↓

Fundamental symmetries existed at the beginning of the universe and then broke as the temperature dropped – just as H_2O which looks the same in every direction, freezes into ice, which has distinct directions.

Expanding matter

↓

White hole

↕ Quantum transition

Black hole

↑

Contracting matter

The Coulomb constant "$\frac{1}{4\pi\varepsilon_0}$" is a proportionality constant in electrostatics equations. It was named after the French physicist Charles-Augustin de Coulomb who introduced Coulomb's law.

Newton's law of gravitation:

$$F_G = \frac{Gm_1 m_2}{r^2}$$

$$F_G \propto \frac{m_1 m_2}{r^2}$$

G → Proportionality constant

$m_1 = m_2 = 1kg$

$r = 1m$

$$\boxed{F_G = G}$$

The universal gravitational constant is numerically equal to the Force of attraction between two unit masses placed at a unit distance apart.

Because $E=mc^2$:

$$F_G = \frac{GE_1 E_2}{c^4 r^2}$$

$$F_G \propto \frac{E_1 E_2}{r^2}$$

$\frac{1}{F_{Planck}}$ → Proportionality constant

$E_1 = E_2 = 1J$

$r = 1m$

$$\boxed{F_G = \frac{1}{F_{Planck}}}$$

The reciprocal of Planck force is numerically equal to the Force of attraction between two unit energies placed at a unit distance apart.

$$\frac{(\text{Stoney mass})^2}{4\pi \times \hbar c \times \text{gravitoelectric gravitational constant}}$$

Fine structure constant: $\alpha = \frac{Z_0}{2R_K} = \frac{\text{impedance of free space}}{2 \times \text{von Klitzing constant}}$

$$\frac{(\text{Stoney mass})^2}{(\text{Planck mass})^2} = \frac{e^2}{q_{Planck}^2}$$

$$\text{Stoney mass} = \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$$

$$\text{Stoney mass} = \text{Planck mass} \times \frac{\text{elementary charge}}{\text{Planck charge}}$$

$$\Delta x \ \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E \ \Delta t \geq \frac{\hbar}{2}$$

$$\Delta x \ \Delta p \geq \frac{\text{Planck length} \ \times \text{Planck momentum}}{2}$$

$$\Delta E \ \Delta t \geq \frac{\text{Planck energy} \ \times \text{Planck time}}{2}$$

$$\frac{\Delta p}{\text{Planck momentum}} \geq \frac{\text{Planck length}}{\Delta x}$$

$$\frac{\Delta E}{\text{Planck energy}} \geq \frac{\text{Planck time}}{\Delta t}$$

Gravitoelectric gravitational constant: $\varepsilon_g = \dfrac{1}{4\pi G}$

Gravitomagnetic gravitational constant: $\mu_g = \dfrac{4\pi G}{c_g^2}$

The speed of gravitation:

$$c_g = \frac{1}{\sqrt{\varepsilon_g \mu_g}}$$

The Schwarzschild radius of the **Stoney mass**:

$$r_S = \underbrace{\frac{2Gm_S}{c^2} = \frac{2G}{c^2}\sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}}$$

$$\text{Planck force} = \frac{4\hbar c \ \times \text{fine structure constant}}{r_S^2}$$

Optical Telescope → **A telescope that is designed to collect visible light**

If we take the mass of electron as m, when it is moving with velocity v, then

$$m = \frac{m_e}{\sqrt{1-\frac{v^2}{c^2}}}$$

where m_e is the rest mass of the electron and m is the relativistic mass.

$$m^2 = \frac{m_e^2}{1-\frac{v^2}{c^2}}$$

If m = **Stoney mass =** $\sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$:

Hypernova → an exploding star that produces even more energy and light than a supernova

$$\underbrace{v = c\sqrt{1 - \frac{\text{Schwarzschild radius of electron}}{2 \times \text{Classical electron radius}}}}$$

Velocity a electron must travel so that its relativistic mass to be equal to **Stoney mass**

The Compton wavelength of the **Stoney mass:**

$$\lambda_C = \underbrace{\frac{h}{m_S c} = \frac{h}{c} \times \sqrt{\frac{4\pi\varepsilon_0 G}{e^2}}}$$

$$\lambda_C = \frac{2\pi \times \text{Planck length}}{\sqrt{\text{Fine structure constant}}}$$

The time it takes for a planet to complete one spin around its axis is called its **rotation period**.

The **Hawking radiation temperature** is:

$$T_{BH} = \frac{\hbar c^3}{8\pi G M k_B}$$

If M = **Stoney mass** = $\sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$:

$$T_{BH} = \underbrace{\frac{\hbar c^3}{8\pi G k_B} \sqrt{\frac{4\pi\varepsilon_0 G}{e^2}}}$$

$$T_{BH} = \frac{\text{Planck energy}}{8\pi k_B \sqrt{\text{Fine structure constant}}}$$

$$T_{BH} = \frac{\text{Planck temperature}}{8\pi \sqrt{\text{Fine structure constant}}}$$

Observatory: A place where telescopes and other astronomical instruments are housed and used.

If a hot body were to reach the temperature of $\sqrt{\frac{\hbar c^5}{G k_B^2}}$, the radiation it would emit would have a wavelength of $\sqrt{\frac{\hbar G}{c^3}}$, at which quantum gravitational effects become relevant.

Planck temperature which equals about 100 million million million million million degrees, denoted by $T_{Planck} = \sqrt{\frac{\hbar c^5}{G k_B^2}}$, is the unit of temperature in the system of natural units known as Planck units. The Planck temperature is thought to be the upper limit of temperature that we know of according to the standard model of particle physics − which governs our universe.

In physics the Stoney units form a system of units named after the Irish physicist **George Johnstone Stoney**, who first proposed them in 1881

$$T_{Planck} = \sqrt{\frac{\hbar c^5}{G k_B^2}} = \frac{c_2}{2\pi L_{Planck}}$$

A fundamental limit of quantum theory in combination with gravitation − first introduced in 1899 by German physicist **Max Planck** together with his introduction of what today is known as the Planck length, the Planck mass and Planck time.

where: $L_{Planck} = \sqrt{\frac{\hbar G}{c^3}}$ is the Planck length and c_2 is the second radiation constant. **This means:**

$T_{Planck} \times L_{Planck}$ can never be less than or greater than $\frac{c_2}{2\pi}$ but $= \frac{c_2}{2\pi}$.

When the gold particles were smashed together, for a split second, the temperature reached 7.2 trillion degrees Fahrenheit. That was hotter than a supernova explosion. That was the hottest temperature that we have ever actually encountered in the **Large Hadron Collider** (the world's largest and most powerful particle accelerator).

Stoney length = $\sqrt{\frac{G e^2}{4\pi\varepsilon_0 c^4}} = \sqrt{\alpha} \times$ Planck length

$T_{Planck} \times$ **Stoney length** = $\frac{\sqrt{\alpha}\, c_2}{2\pi}$

The universe was at T_{Planck} about 10^{-43} seconds after the big bang explosion. At this time, the entire universe was roughly one-billionth of the diameter of a proton.

Planck density $\frac{c^5}{\hbar G^2}$ is very large – about equivalent to 10^{23} solar masses squeezed into the space of a single atomic nucleus. At Planck time after the Big Bang explosion, the cosmic mass density was thought to have been approximately 5.1550×10^{96} kg/m^3.

No temperature $\longrightarrow$ **No heat exchange**.

Hagedorn temperature

$\{1.7\times10^{12}$ K$\}$

The temperature at which hadronic matter is no longer stable and must either "evaporate" or convert into quark matter – as such – it can be thought of as the "boiling point" of hadronic matter.

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

- When the velocity of the particle v is very small compared to velocity of light c, then $\frac{v^2}{c^2}$ is negligible compared to one. Therefore,

$$m = m_0$$

- If the velocity of the particle v is comparable to the velocity of light c, then $\sqrt{1-\frac{v^2}{c^2}}$ is less than one, then

$$m > m_0$$

- If the velocity of a particle v is equal to velocity of light c, then it possesses infinite mass.

$$F_G = \frac{Gm_1m_2}{r^2}$$

$$F_G = \frac{m_1m_2}{m_{Planck}^2} \times \frac{\hbar c}{r^2}$$

$$m_1m_2 = m_{Planck}^2$$

- $m_1 = m_2 = m_{Planck}$
- $m_1 > m_{Planck}$ and $m_2 < m_{Planck}$

$$F_G = \frac{\hbar c}{r^2}$$

$$q_{Planck} = \frac{\text{elementary charge}}{\sqrt{\text{fine structure constant}}}$$

$$F_E = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$

$$F_E = \frac{q_1q_2}{q_{Planck}^2} \times \frac{\hbar c}{r^2}$$

$$q_1q_2 = q_{Planck}^2 \longrightarrow F_E = \frac{\hbar c}{r^2}$$

- $q_1 = q_2 = q_{Planck}$
- $q_1 > q_{Planck}$ and $q_2 < q_{Planck}$

The rest mass energy of any particle is defined by the Albert Einstein's mass energy equivalence relation: $E_{rest} = m_0c^2 = k_BT_{threshold}$, where: m_0 is the mass of a stationary particle, also known as the invariant mass or the rest mass of the particle and $T_{threshold}$ implies the threshold temperature below which that particle is effectively removed from the universe. All particles have an intrinsic real internal vibration in their rest frame: $\upsilon_C = \frac{m_0c^2}{h} = \frac{c}{\lambda_C}$, where: υ_C and λ_C denote the quantum mechanical properties of a particle (i.e., the Compton frequency and Compton wavelength of the particle).

$$h\upsilon_C = \frac{hc}{\lambda_C} = k_BT_{threshold}$$

$$\boxed{\lambda_C \times T_{threshold} = c_2}$$

where: c_2 is the second radiation constant and is related to the **Stefan–Boltzmann constant** (also known as Stefan's constant) by: $\sigma = \frac{\pi^4 c_1}{15c_2^4}$. This means:

$$\boxed{\lambda_C \propto \frac{1}{T_{threshold}}}$$

The Compton wavelength of the particle is inversely proportional to the threshold temperature below which that particle is effectively removed from the universe.

$$T_{Planck} \times L_{Planck} = \frac{c_2}{2\pi}$$

$$T_{Planck} \times L_{Planck} = \frac{\lambda_C \times T_{threshold}}{2\pi}$$

$$(\lambda_C \times T_{threshold}) > (T_{Planck} \times L_{Planck})$$

$r_S \times ƛ_C = 2 \times L_{Planck}^2 = 2 \times$ **Planck area**, where: $ƛ_C = \frac{\hbar}{m_0c}$ is the reduced Compton wavelength of the particle. **This means:** The Schwarzschild radius of the particle times the reduced Compton wavelength of the particle is never smaller than a certain quantity, which is known as Planck area.

If the reduced Compton wavelength of the particle = **Stoney length**:

$$\frac{\hbar}{m_0 c} = \sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^4}}$$

$$\underbrace{m_0 = \frac{m_{Planck}}{\sqrt{\text{Fine structure constant}}}}$$

Mass a particle must possess so that its reduced Compton wavelength to be equal to **Stoney length**

$$\underbrace{E_{rest}^2 = m_0 c^2 \times h\upsilon_C}$$

$$E_{rest} = \text{Planck energy}\sqrt{\frac{\pi \times \text{Schwarzschild radius of the particle}}{\text{Compton wavelength of the particle}}}$$

$$E_{rest} = \text{Stoney mass} \times c^2\sqrt{\frac{\pi \times \text{Schwarzschild radius of the particle}}{\text{Fine structure constant} \times \text{Compton wavelength of the particle}}}$$

Sunspot

A cooler region of the Solar surface – which looks dark in comparison to the hotter material around it.

If the Schwarzschild radius of the particle = **Stoney length**:

$$\frac{2Gm_0}{c^2} = \sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^4}}$$

$$\underbrace{m_0 = \frac{\sqrt{\text{Fine structure constant}} \times \text{Planck mass}}{2}}$$

Mass a particle must possess so that its Schwarzschild radius to be equal to **Stoney length**

Planetary Nebula

A shell of gas ejected by a relatively low-mass star that is in the process of dying and becoming a white dwarf

Planck temperature = $\frac{m_{\text{Planck}} c^2}{k_B}$	Planck temperature = $\frac{m_S c^2}{\sqrt{\alpha}\, k_B}$
Planck area = L_{Planck}^2	Planck area = $\frac{L_S^2}{\alpha}$
Planck volume = L_{Planck}^3	Planck volume = $\frac{L_S^3}{\sqrt[3]{\alpha}}$
Planck energy = $\frac{\hbar}{t_{\text{Planck}}}$	Planck energy = $\frac{\hbar \sqrt{\alpha}}{t_S}$
Planck force = $\frac{m_{\text{Planck}} c^2}{L_{\text{Planck}}}$	Planck force = $\frac{m_S c^2}{L_S}$
Planck force = $\frac{\hbar}{L_{\text{Planck}}\, t_{\text{Planck}}}$	Planck force = $\frac{\alpha \hbar}{L_S\, t_S}$
Planck momentum = $m_{\text{Planck}}\, c$	Planck momentum = $\frac{m_S c}{\sqrt{\alpha}}$
Planck density = $\frac{m_{\text{Planck}}}{L_{\text{Planck}}^3}$	Planck density = $\frac{\alpha\, m_S}{L_S^3}$
Planck acceleration = $\frac{c}{t_{\text{Planck}}}$	Planck acceleration = $\frac{c \sqrt{\alpha}}{t_S}$
Planck frequency = $\frac{c}{L_{\text{Planck}}}$	Planck frequency = $\frac{c \sqrt{\alpha}}{L_S}$
Planck power = $\frac{m_{\text{Planck}} c^2}{t_{\text{Planck}}}$	Planck power = $\frac{m_S c^2}{t_S}$

- m_S = Stoney mass
- L_S = Stoney length
- t_S = Stoney time
- α = Fine structure constant

Astronomical transit is a phenomenon when a celestial body passes directly between a larger body and the observer.

- $m_S = \frac{\text{elementary charge}}{\text{Planck charge}} \times \text{Planck mass}$
- $L_S = \frac{\text{elementary charge}}{\text{Planck charge}} \times \text{Planck length}$
- $t_S = \frac{\text{elementary charge}}{\text{Planck charge}} \times \text{Planck time}$

PLANCK MASS: $m_{Planck} = \sqrt{\frac{\hbar c}{G}} = 2.17647 \times 10^{-8}$ kg, where: c is the speed of light in a vacuum, G is the gravitational constant, and ħ is the reduced Planck constant.

$$\left.\frac{m_{Planck}}{m_0} = n \quad\right\}$$ Number of particle masses that make up one Planck mass.

$$\frac{m_{Planck}c^2}{m_0 c^2} = \frac{k_B T_{Planck}}{k_B T_{threshold}} = n$$

$$\boxed{T_{Planck} = n \times T_{threshold}}$$

$$\lambda_C \times T_{threshold} = c_2 \quad \left\{ \quad \lambda_C \times \frac{T_{Planck}}{n} = c_2 \right.$$

$$\lambda_C = \frac{c_2}{T_{Planck}} \times n \longrightarrow \boxed{\lambda_C \propto n}$$

This means: The Compton wavelength of the particle is directly proportional to the number of particle masses that make up one Planck mass.

$$\frac{\text{Planck charge}}{\text{Planck mass}} = \sqrt{4\pi\varepsilon_0 G} = \sqrt{\frac{\varepsilon_0}{\varepsilon_g}} = \sqrt{\frac{\text{Vacuum permittivity}}{\text{Gravitoelectric gravitational constant}}}$$

$$\frac{\text{electron charge}}{\text{electron mass}} = -\,1.75882001076 \times 10^{11}\ \text{C/ kg}$$

$$\frac{\text{proton charge}}{\text{proton mass}} = +\,9.58 \times 10^{7}\ \text{C/ kg}$$

When negatively charged electrons move in electric and magnetic fields the following two laws apply:

- $F = e(E + v \times B) \rightarrow$ **Lorentz force law**
- $F = m_e a = m_e \frac{dv}{dt} \rightarrow$ **Newton's second law of motion**

$$\frac{m_e}{e} = \frac{\text{electron mass}}{\text{electron charge}} = \frac{(E + v \times B)}{a}$$

- $F_{electric} = eE$
- $F_{magnetic} = eBv$

When equal: $v = \frac{E}{B}$

The **Planck length** $\approx 1.616255 \times 10^{-35}$ m is the scale at which classical ideas about gravity and space-time cease to be valid and quantum effects dominate.

Fine structure constant $= \frac{\mu_0 c}{2R_K} = \frac{\text{Vacuum permeability} \times \text{Planck speed}}{2 \times \text{von Klitzing constant}}$

$$\textbf{Stoney mass} = \sqrt{\frac{\text{Vacuum permeability} \times \text{Planck speed}}{2 \times \text{von Klitzing constant}}} \times \textbf{Planck mass}$$

The **gravitational coupling constant** is a constant characterizing the gravitational attraction between a given pair of elementary particles. α_G is typically defined in terms of the gravitational attraction between two electrons. More precisely,

$\alpha_G = \frac{Gm_e^2}{\hbar c} = \frac{m_e^2}{m_{Planck}^2}$ where: m_e is the invariant mass of an electron

$$\alpha_G = \alpha \times \frac{m_e^2}{m_S^2}$$

- m_S = Stoney mass
- α = Fine structure constant

Number of electrons that make up one Planck mass $= \frac{m_{Planck}}{m_e} = \frac{1}{\sqrt{\alpha_G}}$

$$n = \frac{1}{\sqrt{\alpha_G}}$$

The Compton wavelength of electron:

$$\lambda_{C,e} = n \times \frac{c_2}{T_{Planck}}$$

$$\boxed{\lambda_{C,e} = \frac{1}{\sqrt{\alpha_G}} \times \frac{c_2}{T_{Planck}}}$$

$$\boxed{\lambda_{C,e} \propto \frac{1}{\sqrt{\alpha_G}}}$$

The Compton wavelength of the electron is inversely proportional to the square root of **gravitational coupling constant**.

Gravitational characteristic impedance of free space = $\frac{4\pi G}{c_g}$ → Speed of gravitation

Quantum of circulation: Half the ratio of the Planck constant to the mass of the electron.

$$Q_0 = \frac{h}{2m_e} = 3.636\,947\,5516 \times 10^{-4}\ m^2\ s^{-1}$$

$$E_{rest} = m_e c^2 = \frac{c_1}{4\pi Q_0}$$

c_1 = first radiation constant

$$\boxed{E_{rest} \propto \frac{1}{Q_0}}$$

The intrinsic energy of the electron is inversely proportional to the **Quantum of circulation**

$$Q_0 = \frac{h}{2m_e} = \frac{h}{2\sqrt{\alpha_G}\ m_{Planck}} = \sqrt{\frac{\alpha}{\alpha_G}} \times \frac{h}{2m_S}$$

- m_S = Stoney mass
- α = Fine structure constant

$\lambda_{C,e} = \frac{h}{m_e c}$ is the cutoff below which **quantum field theory** (which can describe particle creation and annihilation) becomes important.

$$\lambda_{C,e} = \frac{2h}{2m_e c} = \frac{2Q_0}{c} = 2Q_0\sqrt{\varepsilon_0 \mu_0}$$

The **classical electron radius** is sometimes known as the **Compton radius** or the Lorentz radius or the Thomson scattering length is a combination of fundamental physical quantities that define a length scale for problems involving an electron interacting with electromagnetic radiation. The classical electron radius is defined by equating the electrostatic potential energy of a sphere of charge e and radius r_e with the intrinsic energy of the electron:

$$\frac{e^2}{4\pi\varepsilon_0 r_e} = m_e c^2$$

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} = \text{Fine structure constant} \times \text{reduced Compton wavelength of the electron}$$

$$r_e = \frac{e^2}{4\pi\varepsilon_0\sqrt{\alpha_G}\, m_{\text{Planck}} c^2} = \frac{\alpha \times L_{\text{Planck}}}{\sqrt{\alpha_G}}$$

$$r_e = \sqrt{\frac{\alpha}{\alpha_G}} \times \textbf{Stoney length} = 2.8179 \times 10^{-15}\text{m}$$

$$\Delta x\, \Delta p \geq \frac{\hbar}{2}$$

$$\Delta x\, \Delta p \geq \frac{\lambda\!\!\!^{-}_C \times m_0 c}{2}$$

$$\frac{\Delta p}{m_0 c} \geq \frac{\lambda\!\!\!^{-}_C}{\Delta x}$$

For an electron, the **Thomson cross-section** is numerically given by:

$$\sigma_T = \frac{8\pi r_e^2}{3}$$

$$\sigma_T = \frac{8\pi}{3} \times \frac{\alpha}{\alpha_G} \times (\textbf{Stoney length})^2$$

Classical electron radius = Bohr radius × (Fine structure constant) ^{2}

$$\text{Fine structure constant} = \sqrt{\frac{\text{Classical electron radius}}{\text{Bohr radius}}}$$

Bohr radius:

$$a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} = \frac{\hbar}{m_e c\,\alpha} = \frac{\hbar}{\sqrt{\alpha_G}\, m_{Planck} c\,\alpha}$$

$$a_0 = \frac{L_{Planck}}{\sqrt{\alpha_G} \times \alpha}$$

The mean radius of the orbit of an electron around the nucleus of a **hydrogen atom** at its ground state (lowest-energy level)

$5.29177210903 \times 10^{-11}$ m

$$a_0 = \frac{\varepsilon_0\, h^2}{\pi\, m_e e^2} = \frac{\varepsilon_0}{\pi} \times 2\left(\frac{h}{2m_e}\right) \times \frac{h}{e^2}$$

$$a_0 = \frac{2\varepsilon_0 \times \text{Quantum of circulation} \times \text{von Klitzing constant}}{\pi}$$

$$a_0 = \frac{2 \times \text{Quantum of circulation} \times \text{von Klitzing constant}}{\pi\mu_0 c^2}$$

Wien's Displacement Law

$$\lambda_{Peak} \times T = b$$

The product of the **peak wavelength** and the temperature at which a blackbody radiates is constant − which means the peak of the radiation shifts to shorter wavelengths as the temperature increases.

Wien's constant: $b = \dfrac{hc}{4.9651 k_B} = \dfrac{c_2}{4.9651}$

$\mathbf{c_2 = 4.9651\, b}$

The second radiation constant is 4.9651 times the Wien's constant

Radiation density constant:

$$a = \frac{4\sigma}{c} = \frac{8\pi^5 k_B^4}{15c^3h^3} = \frac{8\pi^5 k_B}{15c_2^3} = 7.5657 \times 10^{-16}\ \text{J m}^{-3}\ \text{K}^{-4}$$

$$a = \frac{4\sigma}{c} = \frac{4\pi^4 c_1}{15c_2^4}\sqrt{\mu_0 \varepsilon_0}$$

where: μ_0 is the absolute permeability of free space and ε_0 is the absolute permittivity of free space.

$$\underbrace{\frac{8\pi^5 k_B}{15c_2^3} = \frac{4\pi^4 c_1}{15c_2^4}\sqrt{\mu_0 \varepsilon_0}}$$

$$k_B = \frac{c_1}{2\pi c_2}\sqrt{\mu_0 \varepsilon_0} = 1.3807 \times 10^{-23}\ \text{J/K}$$

$$k_B = \frac{c_1}{31.180\ b}\sqrt{\mu_0 \varepsilon_0}$$

Magnetic flux quantum:

$$\Phi_0 = \frac{h}{2e}$$

Conductance quantum:

$$G_0 = \frac{2e^2}{h}$$

where: e is the elementary charge.

$$\Phi_0 \times G_0 = e$$

$$\Phi_0 \times G_0 = \sqrt{\text{Fine structure constant}} \times q_{\text{Planck}}$$

$$\textbf{Planck charge} = \frac{\text{Magnetic flux quantum} \times \text{Conductance quantum}}{\sqrt{\text{Fine structure constant}}}$$

von Klitzing constant:

$$R_K = \frac{h}{e^2} = \frac{h}{\phi_0^2 G_0^2}$$

$$\boxed{R_K = \frac{h}{e^2} = \frac{h}{\alpha \times q_{\text{Planck}}^2}}$$

Conductance quantum:

$$G_0 = \frac{2e^2}{h} = \frac{2\alpha \times q_{\text{Planck}}^2}{h} = \frac{2}{R_K}$$

The magnetic coupling constant:

$$\beta = \frac{\varepsilon_0 hc}{2e^2} = \frac{\pi\hbar}{c\mu_0 e^2}$$

A **fundamental physical constant** characterizing the strength of the magnetic force interaction

$$\beta = \frac{\varepsilon_0 hc}{2e^2} = \frac{1}{4\alpha} = \frac{m_S^2}{4m_{\text{Planck}}^2} = \frac{L_S^2}{4L_{\text{Planck}}^2} = \frac{t_S^2}{4t_{\text{Planck}}^2}$$

Bohr radius is about 19,000 times bigger than the classical electron radius

$$\beta = \sqrt{\frac{\text{Bohr radius}}{16 \times \text{classical electron radius}}}$$

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \qquad c_g = \frac{1}{\sqrt{\mu_g \varepsilon_g}}$$

Time is relative

It changes with speed and in the presence of gravity

$$\left.\begin{aligned} \mu_0 \varepsilon_0 &= \mu_g \varepsilon_g \\ \frac{\mu_0}{\mu_g} &= \frac{\varepsilon_g}{\varepsilon_0} \end{aligned}\right\}$$

If Gravity travel at the Speed of Light

The Planck charge $\sqrt{4\pi\varepsilon_0 \hbar c}$ is approximately 11.706 times greater than electron charge.

$$\Phi_0 \times G_0 \times R_K = \frac{h}{e}$$

Magnetic flux quantum × Conductance quantum × von Klitzing constant = Quantum / Charge Ratio

$$\Phi_0 \times G_0 \times R_K = \frac{h}{\sqrt{\text{Fine structure constant}} \times q_{\text{Planck}}}$$

$$\frac{\phi_0 \times G_0 \times R_K}{2Q_0} = \textbf{Electron mass-to-charge ratio}$$

Planck charge: $q_{\text{Planck}} = \sqrt{4\pi\varepsilon_0 \hbar c}$

$$q_{\text{Planck}}^2 = 4\pi\varepsilon_0 \hbar c = 2h\sqrt{\frac{\varepsilon_0}{\mu_0}}$$

$$\textbf{Planck conductance} = 4\pi\sqrt{\frac{\varepsilon_0}{\mu_0}}$$

$$\underbrace{\frac{q_{\text{Planck}}}{t_{\text{Planck}}} \times q_{\text{Planck}} = 4\pi\sqrt{\frac{\varepsilon_0}{\mu_0}} \times \frac{\hbar}{t_{\text{Planck}}}}$$

$$\text{Planck current} \times q_{\text{Planck}} = 4\pi\sqrt{\frac{\varepsilon_0}{\mu_0}} \times \text{Planck energy}$$

$$\left.\text{Planck current} \times q_{\text{Planck}} = 4\pi\sqrt{\frac{\varepsilon_0}{\mu_0}} \times (q_{\text{Planck}} \times \text{Planck voltage})\right\}$$

$$\frac{1}{\text{Planck resistance}} = 4\pi\sqrt{\frac{\varepsilon_0}{\mu_0}}$$

Impedance of free space:

$$Z_0 = \mu_0 c = \sqrt{\frac{\mu_0}{\varepsilon_0}}$$

Admittance of free space:

$$Y_0 = \frac{1}{Z_0}$$

$$q^2_{\text{Planck}} = \frac{2h}{Z_0} = 2h \times Y_0$$

$$\boxed{q^2_{\text{Planck}} = \frac{2R_K e^2}{Z_0}}$$

$$q_{\text{Planck}} = e\sqrt{\frac{2R_K}{Z_0}} = \phi_0\, G_0\sqrt{\frac{2R_K}{Z_0}}$$

Stefan–Boltzmann law:

The radiative power of a black body is proportional to the surface area and to the fourth power of the black body's temperature

$$P = \varepsilon\sigma T^4 A$$

Emissivity

- For all substances: $\varepsilon < 1$
- For a perfect black body: $\varepsilon = 1$

Stellar Planck constant:

$$h_S = 2 \times M \times R \times C_S$$

- M : mass of the neutron star
- R: radius of the neutron star
- C_S: the characteristic speed of the particles in the neutron star

Stellar Stefan–Boltzmann constant:

$$\Sigma_S = \frac{\text{Luminosity of the galaxy}}{\text{Area of the galaxy} \times (\text{Effective kinetic temperature of the stellar gas of the galaxy})^4}$$

Rydberg constant:

$$\underbrace{R_\infty = \frac{m_e e^4}{8\varepsilon_0^2 ch^3}} = \frac{\text{Fine structure constant}}{4\pi \times \text{Bohr radius}} = 10\,973\,731.6 \text{ m}^{-1}$$

$$R_\infty = \frac{1}{4}\sqrt{\frac{\mu_0}{\varepsilon_0}} \times \frac{\text{Fine structure constant}}{\text{von Klitzing constant} \times \text{Compton wavelength of the electron}}$$

Rydberg energy:

$$\boxed{hc\,R_\infty = \frac{m_e c^2}{4}\sqrt{\frac{\mu_0}{\varepsilon_0}} \times \frac{\text{Fine structure constant}}{\text{von Klitzing constant}}}$$

Rydberg frequency:

$$\boxed{c\,R_\infty = \frac{\text{Compton frequency of the electron}}{4}\sqrt{\frac{\mu_0}{\varepsilon_0}} \times \frac{\text{Fine structure constant}}{\text{von Klitzing constant}}}$$

Rydberg wavelength:

$$\boxed{\frac{1}{R_\infty} = 4\sqrt{\frac{\varepsilon_0}{\mu_0}} \times \frac{\text{von Klitzing constant} \times \text{Compton wavelength of the electron}}{\text{Fine structure constant}}}$$

Hartree energy:

$$E_h = 2R_\infty\,hc = \frac{m_e c^2}{2}\sqrt{\frac{\mu_0}{\varepsilon_0}} \times \frac{\text{Fine structure constant}}{\text{von Klitzing constant}} = 4.3597447222071 \times 10^{-18} \text{ J}$$

$$R_\infty = \frac{\text{Fine structure constant}}{4\pi \times \text{Bohr radius}}$$

$$\underbrace{\text{Fine structure constant} = \frac{e^2}{q_{\text{Planck}}^2} = 4\pi \times \text{Bohr radius} \times R_\infty}$$

$$q_{\text{Planck}} = \frac{e}{\sqrt{4\pi \times \text{Bohr radius} \times R_\infty}}$$

$$R_\infty = \frac{\text{Fine structure constant}}{4\pi \times \text{Bohr radius}}$$

$$\underbrace{\text{Fine structure constant} = \sqrt{\frac{\text{Classical electron radius}}{\text{Bohr radius}}} = 4\pi \times \text{Bohr radius} \times R_\infty}$$

$$R_\infty = \frac{1}{4\pi}\sqrt{\frac{\text{Classical electron radius}}{(\text{Bohr radius})^3}}$$

$$R_\infty = \frac{\text{Fine structure constant}}{4\pi \times \text{Bohr radius}}$$

$$\underbrace{\text{Fine structure constant} = \frac{\text{Conductance quantum} \times \text{impedance of free space}}{4} = 4\pi \times \text{Bohr radius} \times R_\infty}$$

$$R_\infty = \frac{\text{Conductance quantum} \times \text{impedance of free space}}{16\pi \times \text{Bohr radius}}$$

$$\underbrace{\boxed{\Delta S_0 + S_{BH} \geq 0}}$$

The sum of the entropy outside the black hole and the **total black hole entropy** never decreases and typically increases as a consequence of generic transformations of the black hole.

Nernst-Simon statement

↓

The entropy of a system at absolute zero temperature either vanishes or becomes independent of the intensive thermodynamic parameters

The **Bohr magneton** is defined in SI units by:

$$\mu_B = \frac{e\hbar}{2m_e} = \frac{\text{Faraday constant} \times \text{Planck angular momentum}}{2 \times \text{molar electron mass}} = \frac{\sqrt{\alpha} \times q_{\text{Planck}} \times Q_0}{2\pi}$$

↓

$9.27400968 \times 10^{-24} JT^{-1}$

$$\mu_B = \frac{\phi_0 \times G_0 \times Q_0}{2\pi}$$

Conductance quantum = $\frac{2\pi\, \mu_B}{\phi_0 \times G_0}$

The **Nuclear magneton** is defined in SI units by:

$$\frac{\mu_N}{\mu_B} = \frac{m_e}{m_p}$$

$$\mu_N = \frac{e\hbar}{2m_p} = \frac{\text{Faraday constant} \times \text{Planck angular momentum}}{2 \times \text{molar proton mass}} = 5.050783699 \times 10^{-27} JT^{-1}$$

$$\mu_N = \sqrt{\frac{\text{Fine structure constant}}{4\mu_0\varepsilon_0}} \times \text{Planck charge} \times \text{reduced Compton wavelength of proton}$$

Planck angular momentum = $m_{\text{Planck}} \times c \times L_{\text{Planck}} = \hbar$

Planck angular momentum = $\frac{m_S \times c \times L_S}{\alpha}$

Black Hole: A great amount of matter packed into a very small area where gravity is intense enough to prevent the escape of even the fastest moving particles. Not even light can break free.

Temperature → $T_{BH} = \dfrac{\hbar c^3}{8\pi G M k_B}$

$$\frac{T_{BH}}{T_{Planck}} = \frac{m_{Planck}}{8\pi M}$$

Evaporation time of a black hole:

$$t_{ev} = \frac{480 c^2 V}{\hbar G}$$

$$\frac{t_{ev}}{t_{Planck}} = 480 \times \frac{V}{L_{Planck}^3}$$

Density → $\rho_{BH} = \dfrac{M}{\frac{4\pi r_S^3}{3}} = \dfrac{3c^6}{32\pi G^3 M^2}$

$$\frac{\rho_{BH}}{\rho_{Planck}} = \frac{m_{Planck}^2}{32\pi M^2}$$

where: $\rho_{Planck} = \dfrac{c^5}{\hbar G^2}$ is the Planck density.

If the star core's mass is more than about three times the mass of the Sun, the force of gravity overwhelms all other forces and produces a **black hole**.

The rate of evaporation energy loss of the black hole:

$$P = -\frac{dMc^2}{dt} = \frac{\hbar c^6}{15360\pi G^2 M^2}$$

$$\frac{P}{P_{Planck}} = \frac{m_{Planck}^2}{15360\pi M^2}$$

where: $P_{Planck} = \dfrac{c^5}{G}$ is the Planck power.

Entropy → $S_{BH} = \dfrac{4\pi k_B M^2}{m_{Planck}^2}$

$$\frac{S_{BH}}{S_{Planck}} = \frac{4\pi M^2}{m_{Planck}^2}$$

where: $S_{Planck} = k_B$ is the Planck entropy.

If M = $\sqrt{\frac{\hbar c}{G}}$ → Planck mass:

- $T_{BH} = \frac{T_{Planck}}{8\pi}$
- $\rho_{BH} = \frac{\rho_{Planck}}{32\pi}$
- $P = \frac{P_{Planck}}{15360\pi}$
- $S_{BH} = 4\pi \times S_{Planck}$

If V = L^3_{Planck} → Planck volume:

$$t_{ev} = 480 \times t_{Planck} = \frac{480 t_S}{\sqrt{\alpha}}$$

Compton shift:

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\theta)$$

If Δλ = Stoney length:

$$\sqrt{\alpha} \times L_{Planck} = \frac{h}{m_e c}(1-\cos\theta)$$

$$\theta = \cos^{-1}\left(1 - \frac{\sqrt{\alpha_G \alpha}}{2\pi}\right)$$

The wavelength shift of the scattered photon in an angle of $\theta = \cos^{-1}\left(1 - \frac{\sqrt{\alpha_G \alpha}}{2\pi}\right)$ is equal to the **Stoney length**.

Second radiation constant: $c_2 = \frac{2\pi\hbar c}{k_B} = \frac{2\pi \times \text{Planck angular momentum} \times \text{Planck speed}}{\text{Planck entropy}}$

If $\Delta\lambda$ = classical electron radius:

$$\frac{e^2}{4\pi\varepsilon_0 m_e c^2} = \frac{h}{m_e c}(1-\cos\theta)$$

$$\boxed{\theta = \cos^{-1}\left(1-\frac{\alpha}{2\pi}\right)}$$

The wavelength shift of the scattered photon in an angle of $\theta = \cos^{-1}\left(1-\frac{\alpha}{2\pi}\right)$ is equal to the **Classical electron radius** .

If $\Delta\lambda$ = Bohr radius:

$$\frac{4\pi\varepsilon_0 \hbar^2}{m_e e^2} = \frac{h}{m_e c}(1-\cos\theta)$$

$$\boxed{\theta = \cos^{-1}\left(1-\frac{1}{2\pi\alpha}\right)}$$

The wavelength shift of the scattered photon in an angle of $\theta = \cos^{-1}\left(1-\frac{1}{2\pi\alpha}\right)$ is equal to the **Bohr radius** .

First radiation constant: $c_1 = 4\pi^2\hbar c^2$

$c_1 = 4\pi^2$ × Planck angular momentum × (Planck speed) ^{2}

Spin-statistics connection theorem:

- Fermions (such as electrons and protons) having a half integer spin must be described by **Fermi-Dirac statistics**
- Bosons (such as photons and helium-4 atoms) having an integer spin must be described by **Bose-Einstein statistics.**

The time it takes for light to travel a distance equal to $\frac{2GM}{c^2}$:

$$\tau_1 = \frac{2GM}{c^2} \times \frac{1}{c}$$

$$\boxed{E = \frac{P_{Planck}}{2} \times \tau_1}$$

where: E is the energy of the black hole and $P_{Planck} = \frac{c^5}{G}$ is the Planck power.

The time it takes for light to travel a distance equal to **Stoney length**:

$$\tau_2 = \frac{L_S}{c} = \frac{\sqrt{\alpha} \times L_{Planck}}{c}$$

$$\boxed{\tau_2 = \sqrt{\alpha} \times t_{Planck}}$$

The time it takes for light to travel a distance equal to $\frac{h}{m_e c}$:

$$\tau_3 = \frac{h}{m_e c} \times \frac{1}{c} = \frac{h}{m_e c^2} = \frac{1}{\upsilon_C}$$

$$\boxed{\tau_3 = \frac{h}{m_e c^2} = 2Q_0 \times \mu_0 \times \varepsilon_0}$$

$$c_1 = 2\pi hc^2$$

$$c_2 = \frac{hc}{k_B}$$

$$\frac{c_1}{c_2} = 2\pi ck_B$$

$$\frac{c_1}{c_2} = 2\pi \times \text{Planck speed} \times \text{Planck entropy}$$

Unruh temperature:

$$T_U = \frac{\hbar a}{2\pi k_B c}$$

where: ħ is the reduced Planck constant, a is the local acceleration, c is the speed of light and k_B is the Boltzmann constant.

- a of 2.47×10^{20} m/s^2 corresponds approximately to a T_U of 1 K.
- a of 1 m/s^2 corresponds approximately to a T_U of 4.06×10^{-21} K.

$$T_U = \frac{\hbar a\, c_2}{c_1} = \frac{\text{Planck angular momentum} \times a \times c_2}{c_1}$$

Hawking–Unruh temperature:

$$T_H = \frac{\hbar g}{2\pi k_B c}$$

where: g is the surface gravity of a black hole.

$$T_H = \frac{c_2\, g \sqrt{\mu_0 \varepsilon_0}}{4\pi^2}$$

PCT theorem

All interactions are invariant under the Charge, parity and time reversal symmetry

The vacuum energy density or dark energy density is defined as:

$$\varepsilon_\Lambda = \frac{c^4}{8\pi G} \times \Lambda$$

Λ = cosmological constant

The mass density corresponding to the vacuum energy density is expressed as:

$$\rho_\Lambda = \frac{\varepsilon_\Lambda}{c^2}$$

The act of tearing space apart resulting in a sort of "reverse singularity" − where space and time can either be reborn or can disappear into nothingness.

If dark energy gets stronger and stronger over time, it will eventually overcome gravitational force of attraction and then everything is torn apart.

Big Rip

The **ultimate fate of the universe** − in which the matter of the universe and even the fabric of spacetime itself − is progressively torn apart by the expansion of the universe at a certain time in the future − until distances between single atoms will become infinite.

Dark energy

- the cosmological constant from **General theory of Relativity**
- the zero-point energy inherent to space from quantum field theory

maintains a constant energy density and would cause all galaxies to recede from each other at speeds proportional to their distance of separation.

h, c	Quantum Field Theory and the standard model of particle physics
G, c	General Theory of Relativity (**geometric theory of gravitation**) and the standard model of cosmology
h, k_B	Quantum Statistics and Modern quantum physics

Second radiation constant:

$$c_2 = \frac{hc}{k_B} = \frac{N_A\, h}{N_A\, k_B} \times c$$

- N_A = **Avogadro number** (the number of particles that are contained in one mole of a substance) $\left\{ 6.02214076 \times 10^{23} \right\}$

$$c_2 = \frac{\text{Molar Planck constant}}{\text{Ideal gas constant}} \times \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$\frac{F}{R} = \frac{N_A\, e}{N_A\, k_B} = \frac{\textbf{Molar electron charge}}{\text{Ideal gas constant}}$$

$$\frac{F}{R} = \frac{e}{hc} \times c_2$$

$$\boxed{\frac{F}{R} = \frac{K_J}{2} \times c_2 \sqrt{\mu_0 \varepsilon_0}}$$

where: F is the Faraday constant and K_J is the Josephson constant.

Quantum of circulation $= \dfrac{h}{2m_e} = \dfrac{\text{Molar Planck constant}}{2 \times \text{Molar electron mass}}$

The Avogadro number is named after the Italian scientist **Amedeo Avogadro** – who – in 1811 – first proposed that the equal volumes of gases under the same conditions of temperature and pressure will contain equal numbers of molecules.

$$Q_0 \times r_S = \frac{h}{2m_e} \times \frac{2Gm_e}{c^2}$$

$$Q_0 \times r_S = 2\pi \frac{G\hbar}{c^2} = 2\pi \frac{\text{Planck volume}}{\text{Planck time}}$$

$$\textbf{Planck volumetric flow rate} = \frac{Q_0 \times r_S}{2\pi}$$

$$\frac{\text{Energy}}{\text{mass}} = \text{Specific energy}$$

$$\frac{\text{Planck Energy}}{\text{Planck mass}} = \text{Planck Specific energy} = c^2$$

Planck specific energy = (Planck speed) ^{2}

Hawking radiation temperature:

$$T_{BH} = \frac{\hbar c^3}{8\pi G M k_B} = 6 \times 10^{-8}\ \text{K}\ \frac{\text{Solar mass}}{\text{Mass of the black hole}}$$

Unruh temperature:

Black hole's gravitational acceleration

$$T_U = \frac{\hbar a}{2\pi k_B c}$$

If $a = \frac{c^4}{4GM}$:

$$\boxed{T_U = T_{BH}}$$

The temperature of the vacuum − observed by an isolated observer accelerating at the Black hole's gravitational acceleration of $g = \frac{c^4}{4GM}$ m/s^2 is **Hawking radiation temperature**.

$$r_S \times T_{BH} = \underbrace{\frac{2GM}{c^2} \times \frac{\hbar c^3}{8\pi G M k_B}}$$

$$r_S \times T_{BH} = \frac{c_2}{8\pi^2}$$

This means: $r_S \times T_{BH}$ can never be less than or greater than $\frac{c_2}{8\pi^2}$ but = $\frac{c_2}{8\pi^2}$.

Unruh temperature = $\frac{\hbar a}{2\pi k_B c}$

If **Unruh temperature = Planck temperature:**

$$T_{Planck} = \frac{\hbar a}{2\pi k_B c} \longrightarrow \boxed{a = 2\pi \times a_{Planck}}$$

If **a = Planck acceleration:**

$$T_U = \frac{\hbar a_{Planck}}{2\pi k_B c} \longrightarrow \boxed{T_U = \frac{T_{Planck}}{2\pi}}$$

- **Josephson constant:** $K_J = \frac{2e}{h}$
- **Magnetic flux quantum:** $\phi_0 = \frac{h}{2e}$

$$\boxed{K_J \times \phi_0 = 1}$$

- **Conductance quantum:** $G_0 = \frac{2e^2}{h}$
- **Resistance quantum:** $R_0 = \frac{h}{2e^2}$

$$\boxed{G_0 \times R_0 = 1}$$

Modified Newtonian dynamics

Hypothesis proposing a modification of Newton's law of universal gravitation to account for observed properties of galaxies

Schwarzschild radius of electron:

$$r_S = \frac{2Gm_e}{c^2}$$

The threshold temperature below which the electron is effectively removed from the universe:

$$T_{threshold} = \frac{m_e c^2}{k_B}$$

$$\boxed{r_S \times T_{threshold} = \frac{2Gm_e^2}{k_B}}$$

$$r_S \times T_{threshold} = \frac{\alpha_G \times c_2}{\pi}$$

Irradiation

The process by which an object is exposed to radiation

$$KE = e \times V$$

$$KE = \sqrt{\alpha} \times q_{Planck} \times V$$

$$\frac{KE}{E_{Planck}} = \sqrt{\alpha} \times \frac{V}{V_{Planck}}$$

If V = Planck voltage:

$$\boxed{KE = \sqrt{\alpha} \times E_{Planck}}$$

Planck voltage:

$$V_{Planck} = \frac{\text{Planck energy}}{\text{Planck charge}} = \sqrt{\frac{c^4}{4\pi\varepsilon_0 G}} = \sqrt{\text{Planck force} \times \text{Coulomb constant}}$$

Planck current:

$$I_{Planck} = \frac{\text{Planck charge}}{\text{Planck time}} = \sqrt{\frac{4\pi\varepsilon_0 c^6}{G}} = \sqrt{\frac{\text{Planck force} \times \text{Planck specific energy}}{\text{Coulomb constant}}}$$

Planck pressure:

$$\Pi_{\text{Planck}} = \frac{\text{Planck force}}{\text{Planck area}} = \frac{c^7}{\hbar G^2} = \frac{\hbar}{L_{\text{Planck}}^3\, t_{\text{Planck}}} = \frac{\alpha^2 \hbar}{L_S^3\, t_S} = 4.633 \times 10^{113}\ \text{Pa}$$

Most of the matter in the Universe is dark

Dark Matter → nonluminous and it looks like a matter

Why does it gravitate as ordinary matter does, and thus slows the expansion of the universe?

$$\Pi_{\text{Planck}} = \underbrace{\frac{\alpha^2 \hbar}{L_S^3\, t_S}}$$

$$\Pi_{\text{Planck}} = \frac{\text{classical electron radius}}{\text{Bohr radius}} \times \frac{\hbar}{L_S^3\, t_S}$$

$$\text{Planck acceleration} = \frac{\text{Planck frequency}}{\sqrt{\varepsilon_0 \mu_0}}$$

$$\lambda_{C,e} = \frac{h}{m_e c} = \mathbf{2 \times \text{Magnetic flux quantum}} \times \text{Electron Charge to mass ratio} \times \sqrt{\mu_0 \varepsilon_0}$$

Both Albert Einstein's and Sir Isaac Newton's theories of gravitation have a problem when they encounter quantum mechanics and that problem involves the very nature of space and time.

$$\sqrt{\frac{\hbar G}{c^3}} = L_{Planck} \rightarrow \text{a fundamental limit to space}$$

$$\sqrt{\frac{\hbar G}{c^5}} = t_{Planck} \rightarrow \text{a fundamental limit to time}$$

$$\underbrace{S = k_B \ln W}_{\text{A measure of statistical disorder of a system}}$$

This equation takes pride of place on the **Ludwig Eduard Boltzmann's grave** in the Zentralfriedhof, Vienna.

If S = Planck entropy = k_B:

W = *e* = 2.718281828459045

$$\underbrace{\text{Planck capacitance} = \frac{\text{Planck charge}}{\text{Planck voltage}} = \sqrt{4\pi\hbar c\varepsilon_0} \times \sqrt{\frac{4\pi\varepsilon_0 G}{c^4}}}_{\text{Planck capacitance = Coulomb constant × Planck length}}$$

$$\frac{1}{4\pi\varepsilon_0} = \frac{\mu_0 c^2}{4\pi} = \frac{\mu_0}{4\pi} \times \text{Planck specific energy} = \frac{\mu_0}{4\pi} \times (\text{Planck speed})^2$$

$$\left\{ \begin{array}{c} \mathbf{Q = n_e \times e} \\ \frac{dQ}{dt} = \frac{dn_e}{dt} \times e \\ I = \frac{dn_e}{dt} \times e \end{array} \right\}$$

If I = Planck current = $\frac{\text{Planck charge}}{\text{Planck time}}$:

$$\frac{q_{Planck}}{t_{Planck}} = \frac{dn_e}{dt} \times e$$

$$\frac{dn_e}{dt} = \frac{1}{\sqrt{\alpha}\, t_{Planck}}$$

Rate of flow of electrons = $\frac{1}{\text{Stoney time}}$

"The infinite is nowhere to be found in reality, no matter what experiences, observations, and knowledge are appealed to"

– David Hilbert

Standard gravitational parameter:

$$\mu = GM$$

For Planck mass:

$$\mu = Gm_{Planck} = \sqrt{G \times \hbar \times c}$$

For Stoney mass:

$$\mu = Gm_S = \sqrt{\alpha}\ Gm_{Planck} = \sqrt{\alpha \times G \times \hbar \times c}$$

$$\underbrace{GM_{sun}}$$

Heliocentric gravitational constant

Classical electron radius:

$$r_e = \frac{1}{4\pi\varepsilon_0 m_e c^2} \times e^{2}$$

The threshold temperature below which the electron is effectively removed from the universe:

$$T_{threshold} = \frac{m_e c^2}{k_B}$$

$$r_e \times T_{threshold} = \frac{\alpha \times c_2}{2\pi}$$

Bohr radius:

$$a_0 = \frac{\hbar}{m_e c\alpha}$$

$$a_0 \times T_{threshold} = \frac{c_2}{2\pi\alpha}$$

Black Hole Density:

$$\rho_{BH} = \rho_{Planck} \times \frac{m_{Planck}^2}{32\pi M^2} = \rho_{Planck} \times \frac{m_S^2}{32\pi\,\alpha\,M^2}$$

If $M = m_S = \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$:

$$\rho_{BH} = \frac{\rho_{Planck}}{32\pi\,\alpha}$$

The rate of evaporation energy loss of the black hole:

$$P = P_{Planck} \times \frac{m_{Planck}^2}{15360\pi M^2} = P_{Planck} \times \frac{m_S^2}{15360\,\pi\,\alpha\,M^2}$$

If $M = m_S = \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$:

$$P = \frac{P_{Planck}}{15360\,\pi\,\alpha}$$

Black hole Entropy: $S_{BH} = S_{Planck} \times \frac{4\pi M^2}{m_{Planck}^2} = \frac{4\pi\,\alpha\,M^2}{m_S^2}$

If $M = m_S = \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$:

$$S_{BH} = S_{Planck} \times 4\pi\,\alpha$$

$$\underbrace{P \times S_{BH} = P_{Planck} \times \frac{m_{Planck}^2}{15360\pi M^2} \times S_{Planck} \times \frac{4\pi M^2}{m_{Planck}^2}}$$

$$\boxed{P \times S_{BH} = \frac{\text{Planck power} \times \text{Planck entropy}}{3840} = \frac{k_B c^5}{3840G}}$$

$$\underbrace{\rho_{BH} \times S_{BH} = \rho_{Planck} \times \frac{m_{Planck}^2}{32\pi M^2} \times S_{Planck} \times \frac{4\pi M^2}{m_{Planck}^2}}$$

$$\boxed{\rho_{BH} \times S_{BH} = \frac{\text{Planck density} \times \text{Planck entropy}}{8} = \frac{k_B c^5}{8\hbar G^2}}$$

Rydberg wavelength:

$$\lambda_{R_\infty} = \frac{1}{\text{Rydberg constant}} = \frac{8\varepsilon_0^2 h^3 c}{m_e e^4}$$

$$\underbrace{\lambda_{R_\infty} \times T_{threshold} = \frac{8\varepsilon_0^2 h^3 c}{m_e e^4} \times \frac{m_e c^2}{k_B}}$$

$$\boxed{\lambda_{R_\infty} \times T_{threshold} = \frac{2c_2}{\alpha^2}}$$

$$r_S \times r_e = \frac{2Gm_e}{c^2} \times \frac{1}{4\pi\varepsilon_0 m_e c^2}$$

$$\boxed{r_S \times r_e = 2\alpha L_{Planck}^2}$$

$$\left\{ r_S \times r_e = 2 \times \text{Fine structure constant} \times \text{Planck area} \right\}$$

$$r_S \times a_0 = \frac{2Gm_e}{c^2} \times \frac{\hbar}{m_e c \alpha}$$

$$\boxed{r_S \times a_0 = \frac{2L_{Planck}^2}{\alpha}}$$

$$\left\{ r_S \times a_0 = \frac{2 \times \text{Planck area}}{\text{Fine structure constant}} \right\}$$

$$r_S \times r_e = 2L_S^2$$

$$\boxed{r_S \times a_0 = \frac{2L_S^2}{\alpha^2}}$$

Mach's Principle

The inertia of the mass is caused by all other masses in the entire universe

$$\lambda_{R_\infty} \times r_S = \frac{8\varepsilon_0^2 h^3 c}{m_e e^4} \times \frac{2Gm_e}{c^2}$$

$$\boxed{\lambda_{R_\infty} \times r_S = \frac{8\pi L_{Planck}^2}{\alpha^2}}$$

$$\lambda_{R_\infty} \times r_S = \frac{8\pi \times \text{Planck area}}{\alpha^2}$$

$$\boxed{\lambda_{R_\infty} \times r_S = \frac{8\pi L_S^2}{\alpha^3}}$$

Science aims at constructing a world which shall be symbolic of the world of commonplace experience.

– Arthur Eddington

- **Stoney length = L_S =** $\sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^4}} = e\sqrt{\frac{\text{Coulomb constant}}{\text{Planck force}}}$

- **Stoney time = T_S =** $\sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^6}} = e\sqrt{\frac{\mu_0}{4\pi \times \text{Planck force}}}$

$$c = \frac{L_{Planck}}{t_{Planck}} = \frac{L_S}{t_S} = \sqrt{\text{Planck specific energy}}$$

Refractive index: $n = \frac{c}{v} = \frac{1}{v\sqrt{\varepsilon_0\mu_0}} = \frac{L_S}{v \times t_S} = \frac{\text{Planck speed}}{v}$

First radiation constant:

$$c_1 = 4\pi^2 \times \text{Planck angular momentum} \times \frac{(\text{Stoney length})^2}{(\text{Stoney time})^2}$$

Bohr's Quantization Rule:

$$L = n\hbar$$

$$n = \frac{\text{electron angular momentum}}{\text{Planck angular momentum}}$$

For n = 1:

Electron angular momentum = Planck angular momentum

Second radiation constant:

$$c_2 = \frac{hc}{k_B} = \frac{\text{molar Planck constant}}{\text{Ideal gas constant}} \times \frac{\text{Stoney length}}{\text{Stoney time}}$$

Radiation Constant = 4 × Stefan-Boltzmann constant × $\frac{\text{Stoney time}}{\text{Stoney length}}$

Black hole temperature: $T_{BH} = \frac{\hbar c^3}{8\pi G k_B m_0}$

The threshold temperature below which the particle of mass m_0 is effectively removed from the universe:

$$T_{threshold} = \frac{m_0 c^2}{k_B}$$

$$T_{BH} \times T_{threshold} = \frac{T_{Planck}^2}{8\pi}$$

Kardashev scale

Classification of **alien civilization** based on how much energy an extraterrestrial civilization uses

- **Type I civilization** (planetary civilization)**:** A civilization capable of using and storing all of the energy resources available on its planet.
- **Type II civilization** (stellar civilization)**:** A civilization capable of using and controlling all of the energy resources available in its planetary system or all of the energy that its star emits.
- **Type III civilization** (galactic civilization)**:** A civilization capable of accessing and controlling all of the energy resources available in its galaxy.

$$\underbrace{Q_0 \times T_{\text{threshold}} = \frac{h}{2m_e} \times \frac{m_e c^2}{k_B}}$$

$$Q_0 \times T_{\text{threshold}} = \frac{c_2}{\sqrt{4\mu_0\varepsilon_0}} = \frac{c_2 L_S}{2t_S}$$

White's Energy Formula:

C = E × T

- E is a measure of energy consumed per capita per year
- T is the measure of efficiency of technical factors utilizing the energy
- C represents the degree of cultural development

Culture evolves as the amount of energy harnessed per capita per year is increased

$$a \propto t^{\frac{2}{3(1+w)}}$$

$$\rho \propto a^{-3(1+w)}$$

- **Radiation dominated universe** ($w = \frac{1}{3}$) :

$$a \propto t^{\frac{1}{2}}$$

$$\rho \propto a^{-4}$$

- **Non-relativistic matter dominated universe** ($w = 0$):

$$a \propto t^{\frac{2}{3}}$$

$$\rho \propto a^{-3}$$

- **Dark energy dominated universe** ($w = -1$):

$$a \propto e^{Ht} \text{ with } H = \sqrt{\frac{\Lambda}{3}}$$

Planetary engineering

The development and application of technology for the purpose of influencing the environment of a planet

Terraforming

The hypothetical process of deliberately modifying the Planet's atmosphere, temperature, surface topography or ecology to be similar to those of Earth in order to make it suitable for human life

The gravitational force between 2 electrons is:

$$F_G = \frac{G m_e^2}{r^2}$$

The electrical force between 2 electrons is:

$$F_E = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

Geoengineering

Planetary engineering applied to Earth

$\beta \rightarrow$ magnetic coupling constant

$$\frac{F_G}{F_E} = \frac{\alpha_G}{\alpha} = 4\beta \times \alpha_G$$

The electric field **E** is related to the electric force **F** that acts on an electron charge **e** by:

$$E = \frac{F}{e}$$

$$F = \sqrt{\alpha}\, q_{Planck}\, E$$

- **Habitable Planet:** A Planet with an environment hospitable to life.
- **Biocompatible Planet:** A Planet possessing the necessary physical parameters for life to flourish on its surface.

$$\mu_B \times T_{threshold} = \frac{e\hbar}{2m_e} \times \frac{m_e c^2}{k_B} = \frac{e}{4\pi} \times c_2 \times c$$

$$\mu_B \times T_{threshold} = \frac{e}{4\pi} \times c_2 \times \sqrt{\frac{c_1}{2\pi h}}$$

$$\mu_B \times T_{threshold} = c_2 \sqrt{\frac{c_1}{32\pi^3 R_K}}$$

	If $M = m_e$:
$T_{BH} = T_{Planck} \times \frac{m_{Planck}}{8\pi M}$	$T_{BH} = T_{Planck} \times \frac{m_{Planck}}{8\pi m_e}$ $\boxed{T_{BH} = \frac{T_{Planck}}{8\pi\sqrt{\alpha_G}}}$
$\rho_{BH} = \rho_{Planck} \times \frac{m_{Planck}^2}{32\pi M^2}$	$\rho_{BH} = \rho_{Planck} \times \frac{m_{Planck}^2}{32\pi m_e^2}$ $\boxed{\rho_{BH} = \frac{\rho_{Planck}}{32\pi\alpha_G}}$
$P = P_{Planck} \times \frac{m_{Planck}^2}{15360\pi M^2}$	$P = P_{Planck} \times \frac{m_{Planck}^2}{15360\pi m_e^2}$ $\boxed{P = \frac{P_{Planck}}{15360\pi\alpha_G}}$
$S_{BH} = S_{Planck} \times \frac{4\pi M^2}{m_{Planck}^2}$	$S_{BH} = S_{Planck} \times \frac{4\pi m_e^2}{m_{Planck}^2}$ $\boxed{S_{BH} = 4\pi\, S_{Planck}\, \alpha_G}$

$\alpha_G \rightarrow$ Gravitational coupling constant

$v \times v_{Phase} = c^2 = (\text{Planck speed})^2 = \text{Planck specific energy}$

Since the particle speed $v < c$ for any particle that has mass − according to **Albert Einsteinian special theory of relativity**, the phase velocity of matter waves always exceeds c, i.e. $v_{Phase} >$ Planck speed

$$v_{Phase} > \frac{\text{Planck length}}{\text{Planck time}}$$

- $v_{Phase} > \frac{\text{Stoney length}}{\text{Stoney time}}$
- $v < \frac{\text{Stoney length}}{\text{Stoney time}}$

The relativistic energy of an electron can be expressed in terms of its momentum in the expression:

$$E = \sqrt{p^2c^2 + m_e^2c^4}$$

$$E = \sqrt{p^2c^2 + \alpha_G E_{Planck}^2}$$

If p = Planck momentum = $\sqrt{\frac{\hbar c^3}{G}}$:

$$\boxed{E = E_{Planck}\sqrt{1 + \alpha_G}}$$

Relativistic energy a electron must possess so that its **momentum** to be equal to Planck momentum

Stoney energy:

$$E_S = m_S c^2 = \sqrt{\alpha}\,\frac{m_{Planck} L_{Planck}^2}{t_{Planck}^2}$$

$$\frac{m_S L_S^2}{t_S^2}$$

Stoney temperature:

$$T_S = \frac{E_S}{k_B} = \sqrt{\alpha} \times \frac{E_{Planck}}{k_B}$$

$$T_S = \sqrt{\alpha} \times T_{Planck}$$

$$T_{BH} = \frac{T_{Planck} \times m_{Planck}}{8\pi M}$$

$$T_{BH} = \frac{T_S \times m_S}{8\pi \times \alpha \times M}$$

Today's universe in Planck and Stoney units

Age	13.8×10^{9} years	$8.08 \times 10^{60}\ t_{Planck}$	$8.08 \times 10^{60}\ \frac{t_S}{\sqrt{\alpha}}$
Diameter	8.7×10^{26} m	$5.4 \times 10^{61}\ L_{Planck}$	$5.4 \times 10^{61}\ \frac{L_S}{\sqrt{\alpha}}$
Mass	3×10^{52} kg	approx. $10^{60}\ m_{Planck}$	approx. $10^{60}\ \frac{m_S}{\sqrt{\alpha}}$
Density	9.9×10^{-27} kg·m^{-3}	$1.8 \times 10^{-123}\ \frac{m_{Planck}}{L_{Planck}^3}$	$1.8 \times 10^{-123}\ \frac{\alpha\, m_S}{L_S^3}$
Temperature	2.725 K (Temperature of the cosmic microwave background radiation)	$1.9 \times 10^{-32}\ T_{Planck}$	$1.9 \times 10^{-32}\ \frac{T_S}{\sqrt{\alpha}}$
Cosmological constant	1.1×10^{-52} m^{-2}	$2.9 \times 10^{-122}\ \frac{1}{L_{Planck}^2}$	$2.9 \times 10^{-122}\ \frac{\alpha}{L_S^2}$
Hubble constant	2.2×10^{-18} s^{-1}	$1.18 \times 10^{-61}\ \frac{1}{t_{Planck}}$	$1.18 \times 10^{-61}\ \frac{\sqrt{\alpha}}{t_S}$

$$\text{Planck charge density} = \frac{\text{Planck charge}}{\text{Planck volume}} = \sqrt{\frac{c^{10} 4\pi\varepsilon_0}{\hbar^2 G^3}} = \frac{1}{t_{Planck}^2} \times \frac{1}{\sqrt{G \times \text{Coulomb constant}}}$$

$$\left\{ \textbf{Planck charge density} = \frac{\alpha}{t_S^2} \times \frac{1}{\sqrt{G \times \text{Coulomb constant}}} \right\}$$

$$\text{Planck energy density} = \frac{\text{Planck energy}}{\text{Planck volume}} = \frac{c^7}{G^2\hbar}$$

$$\textbf{Planck energy density} = \frac{m_{Planck}}{L_{Planck} \times t_{Planck}^2} = \frac{\alpha \times m_S}{L_S \times t_S^2}$$

$$\text{Planck force density} = \frac{\text{Planck force}}{\text{Planck volume}} = \frac{\hbar}{L_{Planck}^4\, t_{Planck}}$$

$$\text{Planck force density} = \frac{\alpha^{\frac{5}{2}}\,\hbar}{L_S^4\, t_S}$$

Hartree Energy:

$$E_h = 2\, R_\infty hc = \frac{\alpha hc}{2\pi a_0}$$

a_0 = Bohr radius

Hartree Force:

$$F_h = \frac{\text{Hartree Energy}}{\text{Bohr radius}}$$

$$F_h = \frac{\alpha hc}{2\pi a_0^2}$$

r_e = classical electron radius

$$F_h = \frac{\alpha^5 hc}{2\pi r_e^2}$$

$$F_h = \frac{\alpha hc}{2\pi a_0^2} = \frac{\alpha\hbar c}{a_0^2} = \frac{e^2}{4\pi\varepsilon_0 a_0^2}$$

- Z_0 = impedance of free space
- G_0 = conductance quantum

$$\boxed{F_h = \frac{Z_0 G_0 hc}{8\pi a_0^2}}$$

Hartree Momentum:

$$p_h = \frac{\hbar}{a_0} = \frac{\alpha^2\hbar}{r_e}$$

R_K = von Klitzing constant

$$\boxed{p_h = \frac{Z_0^2\,\hbar}{4R_K^2\,r_e}}$$

Hartree Time:

$$\underbrace{t_h = \frac{\hbar}{E_h} = \frac{\hbar}{2R_\infty\,hc}}$$

$$\boxed{t_h = \frac{t_{Planck}}{4\pi R_\infty L_{Planck}} = \frac{t_S}{4\pi R_\infty L_S}}$$

- $E_h \times t_h = \hbar$

- $p_h \times a_0 = \hbar$

$$E_h \times t_h = p_h \times a_0$$

$$\boxed{E_h = p_h \times \frac{a_0}{t_h}}$$

Hartree velocity:

$$\boxed{\text{Planck speed} = \frac{\text{Hartree velocity}}{\text{Fine structure constant}}}$$

$$v_h = \frac{a_0}{t_h} = \alpha \times c$$

$$\boxed{v_h = \frac{\alpha\, L_{Planck}}{t_{Planck}} = \frac{\alpha\, L_S}{t_S}}$$

$$E_{rest} = m_e c^2 = \frac{m_e v_h^2}{\alpha^2}$$

The threshold temperature below which the electron is effectively removed from the universe:

$$\underbrace{T_{threshold} = \frac{m_e c^2}{k_B} = \frac{\text{molar electron mass}}{\text{ideal gas constant}} \times \frac{v_h^2}{\alpha^2}}$$

$$T_{threshold} = \frac{\text{molar electron mass}}{\text{ideal gas constant}} \times \frac{v_h^2 a_0}{r_e}$$

$$c_1 = 4\pi^2 \times \text{Planck angular momentum} \times (\text{Planck speed})^2$$

$$\boxed{c_1 = 4\pi^2 \times \text{Planck angular momentum} \times \frac{(\text{Hartree velocity})^2}{(\text{Fine structure constant})^2}}$$

$$c_1 = \frac{2\pi h v_h^2 a_0}{r_e}$$

$$c_2 = \frac{hc}{k_B} = \frac{\text{molar Planck constant}}{\text{ideal gas constant}} \times \frac{\text{Hartree velocity}}{\text{Fine structure constant}}$$

The Compton wavelength of the electron

$$\frac{h}{m_e c} = 2 \times \text{Quantum of circulation} \times \frac{\text{Fine structure constant}}{\text{Hartree velocity}}$$

$$\boxed{c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}}$$

$$\boxed{v_h = \frac{\alpha}{\sqrt{\mu_0 \varepsilon_0}}}$$

$$\Delta x\ \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E\ \Delta t \geq \frac{\hbar}{2}$$

$$\Delta x\ \Delta p \geq \frac{\text{Bohr radius} \times \text{Hartree momentum}}{2}$$

$$\Delta E\ \Delta t \geq \frac{\text{Hartree energy} \times \text{Hartree time}}{2}$$

$$\downarrow$$

$$\frac{\Delta p}{\text{Hartree momentum}} \geq \frac{\text{Bohr radius}}{\Delta x}$$

$$\frac{\Delta E}{\text{Hartree energy}} \geq \frac{\text{Hartree time}}{\Delta t}$$

Sir Isaac Newton's famous Law of Universal Gravitation states that the force of gravitation is proportional to $\frac{1}{(\text{radius of the planet})^2}$ – which implies that if a radius of the planet shrinks by a factor of 2, then the force of gravitation at its surface must rise by a factor of 4.

$$\text{Planck force} = \frac{c^4}{G} = \frac{a_0^2 v_h^2}{G r_e^2}$$

$$\textbf{Planck power} = \frac{c^5}{G} = \frac{v_h^5}{G\alpha^5} = \frac{a_0^2 v_h^2}{G r_e^2} \times \frac{L_s}{t_s}$$

Black hole surface gravity is given by:

$$g_{BH} = \frac{c^4}{4GM}$$

$$\boxed{\frac{\text{Planck force}}{4} = \text{Black hole mass} \times \text{Black hole surface gravity}}$$

$$\boxed{\frac{g_{BH}}{a_{Planck}} = \frac{m_{Planck}}{4M}}$$

If M = $m_{Planck} = \sqrt{\frac{\hbar c}{G}}$:

$$\boxed{g_{BH} = \frac{a_{Planck}}{4}}$$

If M = $m_S = \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$:

$$\boxed{g_{BH} = \frac{a_{Planck}}{4\sqrt{\alpha}}}$$

Lorentz factor:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

A term by which relativistic mass, time and length changes for an object in motion

The Lorentz factor is always greater than 1 but it grows towards infinity as the object's velocity approaches the speed of light.

If v = **Hartree velocity**:

$$\gamma = \frac{1}{\sqrt{1-\alpha^2}}$$

- $m = \dfrac{m_0}{\sqrt{1-\alpha^2}}$
- $L = L_0\sqrt{1-\alpha^2}$
- $\Delta t = \dfrac{\Delta t_0}{\sqrt{1-\alpha^2}}$
- $KE = m_0c^2\left(\dfrac{1}{\sqrt{1-\alpha^2}} - 1\right)$

Fine structure constant $= \dfrac{1}{4 \times \text{magnetic coupling constant}}$

The wavelength of a relativistic particle is given by:

$$\lambda = \lambda_C\sqrt{\frac{c^2}{v^2} - 1}$$

If $v = \dfrac{c}{\sqrt{2}}$:

$$\lambda = \lambda_C$$

If v = $\mathbf{v_h}$:

$$\lambda = \lambda_C\sqrt{\frac{1}{\alpha^2} - 1} = \lambda_C\sqrt{\frac{a_0}{r_e} - 1}$$

$$\lambda = \lambda_C\sqrt{16\beta^2 - 1}$$

β → magnetic coupling constant

Hartree Temperature:

$$\underbrace{T_h = \frac{E_h}{k_B} = \frac{hc}{k_B} \times \frac{\alpha}{2\pi a_0}}$$

$$\boxed{T_h = \frac{c_2 \alpha}{2\pi a_0}}$$

Hartree electric potential:

$$V_h = \frac{E_h}{e} = 4R_\infty \times c \times \Phi_0 = \frac{4R_\infty \Phi_0}{\sqrt{\mu_0 \varepsilon_0}}$$

$$\boxed{V_h = \frac{4R_\infty v_h \Phi_0}{\alpha}}$$

$$\boxed{V_h = \frac{E_h}{e} = \frac{hc}{e} \times \frac{\alpha}{2\pi a_0} = \frac{\Phi_0 v_h}{\pi a_0}}$$

Hartree pressure:

$$\underbrace{P_h = \frac{E_h}{a_0^3} = \frac{\alpha hc}{2\pi a_0} \times \frac{1}{a_0^3}}$$

$$\boxed{P_h = v_h \times \frac{\hbar}{a_0^4}}$$

Hartree current:

$$\left.I_h = \frac{e}{\hbar} \times E_h = \frac{e}{\hbar} \times \frac{\alpha \hbar c}{a_0}\right\} \quad \boxed{I_h = \frac{e \times v_h}{a_0}}$$

Hartree charge density:

$$\boxed{\frac{e}{a_0^3} = \frac{\alpha^{\frac{13}{2}} q_{Planck}}{r_e^3}}$$

Hartree electric dipole moment:

$$e \times a_0 = \frac{e \times r_e}{\alpha^2}$$

Hartree electric dipole moment = $\alpha^{-\frac{3}{2}} \times q_{Planck} \times r_e$

The gravitational force between 2 electrons:

$$F_G = \frac{Gm_e^2}{r^2}$$

If F_G = **Hartree Force =** $\frac{\alpha\hbar c}{a_0^2}$**:**

$$\frac{\alpha\hbar c}{a_0^2} = \frac{Gm_e^2}{r^2}$$

$$\boxed{r = \sqrt{\frac{\alpha_G}{\alpha}} \times a_0 = \sqrt{4 \times \beta \times \alpha_G} \times a_0}$$

Distance between 2 electrons at which gravitational force between them is equal to Hartree force

The electrical force between 2 electrons:

$$F_E = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

If F_G = **Hartree Force** = $\frac{\alpha\hbar c}{a_0^2}$:

$$\frac{\alpha\hbar c}{a_0^2} = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

$$\underbrace{\boxed{r = a_0 = \frac{r_e}{\alpha^2}}}$$

Distance between 2 electrons at which electrical force between them is equal to Hartree force

Quantum Chromodynamics Units:

QCD Length:

$$L_{QCD} = \frac{\hbar}{m_p c} = \text{reduced Compton wavelength of the proton}$$

QCD Time:

$$t_{QCD} = \frac{\hbar}{m_p c^2} = \frac{1}{\text{Compton angular frequency of the proton}}$$

QCD mass:

$$m_{QCD} = m_p = 1.673 \times 10^{-27}\ \text{kg}$$

QCD energy: $E_{QCD} = m_p c^2$

QCD Temperature:

$$\boxed{T_{QCD} = \frac{E_{QCD}}{k_B} = \text{the threshold temperature below which the proton is effectively removed from the universe}}$$

$$\Delta E \; \Delta t \geq \frac{\hbar}{2}$$

$$\underbrace{\Delta E \; \Delta t \geq \frac{E_{QCD} \times t_{QCD}}{2}}$$

$$\downarrow$$

$$\boxed{\frac{\Delta E}{E_{QCD}} \geq \frac{t_{QCD}}{\Delta t}}$$

$$\underbrace{L_{QCD} \times t_{QCD} \times m_{QCD} = \frac{\hbar}{m_p c} \times \frac{\hbar}{m_p c^2} \times m_p}$$

$$L_{QCD} \times t_{QCD} \times m_{QCD} = \frac{m_{Planck} \times L_{Planck} \times t_{Planck}}{\sqrt{\text{Proton gravitational coupling constant}}}$$

Astronomical range	Typical units
Distances to satellites	kilometers
Distances to near-Earth objects	lunar distance
Planetary distances	astronomical units, gigameters
Distances to nearby stars	parsecs, light-years
Distances at the galactic scale	kiloparsecs
Distances to nearby galaxies	megaparsecs

	Solar mass
Solar mass	1
Jupiter masses	1048
Earth masses	332950

- Hydrogen-2 is called **deuterium**
- Hydrogen-3 is called **tritium**

The energy produced by the nuclear fusion of one kilogram of hydrogen is 177,720,000 kilowatt-hours – which represents enough electricity to run the average American household for 3000 years.

The Sun's mass is 1.99×10^{30} kilograms = 332,900 times the mass of the Planet Earth.

Stars are made of the same chemical elements as found in the Planet Earth though not in the same proportions

"The exploration and use of outer space, including the Moon and other celestial bodies shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind" **(UN 1967).**

Star with mass greater than about 1.5 times that of the Sun fuses hydrogen into helium via the "carbon cycle".

Interplanetary contamination

The introduction of biological material from one planetary body (planet, moon, asteroid) to another – either deliberate or unintentional

Forward contamination

The transfer of biological material from Earth to another celestial body

Backward contamination

The introduction of extraterrestrial organisms and other forms of biological material into Earth's biosphere

$$F = eE$$

If F = **Hartree force** = $\frac{\alpha\hbar c}{a_0^2}$:

$$E = \frac{\Phi_0 v_h}{\pi a_0^2}$$

$$\underbrace{L_{QCD} \times T_{QCD} = \frac{\hbar}{m_p c} \times \frac{m_p c^2}{k_B}}$$

$$L_{QCD} \times T_{QCD} = \frac{c_2}{2\pi}$$

$$\frac{L_{QCD}}{t_{QCD}} = c$$

$$\frac{L_{Planck}}{t_{Planck}} = c$$

$$\frac{L_S}{t_S} = c$$

$$\frac{L_{QCD}}{t_{QCD}} = \frac{L_{Planck}}{t_{Planck}} = \frac{L_S}{t_S}$$

$$c_1 = 2\pi h \times \frac{L_{QCD}}{t_{QCD}} \times \frac{L_{Planck}}{t_{Planck}}$$

$$E_{QCD} = m_{QCD} \times c^2$$

$$E_{QCD} = m_{QCD} \times \frac{L_{QCD}}{t_{QCD}} \times \frac{L_S}{t_S}$$

The electrical force between 2 protons is given by:

$$F_E = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

If $r = L_{QCD}$:

$$F_E = \frac{e^2}{4\pi\varepsilon_0 L_{QCD}^2}$$

$$F_E = \textbf{Fine structure constant} \times \frac{E_{QCD}}{L_{QCD}}$$

The gravitational force between 2 protons is given by:

$$F_G = \frac{Gm_p^2}{r^2}$$

If $r = L_{QCD}$:

$$F_G = \frac{Gm_p^2}{L_{QCD}^2}$$

F_G = **Proton gravitational coupling constant** $\times \frac{E_{QCD}}{L_{QCD}}$

The critical density of the universe:

$$\rho_{critical} = \frac{3H^2}{8\pi G}$$

If $\rho_{critical}$ = **Planck density** = $\frac{c^5}{\hbar G^2}$:

$$H = \sqrt{\frac{8\pi}{3 \times t_{Planck}}}$$

If the galaxy is taken to be spherical and the mass within the radius R is M, **the circular rotational velocity** at distance R is given by: $v_{rot} = \sqrt{\frac{GM}{r}}$**.** Thus, if v_{rot} is constant, it follows that $M \propto R$, so that the total mass within radius R increases linearly with the distance from the centre.

$$\frac{m_e v^2}{2} = \frac{3k_B T}{2}$$

$$\underbrace{v^2 = 3 \times \frac{k_B}{m_e} \times T = 3 \times \frac{\text{ideal gas constant}}{\text{molar electron mass}} \times T}$$

$$v^2 = \frac{3v_h^2}{\alpha^2\sqrt{\alpha_G}} \times \frac{T}{T_{Planck}}$$

- v_h = Hartree velocity and α_G = Electron gravitational coupling constant
- α = Fine structure constant and T_{Planck} = Planck temperature

$$\frac{m_e v^2}{2} = eV$$

$$v^2 = 2 \times \frac{e}{m_e} \times V = 2 \times \text{electron charge to mass ratio} \times V$$

$$\underbrace{v^2 = 2 \times \frac{\text{Faraday constant}}{\text{molar electron mass}} \times V}$$

ε_g = Gravitoelectric gravitational constant

$$v^2 = 2V\sqrt{\frac{\alpha \times \varepsilon_0}{\alpha_G \times \varepsilon_g}}$$

Radiation density constant:

$$a = \frac{4\sigma}{c} = \frac{4\sigma \times t_{QCD}}{L_{QCD}}$$

If I = **Hartree current**:

$$\frac{e}{\hbar} \times E_h = \frac{dn_e}{dt} \times e$$

$$\frac{dn_e}{dt} = \frac{E_h}{\hbar}$$

$$\text{Rate of flow of electrons} = \frac{1}{\text{Hartree time}}$$

Extremophiles

↓

Organisms capable of living in extreme environments

Space debris

Artificial objects in space that are orbiting Earth but no longer serve a useful function

Precisely because Mars is an environment of great potential biological interest, it is possible that on Mars there are pathogens, organisms which, if transported to the terrestrial environment, might do enormous biological damage.

– Carl Sagan

The volume of the black hole:

$$V_{BH} = \frac{4\pi R_S^3}{3}$$

$$\boxed{\frac{V_{BH}}{V_{Planck}} = \frac{32\pi}{3} \times \frac{M^3}{m_{Planck}^3}}$$

If $M = m_{Planck}$:

$$\boxed{V_{BH} = \frac{32\pi\, V_{Planck}}{3}}$$

If $M = m_S = \sqrt{\alpha} \times m_{Planck}$:

$$\boxed{V_{BH} = \frac{32\pi \times \alpha^{\frac{3}{2}} \times V_{Planck}}{3}}$$

The surface area of the black hole:

$$A_{BH} = 4\pi R_S^2$$

$$\boxed{\frac{A_{BH}}{A_{Planck}} = 16\pi \times \frac{M^2}{m_{Planck}^2}}$$

If $M = m_{Planck}$:

$$A_{BH} = 16\pi \times A_{Planck}$$

If $M = m_S$:

$$A_{BH} = 16\pi \times \alpha \times A_{Planck}$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

$$\boxed{L_{QCD} = \frac{t_{QCD}}{\sqrt{\varepsilon_0 \mu_0}}}$$

The Compton wavelength of the electron:

$$\boxed{\lambda_{C,e} = 2\pi \times \alpha \times a_0}$$

$$E_h \times \lambda_{C,e} = \frac{\alpha \hbar c}{a_0} \times (2\pi \times \alpha \times a_0)$$

$$\boxed{E_h \times \lambda_{C,e} = \alpha^2 hc}$$

$$E_h \times L_{QCD} = \frac{\alpha \hbar c}{a_0} \times \frac{\hbar}{m_p c}$$

$$\boxed{E_h \times L_{QCD} = \alpha^2 \hbar c \times \frac{\text{electron mass}}{\text{proton mass}}}$$

$$E_h \times L_{QCD} = \frac{\alpha^2 \hbar c}{1836.15267343}$$

Hartree energy:

$$\underbrace{E_h = \frac{\alpha \hbar c}{a_0} = \alpha \hbar c \times \frac{m_e c \alpha}{\hbar}}$$

$$E_h = \alpha^2 m_e c^2$$

$$\alpha = \sqrt{\frac{E_h}{m_e c^2}} = \frac{e^2}{q_{Planck}^2} = \frac{Z_0 G_0}{4} = \sqrt{\frac{T_h}{T_{threshold}}}$$

$$E_h \times L_{Planck} = \alpha^2 m_e c^2 \times \sqrt{\frac{\hbar G}{c^3}}$$

$$\downarrow$$

α_G = electron gravitational coupling constant

$$\left\{ E_h \times L_{Planck} = \alpha^2 \sqrt{\alpha_G}\, \hbar c \right\}$$

$$\underbrace{E_h \times L_S = \alpha^2 m_e c^2 \times (\sqrt{\alpha}\, L_{Planck})}$$

$$E_h \times L_S = \alpha^{\frac{5}{2}} \sqrt{\alpha_G}\, \hbar c$$

Hartree energy × Rydberg wavelength = 2hc

$$E_h \times r_S = \alpha^2 m_e c^2 \times \frac{2Gm_e}{c^2}$$

$$\boxed{E_h \times r_S = 2\alpha^2 \times \alpha_G \times \hbar c}$$

$$\boxed{F_G = \frac{Gm_p m_e}{r^2}}$$

$$F_G = \frac{Gm_{Planck}^2}{r^2} \sqrt{\text{Proton gravitational coupling constant}} \times \sqrt{\text{Electron gravitational coupling constant}}$$

$$\left\{ F_G = \frac{\hbar c}{r^2} \sqrt{\text{Proton gravitational coupling constant}} \times \sqrt{\text{Electron gravitational coupling constant}} \right\}$$

- $E_h \times t_{QCD} = \dfrac{\alpha^2 \hbar}{1836.15267343}$
- $E_h \times t_{Planck} = \alpha^2 \sqrt{\alpha_G}\, \hbar$
- $E_h \times t_S = = \alpha^{\frac{5}{2}} \sqrt{\alpha_G}\, \hbar$

"there are no arbitrary constants ... nature is so constituted that it is possible logically to lay down such strongly determined laws that within these laws only rationally determined constants occur (not constants, therefore, whose numerical value could be changed without destroying the theory)."

— **Albert Einstein**

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

If $\Delta\lambda = L_{QCD}$:

$$L_{QCD} = \frac{h}{m_e c}(1 - \cos\theta)$$

$$\boxed{\theta = \cos^{-1}\left(1 - \frac{m_e}{2\pi m_p}\right)}$$

The wavelength shift of the scattered photon in an angle of $\theta = \cos^{-1}\left(1 - \frac{m_e}{2\pi m_p}\right)$ is equal to the QCD length.

$$I_h \times t_{QCD} = \frac{e}{\hbar} \times E_h \times \frac{\hbar}{m_p c^2}$$

$$\boxed{I_h \times t_{QCD} = e \times \alpha^2 \times \frac{m_e}{m_p} = \frac{e \times \alpha^2}{1836.15267343}}$$

$$\downarrow$$

$$\boxed{I_h \times t_{QCD} = e \times \alpha^2 \times \sqrt{\frac{\text{electron gravitational coupling constant}}{\text{proton gravitational coupling constant}}}}$$

$$I_h \times t_{Planck} = \frac{e}{\hbar} \times E_h \times \frac{\hbar}{m_{Planck}c^2}$$

$$\left\{ I_h \times t_{Planck} = e \times \alpha^2 \times \sqrt{\text{electron gravitational coupling constant}} \right\}$$

$$\underbrace{I_h \times t_S = \frac{e}{\hbar} \times E_h \times (\sqrt{\alpha} \times t_{Planck})}$$

$$\boxed{I_h \times t_S = e \times \alpha^{\frac{5}{2}} \times \sqrt{\text{electron gravitational coupling constant}}}$$

$$\Phi_0 \times I_h = \frac{h}{2e} \times \frac{e}{\hbar} \times E_h$$

$$\left\{ \Phi_0 \times I_h = \pi\, E_h \right\}$$

$$\frac{\text{Hartree energy}}{\text{Planck energy}} = (\text{Fine structure constant})^2 \times \sqrt{\text{electron gravitational coupling constant}}$$

$$\frac{\text{Hartree force}}{\text{Planck force}} = \alpha^2 \times \sqrt{\text{electron gravitational coupling constant}} \times \frac{\text{Planck length}}{\text{Bohr radius}}$$

Hartree force:

$$F_h = \frac{\alpha^2 m_e c^2}{a_0} = 2\pi\alpha^3 \frac{m_e c^2}{\lambda_{C,e}}$$

$$\left\{ \text{Rest mass energy of electron} = \frac{1}{2\pi\alpha^3} \times \text{Hartree force} \times \text{Compton wavelength of electron} \right\}$$

$$F_h = = 2\pi\alpha^3 \frac{m_e^2 c^3}{h} = 2\pi\alpha^3 \frac{k_B T_{threshold}^2}{c_2}$$

$$E_{QCD} \times t_{Planck} = m_p c^2 \times \frac{\hbar}{m_{Planck} c^2}$$

$$E_{QCD} \times t_{Planck} = \sqrt{\text{proton gravitational coupling constant}} \times \hbar$$

$$E_{QCD} \times t_S = m_p c^2 \times \left(\sqrt{\alpha} \times \frac{\hbar}{m_{Planck} c^2}\right)$$

$$\downarrow$$

$$E_{QCD} \times t_S = \sqrt{\text{Fine structure constant} \times \text{proton gravitational coupling constant}} \times \hbar$$

$$E_{QCD} \times t_h = m_p c^2 \times \frac{\hbar}{E_h}$$

$$E_{QCD} \times t_h = \frac{1836.15267343 \times \hbar}{\alpha^2}$$

Einstein's Photoelectric Equation:

The energy required to eject the electron from the metal surface

$$E = W_0 + KE_{electron}$$

$$\frac{m_e v^2}{2} = h\,(\upsilon - \upsilon_0)$$

$$v = 2\sqrt{Q_0(\upsilon - \upsilon_0)}$$

$$eV_S = h\,(\upsilon - \upsilon_0)$$

$$V_S = 2\,\Phi_0\,(\upsilon - \upsilon_0)$$

$$a_{Planck} \times t_h = \underbrace{\frac{c}{t_{Planck}} \times \frac{\hbar}{\alpha^2 m_e c^2}}$$

$$a_{Planck} \times t_h = \frac{c}{\alpha^2\sqrt{\text{electron gravitational coupling constant}}}$$

$$a_{Planck} \times t_{QCD} = \frac{c}{t_{Planck}} \times \frac{\hbar}{m_p c^2}$$

$$a_{Planck} \times t_{QCD} = \frac{c}{\sqrt{\text{proton gravitational coupling constant}}}$$

$$E_h \times \mu_B = \alpha^2 m_e c^2 \times \frac{e\hbar}{2m_e}$$

$$E_h \times \mu_B = \frac{\alpha^2 \times e \times c_1}{8\pi^2}$$

$$E_h \times \mu_N = \alpha^2 m_e c^2 \times \frac{e\hbar}{2m_p}$$

$$E_h \times \mu_N = \frac{\alpha^2 \times e \times c_1}{8\pi^2} \times \frac{m_e}{m_p} = \frac{\alpha^2 \times e \times c_1}{14689.2213874\ \pi^2}$$

$$E_{Planck} \times \mu_B = m_{Planck}c^2 \times \frac{e\hbar}{2m_e}$$

$$\left\{ E_{Planck} \times \mu_B = \frac{e \times c_1}{\sqrt{\text{electron gravitational coupling constant}} \times 8\pi^2} \right\}$$

$$E_S \times \mu_B = \sqrt{\alpha}\, m_{Planck}c^2 \times \frac{e\hbar}{2m_e}$$

$$E_S \times \mu_B = \frac{\sqrt{\text{Fine structure constant}} \times e \times c_1}{\sqrt{\text{electron gravitational coupling constant}} \times 8\pi^2}$$

$$\text{Planck intensity} = \frac{\text{Planck power}}{\text{Planck area}} = \frac{c^8}{\hbar G^2} = \frac{m_S c^2}{t_S} \times \frac{\alpha}{L_S^2} = \frac{\alpha m_S}{t_S^3}$$

$$\text{Planck intensity} = \frac{(\text{Planck force})^2}{\hbar} = \frac{4\pi^2 \times (\text{Planck power})^2}{\text{First radiation constant}}$$

$$\textbf{Planck power} = \frac{1}{2\pi}\sqrt{\text{First radiation constant} \times \text{Planck intensity}}$$

$$\text{Planck Intensity} = \frac{m_e^2 c^4}{\hbar} \times \frac{c^4}{G^2 m_e^2} = \frac{4\hbar\omega_C^2}{r_S}$$

- ω_C = Compton angular frequency of the electron
- r_S = Schwarzschild radius of the electron

$$E_{QCD} \times \mu_B = m_p c^2 \times \frac{e\hbar}{2m_e}$$

$$\downarrow$$

$$\left\{ E_{QCD} \times \mu_B = \frac{\sqrt{\text{proton gravitational coupling constant}} \times e \times c_1}{\sqrt{\text{electron gravitational coupling constant}} \times 8\pi^2} \right\}$$

$$E_{QCD} \times \mu_N = m_p c^2 \times \frac{e\hbar}{2m_p}$$

$$\boxed{E_{QCD} \times \mu_N = \frac{e \times c_1}{8\pi^2}}$$

$$E_{Planck} \times \mu_N = m_{Planck} c^2 \times \frac{e\hbar}{2m_p}$$

$$\boxed{E_{Planck} \times \mu_N = \frac{e \times c_1}{\sqrt{\text{proton gravitational coupling constant}} \times 8\pi^2}}$$

$$E_S \times \mu_N = \sqrt{\alpha}\, m_{Planck} c^2 \times \frac{e\hbar}{2m_p}$$

$$E_S \times \mu_N = \frac{\sqrt{\text{Fine structure constant}} \times e \times c_1}{\sqrt{\text{proton gravitational coupling constant}} \times 8\pi^2}$$

Planck Temperature:

$$T_{Planck} = \sqrt{\frac{\hbar c^5}{G k_B^2}}$$

$$T_{Planck} = \sqrt{\frac{c^2}{G m_e} \times \frac{hc}{2\pi k_B}} \times \sqrt{\frac{m_e c^2}{k_B}}$$

$$T_{Planck} = \sqrt{\frac{c_2 \times T_{threshold}}{\pi r_S}}$$

"**Fine Structure Constant:** Fundamental numerical constant of atomic physics and quantum electrodynamics, defined as the square of the charge of the electron divided by the product of Planck's constant and the speed of light."

— **Steven Weinberg**

$$F_h \times t_h = \frac{E_h}{a_0} \times \frac{\hbar}{E_h}$$

$$F_h \times t_h = \alpha\, m_e c$$

$$F_h \times t_h = \text{Fine structure constant} \times \sqrt{\text{electron gravitational coupling constant}} \times \text{Planck momentum}$$

$$F_h \times t_{Planck} = \frac{E_h}{a_0} \times \frac{\hbar}{E_{Planck}}$$

$$\left\{ F_h \times t_{Planck} = \alpha^3 \times \text{electron gravitational coupling constant} \times \text{Planck momentum} \right\}$$

$$F_h \times t_S = \frac{E_h}{a_0} \times \frac{\sqrt{\alpha} \times \hbar}{E_{Planck}}$$

$$F_h \times t_S = \alpha^{\frac{7}{2}} \times \text{electron gravitational coupling constant} \times \text{Planck momentum}$$

Reduced mass of hydrogen atom:

$$\mu = \frac{m_e m_p}{(m_e + m_p)}$$

- $\mu \leq m_e$
- $\mu \leq m_p$

$$\mu = \frac{\sqrt{\text{electron gravitational coupling constant}} \times \sqrt{\text{proton gravitational coupling constant}} \times \text{Planck mass}}{(\sqrt{\text{electron gravitational coupling constant}} + \sqrt{\text{proton gravitational coupling constant}})}$$

Hartree Power:

$$P_h = F_h \times v_h = \frac{\alpha^2 m_e c^2}{a_0} \times \alpha c$$

$$P_h = \frac{\alpha^4 m_e^2 c^4}{\hbar}$$

$P_h = \alpha^4 \times$ Electron gravitational coupling constant $\times$ Planck power

$P_h \times t_{Planck} = \alpha^4 \times$ Electron gravitational coupling constant $\times$ Planck energy

$P_h \times t_S = \alpha^{\frac{9}{2}} \times$ Electron gravitational coupling constant $\times$ Planck energy

"The fine-structure constant derives its name from its origin. It first appeared in Sommerfeld's work to explain the fine details of the hydrogen spectrum. ... Since Sommerfeld expressed the energy states of the hydrogen atom in terms of the constant [alpha], it came to be called the fine-structure constant."

— **John S. Rigden**

$$a_{\text{Planck}} \times Q_0 = \frac{c}{t_{\text{Planck}}} \times \frac{h}{2m_e}$$

$$a_{\text{Planck}} \times Q_0 = \frac{\pi \times c^3}{\sqrt{\text{electron gravitational coupling constant}}}$$

$$a_{\text{Planck}} \times \Phi_0 = \frac{c}{t_{\text{Planck}}} \times \frac{h}{2e}$$

$$a_{\text{Planck}} \times \Phi_0 = \frac{\pi c \times \text{Planck voltage}}{\sqrt{\text{Fine structure constant}}}$$

$$E_h \times Q_0 = \alpha^2 m_e c^2 \times \frac{h}{2m_e}$$

$$\downarrow$$

$$\left\{ E_h \times Q_0 = \frac{\alpha^2 c_1}{4\pi^2} \right\}$$

$$E_{QCD} \times Q_0 = m_p c^2 \times \frac{h}{2m_e}$$

$$E_{QCD} \times Q_0 = \frac{\sqrt{\text{proton gravitational coupling constant}} \times c_1}{4\pi^2 \sqrt{\text{electron gravitational coupling constant}}}$$

$$E_{Planck} \times Q_0 = m_{Planck}c^2 \times \frac{h}{2m_e}$$

$$E_{Planck} \times Q_0 = \frac{c_1}{4\pi^2\sqrt{\text{electron gravitational coupling constant}}}$$

$$E_S \times Q_0 = \sqrt{\alpha}\, m_{Planck}c^2 \times \frac{h}{2m_e}$$

$$\downarrow$$

$$\left\{ E_S \times Q_0 = \frac{\sqrt{\text{Fine structure constant}} \times c_1}{4\pi^2\sqrt{\text{electron gravitational coupling constant}}} \right\}$$

A quantum fluctuation can create an proton antiproton pair with energy $\Delta E \geq 2m_pc^2$ provided the fluctuation lives less than the time $\Delta t \leq \frac{\hbar}{\Delta E}$. In that time, the proton and antiproton can separate by a distance of order $\Delta x = c \times \Delta t$. As they separate they gain energy $eE \times \Delta x$, in the electric field with strength E. If they gain sufficient energy to compensate for their rest mass, they no longer have to annihilate: they can become real particles. The condition for real proton– antiproton pair creation is therefore that the electric field be greater than a critical value, $E_{critical}$ given by:

$$e\, E_{critical} \times (c \times \frac{\hbar}{2m_pc^2}) = 2m_pc^2$$

$$E_{critical} = \frac{4m_p^2c^3}{\hbar e}$$

A modern mathematical proof is not very different from a modern machine, or a modern test setup: the simple fundamental principles are hidden and almost invisible under a mass of technical details.

— Hermann Weyl

$$F_h \times t_{QCD} = \frac{E_h}{a_0} \times \frac{\hbar}{m_p c^2}$$

$$F_h \times t_{QCD} = \frac{\alpha^3 \times \text{electron gravitational coupling constant} \times \text{Planck momentum}}{\sqrt{\text{proton gravitational coupling constant}}}$$

$$P_h \times t_{QCD} = \frac{\alpha^4 m_e^2 c^4}{\hbar} \times \frac{\hbar}{m_p c^2}$$

$$P_h \times t_{QCD} = \frac{\alpha^4 \times \text{Electron gravitational coupling constant} \times \text{Planck energy}}{\sqrt{\text{Proton gravitational coupling constant}}}$$

Number of electron charges that make up one Planck charge:

$$n = \frac{\text{Planck charge}}{\text{Electron charge}} = \frac{1}{\sqrt{\alpha}} = \frac{2}{\sqrt{\text{impedance of free space} \times \text{conductance quantum}}}$$

The radius of photon orbit:

$$r = \frac{3GM}{c^2}$$

Any photon orbiting below this distance will plunge into the black hole, while photon that remains further away will spiral out towards infinity.

If $M = m_{Planck} = \sqrt{\frac{\hbar c}{G}}$:

r = 3 × Planck length

The electric potential energy between 2 electrons:

$$E_p = \frac{e^2}{4\pi\varepsilon_0 r}$$

If E_p = **Hartree energy**:

$$\alpha^2 m_e c^2 = \frac{e^2}{4\pi\varepsilon_0 r}$$

$$\boxed{r = \frac{r_e}{\alpha^2}}$$

Distance between 2 electrons at which the electric potential energy between them is equal to **Hartree energy**

The gravitational potential energy between 2 electrons:

$$E_p = \frac{Gm_e^2}{r}$$

If E_p = **Hartree energy**:

$$\alpha^2 m_e c^2 = \frac{Gm_e^2}{r}$$

$$\boxed{r = \frac{r_S}{2 \times \alpha^2}}$$

Distance between 2 electrons at which the gravitational potential energy between them is equal to **Hartree energy**

"It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong. "

− Richard P. Feynman

If $\frac{e^2}{4\pi\varepsilon_0 r}$ = **Planck energy** = $m_{\text{Planck}}c^2$:

$$\boxed{r = \sqrt{\text{electron gravitational coupling constant}} \times r_e}$$

Distance between 2 electrons at which the electric potential energy between them is equal to **Planck energy**

If $\frac{e^2}{4\pi\varepsilon_0 r}$ = **Stoney energy** = $\sqrt{\alpha}\, m_{\text{Planck}}c^2$:

$$\boxed{r = \sqrt{\frac{\text{electron gravitational coupling constant}}{\text{Fine structure constant}}} \times r_e}$$

Distance between 2 electrons at which the electric potential energy between them is equal to **Stoney energy**

If $\frac{Gm_e^2}{r}$ = **Planck energy** = $m_{\text{Planck}}c^2$:

$$\boxed{r = \sqrt{\text{electron gravitational coupling constant}} \times \frac{r_S}{2}}$$

Distance between 2 electrons at which the gravitational potential energy between them is equal to **Planck energy**

If $\frac{Gm_e^2}{r}$ = **Stoney energy** = $\sqrt{\alpha}\, m_{\text{Planck}}c^2$:

$$\boxed{r = \sqrt{\frac{\text{electron gravitational coupling constant}}{\text{Fine structure constant}}} \times \frac{r_S}{2}}$$

Distance between 2 electrons at which the gravitational potential energy between them is equal to **Stoney energy**

"Primitive life is very common and intelligent life is fairly rare. Some would say it has yet to occur on Earth."

– Stephen Hawking

$$F_G = \frac{Gm_1 m_2}{r^2}$$

Because $r_S = \frac{2Gm}{c^2}$:

$$F_G = \frac{F_{Planck}}{4} \times \frac{r_{S_1} \times r_{S_2}}{r^2}$$

$\frac{F_{Planck}}{4}$ → Proportionality constant

$$F_G \propto \frac{r_{S_1} \times r_{S_2}}{r^2}$$

Niels Bohr was a Danish physicist who is generally regarded as one of the foremost physicists of the 20th century. He was the first to apply the quantum concept, which restricts the energy of a system to certain discrete values, to the problem of atomic and molecular structure. For that work he received the Nobel Prize for Physics in 1922. His manifold roles in the origins and development of quantum physics may be his most-important contribution, but through his long career his involvements were substantially broader, both inside and outside the world of physics.

In 1911, fresh from completion of his PhD, the young Danish physicist **Niels Bohr** left Denmark on a foreign scholarship headed for the Cavendish Laboratory in Cambridge to work under J. J. Thomson on the structure of atomic systems. At the time, Bohr began to put forth the idea that since light could no long be treated as continuously propagating waves, but instead as **discrete energy packets** (as articulated by Max Planck and Albert Einstein), why should the classical Newtonian mechanics on which **Thomson's model** was based hold true? It seemed to Bohr that the **atomic model** should be modified in a similar way. If electromagnetic energy is quantized, i.e. restricted to take on only integer values of hυ, where υ is the frequency of light, then it seemed reasonable that the mechanical energy associated with the energy of atomic electrons is also quantized. However, Bohr's still somewhat vague ideas were not well received by Thomson, and Bohr decided to move from Cambridge after his first year to a place where his concepts about **quantization of electronic motion** in atoms would meet less opposition. He chose the University of Manchester, where the chair of physics was held by **Ernest Rutherford**. While in Manchester, Bohr learned about the nuclear model of the atom proposed by Rutherford. To overcome the difficulty associated with the classical collapse of the electron into the nucleus, Bohr proposed that the orbiting electron could only exist in certain special states of motion - called stationary states, in which no electromagnetic radiation was emitted. In these states, the angular momentum of the electron L takes on integer values of Planck's constant divided by 2π, denoted by $\hbar = \frac{h}{2\pi}$ (pronounced h-bar). In these stationary states, the electron angular momentum can take on values $\hbar$, $2\hbar$, $3\hbar$... but never non-integer values. This is known as quantization of angular momentum, and was one of **Bohr's key hypotheses**. He imagined the atom as consisting of electron waves of wavelength $\boldsymbol{\lambda} = \frac{h}{m_e v} = \frac{h}{p}$ endlessly circling atomic nuclei. In his picture, only orbits with circumferences corresponding to an integral multiple of electron wavelengths could survive without **destructive interference** (i.e., $\mathbf{r} = \frac{\mathbf{n}\hbar}{\mathbf{m_e v}}$ could survive without destructive interference). For circular orbits, the position vector of the electron **r** is always perpendicular to its linear momentum p. The angular momentum **L** has magnitude $\mathbf{m_e vr}$ in this case. Thus Bohr's postulate of quantized angular momentum is equivalent to $\mathbf{m_e vr =}$ $n\hbar$ where **n** is a positive integer called principal quantum number. It tells us what energy level the electron occupies.

For an electron moving in a circular orbit of radius r:

$$\omega = \frac{v}{r}$$

Since $\lambda = \frac{h}{m_e v} = \frac{h}{p}$ (de Broglie relation),

$$pv_p = \frac{hv_p}{\lambda} = h\upsilon = \hbar\omega$$

where $\hbar = \frac{h}{2\pi}$ is the reduced Planck constant, $\omega = 2\pi\upsilon$ is the angular frequency and v_p is the phase velocity.

$$pv_p = \frac{\hbar v}{r}$$

Since $n\hbar = pr$ (quantization of angular momentum),

$$\boxed{v = n \times v_p}$$

The velocity of the electron or the group velocity of the corresponding matter wave associated with the electron is the integral multiple of the **phase velocity** of the corresponding matter wave associated with the electron.

Quantum of circulation: $Q_0 = \frac{h}{2m_e}$

$\mathbf{m_e v r} = n\hbar$

$$\boxed{v = \frac{nQ_0}{\pi r} \longrightarrow v = \frac{2Q_0}{\lambda}}$$

$$\boxed{\omega = \frac{v}{r} = \frac{nQ_0}{\pi r^2} = \frac{nQ_0}{\text{Area of circular orbit}}}$$

By the de Broglie hypothesis, we see that:

$$\frac{pv_p}{\lambda} = \frac{h\upsilon}{\lambda}$$

$$\boxed{\frac{pv}{n\lambda} = \frac{h\upsilon}{\lambda}}$$

Substituting $n\lambda = 2\pi r$,

$$\frac{m_e v^2}{r} = 2\pi \frac{h\upsilon}{\lambda}$$

The classical description of the nuclear atom is based upon the Coulomb attraction between the positively charged nucleus and the negative electrons orbiting the nucleus. Furthermore, we consider only circular orbits. The electron, with mass $\mathbf{m_e}$ and charge e^- moves in a circular orbit of radius **r** with constant velocity **v**. The attractive **Coulomb force** provides the necessary acceleration to maintain orbital motion. (Note we neglect the motion of the nucleus since its mass is much greater than the electron). The total force on the electron is thus

$$F = \frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{m_e v^2}{r}$$

where $\varepsilon_0 = 8.854 \times 10^{-12} \frac{F}{m}$ is the permittivity of free space.

$$F = 2\pi \frac{h\upsilon}{\lambda}$$

$$-\frac{Ze^2}{4\pi\varepsilon_0 r} = -2\pi r \frac{h\upsilon}{\lambda}$$

Substituting $2\pi r = n\lambda$,

$$-\frac{Ze^2}{4\pi\varepsilon_0 r} = U = -nh\upsilon$$

The potential energy of the electron

The negative sign indicates that it requires energy to pull the orbiting electron away from the nucleus.

From the equation:

$$KE = \frac{m_e v^2}{2} = \frac{pv}{2}$$

we can determine the kinetic energy of the electron (neglecting relativistic effects)

Substituting $p = \frac{n\hbar}{r}$,

$$KE = \frac{n\hbar v}{2r} = \frac{n\hbar\omega}{2} = \frac{nh\upsilon}{2}$$

The kinetic energy of the electron is the integral multiple of $\frac{h\upsilon}{2}$

The total energy of the electron E = KE + U is thus:

$$E = KE + U = \frac{nh\upsilon}{2} + (-nh\upsilon)$$

$$\boxed{E = -\frac{nh\upsilon}{2}}$$

The frequency of photon absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by:

$$\upsilon_{photon} = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

where E_1 and E_2 denote the energies of the lower and higher allowed energy states respectively. This expression is commonly known as **Bohr's frequency rule**.

$$\upsilon_{photon} = \frac{\left(-\frac{n_2 h \upsilon_2}{2}\right) - \left(-\frac{n_1 h \upsilon_1}{2}\right)}{h}$$

$$n_1\upsilon_1 - n_2\upsilon_2 = 2\upsilon_{photon}$$

In physics (specifically, celestial mechanics), escape velocity is the minimum speed needed for an electron to escape from the electrostatic influence of a nucleus. If the **kinetic energy** $\frac{m_e v^2}{2}$ of the electron is equal in magnitude to the **potential energy** $\frac{Ze^2}{4\pi\varepsilon_0 r}$, then electron could escape from the electrostatic field of a nucleus.

$$\frac{m_e v^2}{2} = \frac{Ze^2}{4\pi\varepsilon_0 r}$$

Orbital velocity:

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{m_e v^2}{r}$$

$$v_{orbital} = \sqrt{\frac{Ze^2}{4\pi\varepsilon_0 r m_e}} = \sqrt{\frac{nh\upsilon}{m_e}}$$

$$\frac{m_e v^2}{2} = nh\upsilon$$

$$v = v_{escape} = \sqrt{\frac{2nh\upsilon}{m_e}} = \sqrt{4nQ_0\upsilon}$$

$$v_{orbital} = c\sqrt{\frac{Z \times \text{classical electron radius}}{r}} = c \times \text{Fine structure constant}\sqrt{\frac{Z \times \text{Bohr radius}}{r}}$$

$$v_{orbital} = \textbf{Hartree velocity} \sqrt{\frac{Z \times \text{Bohr radius}}{r}}$$

Total energy of the electron:

$$E = -\frac{nh\upsilon}{2}$$

$$\boxed{\frac{E}{m_e c^2} = -\frac{n\upsilon}{2\upsilon_C}}$$

$\upsilon_C = \dfrac{m_e c^2}{h}$ is the Compton frequency of the electron.

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{m_e v^2}{r}$$

$$\boxed{\frac{Ze^2}{4\pi\varepsilon_0 r^2} = m_e \omega^2 r}$$

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = m_e \times \frac{4\pi^2}{T^2} \times r$$

$$\boxed{\frac{4\pi^2}{T^2} = r_e c^2 \times \frac{Z}{r^3}}$$

where r_e denote the Classical electron radius

$$\left\{ T^2 \propto \frac{r^3}{Z} \right\}$$

$2\pi r = n\lambda$

(standing-wave condition)

+

$\lambda = \dfrac{h}{p}$

(de Broglie relation)

$\downarrow$

$L = n\hbar$

(Bohr's postulate)

"The very nature of the quantum theory ... forces us to regard the space-time coordination and the claim of causality, the union of which characterizes the classical theories, as complementary but exclusive features of the description, symbolizing the idealization of observation and description, respectively."

— Niels Bohr

The moment of inertia of an electron in n^th orbit is:

particle ← $\lambda = \dfrac{h}{m_e v}$ → wave

$$I = n \times m_e r^2$$

$$m_e r = \frac{n\hbar}{v}$$

Planetary Model failed to explain stability of atoms in accordance with classical laws of physics

$$I = n^2 \times \frac{\hbar r}{v} = \frac{n^2 \hbar}{\omega}$$

$$n = \sqrt{\frac{I\omega}{\hbar}}$$

The acceleration of the electron:

$$a = \frac{v^2}{r} = \omega \times v$$

$$a = \frac{2\pi}{T}\sqrt{\frac{nh\upsilon}{m_e}} = \frac{2\pi\sqrt{2nQ_0\upsilon}}{T}$$

Plum Pudding Model failed to explain large-angle deflections of scattered alpha particles

$$F = Z \times \frac{e^2}{4\pi\varepsilon_0} \times \frac{1}{r^2}$$

$$F = Z \times \text{Fine structure constant} \times \frac{hc}{2 \times \text{Area of the circular orbit}}$$

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{m_e}{r} \times \frac{n^2\hbar^2}{m_e^2 r^2}$$

$$r = \frac{n^2}{Z} \times \text{Bohr radius} = \frac{n^2 r_e}{Z\alpha^2}$$

Rydberg formula:

$$\upsilon_{photon} = \textbf{Rydberg frequency} \times Z^2 \frac{n_2^2 - n_1^2}{n_1^2 n_2^2}$$

For hydrogen atom: Z = 1

$$\boxed{\upsilon_{photon} = \textbf{Rydberg frequency} \times \frac{n_2^2 - n_1^2}{n_1^2 n_2^2}}$$

$$\frac{n_1\upsilon_1 - n_2\upsilon_2}{2} = \textbf{Rydberg frequency} \times \frac{n_2^2 - n_1^2}{n_1^2 n_2^2}$$

$$\boxed{\textbf{Rydberg frequency} = \frac{n_1^2 n_2^2\,(n_1\upsilon_1 - n_2\upsilon_2)}{2(n_2^2 - n_1^2)}}$$

n_1	n_2	Series Name
1	$2 - \infty$	Lyman
2	$3 - \infty$	Balmer
3	$4 - \infty$	Paschen
4	$5 - \infty$	Brackett
5	$6 - \infty$	Pfund
6	$7 - \infty$	Humphreys

- **Area of ellipse (integral form):**

$$\oint L d\varphi$$

- **Area of ellipse (geometrical form):**

$$2\pi n\hbar$$

Bohr-Sommerfeld quantization rule for angular momentum:

$$\oint L d\varphi = 2\pi n\hbar$$

Bohr quantization rule

In the case of circular orbits: L is constant and

$$\oint L d\varphi = L\int_0^{2\pi} d\varphi = 2\pi n\hbar \rightarrow L = n\hbar$$

$$\frac{\text{Hartree electric potential}}{\text{Planck voltage}} = \frac{E_h}{e} \times \frac{q_{Planck}}{E_{Planck}}$$

$$\alpha^{\frac{3}{2}} \times \sqrt{\text{electron gravitational coupling constant}}$$

Total energy of the electron:

$$E = KE + U = -\frac{hc\,R_\infty}{n^2} = -\frac{nh\upsilon}{2}$$

$$\left\{ R_\infty = \frac{n^3\upsilon}{2c} \right\}$$

$$\frac{m_e v^2}{r} = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

$$v = \frac{Ze^2}{4\pi\varepsilon_0 n\hbar} = \frac{Z\alpha c}{n} = \sqrt{\frac{nh\upsilon}{m_e}}$$

$$\alpha = \frac{1}{Z}\sqrt{\frac{n^3\upsilon}{\upsilon_C}}$$

Ionization energy

↓

Electron charge × Ionization potential

{ The minimum energy required to liberate the electron from the binding of nucleus. }

Separation energy

The energy needed to remove a proton or a neutron from an atomic nucleus.

Ground state → Excited state

First excitation potential = $E_2 - E_1$

$$-\frac{hc\,R_\infty}{n_2^2} + \frac{hc\,R_\infty}{n_1^2} = -3.4 + 13.6 = 10.2\ \text{eV}$$

Second excitation potential = $E_3 - E_1$

$$-\frac{hc\,R_\infty}{n_3^2} + \frac{hc\,R_\infty}{n_1^2} = -1.5 + 13.6 = 12.1\ \text{eV}$$

Rydberg formula for the spectrum of the hydrogen atom:

$$\lambda_{max} = \frac{n_1^2 n_2^2}{(n_2^2 - n_1^2)R_\infty}$$

$$\lambda_{min} = \frac{n_1^2}{R_\infty}$$

$$\left\{ \frac{\lambda_{max}}{\lambda_{min}} = \frac{n_2^2}{(n_2^2 - n_1^2)} \right\}$$

E= hυ

Because E = mc^2:

The Planck constant relates mass to frequency.

Bohr's model does not work for systems with more than one electron.

The wavelength associated with an electron is related to the momentum of the electron by the de Broglie relation: $\lambda = \frac{h}{p}$

$$p = \frac{h}{\lambda} \longrightarrow \frac{dp}{dt} = \frac{p^2}{h} \times -\frac{d\lambda}{dt}$$

Sir Isaac Newton first presented his three laws of motion in the "**Principia Mathematica Philosophiae Naturalis**" in 1686. His second law defines a force exerted on the electron to be equal to the rate of change in momentum of the electron: $F = \frac{dp}{dt}$

$$F = \frac{p^2}{h} \times -\frac{d\lambda}{dt}$$

$$m_{relativistic} = \frac{m_e}{\sqrt{1-\frac{v^2}{c^2}}}$$

The mass of the electron is not constant; it varies with changes in its velocity.

$$m^2_{relativistic}c^2 - m^2_{relativistic}v^2 = m_e{}^2c^2$$

On differentiation

$$m_{relativistic}v\,dv + v^2dm_{relativistic} = c^2dm_{relativistic}$$

$$dm_{relativistic}\,(c^2 - v^2) = m_{relativistic}v\,dv$$

$$\frac{dm_{relativistic}}{dt} = \frac{m_{relativistic}va}{(c^2-v^2)}$$

$$m_{relativistic}c^2 = m_ec^2 + KE$$

$$\frac{dm_{relativistic}c^2}{dt} = \frac{dKE}{dt} = Fv$$

$$F = \frac{m_{relativistic} \times a}{1-\frac{v^2}{c^2}} = \frac{m^3_{relativistic}a}{m_e^2}$$

For non-relativistic case ($v << c$):

$$F = m_ea$$

In no experiment, matter exists both as a particle and as a wave simultaneously. It is either the one or the other aspect.

$$F = \frac{m^3_{relativistic}a}{m^2_e} = \frac{p^2}{h} \times -\frac{d\lambda}{dt}$$

$$a = \frac{m^2_e v^2}{hm_{relativistic}} \times -\frac{d\lambda}{dt}$$

Albert Einstein was a German-born theoretical physicist, widely acknowledged to be one of the greatest physicists of all time. Einstein is known for developing the theory of relativity, but he also made important contributions to the development of the theory of quantum mechanics.

For nonrelativistic case (v << c):

$$a = \frac{m_e v^2}{h} \times -\frac{d\lambda}{dt}$$

"It was an act of desperation. For six years I had struggled with the blackbody theory. I knew the problem was fundamental and I knew the answer. I had to find a theoretical explanation at any cost, except for the inviolability of the two laws of thermodynamics."

− Max Planck

Irradiance is power per unit area.

Just like Energy, TOTAL MOMENTUM IS ALWAYS CONSERVED

Classical Picture	Quantum Picture
Energy of EM wave ~ $(\text{Amplitude})^2$	Energy of photon $= \dfrac{hc}{\lambda}$

- Energy density of electric field = $\dfrac{\varepsilon_0 E^2}{2}$
- Energy density of magnetic field = $\dfrac{B^2}{2\mu_0}$

Electromagnetic wave consists of an oscillating electric field with a perpendicular oscillating magnetic field.

"What is known of [photons] comes from observing the results of their being created or annihilated."

– Eugene Hecht

Energy density of EM wave:

$$u_{wave} = \frac{\varepsilon_0 E^2}{2} + \frac{B^2}{2\mu_0}$$

$$c = \frac{E}{B} = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

$$u_{wave} = \varepsilon_0 E^2$$

u_{wave} does not depend on the frequency of the wave

$u_{particle}$ = number density of photons × $h\upsilon$

depend on the frequency of the wave

$u_{wave} = u_{particle}$

number density of photons $\propto E^2$

"The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote.... Our future discoveries must be looked for in the sixth place of decimals."

– Albert A. Michelson, 1894

Radiation pressure = $\dfrac{4\sigma T^4}{3c}$

A very small increase in temperature will result in a very large increase in the radiation pressure

Hydrostatic Equilibrium:

gas and radiation pressure balance the gravity

Thermal Equilibrium:

Energy generated = Energy radiated

$$\frac{\text{Hartree pressure}}{\text{Planck pressure}} = \frac{E_h}{a_0^3} \times \frac{L_{\text{Planck}}^3}{E_{\text{Planck}}}$$

Hartree pressure = α^5 × (electron gravitational coupling constant)^2 × Planck pressure

$$E_{\text{relativistic}}^2 = p^2c^2 + E_{\text{rest}}^2$$

$$E_{\text{relativistic}}^2 - E_{\text{rest}}^2 = p^2c^2$$

$$(E_{\text{relativistic}} - E_{\text{rest}})\,(E_{\text{relativistic}} + E_{\text{rest}}) = p^2c^2$$

$$\text{KE} = \frac{p^2}{(m_{\text{relativistic}} + m_{\text{rest}})}$$

For non-relativistic case:

$$\text{KE} = \frac{m_{\text{rest}}\, v^2}{2}$$

$$F = \frac{p^2}{h} \times -\frac{d\lambda}{dt} \longrightarrow F = \frac{\text{KE}(m_{\text{relativistic}} + m_{\text{rest}})}{h} \times -\frac{d\lambda}{dt}$$

$$\text{KE} = \frac{hF}{(m_{\text{relativistic}} + m_{\text{rest}}) \times -\frac{d\lambda}{dt}}$$

For non-relativistic case:

$$m_{\text{relativistic}} = m_{\text{rest}}$$

$$F = m_{\text{rest}}a$$

$$\text{KE} = \frac{ha}{2 \times -\frac{d\lambda}{dt}}$$

where K_J is the Josephson constant

$$\text{KE} = \frac{3k_BT}{2} = \frac{ha}{2 \times -\frac{d\lambda}{dt}}$$

$$a = \frac{3k_BT}{h} \times -\frac{d\lambda}{dt}$$

$$\text{KE} = eV = \frac{ha}{2 \times -\frac{d\lambda}{dt}}$$

$$a = K_JV \times -\frac{d\lambda}{dt}$$

Cherenkov radiation is the electromagnetic radiation emitted when a charged particle (such as an electron) travels in a medium with speed **v** such that:

$$\boxed{\frac{c}{n} < v < c}$$

where c is speed of light in vacuum, and n is the refractive index of the medium. We define the ratio between the speed of the particle and the speed of light as:

$$\frac{v}{c} = \frac{1}{n \times \cos\theta}$$

$$\boxed{\cos\theta = \frac{c}{n \times v}}$$

The emission of **Cherenkov radiation** depends on the refractive index n of the medium and the velocity v of the charged particle in that medium

The heavier the charged particle, the higher kinetic energy it must possess to be able to emit Cherenkov radiation.

Since the charged particle is relativistic, we can use the relation:

$$\boxed{\lambda = \lambda_C \sqrt{\frac{c^2}{v^2} - 1}}$$

$$\boxed{\lambda = \lambda_C \sqrt{n^2\cos^2\theta - 1}}$$

If $\lambda = \lambda_C$:

$$\theta = \cos^{-1}\left(\frac{\sqrt{2}}{n}\right)$$

The wavelength of the charged particle is equal to its Compton wavelength when Cherenkov angle equals $\cos^{-1}\left(\frac{\sqrt{2}}{n}\right)$

The **Cherenkov Effect** is used as a tool in:

- nuclear physics to detect solar neutrinos
- high energy experiments to identify the nature of particles
- astrophysical experiments to study the cosmic showers

Pavel Alekseyevich Cherenkov was a Soviet physicist who shared the Nobel Prize in physics in 1958 with **Ilya Frank** and **Igor Tamm** for the discovery of Cherenkov radiation, made in 1934.

"The element carbon can be found in more kinds of molecules than the sum of all other kinds of molecules combined. Given the abundance of carbon in the cosmos — forged in the cores of stars, churned up to their surfaces, and released copiously into the galaxy — a better element does not exist on which to base the chemistry and diversity of life. Just edging out carbon in abundance rank, oxygen is common, too, forged and released in the remains of exploded stars. Both oxygen and carbon are major ingredients of life as we know it."

— Neil deGrasse Tyson

For a spherical star of uniform density, the **gravitational binding energy** E_B is given by the equation:

$$E_B = -\frac{3GM^2}{5R}$$

where G is the gravitational constant, M is the mass of the star and R is its radius.

$$\boxed{-\frac{E_B}{0.3Mc^2} = \frac{r_S}{R}}$$

where $r_S = \frac{2GM}{c^2}$ is the Schwarzschild radius of the star. Any star with Radius smaller than its Schwarzschild radius will form a black hole.

If $R < r_S$: $\boxed{|E_B| > 0.3Mc^2}$

$\left\{ \textbf{The star will form a black hole} \right\}$

The **core pressure** of a star of mass M and radius R is given by:

$$P_{core} = \frac{5GM^2}{4\pi R^4}$$

$$\downarrow$$

$$\boxed{P_{core} = -\frac{25E_B}{9V} = -\frac{25}{9} \times \rho_B}$$

where ρ_B is the gravitational binding energy density of the star.

Subrahmanyan Chandrasekhar was an Indian-American astrophysicist who spent his professional life in the United States. He was awarded the 1983 Nobel Prize for Physics with William A. Fowler for **"...theoretical studies of the physical processes of importance to the structure and evolution of the stars"**

$$\frac{10E_B}{3Mc^2} = -\frac{r_S}{R}$$

$$-\frac{9P_{core}V}{25} = E_B:$$

$$\frac{P_{core}}{0.833\rho_E} = \frac{r_S}{R}$$

where $\rho_E = \frac{Mc^2}{V}$ is the mass energy density of the star.

If $R < r_S$:

$$P_{core} > 0.833\rho_E$$

The star will form a black hole.

The **core density** of the star is given by:

$$\rho_{core} = \frac{3M}{\pi R^3}$$

The **core temperature** of the star is given by:

$$T_{core} = \frac{5\mu m_H GM}{3k_B R}$$

where k_B is the **Boltzmann constant**, μ denotes mean molecular weight of the matter inside the star and m_H is the mass of hydrogen nucleus

William Alfred Fowler was an American nuclear physicist, later astrophysicist, who, with Subrahmanyan **Chandrasekhar** won the 1983 Nobel Prize in Physics. He is known for his theoretical and experimental research into nuclear reactions within stars and the energy elements produced in the process.

$$\rho_{core} \times T_{core} = \frac{4\mu m_H P_{core}}{k_B} \longrightarrow P_{core} = \frac{\rho_{core} \times T_{core} \times k_B}{4\mu m_H}$$

$$\rho_B = -\frac{9P_{core}}{25} = -\frac{9 \times \rho_{core} \times T_{core} \times k_B}{100\mu m_H}$$

The ideal gas equation $PV = Nk_BT$ does not hold good for the matter present inside a star. Because, most stars are made up of more than one kind of particle and the gas inside the star is ionized. There is no indication of these facts in the above equation. We need to change the ideal gas equation, so that it holds good for the material present inside the star. It can be shown that the required equation can be written as $PV = \frac{M}{\mu m_H} k_BT$ where μ denotes mean molecular weight of the matter inside the star, M is the mass of the star and m_H is the mass of hydrogen nucleus.

$$\frac{PV}{MT} = \frac{k_B}{\mu m_H} = \frac{4P_{core}}{\rho_{core}T_{core}}$$

$$\frac{P}{P_{core}} = 4 \times \frac{\rho}{\rho_{core}} \times \frac{T}{T_{core}}$$

$$\frac{Mc^2}{2} = T_{BH} \times S_{BH}$$

Specific heat capacity of a black hole $= -\dfrac{2S_{BH}}{M}$

Heat Capacity: $C = \dfrac{dQ}{dT}$

Substituting $dQ = dMc^2$ and $T = \dfrac{\hbar c^3}{8\pi k_B GM}$:

Heat capacity of a black hole $= -\dfrac{8\pi k_B GM^2}{\hbar c}$

Specific heat capacity of a black hole $= -\dfrac{8\pi k_B GM}{\hbar c} = -\dfrac{c^2}{\text{Black hole temperature}}$

$$S_{BH} = \frac{4\pi k_B GM^2}{\hbar c}$$

On differentiation

$$dS_{BH} = \frac{8\pi k_B GM}{\hbar c^3} \times dMc^2$$

$$\left\{ T_{BH} \times dS_{BH} = dMc^2 \right\}$$

"For the past forty-five years, Stephen and hundreds of other physicists have struggled to understand the precise nature of a black hole's randomness. It is a question that keeps on generating new insights about the marriage of quantum theory with general relativity—that is, about the ill-understood laws of quantum gravity."

— Stephen Hawking

Black holes are the harmonic oscillator of quantum gravity.

(A. Strominger)

$$\frac{Mc^2}{2} = T_{BH} \times S_{BH}$$

On differentiation

$$dMc^2 = 2\,(T_{BH} \times dS_{BH}) + 2\,(dT_{BH} \times S_{BH}) = 2\,dMc^2 + 2\,(dT_{BH} \times S_{BH})$$

$$-\frac{dMc^2}{dT_{BH}} = 2S_{BH}$$

- Neutron Star has a hard surface; the curvature is large - but finite.
- **Black Hole:** No Surface − curvature is infinite at the centre.

Gravitational waves are 'ripples' in space-time, generated by accelerated masses that propagate as waves outward from their source at the speed of light. They were proposed by **Henri Poincaré** (French mathematician, theoretical physicist, engineer and philosopher of science) in 1905 and subsequently predicted in 1916 by **Albert Einstein** on the basis of his general theory of relativity.

Gravitational waves were first directly detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015. **Gravitational wave** is to gravity what light is to electromagnetism. It is the transmission of variations in the gravitational field as waves. Predicted by Einstein's theory of general relativity, the waves transport energy known as gravitational radiation. Two objects orbiting each other in highly elliptical orbit or circular orbit about their center of mass comprises binary system. This system loses mass by emitting gravitational wave (**ripple in the geometry of space and time**) whose frequency $\upsilon = \frac{E}{h} <<$ frequency of electromagnetic radiation and this is associated with an in-spiral or decrease in orbit. Suppose that the two masses are m_1 and m_2, and they are separated by a distance "r" orbiting each other in highly circular orbit about their center of mass. The rate of loss of energy from the binary system through gravitational radiation is given by:

$$P = -\frac{dE}{dt} = \frac{32G^4\, m_1^2 m_2^2}{5c^5}\, \frac{(m_1+m_2)}{r^5}$$

$$P = v \times \frac{Gm_1m_2}{2r^2}$$

$$\left\{ F_G = \frac{2P}{v} \right\}$$

where $G = 6.674 \times 10^{-11}$ m^3 kg^{-1} s^{-2} is the **Newtonian gravitational constant** and $c = 3 \times 10^8$ ms^{-1} is the **speed of light in vacuum**. Gravitational radiation robs the energy of orbiting masses. As the energy of the orbiting masses reduces, the distance between the masses decreases, and they orbit more rapidly. More generally, the rate of decrease of distance between the masses with time is given by:

$$v = -\frac{dr}{dt} = \frac{64G^3\, m_1 m_2}{5c^5}\, \frac{(m_1+m_2)}{r^3}$$

where F_G is the force of gravitation between the two masses orbiting each other in highly circular orbit about their center of mass. The loss of energy through **gravitational radiation** could eventually drop the mass m_1 into the mass m_2. The **lifetime of distance** "r" between the masses orbiting each other in highly circular orbit about their center of mass is given by:

$$t_{life} = \frac{5c^5r^4}{256G^3m_1m_2\,(m_1+m_2)} \quad \left\{ t_{life} = \frac{r}{4 \times v} \right.$$

$$F_G = \frac{2P}{v} = \frac{8P \times t_{life}}{r}$$

Two orbiting masses are moving at a common orbital angular frequency given by:

Gravitational waves come in 2 polarization states (called + [plus] and × [cross])

$$\omega = \sqrt{\frac{G\,(m_1+m_2)}{r^3}} = \sqrt{\frac{Gm_1m_2}{\mu r^3}}$$

$$\boxed{\omega^2 = \frac{G\,(m_1+m_2)}{r^3}}$$

Reduced mass:

$$\mu = \frac{m_1m_2}{(m_1+m_2)}$$

$$t_{life} = \frac{5}{256} \times \frac{c^5}{G} \times \frac{r}{Gm_1m_2} \times \frac{r^3}{G\,(m_1+m_2)}$$

$$\frac{Gm_1m_2}{r} = \frac{5\times\text{Planck power}}{256\omega^2 t_{life}}$$

$$\boxed{U_G = -\frac{Gm_1m_2}{r} = -\frac{5\times\text{Planck power}}{256\omega^2 t_{life}}}$$

U_G is the energy is associated with the state of separation between two orbiting masses that attract each other by the gravitational force.

Principle of equivalence

The mass of an object as measured by its resistance to acceleration under the action of a force is equal to the mass as measured by the effect of a gravitational field on the object

Experimental verification of **Quantum Gravity** (**that attempt to unify gravity with the other fundamental forces of physics**) is extremely difficult − primarily due to the small sizes and weak interactions. So far, the existence of **gravitons** (**quantum that is thought to be the carrier of the gravitational field**) has never been verified.

The **gravitational wave signal** was observed by LIGO detectors in Hanford and in Livingston on 14 **September 2015**. An exact analysis of the gravitational wave signal based on the **Albert Einsteinian theory of general relativity** showed that it came from two merging stellar black holes with 29 and 36 solar masses, which merged 1.3 billion light years from Earth. Before the merger, the total mass of both black holes was 36 + 29 solar masses = 65 solar masses. After the merger, the mass of resultant black hole was 62 solar masses.

What happened to three solar masses?

It was turned into the energy transported by the emitted gravitational waves. Using Albert Einstein's equation $E = mc^2$, where E is the energy transported by the emitted gravitational waves, m is the missing mass (3 solar masses) and c is the speed of light, we can estimate the energy released as **gravitational waves**:

$$E = (3 \times 2 \times 10^{30}\ \text{kg}) \times (3 \times 10^{8}\ \text{m/s})^2$$

$$E = 5.4 \times 10^{47}\ \text{J}$$

The amplitude of gravitational waves gets smaller with the distance to the source.

This is roughly 10^{21} more energy than the complete electromagnetic radiation emitted by our sun.

$$\upsilon = \frac{E}{h} = \frac{5.4 \times 10^{47}}{6.626 \times 10^{-34}} = 8.14 \times 10^{80}\text{s}^{-1}$$

- **Gravity** → Curvature of 4-dimensional (3 space + 1 time) space-time fabric produced by matter.
- **Gravitational-waves** → Ripples on 4-dimensional space-time produced by accelerated matter.

"**Newton's law of gravitation**. That's all you need (with a spot of calculus to crunch the numbers) to work out how the Earth will orbit the Sun or how an apple will fall if you let it go at a certain height. The only trouble is that Newton had no idea how this gravity thing worked. His model was simply: There is an attraction between bits of stuff, and let's not bother about why."

— Brian Clegg

Albert Einstein theorized that smaller masses travel toward larger masses, not because they are "attracted" by a mysterious force called gravity, but because the smaller objects travel through space that is warped by the larger object.

"Science finds it hard to decipher the mysteries of the mind largely because we lack efficient tools. Many people, including many scientists, tend to confuse the mind with the brain, but they are really very different things. The brain is a material network of neurons, synapses and biochemicals. The mind is a flow of subjective experiences, such as pain, pleasure, anger and love. Biologists assume that the brain somehow produces the mind, and that biochemical reactions in billions of neurons somehow produce experiences such as pain and love. However, so far we have absolutely no explanation for how the mind emerges from the brain. How come when billions of neurons are firing electrical signals in a particular pattern, I feel pain, and when the neurons fire in a different pattern, I feel love? We haven't got a clue. Hence even if the mind indeed emerges from the brain, at least for now studying the mind is a different undertaking than studying the brain."

— Yuval Noah Harari, 21 Lessons for the 21st Century

Freiherr Christian Johann Dietrich Theodor von Grotthuss was a Lithuanian chemist of German descent known for establishing the first theory of electrolysis in 1806 and formulating the first law of photochemistry in 1817.

John William Draper was an English-born American scientist, philosopher, physician, chemist, historian and photographer. He is credited with producing the first clear photograph of a female face and the first detailed photograph of the moon in 1840.

Possible energy pathways following photon absorption:

$$AB + h\upsilon \longrightarrow AB^*$$

$AB^* \longrightarrow AB^+ + e^-$	**Photoionization**
$AB^* \longrightarrow A + B$	**Photodissociation**
$AB^* \longrightarrow AB + h\upsilon$	**Fluorescence**
$AB^* + M \longrightarrow AB + M^*$	**Quenching**
$AB^* + C \longrightarrow A + BC$	**Chemical reaction**

Johannes Stark was a German physicist who was awarded the Nobel Prize in Physics in 1919 "for his discovery of the Doppler effect in canal rays and the splitting of spectral lines in electric fields". This phenomenon is known as the Stark effect.

$$\textbf{One Einstein} = N_A\, h\upsilon$$

$$\text{One Einstein} = 6.02214076 \times 10^{23}\ \text{mol}^{-1} \times \frac{hc}{\lambda}$$

$$\text{One Einstein} = 6.02214076 \times 10^{23} \times 6.625 \times 10^{-34} \times 3 \times 10^{8} \times \frac{1}{\lambda}$$

$$\textbf{One Einstein} = 119.690047605 \times 10^{-3}\ \text{J-m/mol} \times \frac{1}{\lambda}$$

$\sqrt{\frac{\hbar c}{G}}$ is equal to the mass of about 10^{19} protons. This is roughly the mass of a human embryo at about ten days of age.

Proton – electron mass difference:

$$\Delta m = m_p - m_e = \frac{e\hbar}{2\mu_N} - \frac{e\hbar}{2\mu_B}$$

$$\Delta m = \frac{e\hbar}{2} \times \frac{\mu_B - \mu_N}{\mu_B \mu_N}$$

$$\Delta m = \frac{\sqrt{\text{Fine structure constant}} \times \text{Planck charge} \times \text{Planck angular momentum}}{2} \times \frac{\mu_B - \mu_N}{\mu_B \mu_N}$$

The Planck action = the Planck angular momentum = $\hbar$

$$q^2_{\text{Planck}} = 4\pi\varepsilon_0 \hbar c$$

$$(\text{Planck charge})^2 = \frac{E_{\text{Photon}} \times \lambda_{\text{Photon}}}{2\pi \times \text{Coulomb constant}}$$

$$\text{Planck electric field} = \frac{\text{Planck force}}{\text{Planck charge}} = \sqrt{\frac{c^7}{4\pi\varepsilon_0 \hbar G^2}} = 6.5 \times 10^{61}\ \text{V/m}$$

Planck electric field = Planck speed $\sqrt{\text{Planck density} \times \text{Coulomb constant}}$

Planck current = Planck charge × Planck frequency

Planck magnetic field = $\sqrt{\frac{c^5}{4\pi\varepsilon_0 \hbar G^2}} = \sqrt{\text{Planck density} \times \text{Coulomb constant}} = 2.2 \times 10^{53}\ \text{T}$

Albert Einstein's theory of general relativity predicts that the wavelength of electromagnetic radiation photon will lengthen as it climbs out of a static gravitational well. Photons must expend energy to escape, but at the same time must always travel at the speed of light, so this energy must be lost through a change of frequency rather than a change in speed. If the energy of the photon $E = h\upsilon = \frac{hc}{\lambda} = mc^2$ decreases, the photon frequency also decreases. This corresponds to an increase in the wavelength of the electromagnetic radiation photon, or a shift to the red end of the **electromagnetic spectrum** – hence the name: **GRAVITATIONAL REDSHIFT**. This effect was confirmed in laboratory experiments conducted in the 1960s. For **radiation photons** emitted in a strong gravitational field, such as from the surface of a neutron star or close to the event horizon of a black hole, the gravitational redshift can be very large and is given by:

$$1 + z = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$$

In the **Newtonian limit**, i.e. when r is sufficiently large compared to the Schwarzschild radius $\frac{2GM}{c^2}$, the redshift can be approximated as: $z = \frac{GM}{rc^2}$

In one second, 4.5 million tons of rest mass is converted to radiant energy in the sun.

If a photon of mass $m = \frac{h\upsilon}{c^2}$ is moving under the influence of a weak gravitational field generated by a massive central object of mass M, **Sir Isaac Newton's law of gravitation** shows that the force of gravitation experienced by the photon is given by $\frac{GMm}{r^2}$, where G is Newton's universal constant of gravitation and r is the distance of the photon from the central massive object. The momentum of the photon ($p = mc = \frac{h}{\lambda}$) is poised to vary in the object's gravitational field while its velocity remains as a constant ($c = 3 \times 10^8$ m/s). From this, there is still the possibility of using Newton's classical law of universal gravitation and the second law of Newton to explain the dynamic changes of the photon momentum even if its rest mass, $m_0 = 0$.

Because **$E = mc^2$**:

- A light bulb filament has more mass when it is energized with electricity than when it is turned off.
- A hot cup of tea has more mass than the same cup of tea when cold.

$$-\frac{dp}{dt} = \frac{GMm}{r^2}$$

A cluster of galaxies consists of 3 components:

- Galaxies
- Hot Gas
- Dark Matter

where m is the energy equivalent mass of the photon based on $\mathbf{E = h\upsilon = mc^2}$, h represents the Planck constant. The (−) sign for the change of momentum indicates the reduction of the photon momentum by the gravitational force as it moves away from the central point of a large mass.

Since $p = \frac{h}{\lambda}$. Therefore: $\frac{p^2}{h}\frac{d\lambda}{dt} = \frac{GMm}{r^2}$ $\longrightarrow$ $\boxed{d\ln\lambda = \frac{GM}{c^2 r}\,dt}$

On integration within the limits of $\lambda_{emitted}$ to $\lambda_{observed}$ for wavelength of photon and 0 to t for time we get,

$$\boxed{\ln\left(\frac{\lambda_{observed}}{\lambda_{emitted}}\right) = \frac{GM}{c^2 r}t \longrightarrow \frac{(\lambda_{observed} - \lambda_{emitted})}{\lambda_{emitted}} = e^{\frac{GM\,t}{c^2 r}} - 1}$$

$$\boxed{1 + z = e^{\frac{GM\,t}{c^2 r}}}$$

The equation $1 + z = \frac{1}{\sqrt{1-\frac{2GM}{rc^2}}}$ breaks when r is equal to $\frac{2GM}{c^2}$. However, this equation is not going to break even when r is equal to $\frac{2GM}{c^2}$.

Three Classical Tests of General Relativity

- Precession of Mercury's orbit
- Deflection of starlight (**gravitational lensing**)
- Gravitational Redshift

- From strong field to weak field → **Redshift**
- From weak field to strong field → **Blueshift**

If all of the galaxies are redshifted, then they are all moving apart from each other!!

(**This is the evidence that our Universe is expanding**)

George Francis FitzGerald was an **Irish academic and physicist** who first suggested a method of producing radio waves, thus helping to lay the basis of wireless telegraphy.

Quantum physics

(Behavior of very small things)

+

Relativity theory

(Behavior of very large things)

Theory of Everything

Over the past few years, we have been hearing the term "The Big Bounce Theory", quite a lot. The Big Bounce Theory is a hypothetical scientific theory of the formation of the universe which boils down to the idea that the universe is caught in a cycle where it expands after the Big Bang, then begins to contract.

The Story of the Universe

In the beginning, there was nothing but a universe which was orderly, but it became disorderly as time went on. The total entropy of the universe $\boldsymbol{S_{uni}}$, was continually increasing with time and entropic energy of the universe was never less than or greater than T S_{uni} but = T S_{uni}. The universe obeyed the second law of thermodynamics:

$$dS_{uni} \geq 0.$$

and continued to expand and headed towards an ultimate "Heat Death" or "Big Chill". The stars were shining, supernovae were exploding, black holes were forming, winds on planetary surfaces were blowing dust around, and hot things like coffee mugs were cooling down and the cosmological arrow of time pointed in the direction of the universe's expansion. The space was simply the lowest energy state of the universe. It was neither empty nor uninteresting, and its energy was not necessarily zero. Because $E = mc^2$ (the equation that represents the correlation of energy to matter: essentially, energy and matter were but two different forms of the same thing) and due to the fuzziness of quantum theory (that implies: photon carries mass proportional to its frequency i.e., $m = \frac{h\upsilon}{c^2}$), some of the most incredible mysteries of the quantum realm (a jitter in the amorphous haze of the subatomic world) got far less attention than Schrödinger’s famous cat. Virtual particle-antiparticle pairs of energy ΔE were continually created out of the empty space consistent with the Heisenberg's uncertainty principle of quantum mechanics (which implied: $\Delta E \times \Delta t \geq \frac{\hbar}{2}$, where: Δt stood for time during which virtual particle-antiparticle pairs appeared together, moved apart, then came together and annihilated each other giving energy back to the space without violating the law of energy conservation − which stated that energy can neither be created nor destroyed; rather, it can only be transformed from one form to another).

$$\textbf{Nothing} \rightarrow \boldsymbol{e^{+}} + \boldsymbol{e^{-}} \rightarrow \textbf{Nothing}$$

Virtual Particles

Spontaneous births and deaths of roiling frenzy of particles so called virtual matter – antimatter pairs momentarily occurred everywhere, all the time − violated the Energy-momentum relationship:

$E^2 = m_0^2c^4 + p^2c^2$ − was the conclusion that mass and energy were interconvertible; they were two different forms of the same thing. However, spontaneous births and deaths of so called virtual particles could have produced some remarkable problem, because an infinite number of virtual particle-antiparticle pairs of energy **(ΔE ≠ Δpc)** were spontaneously created out of the empty space, therefore, by Einstein's famous equation $E = mc^2$, infinite number of virtual particle-antiparticle pairs bared an infinite amount of mass and according to general relativity, the infinite amount of mass could have curved up the universe to infinitely small size. But which obviously had not happened. The word virtual particles literally meant that these particles were not observed directly, but their indirect effects were measured to a remarkable degree of accuracy. Their properties and consequences were well established and well understood consequences of quantum mechanics. Everything was quantum. Subatomic particle behavior was governed by quantum mechanics, which produced different rules of physics for the very small entities. Without quantum mechanics, atoms would have not existed. The electrons, as they whizz around the nucleus, would have lost energy and collapsed into the center, destroying the atom. However, quantum mechanics prevented this from happening.

Space had three dimensions, I mean that it took three numbers − length, breadth and height − to specify a point. And adding time to its description, then space became space-time with 4 dimensions. For n spatial dimensions: The Newtonian gravitational force between two massive particles was given by:

$\mathbf{F_G} = \frac{GMm}{r^{\,n-1}}$ where G was the gravitational constant, M and m denoted the masses of the two particles and r was the distance between them. The electrostatic force between two point charges was given by:

$\mathbf{F_E} = \dfrac{Qq}{4\pi\varepsilon_0 r^{n-1}}$ where ε_0 was the absolute permittivity of free space, Q and q denoted the charges and r was the distance between them. Since n was = 3: Both of these forces were proportional to $\frac{1}{r^2}$.

Because $\mathbf{E = mc^2}$, the energy which a particle possessed due to its motion added to its rest mass. This effect was only really significant for particles moving at speeds close to the speed of light. For example, at 10 percent of the speed of light a particle 's mass **m** was only 0.5 percent more than its rest mass m_0, while at 90 percent of the speed of light it was more than twice its rest mass. And as a particle approached the speed of light, its mass raised ever more quickly, it acquired infinite mass and since an infinite mass cannot be accelerated any faster by any force, the issue of infinite mass remained an intractable problem. For this reason all the particles in that universe were forever confined by relativity to move at speeds slower than the speed of light. Only tiny packets or particles of light (dubbed "photon") that had no intrinsic mass moved at the speed of light. Tachyons the putative class of hypothetical particles (with negative mass) was believed to travel faster than the speed of light. But, the existence of tachyons was in question. The mass m in motion at speed v was the mass m_0 at rest divided by the factor $\sqrt{1 - \frac{v^2}{c^2}}$ implied: the mass of a particle was not constant; it varied with changes in its velocity.

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

For non-relativistic case ($v << c$), the above equation was reduced to:

$$m = m_0$$

The known forces of the universe were divided into four classes:

Gravity: This was the weakest of the four; it acted on everything in the universe as an attraction. And if not for this force, everything would have gone zinging off into outer space and the life sustaining star would have detonated like trillions upon trillions of hydrogen bombs.

Electromagnetism: This was much stronger than gravity; it acted only on particles with an electric charge, being repulsive between charges of the same sign and attractive between charges of the opposite sign.

Weak nuclear force: This caused radioactivity and played a vital role in the formation of the elements in stars.

Strong nuclear force: This force held together the protons and neutrons inside the nucleus of an atom. And it was this same force that held together the quarks to form protons and neutrons.

If these forces were unified, the protons − which constituted up much of the mass of ordinary matter − would have been unstable, and eventually decayed into lighter particles such as antielectrons. However, the probability of a proton in the universe gaining sufficient energy to decay was so small that one has to wait at least a million million million million million years.

Observations of galaxies indicated that the universe was expanding: the distance D between almost any pair of galaxies was increasing at a rate

$$\nu = \frac{dD}{dt} = HD$$

Beyond a certain distance, known as the Hubble distance $\frac{c}{H}$, it exceeded the velocity greater than the speed of light in vacuum. But, this was not a violation of relativity, because recession velocity was caused not by motion through space but by the expansion of space.

$$e^{+} + e^{-} \rightarrow 2\gamma$$

When an electron and a positron approached each other, they annihilated i.e., destroyed each other. During the process their masses were converted into energy in accordance with $E = mc^2$. The energy thus released manifested as γ photons. A positron had the same mass as an electron but an opposite charge equal to $+e$. The energy released in the form of 2γ photons during the annihilation of a positron and an electron was therefore $E = 2h\upsilon = 2m_0c^2$ where m_0 is the rest mass of the electron or positron.

$$2h\upsilon = 2m_0c^2$$

Since $\upsilon = \frac{c}{\lambda}$. Therefore:

$$\lambda = \frac{h}{m_0 c} = \lambda_{Compton}$$

which implied: wavelength of the resulted gamma photon was = Compton wavelength of the annihilated electron. The massive bodies that were accelerated caused the emission of gravity waves, ripples in the curvature of 4 dimensional fabric of space-time that traveled away in all directions like waves in a lake at a specific speed, the speed of light. Like light, gravity waves carried energy away from the bodies that emit them.

The ultimate fate of the universe was determined by a parameter called critical density $\frac{3H^2}{8\pi G}$:

- Density of the universe > $\frac{3H^2}{8\pi G}$ implied: the universe will eventually stop expanding then collapse.
- Density of the universe < $\frac{3H^2}{8\pi G}$ implied: the universe will expand forever.

The uncertainty in the position of the particle times the uncertainty in its velocity times the mass of the particle was never smaller than a certain quantity, which was known as Planck's constant. Hence the Heisenberg's uncertainty principle was a fundamental, inescapable property of the universe.

Particles were not particles

They were waves!  Diffraction

No, they were particles!  Photoelectric effect

Sometimes "**particles**" behaved like particles, sometimes like waves!

This expressed the inability of the classical concepts "**particle**" or "**wave**" to fully describe the behavior of quantum-scale objects.

Planck force was the highest possible force and half of this force was responsible for keeping the energy ($E = Mc^2$) of the black hole to a distance ($R_s = \frac{2GM}{c^2}$):

$$E = \frac{F_{Planck}}{2} R_s$$

The stars of radius smaller than $\frac{2GM}{c^2}$ further collapsed to produce dark or frozen stars (i.e., the mass of a star was concentrated in a small enough spherical region, so that its mass divided by its radius exceeded a particular critical value, the resulting space-time warp was so radical that anything, including light, that got too close to the star was unable to escape its gravitational grip). And these dark stars were sufficiently massive and compact and possessed a strong gravitational field that prevented even light from escaping out its influence: any light emitted from the surface of the star was dragged back by the star's gravitational attraction before it could get very far. Such stars become black voids in space and were coined "the black holes" (i.e., black because they cannot emit light and holes because anything getting too close falls into them, never to return). Classically, the gravitational field of the black holes (which seemed to be among the most ordered and organized objects in the whole universe) was so strong that they prevented any information including light from escaping out of their influence i.e., any information was sent down the throat of a black hole or swallowed by a black hole was forever hidden from the outside universe. Anything which fell through the black hole soon reached the region of infinite density and the end of time. However, the laws of classical general relativity did not allowed anything (not even light) to escape the gravitational grip of the black hole but the inclusion of quantum mechanics modified this conclusion− quantum field scattered of a black hole. Because of quantum mechanical effects, the pair of short-lived virtual particles (one with positive energy and the other with negative energy) appeared close to the event horizon of a black hole. The gravitational might of the black hole injected energy into a pair of virtual particles ... that teared them just far enough apart so that one with negative energy was sucked into the hole even before it can annihilate its partner ... its forsaken partner with positive energy... escaped outward to infinity with an energy boost from the gravitational force of the black hole ... where it appeared as a real particle (and to an observer at a distance, it appeared to have been emitted from the black hole). Because **E= mc**^{2} (i.e., energy is equivalent to mass), a fall of negative energy particle into the black hole therefore reduced its mass with its horizon shrinking in size. As the black hole lost mass, the temperature of the black hole (which was = $\frac{\hbar c^3}{8\pi GMk_B}$) raised and its rate of emission of particle increased, so it lost energy more and more quickly at a rate proportional to $\frac{1}{M^2}$. The black hole ought to emit particles and radiation as if it were a hot body with a temperature that depended only on the black hole's mass: the higher the mass, the lower the temperature. The total positive charge due to protons plus the total negative charge due to electrons in the universe was = 0 (Just what it was if electromagnetism would not dominate over gravity and for the universe to remain electrically neutral).

The energy of the photon was given by:

$$E_{photon} = h\upsilon = \frac{hc}{\lambda}$$

Thus, the larger frequency (shorter wavelength) implied larger photon energy and smaller frequency (longer wavelength) implied smaller photon energy. Because **h** was incredibly small (i.e., 6.625×10^{-34} Js), the frequency of the photon was always greater than its energy, so it did not took many quanta to radiate even ten thousand megawatts. All the known subatomic particles in the universe belonged to one of two groups, Fermions or bosons. **Fermions** were particles with integer spin ½ and they made up ordinary matter. Their ground state energies were negative. **Bosons** were particles (whose ground state energies were positive) with integer spin 0, 1, 2 and they acted as the force carriers between fermions (For example: The electromagnetic force of attraction between electron and a proton was pictured as being caused by the exchange of large numbers of virtual massless bosons of spin 1, called photons). The rest mass energy of each particle in the universe was given by: $m_0c^2 = k_BT_p$, where: T_p implied the threshold temperature below which that particle was effectively removed from the universe. The equation: $\frac{E}{B} = c$ successfully united electricity and magnetism in the framework of the electromagnetic field and asserted electromagnetic disturbances travel at a fixed and never-changing speed equal to that of light.

- Below Planck Time: $\sqrt{\frac{\hbar G}{c^5}}$
- Below Planck Length: $\sqrt{\frac{\hbar G}{c^3}}$
- Above Planck Temperature: $\sqrt{\frac{\hbar c^5}{G k_B^2}}$

All the known laws of physics were meaningless. **Absolute zero** (–273°C) was the lowest possible temperature, at which substances contained no heat energy and all vibrations ceased — almost. Weird things occurred **at the atomic and subatomic level:**

- Energy was quantized (**E = *n*h*υ***).
- Momentum was quantized (**L = *n*ħ**).
- Charge was quantized (**Q = *ne***).

4 NUMBERS described the characteristics of electrons and their orbitals:

- **Principal quantum number:** a number that described the average distance of the orbital from the nucleus and the energy of the electron in an atom.
- **Angular momentum quantum number:** a number that described the shape of the orbital.
- **Magnetic quantum number:** a number that described how the various orbitals were oriented in space.
- **Spin quantum number:** a number that described the direction the electron was spinning in a magnetic field — either clockwise or counterclockwise.

There were a number of different varieties of quarks: there were **six flavors**, which we now call up, down, strange, charmed, bottom, and top. And among the **leptons** the electron was a stable object and muon (that had mass 207 times larger than electron and now belongs to the second redundant generation of particles found in the Standard Model) and the **tauon** (that had mass 3,490 times the mass of the electron) were allowed to decay into other particles. And associated to each charged lepton, there were three distinct kinds of ghostly particles called **neutrinos**:

- the electron neutrino
- the muon neutrino
- the tauon neutrino

The proton was composed of two up quarks and one down quark and the neutron was composed of two down quarks and one up quark. The charge on the up quark was = $+\frac{2}{3}\boldsymbol{e}$ and the charge on the down quark was = $-\frac{1}{3}\boldsymbol{e}$. The other quarks possessed charges of $+\frac{2}{3}\boldsymbol{e}$ or $-\frac{1}{3}\boldsymbol{e}$. The charges of the quarks added up in the combination that composed the proton but cancelled out in the combination that composed the neutron i.e. **Proton charge was** = $+\frac{2}{3}\boldsymbol{e}+\frac{2}{3}\boldsymbol{e}-\frac{1}{3}\boldsymbol{e}=\boldsymbol{e}$. **Neutron charge was** = $+\frac{2}{3}\boldsymbol{e}-\frac{1}{3}\boldsymbol{e}-\frac{1}{3}\boldsymbol{e}=0$.

Each quark possessed baryon number = $\frac{1}{3}$: the total baryon number of the proton or the neutron was the sum of the baryon numbers of the quarks from which it was composed. And the electrons and neutrinos contained no quarks; they were themselves truly fundamental particles. And since there were no electrically charged particles lighter than an electron and a proton, the electrons and protons were prevented from decaying into lighter particles – such as photons (that carried zero mass, zero charge, a definite energy $E_{photon} = pc = hc/\lambda$ and a momentum $p = mc$) and less massive neutrinos (with very little mass, no electric charge, and no radius — and, adding insult to injury, no strong force acted on it). And a free neutron being heavier than the proton was not prevented from decaying into a proton (plus an electron and an antineutrino). The effective temperature experienced by a uniformly accelerating observer in a vacuum field was given by: $T_U = \frac{\hbar a}{2\pi c k_B}$, where a denoted the acceleration of the observer, k_B the Boltzmann constant, ħ the reduced Planck constant, and c the speed of light in vacuum. The entire electromagnetic spectrum — from radio waves to gamma rays, most of the light in the universe — resembled nothing but transverse waves of energy $E = \frac{hc}{\lambda}$, which in turn were vibrating Maxwell force fields differing only in their wavelength $\lambda = \frac{h}{p}$. The Coulombic repulsive force between two protons inside the nucleus was 10^{36} times the gravitational force between them. The nuclear attractive force between two neutrons was 10^{38} times the gravitational force between them. The nuclear reaction occurring inside the sun, irrespective of pp or CNO cycle, was as follows: 4 protons → 1 helium nucleus + 2 positrons + E, where E denoted the energy released in the form of radiation. Approximately it was 25 MeV ≈ 40×10^{-13}J. The unification of so called weak nuclear forces with the Maxwell equations was what known as the Electro weak theory. And the electro weak theory and QCD together constituted the so called Standard Model of particle physics, which described everything except gravity. Material, such as gas, dust and other stellar debris that approached the black hole prevented themselves from falling into it by forming a flattened band of spinning matter around the event horizon called the accretion disk. And since the spinning matter accelerated to tremendous speeds ($v \approx c$) by the huge gravity of the black hole the heat and powerful X-rays and gamma rays were released into the universe. Because $r = \frac{3GM}{c^2}$ the photon spheres existed only in the space surrounding an extremely compact object (a black hole or possibly an "ultracompact" neutron star).

This story of a universe that started off very hot and cooled as it expanded is in agreement with all the observational evidence that we have today. Nevertheless, it leaves an important question unanswered whether the laws of physics had any choice in the creation of the world. And this is a fundamental question. And compared to this question, all other questions seem trivial. Yes, it would have had many choices if it had wanted to set the value of the speed of light much smaller than its actual value and the values of electron mass, proton mass, and constants determining the magnitudes of electromagnetic interaction, strong interaction, and weak interaction much larger than their actual values. However, in order to have sun-like stars in the universe which can sustain life; it seemed that it had only limited choices.

Big Bounce Model: The universe is expanding with time − the universe continues to decrease in density and fall in temperature, hence the typical energy of each particle is decreased in proportion to the fall in temperature (since the average energy – or speed – of the particles is simply a measure of the temperature of the universe) − and at a certain point of expansion, the density of the universe will be greater than critical density. The universe will lack the repulsive effect of dark energy, then gravity eventually cease the expansion and it start to contract the universe until all the matter in the universe collapses to a one-dimensional point which contains a huge mass in an infinitely small space, where density and gravity become infinite and space-time curves infinitely, and where the laws of science as we know them cease to operate. At first, the rate of contraction will be slow, but the pace gradually pick up − the universe shrink more or less evenly on a gross scale. The temperature will begin to increase exponentially – stars explode and vaporize, and eventually atoms and even nuclei tear apart in a reverse performance of the early stages after the Big Bang

Matter will be under extreme conditions:

Matter + heat + pressure → quark–gluon plasma + photons + other elementary particles

As the universe become compact into a very small volume, slight irregularities become ever more magnified and, in the final stages, the collapse turn to be wildly chaotic, and gravity and the warping of space-time vary immensely depending on the direction the singularity is approached by an in-falling matter. Very close to the singularity, the common laws of physics governing our daily environment are abandoned and the rules of quantum mechanics come into play − the universe continues to contract not to the point of singularity, but to a point (finite critical size, well above the Planck length $\sqrt{\frac{\hbar G}{c^3}}$ = 1.616255(18) × 10^{-35} m) before that where the quantum effects of gravity become so strongly repulsive that the universe rebounds back out, forming a new branch. This implies that the Universe operates sort of like a balloon, where it expands from a single point, grows and grows until it reaches some maximum distance, and then contracts back to the original point, starting the whole process over again.

The Big Bounce is a hypothetical cosmological model for the origin of the present universe. It was originally suggested as a phase of the cyclic model or oscillatory universe interpretation of the Big Bang, where the first cosmological event was the result of the collapse of a previous universe – so in this way the universe would last forever, but would pass through phases of expansion (Big Bang) and contraction (Big Crunch). When it comes to models of the universe, the Big Bang theory is almost accepted as a fact. However, it's still uncertain, and some believe that the universe didn't kick-started with a bang, but a bounce.

Time travel used to be thought of as just science fiction, but Einstein's general theory of relativity allows for the possibility that we could warp space-time so much that you could go off in a rocket and return before you set out.

— Stephen Hawking

It is our responsibility as scientists, knowing the great progress and great value of a satisfactory philosophy of ignorance, the great progress that is the fruit of freedom of thought, to proclaim the value of this freedom, to teach how doubt is not to be feared but welcomed and discussed, and to demand this freedom as our duty to all coming generations.

— Richard Feynman, The Pleasure of Finding Things Out: The Best Short Works of Richard P. Feynman

Gravitational Bohr radius:

If a star is about **1.5 solar masses**, the resulting object formed would be a neutron star.

$$a_{G_0} = \frac{\hbar^2}{Gm_e^2 m_p}$$

$$a_{G_0} \times r_S = \frac{\hbar^2}{Gm_e^2 m_p} \times \frac{2Gm_p}{c^2}$$

$a_{G_0} \times r_S = 2 \times$ (**reduced Compton wavelength of the electron**)^2

$$a_{G_0} \times r_S = \underbrace{\frac{\hbar^2}{Gm_e^2 m_p} \times \frac{2Gm_e}{c^2}}$$

2 × **reduced Compton wavelength of the electron** × **reduced Compton wavelength of the proton**

Because the moon has less mass than Earth, the **force due to gravity** at the moon surface is only about $\frac{1}{6}$ of that on Earth.

The central pressure of the sun is at least 10,000 times greater than that at the center of the earth, which is 3,500 Kilobars.

Historical Landmarks of Particle Physics

Time	Event
1800	**Sir William Herschel** [German-born British astronomer] discovered **infrared radiation**
1801	**Johann Wilhelm Ritter** [German physicist] discovered **UV radiation**
1895	**Victor Schumann** [German physicist and spectroscopist] discovered **vacuum ultraviolet radiation**
1895	**Wilhelm Röntgen** [German mechanical engineer and physicist] discovered **X-ray**s
1897	**Joseph John Thomson** [English physicist] discovered **electron**
1899	**Ernest Rutherford** [New Zealand physicist] discovered **Alpha particle**
1900	**Paul Ulrich Villard** [French chemist and physicist] discovered **Gamma ray**s
1911	**Hans Gelger** and **Ernest Marsden** (working under the direction of **Ernest Rutherford**) conducted an experiment involving alpha particles and gold foil that led to the discovery of the nucleus in atoms
1919	**Ernest Rutherford** discovered **Proton**
1931	**Harold Clayton Urey** [American physical chemist] discovered **Deuteron**
1932	**Sir James Chadwick** [British physicist] discovered **Neutron**

1932	**Carl David Anderson** [American physicist] discovered **Antielectron**
1937	**Seth Neddermeyer**, **Carl D. Anderson**, **J.C. Street** and **E.C. Stevenson** discovered **Muon**
1947	**Cecil Frank Powell's team** discovered **Pion** (predicted by a **Japanese theoretical physicist and the first Japanese Nobel laureate** "**Hideki Yukawa**" in 1935)
1947	**George Dixon Rochester** and **Clifford Charles Butler** discovered **K meson**
1950	**Lambda baryon** was discovered during a study of cosmic-ray interactions
1955	**Owen Chamberlain**, **Emilio Segrè**, **Clyde Wiegand** and **Thomas Ypsilantis** discovered **Antiproton**
1956	**Frederick Reines** and **Clyde Cowan** detected **Electron neutrino** (the "**lightest lepton**" proposed by **an Austrian theoretical physicist and one of the pioneers of quantum physics** "**Wolfgang Pauli**" in 1930 to explain the apparent violation of conservation of energy in beta decay)
1962	**Muon neutrino** was discovered by a group headed by **Leon Max Lederman** [American experimental physicist]
1964	**Xi baryon** was discovered at **Brookhaven National Laboratory** [**United States Department of Energy national laboratory**]
1969	**Partons** (**internal constituents of hadrons**) were observed in deep inelastic scattering experiments between protons and electrons at **Stanford Linear Accelerator Center**. This was eventually associated with the quark model (predicted by **Murray Gell-Mann** and **George Zweig** in 1964) and thus constituted the discovery of the **up quark**, **down quark** and **strange quark**.
1974	**J/psi meson** was discovered by groups headed by **Burton Richter** and **Samuel Ting**. This demonstrated the existence of the **charm quark** (proposed by **James Bjorken** and **Sheldon**

	Glashow in 1964)
1975	**Tau** was discovered by a group headed by **Martin Lewis Perl** [American chemical engineer and physicist]
1977	**Upsilon meson** was discovered at **Fermilab**. This demonstrated the existence of the **bottom quark** (a **third-generation heavy quark** proposed by **Kobayashi** and **Maskawa** in 1973)
1979	**Gluon** was discovered at the electron-positron collider called **PETRA** at **DESY** in Hamburg
1983	**W and Z bosons** were discovered by **Carlo Rubbia**, **Simon van der Meer** and the **CERN UA1 collaboration** (predicted by **Sheldon Glashow**, **Mohammad Abdus Salam** and **Steven Weinberg**)
1995	**Top quark** was discovered at **Fermilab**
1995	**Antihydrogen** was produced and measured by the **Low Energy Antiproton Ring experiment** at CERN
2000	**Quark-gluon fireball** was discovered at CERN
2000	**Tau neutrino** was first observed directly at Fermilab
2011	**Antihelium-4** was produced and measured by the STAR (**Solenoidal Tracker at Relativistic Heavy Ion Collider**) detector
2012	A particle exhibiting most of the predicted characteristics of the **Higgs boson** was discovered by researchers conducting the **Compact Muon Solenoid** and **ATLAS experiments** at CERN's Large Hadron Collider

Exotic hadrons

{ Subatomic particles composed of quarks and gluons − but do not fit into the usual design of hadrons }

Gauge boson → a **Bosonic particle** that mediates the interaction between elementary particles

- photons for electromagnetic interaction
- W and Z intermediate vector bosons for weak interaction
- gravitons for gravitational interaction

3 generations of quarks and leptons + force carriers

Essentially all data we have today agrees with Standard Model

The Standard Model:

- Gauge Invariance
- The Higgs Mechanism
- Symmetries …

Despite all its successes, many questions unanswered by Standard Model – Why 3 generations, particle masses, why do the generations mix …

Are there still smaller particles?

The Large Hadron Collider will address these questions!

Deflection of Starlight during an Eclipse:

- Deflection = 1.74 arcseconds ⟶ General Relativity Prediction
- Deflection = 0.87 arcseconds ⟶ Newtonian Prediction
- Deflection = 0.0 arcseconds ⟶ Both wrong

Observed Deflection ≈ 1.75 arcseconds

Clocks those are deeper in a gravitational potential well run more slowly! – A clock on earth's surface runs 20 milliseconds slow over the course of a year compared to a clock in space.

Possible hints from observation: Accelerating expansion of the Universe

General Relativity and Quantum Mechanics need to be merged.

Coulomb Force Law:

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

- **Double one of the charges**

Force doubles

- **Change sign of one of the charges**

Force changes direction

- **Change sign of both charges**

Force stays the same

- **Double the distance between charges**

Force becomes four times weaker

- **Double both charges**

Force becomes four times stronger

Crises in physics that demanded Quantum Mechanics

Why don't **atoms** disintegrate in nanoseconds?

Why don't hot objects emit more UV light than they do?

The victory of the quantum theory:

String theory is an attempt at a deeper description of nature by thinking of an elementary particle not as a little point but as a little loop of vibrating string.

— Edward Witten

- Semiconductor devices
- Computers, cell phones, etc.
- Lasers
- CD/DVD players, bar-code scanners, surgical applications
- MRI (magnetic resonance imaging) technology
- Nuclear reactors
- Atomic clocks

Nucleus of an atom → 0.00001 times size of atom, 2000 times the mass of the electron.

No isotope of uranium is perfectly stable:

- ^{235}U has a half-life of 704 million years
- ^{238}U has a half-life of 4.5 billion years (age of earth)

Fusion has been accomplished in labs, in big plasma machines called **Tokamaks.**

"My guiding principle is … that the Universe in its essence has always been what it is now: matter, energy, and life have only varied as to shape and position in space."

− Svante Arrhenius 1908

Sun's atmosphere has three main layers:

- the photosphere
- the chromosphere
- the corona

Photodisintegration:

$$^{56}Fe + \gamma \longrightarrow \text{lighter elements}$$

The history of atomism is one of reductionism – the effort to reduce all the operations of nature to a small number of laws governing a small number of primordial objects.

— Leon M. Lederman

Neutron star:

$$\text{Density} \sim 10^{15}\ \text{g cm}^{-3}$$

$$\text{Radius} \sim 10\ \text{km}$$

$$v_{escape} = \sqrt{\frac{2GM}{R}}$$

When $v_{escape} > c$, not even light can escape. The enclosed region becomes a **black hole**.

At the event horizon of the black hole, the gravitational force is infinite, and the time stops.

Evidence for the Dark Matter:

- Gravitational lensing
- Cosmic Microwave Background fluctuations

The Tully-Fisher Scaling Relation for **spiral galaxy:**

$\gamma \approx 4 \longrightarrow$ varies with wavelength.

$$\text{Luminosity} \approx [\text{rotational speed}]^{\gamma}$$

The Scaling Relation for **Elliptical galaxy:**

$$\text{Radius} \approx [\text{velocity dispersion}]^{1.4} \times [\text{mean surface brightness}]^{-0.8}$$

General relativity + **modern particle theories** → at very high energies, there exists forms of matter that create a gravitational repulsion!

1GeV≈ mass energy of a proton

The lifetime of a black hole is given by:

$$t_{ev} = \frac{5120\pi G^2 M^3}{\hbar c^4}$$

$$\boxed{P = \frac{Mc^2}{3t_{ev}}}$$

Rate of energy loss of the black hole

- **Schwarzschild Black holes** → spherical and do not rotate, defined only by their total mass.
- **Reissner-Nordstrom Black holes** → possess mass and charge but do not rotate.
- **Kerr Black holes** → rotate and described only by their mass and angular momentum.
- **Kerr-Nordstrom Black holes** → possess mass and charge, and they rotate.

Four types of hyperons

Lambda hyperons, Sigma Hyperons, Xi Hyperons, Omega Hyperons

Baryon containing one or more strange quarks − but no charm, bottom or top quark

Law of conservation of Lepton-Number: In any process the total lepton number is always conserved.

Law of conservation of baryons number: In any process, the total baryon number is always conserved.

Is the purpose of theoretical physics to be no more than a cataloging of all the things that can happen when particles interact with each other and separate? Or is it to be an understanding at a deeper level in which there are things that are not directly observable (as the underlying quantized fields are) but in terms of which we shall have a more fundamental understanding?

— Julian Schwinger

Objects appear to 'freeze' near a **Black Hole**

The SM is incomplete!

In the SM, there are no particles with the correct properties for Dark Matter

Neutrinos oscillate – they can change flavor as they propagate!

W boson has a mass of 80 GeV/c^2 → Range of weak force is 197 MeV fm / 8×10^5 MeV = 2×10^{-3} fm

Ergosphere

The region wherein the spacetime continuum has been deformed by the black hole to such an extent that we can enter it and leave if we travelled fast enough (but less than at the speed of light)

Spaghettification: In Astrophysics, this term refers to the effect a black hole imposes on a body or matter. The term was proposed by Stephen Hawkins in his book "**A Brief History of Time**", where he compared this effect to spaghettis, saying that you are stretched, and you turn so thin that you break apart, and transform into matter.

The role played by time at the beginning of the universe is, I believe, the final key to removing the need for a Grand Designer, and revealing how the universe created itself. … Time itself must come to a stop. You can't get to a time before the big bang, because there was no time before the big bang. We have finally found something that does not have a cause because there was no time for a cause to exist in. For me this means there is no possibility of a creator because there is no time for a creator to have existed. Since time itself began at the moment of the Big Bang, it was an event that could not have been caused or created by anyone or anything. … So when people ask me if a god created the universe, I tell them the question itself makes no sense. Time didn't exist before the Big Bang, so there is no time for God to make the universe in. It's like asking for directions to the edge of the Earth. The Earth is a sphere. It does not have an edge, so looking for it is a futile exercise.

— Stephen W. Hawking

"The fact that we live at the bottom of a deep gravity well, on the surface of a gas covered planet going around a nuclear fireball 90 million miles away and think this to be normal is obviously some indication of how skewed our perspective tends to be."

— Douglas Adams

Composition of Earth's Atmosphere	
Nitrogen	78.1%
Oxygen	20.9%
Argon	0.9%
Carbon dioxide, Methane, Rare (inert) gases	0.1%

Eddington number:

$$N_{Edd} = 1.57 \times 10^{79} = 136 \times 2^{256}$$

$$\left\{ \textbf{The number of protons in the observable universe} \right\}$$

Hubble radius:

$$r_H = \frac{c}{H}$$

The radius of the observable Universe

where c is the speed of light and H is the **Hubble parameter**.

$$\frac{dr_H}{dt} = -\frac{dH}{dt} \times \frac{c}{H^2}$$

$\frac{dH}{dt} = -H^2 (1+ q_0)$ where q_0 is the **deceleration parameter**

"In other words, our destiny is to become the gods that we once feared and worshipped. Science will give us the means by which we can shape the universe in our image. The question is whether we will have the wisdom of Solomon to accompany this vast celestial power."

— Michio Kaku

$$\frac{dr_H}{dt} = c\,(1+ q_0)$$

Photon gas

A gas consisting of photons − which possess many of the properties of a conventional gas like hydrogen or neon – including pressure, temperature and entropy

$\text{Entropy} = \dfrac{4 \times \text{Internal energy}}{3 \times \text{Temperature}}$	$S = \dfrac{4U}{3T}$
$\text{Enthalpy} = \dfrac{4 \times \text{Internal energy}}{3}$	$H = \dfrac{4U}{3}$
$\text{Helmholtz free energy} = -\dfrac{\text{Internal energy}}{3}$	$A = -\dfrac{U}{3}$
$\text{Pressure} = \dfrac{\text{Internal energy}}{3 \times \text{Volume}}$	$P = \dfrac{U}{3V}$
Gibbs free energy = 0	G = 0

$$H \times A = -\frac{4U^2}{9} \longrightarrow U^2 = -\frac{9\,(H \times A)}{4}$$

$$U = 3PV$$

$$U = \frac{3ST}{4}$$

$$U^2 = \frac{9 \times (PV) \times (ST)}{4}$$

$$-\frac{9\,(H \times A)}{4} = \frac{9 \times (PV) \times (ST)}{4}$$

$$-(H \times A) = (PV) \times (ST)$$

$$H + A = \frac{4U}{3} - \frac{U}{3} = U$$

$$\boxed{PV = \frac{(H + A)}{3}}$$

$$-(H \times A) = (PV) \times (ST)$$

$$-(H \times A) = \frac{(H + A)}{3} \times (ST)$$

Entropic energy of the photon gas $= TS = -\frac{3HA}{(H + A)}$

$$\boxed{U = \frac{3ST}{4} = -\frac{9HA}{4(H + A)}}$$

"Science is opposed to theological dogmas because science is founded on fact. To me, the universe is simply a great machine which never came into being and never will end. The human being is no exception to the natural order. Man, like the universe, is a machine. Nothing enters our minds or determines our actions which is not directly or indirectly a response to stimuli beating upon our sense organs from without. Owing to the similarity of our construction and the sameness of our environment, we respond in like manner to similar stimuli, and from the concordance of our reactions, understanding is born. In the course of ages, mechanisms of infinite complexity are developed, but what we call 'soul' or 'spirit,' is nothing more than the sum of the functionings of the body. When this functioning ceases, the 'soul' or the 'spirit' ceases likewise.

I expressed these ideas long before the behaviorists, led by Pavlov in Russia and by Watson in the United States, proclaimed their new psychology. This apparently mechanistic conception is not antagonistic to an ethical conception of life."

— Nikola Tesla, Inventions, Researches and Writings of Nikola Tesla

This was a form of insurance policy for me. I have done a lot of work on black holes, and it would all be wasted if it turned out that black holes do not exist. But in that case, I would have the consolation of winning my bet, which would win me four years of the magazine Private Eye. If black holes do exist, Kip will get one year of Penthouse. When we made the bet in 1975, we were 80% certain that Cygnus X-1 was a black hole. By now, I would say that we are about 95% certain, but the bet has yet to be settled.

— Stephen Hawking, A Brief History of Time (1988)

$$Mc^2 \times Mc^2 = \frac{\text{Planck force}}{2} \times r_S \times \frac{\text{Planck force}}{3} \times r$$

$$\boxed{Mc^2 = 0.4082 \times \text{Planck force} \times \sqrt{r_S r}}$$

where: $r \rightarrow$ radius of photon orbit and $r_S \rightarrow$ Schwarzschild radius of the Black Hole.

"It is possible that these millions of suns, along with thousands of millions more we cannot see, make up altogether but a globule of blood or lymph in the veins of an animal, of a minute insect, hatched in a world of whose vastness we can frame no conception, but which nevertheless would itself, in proportion to some other world, be no more than a speck of dust."

— Anatole France, The Garden of Epicurus

Penrose Singularity Theorem

Inside every black hole there is a singularity – a place with infinite gravity

Singularity → place where all the known laws of physics breaks down

Price's Theorem

Whatever can be radiated is radiated

Naked singularity

A hypothetical gravitational singularity without an event horizon

The **total electric charge** Q and the **total angular momentum** J of a black hole of **mass** M is expected to satisfy the condition:

$$\boxed{Q^2 + \frac{J^2}{M^2} \leq M^2}$$

- **Kerr-Newman Black Hole:** A rotating charged black hole.
- **Kerr Black Hole:** A rotating black hole.

Hoop Conjecture

When the mass M of a system (in 4 dimensions) gets compacted into a region whose circumference in every direction has radius $R \leq r_S$, **a horizon** – and thus a Black Hole forms.

The basic structure of a **black hole** consists of a singularity hidden by an event horizon. Within the event horizon, the escape speed > speed of light and a particle is trapped forever. Outside the event horizon, escape speed < speed of light and the particle is able to escape.

The circumference C of a sphere of radius r_S is:

$$C = 2\pi r_S = \frac{4\pi GM}{c^2}$$

$$\boxed{Mc^2 = \frac{\text{Planck force}}{4\pi} \times C}$$

Eternal black holes are the ultimate cosmic safes

↓

It's as if we just put the information inside a box and at the end we still have the box

Blandford–Znajek process

A mechanism which uses magnetized plasma to extract energy from a rotating black hole

Yarkovsky Effect

A force acting on a rotating body in space caused by the anisotropic emission of thermal photons − which carry momentum

Brown dwarfs which are sometimes called "failed stars" usually have a mass less than 0.075 that of the Sun − or roughly 75 times that of Jupiter.

Bondi-Gold Steady-State Cosmological Model: A cosmological model that assumes the perfect cosmological principle, so that the Hubble constant H is truly a constant not only in all directions, but at all time. The experimental objection to this theory is the cosmic background radiation.

Hoyle-Narlikar Cosmological Model

A view that the universe is always expanding but maintaining a constant average density, with matter being continuously created to form new stars and galaxies at the same rate that old ones become unobservable as a consequence of their increasing distance and velocity of recession.

Perfect Cosmological Principle: The universe is homogeneous and isotropic in space and time

"Whether in the intellectual pursuits of science or in the mystical pursuits of the spirit, the light beckons ahead, and the purpose surging in our nature responds."

— **Arthur Eddington**, The Nature of the Physical World

Planck Occupancy:

In terms of frequency,

$$j_\nu = \frac{2h\upsilon^3}{c^2}$$

and in terms of wavelength

$$j_\lambda = \frac{2hc^2}{\lambda^5} = \frac{\text{First radiation constant}}{\pi\lambda^5}$$

Spectral radiance of electromagnetic radiation as a function of wavelength from a black body at a given temperature is given by:

$$B_\lambda(T) = \frac{2ck_BT}{\lambda^4}$$

$$B_\lambda(T) = \frac{\text{First radiation constant} \times T}{\text{Second radiation constant} \times \pi \times \lambda^4}$$

In the **Reissner–Nordström metric**, which describes electrically charged but non-rotating black holes, there is a quantity r_q, defined by:

$$r_q = \sqrt{\frac{e^2 G}{4\pi\varepsilon_0 c^4}}$$

where $e = -1.602 \times 10^{-19}$ C is the electron charge and ε_0 is the vacuum permittivity.

$$r_q = \frac{e \times L_{Planck}}{q_{Planck}} = \sqrt{\alpha}\ L_{Planck}$$

"In 5 billion years, the expansion of the universe will have progressed to the point where all other galaxies will have receded beyond detection. Indeed, they will be receding faster than the speed of light, so detection will be impossible. Future civilizations will discover science and all its laws, and never know about other galaxies or the cosmic background radiation. They will inevitably come to the wrong conclusion about the universe......We live in a special time, the only time, where we can observationally verify that we live in a special time."

— Lawrence M. Krauss

A Universe from Nothing: Why There Is Something Rather Than Nothing

Both Bohr and Einstein were subtle men. Einstein tried very hard to show that quantum mechanics was inconsistent; Bohr, however, was always able to counter his arguments. But in his final attack Einstein pointed to something so deep, so counterintuitive, so troubling, and yet so exciting, that at the beginning of the twenty first century it has returned to fascinate theoretical physicists. Bohr's only answer to Einstein's last great discovery—the discovery of entanglement—was to ignore it.

— Leonard Susskind

A Planck particle, named after German theoretical physicist **Max Planck** **(whose discovery of energy quanta won him the Nobel Prize in Physics in 1918)**, is a hypothetical particle defined as a tiny black hole whose Compton wavelength is equal to its Schwarzschild radius.

$$\frac{h}{mc} = \frac{2Gm}{c^2}$$

$$\boxed{m = \sqrt{\frac{hc}{2G}}}$$

$$\left\{ m = \sqrt{\pi} \times \text{Planck mass} \right\}$$

Its radius will be the Compton wavelength:

$$r = \frac{h}{mc} = \sqrt{\frac{2hG}{c^3}}$$

$$\left\{ r = 2 \times \sqrt{\pi} \times \text{Planck length} \right\}$$

$$m \times r = \frac{h}{c} \quad \text{or} \quad r = \frac{h}{mc}$$

$$mc^2 = \frac{hc}{r} = \frac{q_{Planck}^2}{2\varepsilon_0 r}$$

$$A_2 + h\upsilon \rightarrow A + A$$

$$\boxed{h\upsilon = E_B + KE}$$

- $h\upsilon \rightarrow$ Energy of the absorbed photon
- $E_B \rightarrow$ Bond dissociation energy (the energy required to break a chemical bond between two atoms)
- $KE \rightarrow$ Kinetic energy of the liberated atoms

If the kinetic energy of a thermal particle were equal in magnitude to the potential energy, then it could escape from the planet surface:

$$\frac{3k_BT}{2} = \frac{GMm}{R}$$

$$\boxed{T = \frac{2GMm}{3k_BR}}$$

If the satellite moves in circular motion, then the net centripetal force acting upon this orbiting satellite is given by:

$$F = \frac{mv^2}{R}$$

This net centripetal force is the result of the gravitational force that attracts the satellite towards the central body and can be represented as:

$$F_G = \frac{GMm}{R^2}$$

Since $F_G = F$:

$$F_G^2 = \frac{mv^2}{R} \times \frac{GMm}{R^2}$$

$$F_G = p\sqrt{\frac{GM}{R^3}}$$

where: p → momentum of the satellite. The gravitational acceleration experienced by the satellite is given by:

$$a = \frac{GM}{R^2}$$

The gravitational acceleration depends on only the mass of the gravitating body M and the distance R from it.

$$da = -\frac{2GM}{R^3} \times dR$$

The tidal acceleration is the differential acceleration between two points due to the difference in gravitational acceleration caused by their differing distances from a body. So the tidal acceleration between two points separated by a distance dR << R is given by:

$$\boxed{a_{tidal} = - da}$$

$$a_{tidal} = \frac{2GM}{R^3} \times dR$$

$$F_G = p\sqrt{\frac{GM}{R^3}} = p\sqrt{\frac{a_{tidal}}{2dR}}$$

$$\boxed{F_G = p\sqrt{\frac{a_{tidal}}{2dR}}}$$

"Three principles — the conformability of nature to herself, the applicability of the criterion of simplicity, and the "unreasonable effectiveness" of certain parts of mathematics in describing physical reality — are thus consequences of the underlying law of the elementary particles and their interactions. Those three principles need not be assumed as separate metaphysical postulates. Instead, they are emergent properties of the fundamental laws of physics."

−Murray Gell-Mann

"people... think mathematics is... the most general formal abstract system... [but]... that's not how it originally started out. In ancient Babylon... there was arithmetic for commerce... and geometry for land surveying... [Our] mathematics is the... generalization of arithmetic and geometry plus one key methodological idea: one can make theorems and [their] abstract proofs... if one arbitrarily looks at formal systems will they... have the character of [our] mathematics? Will they have the feature that most of the things one asks about one can prove theorems about? I think in both cases the answer is no."

−Stephen Wolfram

"I have sometimes wondered whether a brain like von Neumann's does not indicate a species superior to that of man."

–Hans Bethe

When the legendary Indian mathematician Srinivasa Ramanujan was 16, he obtained a copy of the book "A Synopsis of Elementary Results in Pure and Applied Mathematics" by G. S. Carr, which he studied in great detail.

In the course of a single year, his studies "started to mutate seamlessly" into his own research.

It is almost incomprehensible how the young Ramanujan jumped from the basic problems in the "Synopsis" book to the advanced mathematics contained in his letters to G.H. Hardy.

The German theoretical physicist Werner Heisenberg, one of the founding fathers of quantum mechanics, had a very complicated relationship with his brother Erwin. Both were extremely ambitious and competitive.

This (often unhealthy) spirit of competition was incited by their father August, who challenged the brothers to compete in mathematics. Werner, the younger brother, noticed his superior mathematical abilities, and this led him to develop a particular interest in the subject.

August did the same with music training. Erwin studied the violin. Werner studied the piano (after studying the cello) and even contemplated becoming a professional pianist.

As told by Leonard Mlodinow, in this excellent book "The Upright Thinkers," the intense competition "culminated in a bloody fight in which they beat each other with wooden chairs and then called a truce."

After that, the brothers never spoke again.

In the late 1670s, Newton and Robert Hooke exchanged letters with diagrams showing what would happen to a ball dropped from the surface of a void Earth. Newton's first diagram showed a ball spiraling to the center of the Earth (1st diagram). This was wrong.

Though Hooke vowed to keep their letters private, he openly contradicted Newton. He argued, correctly, that the ball would act as an orbiting body: "My theory supposes the ball continues to fall and rise perhaps in an ellipse" (2nd diagram).

Hooke didn't have Newton's mathematical powers but had great physical intuition.

Newton replied with 2 diagrams: one where the attractive force was constant (3rd diagram) and one where gravity was stronger near the center. He then explained that the calculations were made using "the method of indivisibles," i.e., calculus.

But as Gleick writes in his Newton biography:
"Hooke [wasn't] the 1st to propose the inverse-square law [...]; anyway, for him, it was a guess[...] like countless other guesses at the nature of the world. For Newton, it was embedded, linked, inevitable. Each part of Newton's growing system reinforced the others. In its mutual dependency lay its strength."

- **Hideki Yukawa** proposed the pi meson's existence to explain how protons and neutrons interact in the nucleus. His prediction was measured in 1947, and in 1949 he received the Nobel Prize.
- **Homi Bhabha** explained the absorption features and electron shower production in cosmic rays, performed the first calculation of the cross-section of electron-positron scattering, and is considered the "father of the Indian nuclear program."
- **John Wheeler** revived the interest in general relativity in the US after the war, explained (with Bohr) the principles behind nuclear fission, and developed the concept of the Breit–Wheeler process. He also invented the terms "black hole," "quantum foam," "wormhole," and "it from bit."

When Paul Dirac, one of the greatest physicists of the last century, was developing quantum mechanics, he introduced an unrigorous mathematical function: the Dirac delta function.

Quoting Dirac's biographer Graham Farmelo:

"[The function] resembles the outer edge of the finest of needles, pointing vertically upwards from its base. Away from that base, [its] numerical value is zero, but its height is such that the area enclosed between the perimeter and the base is one unit."

Tough Dirac acknowledged that the function was unrigorous, he noted it could be used 'as though it were a proper function for practically all purposes in quantum mechanics.'

Later, he remarked that his study of engineering led him to it:

"I think it was that sort of training that gave me the idea of the delta function because when you think of load in engineering structures, sometimes you have a distributed load, and sometimes you have a concentrated load at the point. It is [...] the same whether you have a concentrated load or a distributed one, but you use somewhat different equations in the two cases. [I]t's only to unify these two things which sort of led to the delta function."

In the essay "Thursday Afternoons," George Anastaplo, a Professor at the Loyola University Chicago School of Law, described a conversation with the legendary Indian physicist Subrahmanyan Chandrasekhar. At that time, Chandrasekhar was writing "Newton's Principia for the Common Reader," which, quoting Anastaplo, was "the most serious reading of [Newton's] Principia by a first-rate scientist in the century."

Anastaplo writes:

"I then asked Mr. Chandrasekhar, 'I hear you are studying Newton these days. Are you finding him as interesting as you had hoped he would be?'

He replied that somebody else who had heard he was studying Newton had recently asked him, 'How do you feel?' And (Mr. Chandrasekhar continued) he had answered:

'I am like a small boy going to the zoo for the first time and seeing a lion.'"

In the talk "Shakespeare, Newton, and Beethoven" in April 1975 at the University of Chicago, Chandrasekhar made the following remark:
"It is only when we observe the scale of Newton's achievement that comparisons, which have sometimes been made with other men of science, appear altogether inappropriate both with respect to Newton and with respect to the others."

The Norwegian mathematician **Niels Henrik Abel** died at the tragically young age of 26 years old of tuberculosis.

During his short life, he suffered from poverty, starvation, and painful frustration while trying hopelessly to find a university teaching position.

Abel made a multitude of fundamental contributions to various fields of mathematics, the most famous one probably being the proof of the impossibility of solving quintic equations in terms of radicals (independently of the work of the French mathematician Évariste Galois). Today, anyone who reads books on advanced mathematics will find his name in several theorems and theories.

The great French mathematician Charles Hermite said about Abel:

"He has left mathematicians something to keep them busy for five hundred years."

Abel made most of his enormous body of contributions in only six or seven years of his life.

The American mathematician, philosopher (and originator of cybernetics), **Norbert Wiener**, was known for sleeping through talks and then suddenly awakening up at the end of the talk and making relevant observations.

Once, the American mathematician (and co-founder of category theory) Saunders MacLane was giving a talk about abstract algebra. In the end, MacLane said loudly, directing his voice toward Wiener, who was sound asleep:

"Thus, we see that the subject has absolutely nothing to do with ergodic theory."

Wiener promptly woke up and started talking about ergodic theory!

The Prussian polymath, geographer, and naturalist **Alexander von Humboldt** asked the great French mathematician and physicist Pierre-Simon de Laplace who he considered to be the greatest mathematician in Germany.

Laplace replied:

"Johann Friedrich Pfaff."

Pfaff was "one of Germany's most eminent mathematicians during the 19th century".

von Humboldt was quite surprised by the answer and asked:

"But what about [the German mathematician and physicist Carl Friedrich] Gauss?"

Laplace then explained:

"Gauss is the greatest mathematician IN THE WORLD."

The great polymath Leibniz was an indefatigable worker. His secretary, Johann Georg Eckhart described some of his working habits:

> "Normally he first went to bed at one or two in the morning. Often he just slept in his chair, and would be awake again and ready to go at six or seven in the morning. Sometimes he would remain several days in his chair. I believe that this is what led to his having an open sore on his right leg. This caused him difficulty in walking; he tried to remedy it, but only by putting blotting paper on it."
>
> "Later, to reduce the pain and to make the nerves insensitive he had a number of wooden clamps made, and these he screwed onto himself wherever he felt pain. I suspect that by doing this he so damaged his nerves that eventually he could no longer use his feet and had to stay in bed."

In 1876, the French mathematician François Lucas proved, using methods he developed, that $2^{67} - 1$ is not a prime number (i.e., it can be factorized), but he couldn't find the values of the factors. Some years later, in the 1903 meeting of the American Mathematical Society, an interesting episode happened.

The American mathematician Frank Nelson Cole announced a talk with the title "On the Factorization of Large Numbers." When the lecture started, Cole went to the chalkboard and silently calculated the value of $2^{67} - 1$, which is 147,573,952,589,676,412,927.

He then moved to an empty part of the chalkboard, wrote the product 193,707,721 × 761,838,257,287, and performed the calculation, which turned out to be equal to the number he had previously written i.e. $2^{67} - 1$. He then silently returned to his seat. Not one word was spoken during the presentation, which took around one hour.

The audience greeted Cole's presentation "with a standing ovation." It seems that this was the only talk during an American Mathematical Society meeting where the audience applauded.

In a famous letter to **Jost Winteler** the great scientist Albert Einstein wrote:

"Unthinking respect for authority is the greatest enemy of truth."

It is a well-known fact that Albert Einstein was slow in learning how to talk. He started talking when he was (more or less) four years old. Also, whenever he had to speak something, he would first try it out (on himself) by murmuring it softly until it he was sure it sounded good enough to express it aloud.

Quoting his younger sister Maja "Every sentence he uttered... no matter how routine, he repeated to himself softly, moving his lips." In more technical terms Einstein had a weak form of echolalia (which led the family maid to dub him "the dopey one"). The family was very concerned, "He had such difficulty with language that those around him feared he would never learn," according to Maja.

Since very young, he was defiant toward authority, leading the school headmaster to declare that he would "never amount to anything." However, these peculiarities arguably helped to turn him into the genius that he was. First, due to his insubordination to authority, he challenged traditional wisdom. Second, according to Einstein himself, his slow verbal progress made him inquisitive about ordinary things that adults take for granted and well-trained academic professors never consider.

"If others would but reflect on mathematical truths as deeply and as continuously as I have, they would make my discoveries."

–Johann Carl Friedrich Gauss

Ettore Majorana was a brilliant physicist who mysteriously vanished in 1938. According to the Nobelist Enrico Fermi:

"There are [many] categories of scientists; those of 2nd or 3rd rank [...] never get very far. Then there is the 1st rank, those who make important discoveries [...]. But then there are the geniuses, like Galileo and Newton. Majorana was one of these."

Indeed, according to colleagues, his grasp of physics was rivaled by few others.

He published his first paper as an undergrad. A flurry of important papers followed. However, according to the CERN Courier Magazine, "[He was] a genius who looked on his work as completely banal: once a problem was solved, [he] did his best to leave no trace of his brilliance."

At some point in his life, he started to suffer from nervous exhaustion, became a hermit, and shut himself off from the world.

Theories about his disappearance abound: suicide, fleeing to South America, entering a monastery, kidnapping or murder, etc.

Fermi told his wife, "Ettore was too intelligent. If he has decided to disappear, no-one will be able to find him."

In the spring of 1955, not long before he died (April 18), Einstein entered the hospital because his heart was beginning to fail. His friend Abraham Pais recounted, "[A few days before Einstein died] on April 15, he called his secretary. He wanted his fountain pen, his glasses, and his latest piece of notes. And Einstein, of course, knew that his time was imminent, to go. But he wanted a calculator. And he sat down and began to calculate. That is a story that makes you shudder. It makes me shudder. He knew he would not see whatever would come out of these calculations by way of achievement. It didn't matter to him."

Milestones in the History of Weak Interactions

- 1896 Discovery of radioactivity (Becquerel)
- 1930 Birth of neutrino (Pauli)
- 1934 Theory of beta decay (Fermi)
- 1939 Theory of thermonuclear fusion in the Sun (Bethe and Wesszacker)
- 1954 Nonabelian gauge theory (Yang and Mills)
- 1956 Discovery of parity violation (Lee, Yang and Wu)
- 1956 Detection of the neutrino (Cowan and Reines)
- 1957 Discovery of $V - A$ (Sudarshan, Marshak and others)
- 1957 Current × current formulation (Feynman and Gell-mann)
- 1961 $SU(2) \times U(1)$ as the electroweak group (Glashow)
- 1964 Discovery of CP violation (Cronin and Fitch)
- 1964 Abelian Higgs mechanism (Higgs and others)
- 1967 Nonabelian Higgs − Kibble mechanism (Kibble)
- 1967 Electroweak theory (Salam and Weinberg)
- 1972 Renormalizability of EW theory (t'Hooft and Veltman)
- 1973 Discovery of neutral current (55 physicists at CERN)
- 1973 CKM phase for CP violation (Kobayashi and Maskawa)
- 1982 Discovery of W and Z (Rubbia and van der Meer)
- 1992 Precision tests of EW theory (International Collaboration at CERN)
- 1998 Discovery of neutrino mass (Davis, Koshiba and others)
- 2002 Experimental proof of thermonuclear fusion in the Sun (SNO)
- 2007 Verification of CKM theory of CP violation (KEK, Stanford)
- 2012 Discovery of Higgs boson (ATLAS and CMS Collaborations, CERN)

Black hole starship

↓

An interstellar spacecraft powered by the radiation emitted by a tiny, manmade black hole

A black hole to be used in interstellar space travel needs to meet 5 criteria:

- Should possess a long enough lifespan to be useful.
- Should be powerful enough to accelerate itself up to a reasonable fraction of the speed of light in a reasonable amount of time.
- Should be small enough that we can access the energy to make it.
- Should be large enough that we can focus the energy to make it.
- Should possess mass comparable to a starship.

Non relativistic Bohr Model:

$$F = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

When a strong electric field operates in a vacuum, the latter undergoes a polarization (**vacuum polarization**), which means a spontaneous creation of matter, more specifically, of particle-antiparticle pairs.

If no matter falls into the black hole, its mass and its event horizon gradually shrink. The black hole evaporation process speeds up as the black hole becomes smaller.

$$\boxed{F = \frac{m_e v^2}{r}}$$

$$F^2 = \frac{Ze^2}{4\pi\varepsilon_0 r^2} \times \frac{m_e v^2}{r}$$

$$\left\{ \sqrt{\frac{m_e e^2}{4\pi\varepsilon_0}} \rightarrow \text{Constant} \right\}$$

$$\boxed{F \propto v\sqrt{\frac{Z}{r^3}}}$$

$$\sqrt{\frac{m_e e^2}{4\pi\varepsilon_0}} = \frac{h}{\text{Compton wavelength of the electron}\sqrt{\text{classical electron radius}}}$$

$$F = \frac{hv}{\text{Compton wavelength of the electron}\sqrt{\text{classical electron radius}}}\sqrt{\frac{Z}{r^3}}$$

Relativistic case:

$$dE_K = F \times dx$$

$$\boxed{\frac{d(mc^2 - m_e c^2)}{dt} = F \times v}$$

A black star is created when matter compresses at a rate significantly less than the free fall velocity of a hypothetical particle falling to the center of its star

$$\frac{dmc^2}{dt} = \frac{Ze^2}{4\pi\varepsilon_0 r^2} \times v$$

$$\boxed{\frac{dm}{dt} \propto \frac{Zv}{r^2}}$$

A **black hole** with 3 times the mass of the sun would have a diameter of about 18 km − comparable to the length of Manhattan.

The compactness of a star is given by:

$$\boxed{\text{Compactness} = \frac{GM}{c^2 R}}$$

$$Mc^2 = \text{Planck force} \times \textbf{Compactness} \times R$$

$$U = -\frac{3GM^2}{5R}$$

$$\frac{U}{Mc^2} = -\frac{3 \times \text{Compactness}}{5}$$

Dark-energy star

A hypothetical compact astrophysical object formed not by stellar collapse but by fluctuations of space-time itself − like blobs of liquid condensing spontaneously out of a cooling gas

As the matter falls through the **event horizon**, the in-falling matter is converted into dark energy. The space within the event horizon would end up with the negative gravity of dark energy − which may cause matter to bounce back out again.

Gravastar

[Gravitational Vacuum Condensate Star]

↓

As a star collapses further – past the point of neutron degeneracy − the particles fall into a Bose-Einstein state where all of the collapsing material of the entire star reaches absolute zero and is able to get very compact. As a result, it acts as a giant atom composed of bosons.

Tidal forces on classical test bodies falling through the event horizon are arbitrarily weak and proportional to $\frac{M}{r_S^2}$

Inside the sun, we have $N_{protons}$ (say), which can be calculated as follows:

$$N_{protons} = \frac{\text{mass of the sun}}{\text{mass of the proton}}$$

$$N_{protons} = 1.2 \times 10^{57}$$

Hence, the number of **fusion reactions** inside the sun is:

$$N_{reactions} \approx \frac{1.2 \times 10^{57}}{4} \approx 3\times10^{56}$$

Karl Weierstrass was one of the great mathematicians in history. However, he was a late bloomer and was almost 40 when he finally came to the spotlight.

His father wanted him to study finance. He reacted to the struggle of either accepting his father's wish or studying mathematics by pretending not to care about his studies, spending all his university years either fencing or drinking. Having eventually decided to become a mathematician, he did not study the subjects he was enrolled for, leaving without a degree. His father then decided he should become a school teacher. In 1839 he attended C. Gudermann's lectures, and in the teacher's examination, at his own request, he was given an unsolved question and presented his original research as an answer. Gudermann wrote, "... [his answer is] of equal rank with the discoverers who were crowned with glory."

Weierstrass began his teaching career in 1842, and in 1854 he published his first famous paper. He was finally noticed. He then started a stellar career, and today is known as the "father of modern analysis," one of the most important fields of mathematics.

Time required for a white dwarf to reach this state is calculated to be longer than the current age of the universe (**13.8 billion years**)

Black dwarf

Theoretical stellar remnant, specifically a white dwarf that has cooled sufficiently that it no longer emits significant heat or light.

The radius of curvature of space of the **Einstein static universe** is equal to

$$R_E = \frac{c}{\sqrt{4\pi G\rho}} = \frac{1}{2c}\sqrt{\frac{\text{Planck force}}{\pi\rho}}$$

where G is Newtonian gravitational constant, ρ is the energy density of the matter in the universe and c is the speed of light.

Fermi temperature:

$$T_F = \frac{E_F}{k_B}$$

Fermi velocity:

$$v_F = \frac{p_F}{m_0}$$

Fermi momentum:

$$p_F = \sqrt{2m_0E_F} = \sqrt{2m_0k_BT_F}$$

Fermi wavelength:

$$\lambda_F = \frac{h}{\sqrt{2m_0k_BT_F}} = \sqrt{\frac{\text{Compton wavelength of the fermion} \times \text{second radiation constant}}{2 \times \text{Fermi temperature}}}$$

In his wonderful biography about Einstein, Walter Isaacson relates a fascinating story:

"Einstein and his wife were at a dinner party when a guest expressed a belief in astrology. Einstein ridiculed the notion as pure superstition. Another guest [...] similarly disparaged religion [...]. [T]he host tried to silence him by invoking the fact that even Einstein harbored religious beliefs."

The skeptical guest found it impossible to believe and asked Einstein "if he was, in fact, religious."

Einstein's response was as surprising (at least to the guest) as it was profound. He said:

"Yes, you can call it that... Try and penetrate with our limited means the secrets of nature, and you will find that, behind all the discernible laws and connections, there remains something subtle, intangible, and inexplicable. Veneration for this force beyond anything that we can comprehend is my religion. To that extent, I am, in fact, religious."

That "something subtle, intangible, and inexplicable" he refers to is what makes me love science so deeply.

When **Blaise Pascal** was a young boy, his father determined his son should study languages instead of mathematics. That stimulated Pascal's interest in math, which he secretively began to study. In a short time, his extraordinary mathematical talents flourished. He found several properties of geometric figures (he probably did this by folding a paper triangle, as shown in the picture below). When his father found out about Pascal's private mathematical explorations, he was naturally impressed and gave him a copy of "The Elements" by Euclides. Pascal quickly mastered it. At fourteen, Pascal was already joining a weekly gathering of French mathematicians. These gatherings eventually became the French Academy. At 16, he wrote an article on conic sections that the great French philosopher and mathematician Descartes thought the boy couldn't have done. At 18, he invented the first calculating machine. At 23, after reading about the Italian physicist and mathematician Evangelista Torricelli's work on atmospheric pressure, he began to apply himself to physics, eventually discovering the now-famous Pascal's principle of hydrodynamics.

The great physics titans Einstein and Bohr had a famous series of public debates about quantum mechanics (QM) where Einstein invented thought experiments to challenge the Copenhagen interpretation of QM.

At the 1930 Congress of Solvay, their discussion was about the indeterminacy between energy and time, according to which, loosely speaking, a particle associated with a wave of different frequencies should not possess a well-defined energy.

Einstein conceived a thought experiment that apparently couldn't be refused. The physicist Leo Rosenfeld described the situation:

"It was a real shock for Bohr...who, at first, could not think of a solution [...] [H]e couldn't come up with any way to resolve the paradox. I will never forget the image of the two antagonists as they left the club: Einstein, with his tall and commanding figure, who walked tranquilly, with a mildly ironic smile, and Bohr who trotted along beside him, full of excitement...".

Bohr eventually found a problem with Einstein's thought experiment. The irony was that Bohr's solution used one of Einstein's own discoveries, the gravitational redshift.

In the end, the consensus was that Bohr was victorious.

In his 2005 essay "A Short Talk about Richard Feynman," the British-American computer scientist, physicist, and businessman, Stephen Wolfram makes the following remarks about Feynman:

"Some scientists (myself probably included) are driven by the ambition to build grand intellectual edifices. I think Feynman - at least in the years I knew him - was much more driven by the pure pleasure of actually doing the science. He seemed to like best to spend his time figuring things out and calculating. And he was a great calculator. All around perhaps the best human calculator there's ever been... I always found it incredible. He would start with some problem, and fill up pages with calculations. And at the end of it, he would actually get the right answer! But he usually wasn't satisfied with that. Once he'd gotten the answer, he'd go back and try to figure out why it was obvious."

Electron Capture

$$\text{Proton} + \text{electron} \rightarrow \text{neutron}$$

When an electron is absorbed by the Nucleus, a nuclear proton becomes a neutron. Thus in this process Z is reduced to (Z−1) and N is increased by (N+1).

Before absorption of electron:

- Nuclear charge = + Ze
- Nuclear volume = $\frac{4\pi R_0^3 A}{3} = \frac{4\pi R_0^3}{3}$ [N+ Z]

After absorption of electron:

- Nuclear charge = + (Z−1) e
- Nuclear volume = $\frac{4\pi R_0^3 A}{3} = \frac{4\pi R_0^3}{3}$ [(N +1) + (Z−1)] = $\frac{4\pi R_0^3}{3}$ [N+ Z]

Weak interaction is a universal property of all elementary particles.

Discovery of matter-antimatter asymmetry by Cronin and Fitch in the weak decays of neutral kaons is of fundamental importance since it can explain why the Universe contains only matter.

- **Cosmic-ray** produced neutrinos were detected in the underground laboratory at Kolar Gold Fields in 1965.
- **Yang–Mills theory** which is a generalization of Maxwell's electrodynamics provided the framework for the electroweak theory.
- The **CERN experiments** discovered the W and Z bosons exactly at the masses predicted by electroweak theory.
- Discovery of the **Higgs boson** in 2012 established electroweak theory.
- At the fundamental level, weak interaction acts on the quarks and leptons.
- We still do not know whether neutrino is a Dirac particle or a **Majorana particle**.

Black hole

↓

Event Horizon + Singularity

FuzzBall

↓

No Event Horizon

No Singularity

All the mass of a black hole is not getting sucked into the center

When the black hole **(a cosmic object of extremely intense gravity from which even photon cannot escape)** tries to squeeze things to a point, the things get stretched into the strings − and the strings start to stretch and expand and it becomes the fuzzball that expands to fill up the entirety of the black hole. A fuzzball is so insanely dense that we drop anything into it, and it stays in there, but it takes an insane amount of time for the thing to come out again

The larger the black hole, the more energy that goes in, and the bigger the fuzzball becomes

Non relativistic case:

When an electron moves in a circular path in a magnetic field of strength B:

$$F = \frac{m_e v^2}{r} = Bev$$

$$\boxed{F^2 = \frac{m_e v^2}{r} \times Bev}$$

$$\left\{ F \propto \frac{Bv^3}{r} \right\}$$

$m_e e \longrightarrow$ **constant**

Relativistic case:

$$\frac{dmc^2}{dt} = Fv = Bev^2$$

$$\left\{ \frac{dm}{dt} \propto Bv^2 \right\}$$

$\frac{e}{c^2} \longrightarrow$ **constant**

Black hole firewall

↓

A **hypothetical phenomenon** where an observer falling into a black hole encounters high-energy quanta at (or near) the event horizon

Magnetospheric Eternally Collapsing Objects

When the collapsing object gets super dense and hot, the radiation it produces creates outward pressure that halts its collapse, leaving it as a hot ball of plasma rather than a black hole.

White Dwarf Composition

Mass of white dwarf < 0.45 Solar mass → Helium

0.45 Solar mass < **Mass of white dwarf** < 1.2 Solar mass → Carbon-Oxygen

1.2 Solar mass < **Mass of white dwarf** < 1.4 Solar mass → Oxygen-Neon-Magnesium

Thermonuclear fusion takes place in relatively hot and dilute plasmas inside stars where high-energetic nuclei contribute to the fusion process.	**Pycnonuclear fusion** occurs at rather high densities where mostly low-energetic nuclei contribute to the fusion process.

$$\textbf{Hubble time} = \frac{1}{H}$$

$$\textbf{Hubble radius} = \frac{c}{H}$$

$$c = \frac{\text{Hubble radius}}{\text{Hubble time}}$$

Respiration:

$C_6H_{12}O_6$ (organic matter) + $6O_2$ → $6CO_2$ + $6H_2O$ + energy

Photosynthesis:

Energy (sunlight) + $6CO_2$ + H_2O → $C_6H_{12}O_6$ + $6O_2$

$T_{threshold_{proton}}$ ⟶ Threshold temperature below which the proton is effectively removed from the universe

$T_{threshold_{electron}}$ ⟶ Threshold temperature below which the electron is effectively removed from the universe

$$\frac{T_{threshold_{proton}}}{T_{threshold_{electron}}} = \frac{\text{proton mass}}{\text{electron mass}} = \frac{\text{Bohr magneton}}{\text{Nuclear magneton}}$$

$$\frac{T_{threshold_{proton}}}{T_{threshold_{electron}}} = \sqrt{\frac{\text{proton gravitational coupling constant}}{\text{electron gravitational coupling constant}}}$$

Valence quarks

↓

Quarks that determine the most important properties of a Hadron such as mass, momentum, electric charge and spin

For the proton, the **valance quarks** are one down quark and two up quarks.

Number of protons that make up one Solar mass:

$$N_{protons} = \frac{\text{Solar mass}}{\text{proton mass}} = \frac{1.9891 \times 10^{30}\text{kg}}{1.6726219 \times 10^{-27}\text{ kg}} = 1.18921078338 \times 10^{57}$$

$1.18921078338 \times 10^{57}$ **protons make up one Solar mass**

Number of electrons that make up one Solar mass:

$$N_{electrons} = \frac{\text{Solar mass}}{\text{electron mass}} = \frac{1.9891 \times 10^{30}\text{kg}}{9.10938356 \times 10^{-31}\text{ kg}} = 2.1835725621 \times 10^{60}$$

$2.1835725621 \times 10^{60}$ **electrons make up one Solar mass**

Number of neutrons that make up one Solar mass:

$$N_{protons} = \frac{\text{Solar mass}}{\text{neutron mass}} = \frac{1.9891 \times 10^{30}\text{kg}}{1.67493 \times 10^{-27}\text{ kg}} = 1.18757201794 \times 10^{57}$$

$1.18757201794 \times 10^{57}$ **neutrons make up one Solar mass**

Number of Planck masses that make up one Solar mass:

$$N_{planck\ mass} = \frac{\text{Solar mass}}{\text{Planck mass}} = \frac{1.9891 \times 10^{30}\text{kg}}{2.176434 \times 10^{-8}\text{ kg}} = 9.1392617465 \times 10^{37}$$

$9.1392617465 \times 10^{37}$ **Planck masses make up one Solar mass**

Lamarckian evolutionary theory

Organisms changed out of need and after a change in the environment

Darwinian evolutionary theory

Organisms changed by chance when they were born and before there was a change in the environment

One abcoulomb = 10 coulombs

Above-threshold ionization

{ An atom is ionized with more than the required number of energetic photons }

$$E_s = (n + s)\,\hbar\omega - W$$

electron kinetic energy of the peak corresponding to additional photons being absorbed

Ionization energy of an atom

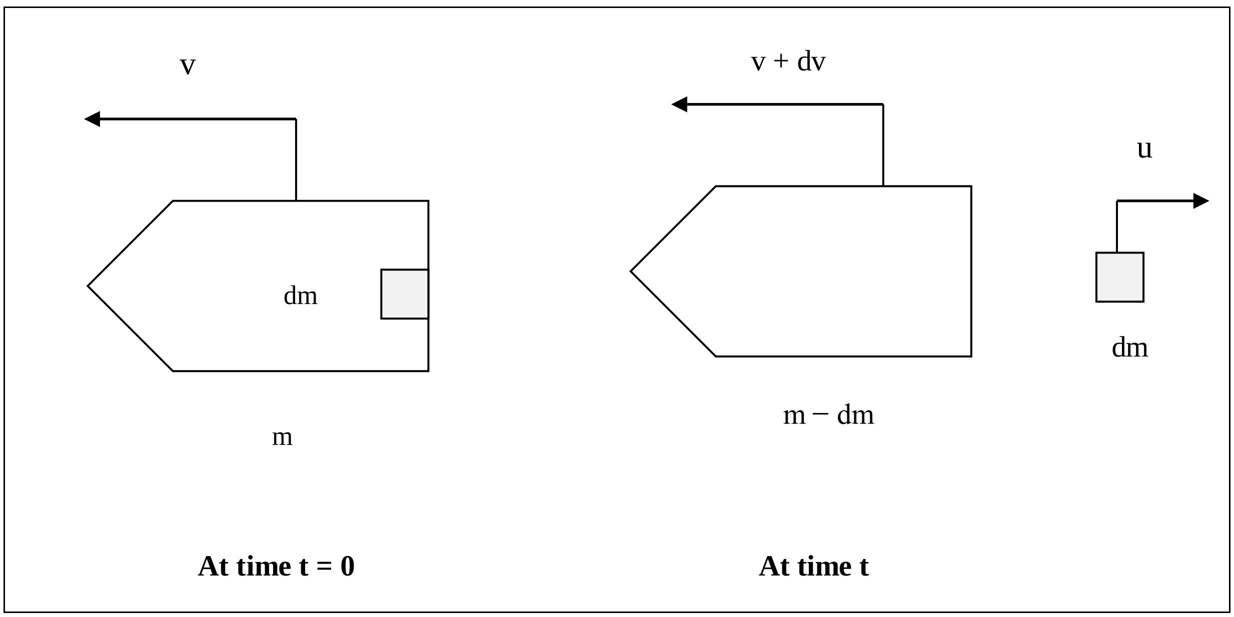
Number of photons required to ionize the atom

Additional number of photons being absorbed

It is not good to introduce the concept of the mass $M = \frac{m}{\sqrt{1-\frac{v^2}{c^2}}}$ of a moving body for which no clear definition can be given. It is better to introduce no other mass concept than the 'rest mass' m. Instead of introducing M it is better to mention the expression for the momentum and energy of a body in motion.

—Albert Einstein in letter to *Lincoln Barnett*, 19 June 1948 (quote from *L.B. Okun* (1989), p. 42)

Rocket Equation



Initial momentum of the rocket and fuel = mv

Final momentum of the rocket and fuel = (m − dm) (v + dv) + dm (v − u)

where: u → exhaust velocity in the rocket frame

(v − u) → exhaust velocity in the observer frame

Final momentum of the rocket and fuel = $mv + mdv - dmv - dmdv + dmv - dmu$

By conservation of momentum, the momentum of the system at time $t = 0$ must equal the momentum at time t:

$$\boxed{mv = mv + mdv - dmv - dmdv + dmv - dmu}$$

$$0 = mdv - dmu - dmdv$$

Since **dmdv** is the product of two very small values, it can be ignored:

$$0 = mdv - dmu$$

The mass is decreasing so the change in mass dm is intrinsically negative, $dm < 0$.

$$0 = mdv + dmu$$

$$\boxed{mdv = -dmu}$$

My habits are methodical, and this has been of not a little use for my particular line of work. Lastly, I have had ample leisure from not having to earn my own bread. Even ill-health, though it has annihilated several years of my life, has saved me from the distractions of society and amusement.

Therefore, my success as a man of science, whatever this may have amounted to, has been determined, as far as I can judge, by complex and diversified mental qualities and conditions. Of these the most important have been--the love of science--unbounded patience in long reflecting over any subject--industry in observing and collecting facts--and a fair share of invention as well as of common-sense. With such moderate abilities as I possess, it is truly surprising that thus I should have influenced to a considerable extent the beliefs of scientific men on some important points.

−Charles Robert Darwin in his Autobiography

$$-u\int_{m_0}^{m} d\ln m = \int_{v_0}^{v} dv$$

$$v = v_0 + u\ln\frac{m_0}{m}$$

Tsiolkovskiy's rocket equation – a classical rocket equation which was first published in 1903 — the year the Wright siblings fled plane, 23 years before Robert Goddard assembled the first liquid fuel rocket, 54 years before the Soviet Association put the first artificial satellite in orbital path around the planet Earth and 66 years before the United States sent people to play golf on the moon

What are we? Where do we come from? Where will we go?

Every human being is confronted with these age-old questions without any satisfactory answers.

Nothing in biology makes sense except in the light of evolution.

−Theodosius Dobzhansky

In 1825, **Charles Darwin** was sent to Edinburgh University by his father, Robert. **Robert** wanted his son to become a doctor, but Charles showed no interest in the subject.

Richard then wrote to his son:

"You care for nothing but shooting, dogs, and rat-catching and you will be a disgrace to yourself and all your family."

Richard Feynman recounts that since he was a young boy, one of the things his father taught him was a healthy disrespect for authority. I fully agree with this perspective. This text, from an interview with Feynman, is absolutely brilliant: "One of the things my father taught me besides physics, whether it's correct or not, was disrespect for certain kinds of things. For example, when I was a little boy he used to sit me again on his knee, and he'd open a picture of the Pope, and everybody was bowing in front of him. And he'd say, 'Now look at these humans. Here is one human standing here, and all these others are bowing. Now, what is the difference? This one is the Pope' and he'd say, 'the difference is epaulets' - of course not in the case of the Pope, but if he was a general - it was always the uniform, the position, 'but this man has the same human problems, he eats dinner like anybody else, goes to the bathroom, has the same kind of problems as everybody, he's a human being. Why are they all bowing to him? Only because of his name and his position, because of his uniform, not because of something special he did, or his honor, or something like that.'

"People think of education as something that they can finish. And when they finish, it's a rite of passage. You're finished with school. You're no more a child, and anything that reminds you of school - reading books, having ideas, asking questions - that's kid's stuff. Now you're an adult, you don't do that sort of thing anymore.

You have everybody looking forward to no longer learning, and you make them ashamed afterward of going back to learning. [A]nyone, at any age, can learn by himself, can continue to be interested. If you enjoy learning, there's no reason why you should stop. People don't stop things they enjoy doing just because they reach a certain age.

What's exciting is the process of broadening yourself, of knowing there's now an extra facet of the universe you know about and can think about and understand.

It seems to me that when it's time to die, there would be pleasure in thinking you utilized your life well, learned as much as you could, and enjoyed it. There's only this one universe and only this one lifetime to try to grasp it. And while [nobody] can grasp more than a tiny portion of it, at least you can do that much. What a tragedy just to pass through and get nothing out of it."

−Isaac Asimov

The **luminosity** L of a star is related to its **apparent brightness** b and its **distance** d to us by:

$$L = b \times 4\pi d^2$$

The **luminosity** L of a star is related to its **radius** R and its **temperature** T by:

$$L = \varepsilon\sigma T^4 \times 4\pi R^2$$

$$\sqrt{b} \propto \frac{\sqrt{\varepsilon}\, RT^2}{d}$$

- **Luminosity** is the rate at which a star radiates energy into space.
- **Apparent brightness** is the rate at which a star's radiated energy reaches an observer on the planet Earth.
- **Apparent brightness of a star** depends on both luminosity and distance.

Gravitational energy ⟶ **Accretion** ⟶ **radiation**

Escape velocity:

$$v_{escape}^2 = \frac{2GM}{R}$$

$$-\frac{dv_{escape}}{dR} = \frac{g}{v_{escape}}$$

where: g ⟶ acceleration due to gravity

The **radiative efficiency** of an accreting black hole:

$$\eta = \frac{L}{\frac{dMc^2}{dt}}$$

where L is the luminosity and $\frac{dM}{dt}$ is the mass accretion rate.

When inward force of gravity = outward pressure of the gas

Star cannot exceed the radius defined by the **Hayashi limit**

One of the most famous anecdotes in the history of science is the discovery of the ring structure of the benzene molecule, by the great German organic chemist Friedrich Kekulé. Benzene is an organic compound consisting of 6 carbon atoms joined in a planar ring with one atom of hydrogen attached to each of them.

He was trying to discover the configuration of benzene and wasn't making progress. He eventually stopped writing and dozed off to sleep, in front of the fire. He then had his famous dream. According to National Geographic, "He saw atoms whirling and dancing before his eyes. [They] began to reassemble themselves into long rows that seemed to move about in a snake-like motion [...] the vision progressed until the snake formed itself into an image he had seen years before at a 1850 murder trial: the snake devouring its own tail" (a snake curled in a loop with its tail in its mouth is an ancient mythological symbol, the ouroboros, shown below on the right). He woke up, exclaiming to himself, "The molecule is in the form of a ring!".

"There I sat and wrote my Lehrbuch, but it did not proceed well, my mind was elsewhere. I turned the chair to the fireplace and fell half asleep. Again the atoms gamboled before my eyes. Smaller groups this time kept modestly to the background. My mind's eyes, trained by visions of a similar kind, now distinguished larger formations of various shapes. Long rows, in many ways more densely joined; everything in movement, winding and turning like snakes. And look, what was that? One snake grabbed its own tail, and mockingly the shape whirled before my eyes. As if struck by lightning I awoke. This time again I spent the rest of the night working out the consequences."

–Friedrich August Kekulé

If the Sun were the size of a beach ball then Jupiter would be the size of a golf ball and the Earth would be as small as a pea.

List of Nobel laureates in Physics

1901	**Wilhelm Röntgen**	"in recognition of the extraordinary services he has rendered by the discovery of the remarkable rays subsequently named after him"
1902	**Hendrik Lorentz**	"in recognition of the extraordinary service they rendered by their researches into the influence of magnetism upon radiation phenomena"
	Pieter Zeeman	
1903	**Antoine Henri Becquerel**	"for his discovery of spontaneous radioactivity"
	Pierre Curie	"for their joint researches on the radiation phenomena discovered by Professor Henri Becquerel"
	Marie Skłodowska-Curie	
1904	**Lord Rayleigh**	"for his investigations of the densities of the most important gases and for his discovery of argon in connection with these studies"
1905	**Philipp Eduard Anton von Lenard**	"for his work on cathode rays"
1906	**Joseph John Thomson**	"for his theoretical and experimental investigations on the conduction of electricity by gases"
1907	**Albert Abraham Michelson**	"for his optical precision instruments and the spectroscopic and metrological investigations

		carried out with their aid"
1908	**Gabriel Lippmann**	"for his method of reproducing colours photographically based on the phenomenon of interference"
1909	**Guglielmo Marconi**	"for their contributions to the development of wireless telegraphy"
	Karl Ferdinand Braun	
1910	**Johannes Diderik van der Waals**	"for his work on the equation of state for gases and liquids"
1911	**Wilhelm Wien**	"for his discoveries regarding the laws governing the radiation of heat"
1912	**Nils Gustaf Dalén**	"for his invention of automatic valves designed to be used in combination with gas accumulators in lighthouses and buoys"
1913	**Heike Kamerlingh-Onnes**	"for his investigations on the properties of matter at low temperatures which led, inter alia, to the production of liquid helium"
1914	**Max von Laue**	"For his discovery of the diffraction of X-rays by crystals", an important step in the development of X-ray spectroscopy.
1915	**William Henry Bragg**	"'For their services in the analysis of crystal structure by means of X-rays', an important step in the development of X-ray crystallography"
	William Lawrence Bragg	

1916	**Not awarded due to World War I**	
1917	**Charles Glover Barkla**	"'For his discovery of the characteristic Röntgen radiation of the elements', another important step in the development of X-ray spectroscopy"
1918	**Max Planck**	"for the services he rendered to the advancement of physics by his discovery of energy quanta"
1919	**Johannes Stark**	"for his discovery of the Doppler effect in canal rays and the splitting of spectral lines in electric fields"
1920	**Charles Édouard Guillaume**	"for the service he has rendered to precision measurements in physics by his discovery of anomalies in nickel-steel alloys"
1921	**Albert Einstein**	"for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect"
1922	**Niels Bohr**	"for his services in the investigation of the structure of atoms and of the radiation emanating from them"
1923	**Robert Andrews Millikan**	"for his work on the elementary charge of electricity and on the photoelectric effect"
1924	**Manne Siegbahn**	"for his discoveries and research in the field of X-ray spectroscopy"
1925	**James Franck**	"for their discovery of the laws governing the impact of

	Gustav Hertz	an electron upon an atom"
1926	**Jean Baptiste Perrin**	"for his work on the discontinuous structure of matter, and especially for his discovery of sedimentation equilibrium"
1927	**Arthur Holly Compton**	"for his discovery of the effect named after him"
	Charles Thomson Rees Wilson	"for his method of making the paths of electrically charged particles visible by condensation of vapour"
1928	**Owen Willans Richardson**	"for his work on the thermionic phenomenon and especially for the discovery of the law named after him"
1929	**Louis Victor Pierre Raymond, 7th Duc de Broglie**	"for his discovery of the wave nature of electrons"
1930	**Chandrasekhara Venkata Raman**	"for his work on the scattering of light and for the discovery of the effect named after him"
1931	**Not awarded**	
1932	**Werner Heisenberg**	"for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen"
1933	**Erwin Schrödinger**	"for the discovery of new productive forms of atomic theory"
	Paul Dirac	

1934	**Not awarded**	
1935	**James Chadwick**	"for the discovery of the neutron"
1936	**Victor Francis Hess**	"for his discovery of cosmic radiation"
	Carl David Anderson	"for his discovery of the positron"
1937	**Clinton Joseph Davisson**	"for their experimental discovery of the diffraction of electrons by crystals"
	George Paget Thomson	
1938	**Enrico Fermi**	"for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons"
1939	**Ernest Lawrence**	"for the invention and development of the cyclotron and for results obtained with it, especially with regard to artificial radioactive elements"
1940	**Not awarded due to World War II**	
1941		
1942		
1943	**Otto Stern**	"for his contribution to the development of the molecular ray method and his discovery of the magnetic moment of

		the proton"
1944	**Isidor Isaac Rabi**	"for his resonance method for recording the magnetic properties of atomic nuclei"
1945	**Wolfgang Pauli**	"for the discovery of the Exclusion Principle, also called the Pauli principle"
1946	**Percy Williams Bridgman**	"for the invention of an apparatus to produce extremely high pressures, and for the discoveries he made there within the field of high pressure physics"
1947	**Edward Victor Appleton**	"for his investigations of the physics of the upper atmosphere especially for the discovery of the so-called Appleton layer"
1948	**Patrick Maynard Stuart Blackett**	"for his development of the Wilson cloud chamber method, and his discoveries therewith in the fields of nuclear physics and cosmic radiation"
1949	**Hideki Yukawa**	"for his prediction of the existence of mesons on the basis of theoretical work on nuclear forces"
1950	**Cecil Frank Powell**	"for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method"
1951	**John Douglas Cockcroft**	"for their pioneer work on the transmutation of atomic nuclei by artificially accelerated atomic particles"
	Ernest Thomas Sinton	

	Walton	
1952	**Felix Bloch**	"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"
	Edward Mills Purcell	
1953	**Frits Zernike**	"for his demonstration of the phase contrast method, especially for his invention of the phase contrast microscope"
1954	**Max Born**	"for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction"
	Walther Bothe	"for the coincidence method and his discoveries made therewith"
1955	**Willis Eugene Lamb**	"for his discoveries concerning the fine structure of the hydrogen spectrum"
	Polykarp Kusch	"for his precision determination of the magnetic moment of the electron"
1956	**John Bardeen**	"for their researches on semiconductors and their discovery of the transistor effect"
	Walter Houser Brattain	
	William Bradford Shockley	

1957	**Tsung-Dao Lee**	"for their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles"
	Chen-Ning Yang	
1958	**Pavel Alekseyevich Cherenkov**	"for the discovery and the interpretation of the Cherenkov effect"
	Ilya Frank	
	Igor Yevgenyevich Tamm	
1959	**Emilio Gino Segrè**	"for their discovery of the antiproton"
	Owen Chamberlain	
1960	**Donald Arthur Glaser**	"for the invention of the bubble chamber"
1961	**Robert Hofstadter**	"for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the structure of the nucleons"
	Rudolf Ludwig Mössbauer	"for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name"
1962	**Lev Davidovich Landau**	"for his pioneering theories for condensed matter, especially liquid helium"
1963	**Eugene Paul Wigner**	"for his contributions to the theory of the atomic

		nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles"
	Maria Goeppert-Mayer	"for their discoveries concerning nuclear shell structure"
	J. Hans D. Jensen	
1964	**Nicolay Gennadiyevich Basov**	"for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser–laser principle"
	Alexander Prokhorov	
	Charles Hard Townes	
1965	**Richard Phillips Feynman**	"for their fundamental work in quantum electrodynamics (QED), with deep-ploughing consequences for the physics of elementary particles"
	Julian Schwinger	
	Shin'ichirō Tomonaga	
1966	**Alfred Kastler**	"for the discovery and development of optical methods for studying Hertzian resonances in atoms"
1967	**Hans Albrecht Bethe**	"for his contributions to the theory of nuclear reactions, especially his discoveries concerning the energy production in stars"
1968	**Luis Walter Alvarez**	"for his decisive contributions to elementary particle physics, in particular the discovery of a large number

		of resonance states, made possible through his development of the technique of using hydrogen bubble chamber and data analysis"
1969	**Murray Gell-Mann**	"for his contributions and discoveries concerning the classification of elementary particles and their interactions"
1970	**Hannes Olof Gösta Alfvén**	"for fundamental work and discoveries in magneto-hydrodynamics with fruitful applications in different parts of plasma physics"
	Louis Néel	"for fundamental work and discoveries concerning antiferromagnetism and ferrimagnetism whic h have led to important applications in solid state physics"
1971	**Dennis Gabor**	"for his invention and development of the holographic method"
1972	**John Bardeen**	"for their jointly developed theory of superconductivity, usually called the BCS-theory"
	Leon Neil Cooper	
	John Robert Schrieffer	
1973	**Leo Esaki**	"for their experimental discoveries regarding tunneling phenomena in semiconductors and superconductors, respectively"
	Ivar Giaever	
	Brian David Josephson	"for his theoretical predictions of the properties of

		a supercurrent through a tunnel barrier, in particular those phenomena which are generally known as the Josephson effect"
1974	**Martin Ryle**	"for their pioneering research in radio astrophysics: Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars"
	Antony Hewish	
1975	**Aage Bohr**	"for the discovery of the connection between collective motion and particle motion in atomic nuclei and the development of the theory of the structure of the atomic nucleus based on this connection"
	Ben Roy Mottelson	
	Leo James Rainwater	
1976	**Samuel Chao Chung Ting**	"for their pioneering work in the discovery of a heavy elementary particle of a new kind"
	Burton Richter	
1977	**Philip Warren Anderson**	"for their fundamental theoretical investigations of the electronic structure of magnetic and disordered systems"
	Nevill Francis Mott	
	John Hasbrouck Van Vleck	
1978	**Pyotr Leonidovich Kapitsa**	"for his basic inventions and discoveries in the area of low-temperature physics"

	Arno Allan Penzias	"for their discovery of cosmic microwave background radiation"
	Robert Woodrow Wilson	
1979	**Sheldon Lee Glashow**	"for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including, inter alia, the prediction of the weak neutral current"
	Abdus Salam	
	Steven Weinberg	
1980	**James Watson Cronin**	"for the discovery of violations of fundamental symmetry principles in the decay of neutral K-mesons"
	Val Logsdon Fitch	
1981	**Nicolaas Bloembergen**	"for their contribution to the development of laser spectroscopy"
	Arthur Leonard Schawlow	
	Kai Manne Börje Siegbahn	"for his contribution to the development of high-resolution electron spectroscopy"
1982	**Kenneth G. Wilson**	"for his theory for critical phenomena in connection with phase transitions"
1983	**Subrahmanyan Chandrasekhar**	"for his theoretical studies of the physical processes of importance to the structure and evolution of the stars"

	William Alfred Fowler	"for his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe"
1984	**Carlo Rubbia**	"for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction"
	Simon van der Meer	
1985	**Klaus von Klitzing**	"for the discovery of the quantized Hall effect"
1986	**Ernst Ruska**	"for his fundamental work in electron optics, and for the design of the first electron microscope"
	Gerd Binnig	"for their design of the scanning tunneling microscope"
	Heinrich Rohrer	
1987	**Johannes Georg Bednorz**	"for their important break-through in the discovery of superconductivity in ceramic materials"
	Karl Alexander Müller	
1988	**Leon Max Lederman**	"for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino"
	Melvin Schwartz	
	Jack Steinberger	
1989	**Norman Foster Ramsey**	"for the invention of the separated oscillatory fields method and its use in the hydrogen maser and

		other atomic clocks"
	Hans Georg Dehmelt	"for the development of the ion trap technique"
	Wolfgang Paul	
1990	**Jerome I. Friedman**	"for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics"
	Henry Way Kendall	
	Richard E. Taylor	
1991	**Pierre-Gilles de Gennes**	"for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers"
1992	**Georges Charpak**	"for his invention and development of particle detectors, in particular the multiwire proportional chamber"
1993	**Russell Alan Hulse**	"for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation"
	Joseph Hooton Taylor Jr.	
1994	**Bertram Brockhouse**	"for the development of neutron spectroscopy" and "for pioneering contributions to the development of neutron scattering techniques for studies of condensed matter"
	Clifford Glenwood	"for the development of the neutron diffraction technique" and "for pioneering contributions

	Shull	to the development of neutron scattering techniques for studies of condensed matter"
1995	**Martin Lewis Perl**	"for the discovery of the tau lepton" and "for pioneering experimental contributions to lepton physics"
	Frederick Reines	"for the detection of the neutrino" and "for pioneering experimental contributions to lepton physics"
1996	**David Morris Lee**	"for their discovery of superfluidity in helium-3"
	Douglas D. Osheroff	
	Robert Coleman Richardson	
1997	**Steven Chu**	"for development of methods to cool and trap atoms with laser light."
	Claude Cohen-Tannoudji	
	William Daniel Phillips	
1998	**Robert B. Laughlin**	"for their discovery of a new form of quantum fluid with fractionally charged excitations"
	Horst Ludwig Störmer	
	Daniel Chee Tsui	
1999	**Gerard 't Hooft**	"for elucidating the quantum structure of electroweak

	Martinus J. G. Veltman	interactions in physics"
2000	**Zhores Ivanovich Alferov**	"for developing semiconductor heterostructures used in high-speed- and optoelectronics"
	Herbert Kroemer	
	Jack St. Clair Kilby	"for his part in the invention of the integrated circuit"
2001	**Eric Allin Cornell**	"for the achievement of Bose–Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates"
	Carl Edwin Wieman	
	Wolfgang Ketterle	
2002	**Raymond Davis Jr.**	"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"
	Masatoshi Koshiba	
	Riccardo Giacconi	"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"
2003	**Alexei Alexeyevich Abrikosov**	"for pioneering contributions to the theory of superconductors and superfluids"
	Vitaly Lazarevich Ginzburg	
	Anthony James	

	Leggett	
2004	**David J. Gross**	"for the discovery of asymptotic freedom in the theory of the strong interaction"
	Hugh David Politzer	
	Frank Wilczek	
2005	**Roy J. Glauber**	"for his contribution to the quantum theory of optical coherence"
	John L. Hall	"for their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique"
	Theodor W. Hänsch	
2006	**John C. Mather**	"for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"
	George F. Smoot	
2007	**Albert Fert**	"for the discovery of giant magnetoresistance"
	Peter Grünberg	
2008	**Makoto Kobayashi**	"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"
	Toshihide Maskawa	
	Yoichiro Nambu	"for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

2009	**Charles K. Kao**	"for groundbreaking achievements concerning the transmission of light in fibers for optical communication"
	Willard S. Boyle	"for the invention of an imaging semiconductor circuit – the CCD sensor"
	George E. Smith	
2010	**Andre Geim**	"for groundbreaking experiments regarding the two-dimensional material graphene"
	Konstantin Novoselov	
2011	**Saul Perlmutter**	"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"
	Brian P. Schmidt	
	Adam G. Riess	
2012	**Serge Haroche**	"for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems."
	David J. Wineland	
2013	**François Englert**	"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"
	Peter Higgs	

2014	**Isamu Akasaki**	"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"
	Hiroshi Amano	
	Shuji Nakamura	
2015	**Takaaki Kajita**	"for the discovery of neutrino oscillations, which shows that neutrinos have mass"
	Arthur B. McDonald	
2016	**David J. Thouless**	"for theoretical discoveries of topological phase transitions and topological phases of matter"
	F. Duncan M. Haldane	
	John M. Kosterlitz	
2017	**Rainer Weiss**	"for decisive contributions to the LIGO detector and the observation of gravitational waves"
	Kip Thorne	
	Barry Barish	
2018	**Arthur Ashkin**	"for groundbreaking inventions in the field of laser physics", in particular "for the optical tweezers and their application to biological systems"
	Gérard Mourou	"for groundbreaking inventions in the field of laser physics", in particular "for their method of generating high-intensity, ultra-short optical pulses"
	Donna Strickland	

2019	**James Peebles**	"for theoretical discoveries in physical cosmology"
	Michel Mayor	"for the discovery of an exoplanet orbiting a solar-type star"
	Didier Queloz	
2020	**Roger Penrose**	"for the discovery that black hole formation is a robust prediction of the general theory of relativity"
	Reinhard Genzel	"for the discovery of a supermassive compact object at the centre of our galaxy"
	Andrea Ghez	

Each rubber molecule is made of 65,000 individual atoms.

Around a million, billion neutrinos from the Sun will pass through our body every day.

Quasars are the most distant objects in the Universe which emit more energy than 100 giant galaxies.

List of Nobel laureates in Chemistry

1901	**Jacobus Henricus van 't Hoff**	"[for his] discovery of the laws of chemical dynamics and osmotic pressure in solutions"
1902	**Hermann Emil Fischer**	"[for] his work on sugar and purine syntheses"
1903	**Svante August Arrhenius**	"[for] his electrolytic theory of dissociation"
1904	**Sir William Ramsay**	"[for his] discovery of the inert gaseous elements in air, and his determination of their place in the periodic system"
1905	**Adolf von Baeyer**	"[for] the advancement of organic chemistry and the chemical industry, through his work on organic dyes and hydroaromatic compounds"
1906	**Henri Moissan**	"[for his] investigation and isolation of the element fluorine, and for [the] electric furnace called after him"
1907	**Eduard Buchner**	"for his biochemical researches and his discovery of cell-free fermentation"
1908	**Ernest Rutherford**	"for his investigations into the disintegration of the elements, and the chemistry of radioactive substances"
1909	**Wilhelm Ostwald**	"[for] his work on catalysis and for his investigations into the fundamental principles

		governing chemical equilibria and rates of reaction"
1910	**Otto Wallach**	"[for] his services to organic chemistry and the chemical industry by his pioneer work in the field of alicyclic compounds"
1911	**Maria Skłodowska-Curie**	"[for] the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element"
1912	**Victor Grignard**	"for the discovery of the [...] Grignard reagent"
	Paul Sabatier	"for his method of hydrogenating organic compounds in the presence of finely disintegrated metals"
1913	**Alfred Werner**	"[for] his work on the linkage of atoms in molecules [...] especially in inorganic chemistry"
1914	**Theodore William Richards**	"[for] his accurate determinations of the atomic weight of a large number of chemical elements"
1915	**Richard Martin Willstätter**	"for his researches on plant pigments, especially chlorophyll"
1916	**Not awarded**	
1917		

1918	**Fritz Haber**	"for the synthesis of ammonia from its elements"
1919	**Not awarded**	
1920	**Walther Hermann Nernst**	"[for] his work in thermochemistry"
1921	**Frederick Soddy**	"for his contributions to our knowledge of the chemistry of radioactive substances, and his investigations into the origin and nature of isotopes"
1922	**Francis William Aston**	"for his discovery, by means of his mass spectrograph, of isotopes, in a large number of non-radioactive elements, and for his enunciation of the whole-number rule"
1923	**Fritz Pregl**	"for his invention of the method of micro-analysis of organic substances"
1924	**Not awarded**	
1925	**Richard Adolf Zsigmondy**	"for his demonstration of the heterogeneous nature of colloid solutions and for the methods he used"
1926	**The (Theodor) Svedberg**	"for his work on disperse systems"
1927	**Heinrich Otto Wieland**	"for his investigations of the constitution of the bile acids and related substances"

1928	**Adolf Otto Reinhold Windaus**	"[for] his research into the constitution of the sterols and their connection with the vitamins"
1929	**Arthur Harden**	"for their investigations on the fermentation of sugar and fermentative enzymes"
	Hans Karl August Simon von Euler-Chelpin	
1930	**Hans Fischer**	"for his researches into the constitution of haemin and chlorophyll and especially for his synthesis of haemin"
1931	**Carl Bosch**	"[for] their contributions to the invention and development of chemical high pressure methods"
	Friedrich Bergius	
1932	**Irving Langmuir**	"for his discoveries and investigations in surface chemistry"
1933	**Not awarded**	
1934	**Harold Clayton Urey**	"for his discovery of heavy hydrogen"
1935	**Frédéric Joliot**	"[for] their synthesis of new radioactive elements"
	Irène Joliot-Curie	
1936	**Peter Debye**	"[for his work on] molecular structure through his investigations on dipole moments and

		the diffraction of X-rays and electrons in gases"
1937	**Walter Norman Haworth**	"for his investigations on carbohydrates and vitamin C"
	Paul Karrer	"for his investigations on carotenoids, flavins and vitamins A and B_2"
1938	**Richard Kuhn**	"for his work on carotenoids and vitamins"
1939	**Adolf Friedrich Johann Butenandt**	"for his work on sex hormones"
	Leopold Ruzicka	"for his work on polymethylenes and higher terpenes"
1940	**Not awarded**	
1941		
1942		
1943	**George de Hevesy**	"for his work on the use of isotopes as tracers in the study of chemical processes"
1944	**Otto Hahn**	"for his discovery of the fission of heavy nuclei"
1945	**Artturi Ilmari Virtanen**	"for his research and inventions in agricultural and nutrition chemistry, especially for his fodder

		preservation method"
1946	**James Batcheller Sumner**	"for his discovery that enzymes can be crystallized"
	John Howard Northrop	"for their preparation of enzymes and virus proteins in a pure form"
	Wendell Meredith Stanley	
1947	**Sir Robert Robinson**	"for his investigations on plant products of biological importance, especially the alkaloids"
1948	**Arne Wilhelm Kaurin Tiselius**	"for his research on electrophoresis and adsorption analysis, especially for his discoveries concerning the complex nature of the serum proteins"
1949	**William Francis Giauque**	"for his contributions in the field of chemical thermodynamics, particularly concerning the behaviour of substances at extremely low temperatures"
1950	**Otto Paul Hermann Diels**	"for their discovery and development of the diene synthesis"
	Kurt Alder	
1951	**Edwin Mattison McMillan**	"for their discoveries in the chemistry of transuranium elements"

	Glenn Theodore Seaborg	
1952	**Archer John Porter Martin**	"for their invention of partition chromatography"
	Richard Laurence Millington Synge	
1953	**Hermann Staudinger**	"for his discoveries in the field of macromolecular chemistry"
1954	**Linus Pauling**	"for his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances"
1955	**Vincent du Vigneaud**	"for his work on biochemically important sulphur compounds, especially for the first synthesis of a polypeptide hormone"
1956	**Sir Cyril Norman Hinshelwood**	"for their researches into the mechanism of chemical reactions"
	Nikolay Nikolaevich Semenov	
1957	**Lord (Alexander R.) Todd**	"for his work on nucleotides and nucleotide co-enzymes"
1958	**Frederick Sanger**	"for his work on the structure of proteins,

		especially that of insulin"
1959	**Jaroslav Heyrovský**	"for his discovery and development of the polarographic methods of analysis"
1960	**Willard Frank Libby**	"for his method to use carbon-14 for age determination in archaeology, geology, geophysics, and other branches of science"
1961	**Melvin Calvin**	"for his research on the carbon dioxide assimilation in plants"
1962	**Max Ferdinand Perutz**	"for their studies of the structures of globular proteins"
	John Cowdery Kendrew	
1963	**Karl Ziegler**	"for their discoveries in the field of the chemistry and technology of high polymers"
	Giulio Natta	
1964	**Dorothy Crowfoot Hodgkin**	"for her determinations by X-ray techniques of the structures of important biochemical substances"
1965	**Robert Burns Woodward**	"for his outstanding achievements in the art of organic synthesis"
1966	**Robert S. Mulliken**	"for his fundamental work concerning chemical bonds and the electronic structure of molecules by the molecular orbital method"

1967	**Manfred Eigen**	"for their studies of extremely fast chemical reactions, effected by disturbing the equilibrium by means of very short pulses of energy"
	Ronald George Wreyford Norrish	
	George Porter	
1968	**Lars Onsager**	"for the discovery of the reciprocal relations bearing his name, which are fundamental for the thermodynamics of irreversible processes"
1969	**Derek H. R. Barton**	"for their contributions to the development of the concept of conformation and its application in chemistry"
	Odd Hassel	
1970	**Luis F. Leloir**	"for his discovery of sugar nucleotides and their role in the biosynthesis of carbohydrates"
1971	**Gerhard Herzberg**	"for his contributions to the knowledge of electronic structure and geometry of molecules, particularly free radicals"
1972	**Christian B. Anfinsen**	"for his work on ribonuclease, especially concerning the connection between the amino acid sequence and the biologically active conformation"
	Stanford Moore	"for their contribution to the understanding of the

	William H. Stein	connection between chemical structure and catalytic activity of the active centre of the ribonuclease molecule"
1973	**Ernst Otto Fischer**	"for their pioneering work, performed independently, on the chemistry of the organometallic, so called sandwich compounds"
	Geoffrey Wilkinson	
1974	**Paul J. Flory**	"for his fundamental work, both theoretical and experimental, in the physical chemistry of macromolecules"
1975	**John Warcup Cornforth**	"for his work on the stereochemistry of enzyme-catalyzed reactions"
	Vladimir Prelog	"for his research into the stereochemistry of organic molecules and reactions"
1976	**William N. Lipscomb**	"for his studies on the structure of boranes illuminating problems of chemical bonding"
1977	**Ilya Prigogine**	"for his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures"
1978	**Peter D. Mitchell**	"for his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory"

1979	**Herbert C. Brown**	"for their development of the use of boron- and phosphorus-containing compounds, respectively, into important reagents in organic synthesis"
	Georg Wittig	
1980	**Paul Berg**	"for his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant-DNA"
	Walter Gilbert	"for their contributions concerning the determination of base sequences in nucleic acids"
	Frederick Sanger	
1981	**Kenichi Fukui**	"for their theories, developed independently, concerning the course of chemical reactions"
	Roald Hoffmann	
1982	**Aaron Klug**	"for his development of crystallographic electron microscopy and his structural elucidation of biologically important nucleic acid-protein complexes"
1983	**Henry Taube**	"for his work on the mechanisms of electron transfer reactions, especially in metal complexes"
1984	**Robert Bruce Merrifield**	"for his development of methodology for chemical synthesis on a solid matrix"
1985	**Herbert A. Hauptman**	"for their outstanding achievements in

	Jerome Karle	developing direct methods for the determination of crystal structures"
1986	**Dudley R. Herschbach**	"for their contributions concerning the dynamics of chemical elementary processes"
	Yuan T. Lee	
	John C. Polanyi	
1987	**Donald J. Cram**	"for their development and use of molecules with structure-specific interactions of high selectivity"
	Jean-Marie Lehn	
	Charles J. Pedersen	
1988	**Johann Deisenhofer**	"for their determination of the three-dimensional structure of a photosynthetic reaction centre"
	Robert Huber	
	Hartmut Michel	
1989	**Sidney Altman**	"for their discovery of catalytic properties of RNA"
	Thomas Cech	
1990	**Elias James Corey**	"for his development of the theory and methodology of organic synthesis"
1991	**Richard R. Ernst**	"for his contributions to the development of the

		methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"
1992	**Rudolph A. Marcus**	"for his contributions to the theory of electron transfer reactions in chemical systems"
1993	**Kary B. Mullis**	"for contributions to the developments of methods within DNA-based chemistry [...] for his invention of the polymerase chain reaction (PCR) method"
	Michael Smith	"for contributions to the developments of methods within DNA-based chemistry [...] for his fundamental contributions to the establishment of oligonucleotide-based, site-directed mutagenesis and its development for protein studies"
1994	**George A. Olah**	"for his contribution to carbocation chemistry"
1995	**Paul J. Crutzen**	"for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone"
	Mario J. Molina	
	F. Sherwood Rowland	
1996	**Robert F. Curl Jr.**	"for their discovery of fullerenes"
	Sir Harold W. Kroto	
	Richard E. Smalley	

1997	**Paul D. Boyer**	"for their elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP)"
	John E. Walker	
	Jens C. Skou	"for the first discovery of an ion-transporting enzyme, Na^+, K^+ -ATPase"
1998	**Walter Kohn**	"for his development of the density-functional theory"
	John A. Pople	"for his development of computational methods in quantum chemistry"
1999	**Ahmed Zewail**	"for his studies of the transition states of chemical reactions using femtosecond spectroscopy"
2000	**Alan J. Heeger**	"for their discovery and development of conductive polymers"
	Alan G. MacDiarmid	
	Hideki Shirakawa	
2001	**William S. Knowles**	"for their work on chirally catalysed hydrogenation reactions"
	Ryōji Noyori	
	K. Barry Sharpless	"for his work on chirally catalysed oxidation reactions"

2002	**John B. Fenn**	"for the development of methods for identification and structure analyses of biological macromolecules [...] for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules"
	Koichi Tanaka	
	Kurt Wüthrich	"for the development of methods for identification and structure analyses of biological macromolecules [...] for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"
2003	**Peter Agre**	"for discoveries concerning channels in cell membranes [...] for the discovery of water channels"
	Roderick MacKinnon	"for discoveries concerning channels in cell membranes [...] for structural and mechanistic studies of ion channels"
2004	**Aaron Ciechanover**	"for the discovery of ubiquitin-mediated protein degradation"
	Avram Hershko	
	Irwin Rose	
2005	**Yves Chauvin**	"for the development of the metathesis method in

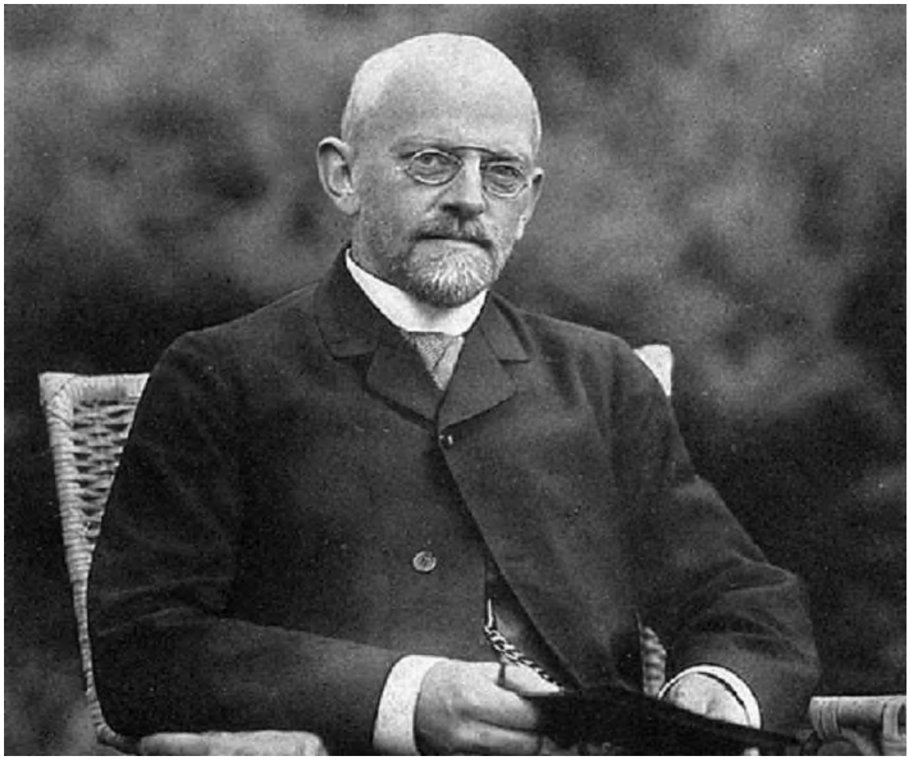
	Robert H. Grubbs	organic synthesis"
	Richard R. Schrock	
2006	**Roger D. Kornberg**	"for his studies of the molecular basis of eukaryotic transcription"
2007	**Gerhard Ertl**	"for his studies of chemical processes on solid surfaces"
2008	**Osamu Shimomura**	"for the discovery and development of the green fluorescent protein, GFP"
	Martin Chalfie	
	Roger Y. Tsien	
2009	**Venkatraman Ramakrishnan**	"for studies of the structure and function of the ribosome"
	Thomas A. Steitz	
	Ada E. Yonath	
2010	**Richard F. Heck**	"for palladium-catalyzed cross couplings in organic synthesis"
	Ei-ichi Negishi	
	Akira Suzuki	

2011	**Dan Shechtman**	"for the discovery of quasicrystals"
2012	**Robert Lefkowitz**	"for studies of G-protein-coupled receptors"
	Brian Kobilka	
2013	**Martin Karplus**	"for the development of multiscale models for complex chemical systems"
	Michael Levitt	
	Arieh Warshel	
2014	**Eric Betzig**	"for the development of super-resolved fluorescence microscopy"
	Stefan W. Hell	
	William E. Moerner	
2015	**Tomas Lindahl**	"for mechanistic studies of DNA repair"
	Paul L. Modrich	
	Aziz Sancar	
2016	**Jean-Pierre Sauvage**	"for the design and synthesis of molecular machines"
	Fraser Stoddart	

	Ben Feringa	
2017	**Jacques Dubochet**	"for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution"
	Joachim Frank	
	Richard Henderson	
2018	**Frances Arnold**	"for the directed evolution of enzymes"
	George Smith	"for the phage display of peptides and antibodies"
	Sir Gregory Winter	
2019	**John B. Goodenough**	"for the development of lithium ion batteries"
	M. Stanley Whittingham	
	Akira Yoshino	
2020	**Emmanuelle Charpentier**	"for the development of a method for genome editing"
	Jennifer Doudna	

Light would take 0.13 seconds to travel around the Earth.

To escape the **Earth's gravity** a rocket need to travel at 7 miles a second.



No one shall expel us from the paradise which Cantor has created for us.

{Expressing the importance of Georg Cantor's set theory in the development of mathematics.}

— David Hilbert

The largest dinosaur ever discovered was Seismosaurus which was over 100 feet long and weighed up to 80 tones.

The risk of being struck by a falling meteorite for a human is one occurrence every 9,300 years.

List of Nobel laureates in Physiology or Medicine

1901	**Emil Adolf von Behring**	"for his work on serum therapy, especially its application against diphtheria, by which he has opened a new road in the domain of medical science and thereby placed in the hands of the physician a victorious weapon against illness and deaths"
1902	**Sir Ronald Ross**	"for his work on malaria, by which he has shown how it enters the organism and thereby has laid the foundation for successful research on this disease and methods of combating it"
1903	**Niels Ryberg Finsen**	"[for] his contribution to the treatment of diseases, especially lupus vulgaris, with concentrated light radiation, whereby he has opened a new avenue for medical science"
1904	**Ivan Petrovich Pavlov**	"in recognition of his work on the physiology of digestion, through which knowledge on vital aspects of the subject has been transformed and enlarged"
1905	**Robert Koch**	"for his investigations and discoveries in relation to tuberculosis"
1906	**Camillo Golgi**	"in recognition of their work on the structure of the nervous system"
	Santiago Ramón y Cajal	
1907	**Charles Louis Alphonse**	"in recognition of his work on the role played

	Laveran	by protozoa in causing diseases"
1908	**Ilya Ilyich Mechnikov**	"in recognition of their work on immunity"
	Paul Ehrlich	
1909	**Emil Theodor Kocher**	"for his work on the physiology, pathology and surgery of the thyroid gland"
1910	**Albrecht Kossel**	"in recognition of the contributions to our knowledge of cell chemistry made through his work on proteins, including the nucleic substances"
1911	**Allvar Gullstrand**	"for his work on the dioptrics of the eye"
1912	**Alexis Carrel**	"[for] his work on vascular suture and the transplantation of blood vessels and organs"
1913	**Charles Richet**	"[for] his work on anaphylaxis"
1914	**Robert Bárány**	"for his work on the physiology and pathology of the vestibular apparatus"
1915	**Not awarded**	
1916		
1917		
1918		

1919	**Jules Bordet**	"for his discoveries relating to immunity"
1920	**Schack August Steenberg Krogh**	"for his discovery of the capillary motor regulating mechanism"
1921	**Not awarded**	
1922	**Archibald Vivian Hill**	"for his discovery relating to the production of heat in the muscle"
	Otto Fritz Meyerhof	"for his discovery of the fixed relationship between the consumption of oxygen and the metabolism of lactic acid in the muscle"
1923	**Sir Frederick Grant Banting**	"for the discovery of insulin"
	John James Rickard Macleod	
1924	**Willem Einthoven**	"for the discovery of the mechanism of the electrocardiogram"
1925	**Not awarded**	
1926	**Johannes Andreas Grib Fibiger**	"for his discovery of the Spiroptera carcinoma"
1927	**Julius Wagner-Jauregg**	"for his discovery of the therapeutic value of malaria inoculation in the treatment of dementia paralytica"

1928	**Charles Jules Henri Nicolle**	"for his work on typhus"
1929	**Christiaan Eijkman**	"for his discovery of the antineuritic vitamin"
	Sir Frederick Gowland Hopkins	"for his discovery of the growth-stimulating vitamins"
1930	**Karl Landsteiner**	"for his discovery of human blood groups"
1931	**Otto Heinrich Warburg**	"for his discovery of the nature and mode of action of the respiratory enzyme"
1932	**Sir Charles Scott Sherrington**	"for their discoveries regarding the functions of neurons"
	Edgar Douglas Adrian	
1933	**Thomas Hunt Morgan**	"for his discoveries concerning the role played by the chromosome in heredity"
1934	**George Hoyt Whipple**	"for their discoveries concerning liver therapy in cases of anaemia"
	George Richards Minot	
	William Parry Murphy	
1935	**Hans Spemann**	"for his discovery of the organizer effect in embryonic development"

1936	**Sir Henry Hallett Dale**	"for their discoveries relating to chemical transmission of nerve impulses"
	Otto Loewi	
1937	**Albert Szent-Györgyi von Nagyrapolt**	"for his discoveries in connection with the biological combustion processes, with special reference to vitamin C and the catalysis of fumaric acid"
1938	**Corneille Jean François Heymans**	"for the discovery of the role played by the sinus and aortic mechanisms in the regulation of respiration"
1939	**Gerhard Domagk**	"for the discovery of the antibacterial effects of prontosil"
1940	**Not awarded**	
1941		
1942		
1943	**Carl Peter Henrik Dam**	"for his discovery of vitamin K"
	Edward Adelbert Doisy	"for his discovery of the chemical nature of vitamin K"
1944	**Joseph Erlanger**	"for their discoveries relating to the highly differentiated functions of single nerve fibres"
	Herbert Spencer Gasser	
1945	**Sir Alexander Fleming**	"for the discovery of penicillin and its curative effect in

	Sir Ernst Boris Chain	various infectious diseases"
	Howard Walter Florey	
1946	**Hermann Joseph Muller**	"for the discovery of the production of mutations by means of X-ray irradiation"
1947	**Carl Ferdinand Cori**	"for their discovery of the course of the catalytic conversion of glycogen"
	Gerty Theresa Cori, née Radnitz	
	Bernardo Alberto Houssay	"for his discovery of the part played by the hormone of the anterior pituitary lobe in the metabolism of sugar"
1948	**Paul Hermann Müller**	"for his discovery of the high efficiency of DDT as a contact poison against several arthropods"
1949	**Walter Rudolf Hess**	"for his discovery of the functional organization of the interbrain as a coordinator of the activities of the internal organs"
	António Caetano Egas Moniz	"for his discovery of the therapeutic value of leucotomy (lobotomy) in certain psychoses"
1950	**Philip Showalter Hench**	"for their discoveries relating to the hormones of the adrenal cortex, their structure and biological effects"
	Edward Calvin Kendall	
	Tadeusz Reichstein	

1951	**Max Theiler**	"for his discoveries concerning yellow fever and how to combat it"
1952	**Selman Abraham Waksman**	"for his discovery of streptomycin, the first antibiotic effective against tuberculosis"
1953	**Sir Hans Adolf Krebs**	"for his discovery of the citric acid cycle"
	Fritz Albert Lipmann	"for his discovery of co-enzyme A and its importance for intermediary metabolism"
1954	**John Franklin Enders**	"for their discovery of the ability of poliomyelitis viruses to grow in cultures of various types of tissue"
	Frederick Chapman Robbins	
	Thomas Huckle Weller	
1955	**Axel Hugo Theodor Theorell**	"for his discoveries concerning the nature and mode of action of oxidation enzymes"
1956	**André Frédéric Cournand**	"for their discoveries concerning heart catheterization and pathological changes in the circulatory system"
	Werner Forssmann	
	Dickinson W. Richards	
1957	**Daniel Bovet**	"for his discoveries relating to synthetic compounds that inhibit the action of certain body substances, and

		especially their action on the vascular system and the skeletal muscles"
1958	**George Wells Beadle**	"for their discovery that genes act by regulating definite chemical events"
	Edward Lawrie Tatum	
	Joshua Lederberg	"for his discoveries concerning genetic recombination and the organization of the genetic material of bacteria"
1959	**Arthur Kornberg**	"for their discovery of the mechanisms in the biological synthesis of ribonucleic acid and deoxyribonucleic acid"
	Severo Ochoa	
1960	**Sir Frank Macfarlane Burnet**	"for discovery of acquired immunological tolerance"
	Sir Peter Brian Medawar	
1961	**Georg von Békésy**	"for his discoveries of the physical mechanism of stimulation within the cochlea"
1962	**Francis Harry Compton Crick**	"for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material"
	James Dewey Watson	
	Maurice Hugh Frederick Wilkins	

1963	**Sir John Carew Eccles**	"for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane"
	Sir Alan Lloyd Hodgkin	
	Sir Andrew Fielding Huxley	
1964	**Konrad Bloch**	"for their discoveries concerning the mechanism and regulation of the cholesterol and fatty acid metabolism"
	Feodor Lynen	
1965	**François Jacob**	"for their discoveries concerning genetic control of enzyme and virus synthesis"
	André Lwoff	
	Jacques Monod	
1966	**Peyton Rous**	"for his discovery of tumour-inducing viruses"
	Charles Brenton Huggins	"for his discoveries concerning hormonal treatment of prostatic cancer"
1967	**Ragnar Granit**	"for their discoveries concerning the primary physiological and chemical visual processes in the eye"
	Haldan Keffer Hartline	
	George Wald	
1968	**Robert W. Holley**	"for their interpretation of the genetic code and its

	Har Gobind Khorana	function in protein synthesis"
	Marshall W. Nirenberg	
1969	**Max Delbrück**	"for their discoveries concerning the replication mechanism and the genetic structure of viruses"
	Alfred D. Hershey	
	Salvador E. Luria	
1970	**Julius Axelrod**	"for their discoveries concerning the humoral transmittors in the nerve terminals and the mechanism for their storage, release and inactivation"
	Ulf von Euler	
	Sir Bernard Katz	
1971	**Earl W. Sutherland, Jr.**	"for his discoveries concerning the mechanisms of the action of hormones"
1972	**Gerald M. Edelman**	"for their discoveries concerning the chemical structure of antibodies"
	Rodney R. Porter	
1973	**Karl von Frisch**	"for their discoveries concerning organization and elicitation of individual and social behavior patterns"
	Konrad Lorenz	
	Nikolaas Tinbergen	

1974	**Albert Claude**	"for their discoveries concerning the structural and functional organization of the cell"
	Christian de Duve	
	George E. Palade	
1975	**David Baltimore**	"for their discoveries concerning the interaction between tumour viruses and the genetic material of the cell"
	Renato Dulbecco	
	Howard Martin Temin	
1976	**Baruch S. Blumberg**	"for their discoveries concerning new mechanisms for the origin and dissemination of infectious diseases"
	D. Carleton Gajdusek	
1977	**Roger Guillemin**	"for their discoveries concerning the peptide hormone production of the brain"
	Andrew V. Schally	
	Rosalyn Yalow	"for the development of radioimmunoassays of peptide hormones"
1978	**Werner Arber**	"for the discovery of restriction enzymes and their application to problems of molecular genetics"
	Daniel Nathans	
	Hamilton O. Smith	

1979	**Allan M. Cormack**	"for the development of computer assisted tomography"
	Sir Godfrey N. Hounsfield	
1980	**Baruj Benacerraf**	"for their discoveries concerning genetically determined structures on the cell surface that regulate immunological reactions"
	Jean Dausset	
	George D. Snell	
1981	**Roger W. Sperry**	"for his discoveries concerning the functional specialization of the cerebral hemispheres"
	David H. Hubel	"for their discoveries concerning information processing in the visual system"
	Torsten N. Wiesel	
1982	**Sune K. Bergström**	"for their discoveries concerning prostaglandins and related biologically active substances"
	Bengt I. Samuelsson	
	Sir John R. Vane	
1983	**Barbara McClintock**	"for her discovery of mobile genetic elements"
1984	**Niels K. Jerne**	"for theories concerning the specificity in development and control of the immune system and the discovery of the principle for production of monoclonal antibodies"
	Georges J.F. Köhler	

	César Milstein	
1985	**Michael S. Brown**	"for their discoveries concerning the regulation of cholesterol metabolism"
	Joseph L. Goldstein	
1986	**Stanley Cohen**	"for their discoveries of growth factors"
	Rita Levi-Montalcini	
1987	**Susumu Tonegawa**	"for his discovery of the genetic principle for generation of antibody diversity"
1988	**Sir James W. Black**	"for their discoveries of important principles for drug treatment"
	Gertrude B. Elion	
	George H. Hitchings	
1989	**J. Michael Bishop**	"for their discovery of the cellular origin of retroviral oncogenes"
	Harold E. Varmus	
1990	**Joseph E. Murray**	"for their discoveries concerning organ and cell transplantation in the treatment of human disease"
	E. Donnall Thomas	
1991	**Erwin Neher**	"for their discoveries concerning the function of

	Bert Sakmann	single ion channels in cells"
1992	**Edmond H. Fischer**	"for their discoveries concerning reversible protein phosphorylation as a biological regulatory mechanism"
	Edwin G. Krebs	
1993	**Sir Richard J. Roberts**	"for their discoveries of split genes"
	Phillip A. Sharp	
1994	**Alfred G. Gilman**	"for their discovery of G-proteins and the role of these proteins in signal transduction in cells"
	Martin Rodbell	
1995	**Edward B. Lewis**	"for their discoveries concerning the genetic control of early embryonic development"
	Christiane Nüsslein-Volhard	
	Eric F. Wieschaus	
1996	**Peter C. Doherty**	"for their discoveries concerning the specificity of the cell mediated immune defence"
	Rolf M. Zinkernagel	
1997	**Stanley B. Prusiner**	"for his discovery of Prions - a new biological principle of infection"
1998	**Robert F. Furchgott**	"for their discoveries concerning nitric oxide as a

	Louis J. Ignarro	signaling molecule in the cardiovascular system"
	Ferid Murad	
1999	**Günter Blobel**	"for the discovery that proteins have intrinsic signals that govern their transport and localization in the cell"
2000	**Arvid Carlsson**	"for their discoveries concerning signal transduction in the nervous system"
	Paul Greengard	
	Eric R. Kandel	
2001	**Leland H. Hartwell**	"for their discoveries of key regulators of the cell cycle"
	Sir Tim Hunt	
	Sir Paul M. Nurse	
2002	**Sydney Brenner**	"for their discoveries concerning 'genetic regulation of organ development and programmed cell death'"
	H. Robert Horvitz	
	Sir John E. Sulston	
2003	**Paul Lauterbur**	"for their discoveries concerning magnetic resonance imaging"
	Sir Peter Mansfield	

2004	**Richard Axel**	"for their discoveries of odorant receptors and the organization of the olfactory system"
	Linda B. Buck	
2005	**Barry J. Marshall**	"for their discovery of the bacterium Helicobacter pylori and its role in gastritis and peptic ulcer disease"
	J. Robin Warren	
2006	**Andrew Z. Fire**	"for their discovery of RNA interference - gene silencing by double-stranded RNA"
	Craig C. Mello	
2007	**Mario R. Capecchi**	"for their discoveries of principles for introducing specific gene modifications in mice by the use of embryonic stem cells."
	Sir Martin J. Evans	
	Oliver Smithies	
2008	**Harald zur Hausen**	"for his discovery of human papilloma viruses causing cervical cancer"
	Françoise Barré-Sinoussi	"for their discovery of human immunodeficiency virus"
	Luc Montagnier	
2009	**Elizabeth H. Blackburn**	"for the discovery of how chromosomes are protected by telomeres and the enzyme telomerase"
	Carol W. Greider	

	Jack W. Szostak	
2010	**Sir Robert G. Edwards**	"for the development of in vitro fertilization"
2011	**Bruce A. Beutler**	"for their discoveries concerning the activation of innate immunity"
	Jules A. Hoffmann	
	Ralph M. Steinman	"for his discovery of the dendritic cell and its role in adaptive immunity"
2012	**Sir John B. Gurdon**	"for the discovery that mature cells can be reprogrammed to become pluripotent"
	Shinya Yamanaka	
2013	**James E. Rothman**	"for their discoveries of machinery regulating vesicle traffic, a major transport system in our cells"
	Randy W. Schekman	
	Thomas C. Südhof	
2014	**John O'Keefe**	"for their discoveries of cells that constitute a positioning system in the brain"
	May-Britt Moser	
	Edvard I. Moser	
2015	**William C. Campbell**	"for their discoveries concerning a novel

	Satoshi Ōmura	therapy against infections caused by roundworm parasites"
	Tu Youyou	"for her discoveries concerning a novel therapy against malaria"
2016	**Yoshinori Ohsumi**	"for his discoveries of mechanisms for autophagy"
2017	**Jeffrey C. Hall**	"for their discoveries of molecular mechanisms controlling the circadian rhythm"
	Michael Rosbash	
	Michael W. Young	
2018	**James P. Allison**	"for their discovery of cancer therapy by inhibition of negative immune regulation"
	Tasuku Honjo	
2019	**William Kaelin Jr.**	"for their discoveries of how cells sense and adapt to oxygen availability"
	Peter J. Ratcliffe	
	Gregg L. Semenza	
2020	**Harvey J. Alter**	"for the discovery of Hepatitis C virus"
	Michael Houghton	
	Charles M. Rice	

Interaction	**Current theory**	**Mediators**	**Relative strength**	**Long-distance behavior**	**Range (m)**
Weak	Electroweak theory (EWT)	W and Z bosons	10^{25}	$\frac{1}{r}\,e^{-m_{W,Z}r}$	10^{-18}
Strong	Quantum chromodynamics (QCD)	gluons	10^{38}	$\approx r$ (Color confinement)	10^{-15}
Electromagnetic	Quantum electrodynamics (QED)	photons	10^{36}	$\frac{1}{r^2}$	∞
Gravitation	General relativity (GR)	gravitons (hypothe tical)	1	$\frac{1}{r^2}$	∞

Mathematical disaster:

$$\infty + 1 = \infty$$

$$1 = 0$$

$$\infty + \infty = \infty$$

$$2\infty = \infty$$

$$2 = 1$$

$$\infty \times \infty = \infty$$

$$\infty = 1$$

THE SLOWING DOWN OF TIME

Mountain $\xrightarrow[\text{More time}]{\hspace{12em}}$

Sea level $\xrightarrow[\text{Less time}]{\hspace{12em}}$

Time is not a line with two equal directions: it is an arrow with different extremities

Past $\xrightarrow{\hspace{12em}}$ Future

Second principle of thermodynamics $\rightarrow \Delta S \geq 0$

$E = mc^2$

$E = \frac{hc}{\lambda}$

$$E^2 = \frac{mhc^3}{\lambda} = \frac{2\pi}{\lambda} \times (Gm) \times c^2 \text{ (Planck mass)}^2$$

$$\boxed{E = \text{Planck momentum} \sqrt{\mu\, k}}$$

$\mu \rightarrow$ standard gravitational parameter

$k \rightarrow$ angular wave number of photon

The argument can be used to explain why the conditions happen to be just right for the existence of (intelligent) life on the Earth at the present time. For if they were not just right, then we should not have found ourselves to be here now, but somewhere else, at some other appropriate time. This principle was used very effectively by Brandon Carter and Robert Dicke to resolve an issue that had puzzled physicists for a good many years. The issue concerned various striking numerical relations that are observed to hold between the physical constants (the gravitational constant, the mass of the proton, the age of the universe, etc.). A puzzling aspect of this was that some of the relations hold only at the present epoch in the Earth's history, so we appear, coincidentally, to be living at a very special time (give or take a few million years!). This was later explained, by Carter and Dicke, by the fact that this epoch coincided with the lifetime of what are called main-sequence stars, such as the Sun. At any other epoch, the argument ran, there would be no intelligent life around to measure the physical constants in question—so the coincidence had to hold, simply because there would be intelligent life around only at the particular time that the coincidence did hold!

−Roger Penrose

What emerges is the suggestion that cosmology may at last be in possession of some raw material for a postmodern creation myth.

— Karl W. Giberson

The author unjustifiably stated a difference of Lorentz's view and that of mine concerning the physical facts. The question as to whether length contraction really exists or not is misleading. It doesn't "really" exist, in so far as it doesn't exist for a comoving observer; though it "really" exists, i.e. in such a way that it could be demonstrated in principle by physical means by a non-comoving observer.

— Albert Einstein, 1911

The wave number: $\nu = \dfrac{1}{\lambda}$

$$\frac{d\nu}{dt} = -\frac{d\lambda}{dt} \times \frac{1}{\lambda^2}$$

$$F = \frac{p^2}{h} \times -\frac{d\lambda}{dt}$$

$$\boxed{F = h\,\frac{d\nu}{dt}}$$

What would happen if we could communicate by signals other than those of light, the velocity of propagation of which differed from that of light? If, after having regulated our watches by the optimal method, we wished to verify the result by means of these new signals, we should observe discrepancies due to the common translatory motion of the two stations. And are such signals inconceivable, if we take the view of Laplace, that universal gravitation is transmitted with a velocity a million times as great as that of light?

−Henri Poincaré

Non-relativistic case

$$KE = \frac{p^2}{2m_0}$$

Relativistic case

$$KE = mc^2 - m_0c^2$$

Ultra relativistic case

$$KE = \sqrt{p^2c^2 + m_0^2c^4} - m_0c^2$$

$pc >> m_0c^2$

$$\boxed{KE = pc}$$

Electrostatic potential energy:

$$E_P = -\frac{Ze^2}{4\pi\varepsilon_0 r}$$

$$\frac{dE_P}{dr} = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

$$\boxed{\frac{dE_P}{dr} = F}$$

$$\frac{dE_P}{dr} = \frac{p^2}{h} \times -\frac{d\lambda}{dt}$$

Extract heat from the solar system—and the temperature of the system is raised. In brief, the heat capacity $\frac{\Delta Q}{\Delta T}$ of the solar system is negative. This startling conclusion applies not only to the solar system but to all systems maintained by gravitation: **the thermal capacity of all self-gravitating systems is negative.** It can easily be shown that, as long as self-gravitating systems are present, a stable thermal equilibrium cannot exist because the existence of systems with negative thermal capacity is thermodynamically destabilizing.

—Ben-Menahem

Although mechanical energy is indestructible, there is a universal tendency to its dissipation, which produces throughout the system a gradual augmentation and diffusion of heat, cessation of motion and **exhaustion of the potential energy of the material Universe.**

— **Thomson, William**

The quantity factor of **potential energy** is space or volume which however **is equivalent to mass.**

— **Mathews, Albert P**

As the protostar contracts, half of the gravitational potential energy released will be stored as internal heat, and the remaining half will be radiated away from the surface.

— **Cameron**

Zero-point energy → the lowest possible energy that a quantum mechanical system may have

The concept of zero-point energy was developed by **Max Planck** in Germany in 1911 as a corrective term added to a zero-grounded formula developed in his original quantum theory in 1900.

$$E_{\text{(Zero Point Energy)}} = E_{\text{(quantum minimum)}} - E_{\text{(classical minimum)}} > 0$$

$$E_{\text{(Zero Point Energy)}} = \frac{\hbar}{2}\,\omega_0$$

where ħ is reduced Planck's constant and ω_0 is the natural oscillation frequency.

There is a weighty argument to be adduced in favour of the aether hypothesis. To deny the aether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view... according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an aether. According to the general theory of relativity space without aether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. But this aether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it.

−Einstein

The light-quantum has the peculiarity that it apparently ceases to exist when it is in one of its stationary states, namely, the zero state, in which its momentum and therefore also its energy, are zero. When a light-quantum is absorbed it can be considered to jump into this zero state, and when one is emitted it can be considered to jump from the zero state to one in which it is physically in evidence, so that it appears to have been created. Since there is no limit to the number of light-quanta that may be created in this way, we must suppose that there are an infinite number of light quanta in the zero state...

− Dirac

From quantum theory there follows the existence of so called zero-point oscillations; for example each oscillator in its lowest is not completely at rest but always is moving about its equilibrium position. Therefore electromagnetic oscillations also can never cease completely. Thus the quantum nature of the electromagnetic field has as its consequence zero point oscillations of the field strength in the lowest energy state, in which there are no light quanta in space... The zero point oscillations act on an electron in the same way as ordinary electrical oscillations do. They can change the eigenstate of the electron, but only in a transition to a state with the lowest energy, since empty space can only take away energy, and not give it up. In this way spontaneous radiation arises as a consequence of the existence of these unique field strengths corresponding to zero point oscillations. Thus spontaneous radiation is induced radiation of light quanta produced by zero point oscillations of empty space.

−Victor Weisskopf

If classical kinetic energy is equal to the quantum energy:

$$\frac{m_0 v^2}{2} = h\upsilon$$

$$\frac{m_0 v^2}{2} = \frac{h v_P}{\lambda}$$

$$\boxed{v = 2v_P}$$

According to **linear density model**, age of our sun is around 10 million years. But geologists have the proof that age of some of the rocks on the earth is greater than above mentioned value. Hence the earth existed even before the birth of the sun! − which is absolutely has no sense. Hence, gravitational PE cannot account for the age of stars and hence gravitational PE cannot become the main source of energy in stars.

Triple alpha process

A **nuclear fusion reaction** in which 3 helium nuclei (**alpha particles**) fuse to form a carbon nucleus − thereby releasing energy

$$^{4}\text{He} + {}^{4}\text{He} \leftrightarrow {}^{8}\text{Be}$$

$$^{8}\text{Be} + {}^{4}\text{He} \rightarrow {}^{12}\text{C} + \text{energy}$$

2 helium nuclei fuse to form unstable beryllium. If another helium nucleus can fuse with the **beryllium nucleus** before it decays, stable carbon is formed – thereby releasing energy.

Coalescence is the process by which 2 or more stars of lower mass merge during contact to form a single massive star.

Bok Globules

↓

Small interstellar clouds of very cold gas and dust that are so thick they block the passage of visible light

Pre-main-sequence star

Young stellar object that has not yet initiated core hydrogen burning

Herbig–Haro object

A small bright nebula in a star-forming region − created when gas ejected by young stars collides with clouds of gas and dust nearby at speeds of several hundred kilometers per second.

FU Orionis star

A pre-main-sequence star which displays an extreme change in magnitude and spectral type

Red clump

A clustering of red giants in the Hertzsprung–Russell diagram at about 5,000 K and $75L_{sun}$

- **Luminous blue variables** are massive unstable hot supergiant stars that have ejections with greatly enhanced mass outflow (10^{-5} to 10^{-4} solar mass per year)

Blue Straggler Stars

Hot and bright stars found in the cores of ancient star clusters known as globulars

Superluminous supernova

Stellar explosion with luminosity 10 or more times higher than that of standard supernovae

Hypernova is the most powerful supernova explosion in the universe − 10 to even up to 100 times brighter than a typical supernova.

Extreme helium star

A low-mass supergiant where **hydrogen** [**the most common chemical element of the universe**] is underabundant by a factor of 10,000 or more

The gravitational force between 2 electrons:

$$F_G = \frac{Gm_e^2}{r^2}$$

When $r = \sqrt{\frac{\hbar G}{c^3}}$:

$$\boxed{F_G = 2\pi \frac{m_e c^2}{\lambda_{C,e}}}$$

The **gravitational force between 2 electrons** when the distance between them is equal to Planck length

The electrical force between 2 electrons:

$$F_E = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

When $r = \sqrt{\frac{\hbar G}{c^3}}$:

$$\boxed{F_E = \alpha \times F_{Planck}}$$

The **electrical force between 2 electrons** when the distance between them is equal to Planck length

Blue dwarf → a star that develops from a **red dwarf** after it has exhausted much of its hydrogen fuel supply.

Blue dwarfs do not exist at the present time because Our Cosmos is far too young for Red Dwarfs to turn into them.

"Environmental history fit[s] into the framework of New Left history. [It is] history "from the bottom up," except that here the exploited element [is] the biota and the land itself."

Roderick Nash, "American Environmental History: A New Teaching Frontier," Pacific Historical Review 41: 362-372 (1972), quotations on p. 363.

Types of Pollution

- Air pollution
- Water pollution
- Soil pollution
- Radioactive pollution
- Noise pollution

Observations

Questions

Hypothesis

Predictions

Test

Results

Reject hypothesis

Fail to reject hypothesis

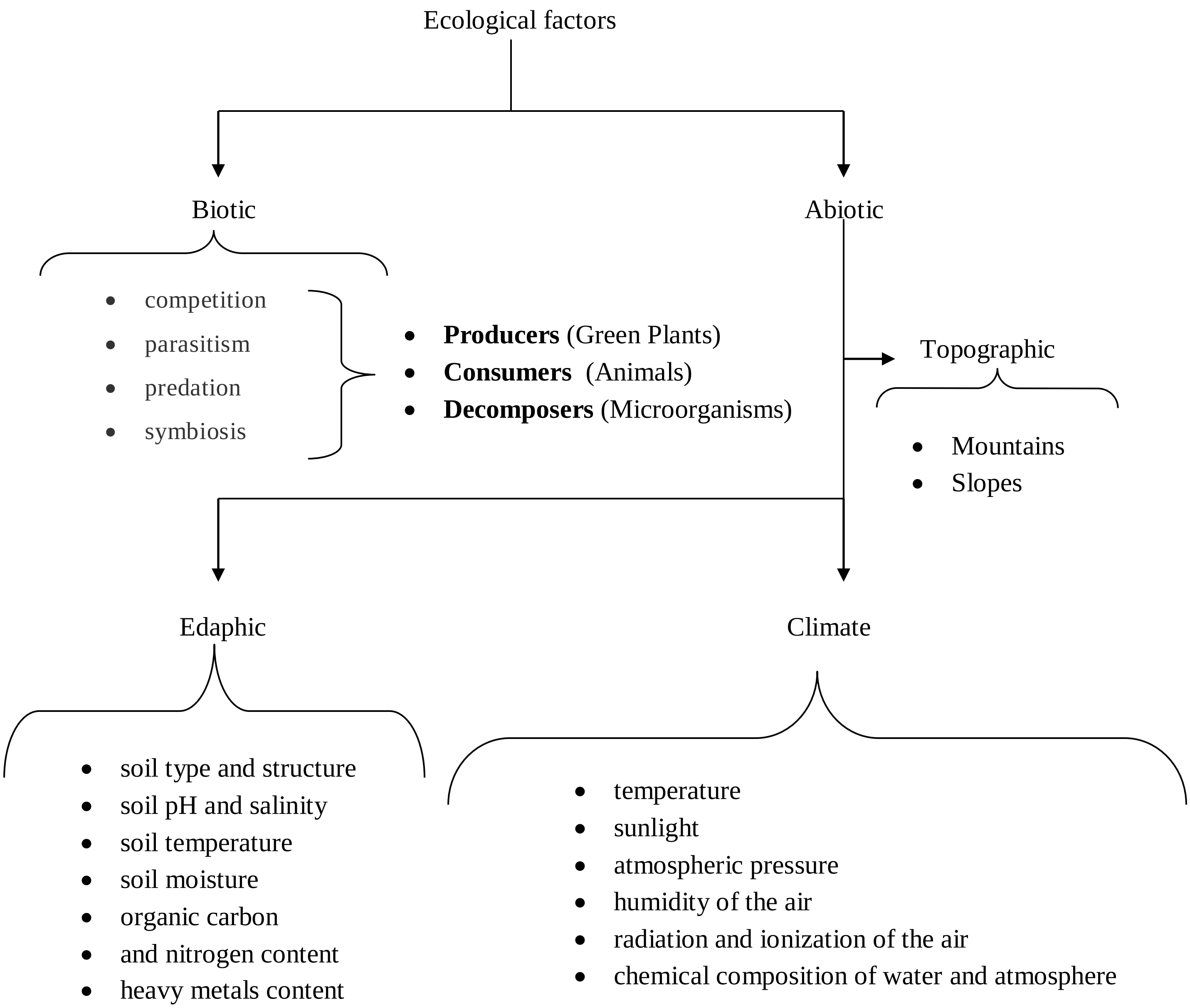
Fluoride toxicity

- **Acute toxicity:** Excessive intake of fluoride over short period of time
- **Chronic toxicity:** Excessive intake of fluoride over long period of time

Renewable resources	cannot be depleted	sunlight, wind, wave energy
Nonrenewable resources	can be depleted	Oil, coal, minerals

Risks

- Dental fluorosis
- Skeletal fluorosis
- Thyroid problems
- Neurological problems



> There is a deep interconnectedness of all life on earth, from the tiniest organisms, to the largest ecosystems, and absolutely between each person.
>
> **Bryant McGill**

	Jean-Baptiste Lamarck	Charles Darwin
Origin of life	Permanent spontaneous generation	Derived from an ancestral form
Driving force for evolution	Complexification over time	Natural selection
Modifications	Adaptation to the environment	Spontaneous variations transmitted to the progeny
Species extinction	No, unless due to human activities	Yes

Biological Evolution is a consequence of these 4 factors

- overproduction
- genetic variation
- natural selection
- competition

In prehistoric times, Homo sapiens was deeply endangered. Early humans were less fleet of foot, with fewer natural weapons and less well-honed senses than all the predators that threatened them. Moreover, they were hampered in their movements by the need to protect their uniquely immature young - juicy meals for any hungry beast.

Robert Winston

Through the study of fossils I had already been initiated into the mysteries of prehistoric creations.

Pierre Loti

Through the release of atomic energy, our generation has brought into the world the most revolutionary force since prehistoric man's discovery of fire. This basic force of the universe cannot be fitted into the outmoded concept of narrow nationalisms.

Albert Einstein

Since Serengeti-scale savanna scenes are only one or two million years old, our earliest after-the-apes ancestors didn't move into this scene so much as they evolved with it, as the slower climate changes and uplift produced more grass and less forest.

William Calvin, A Brain for All Seasons: Human Evolution and Abrupt Climate Change University of Chicago Press 2002

[When environments change], they usually do so pretty rapidly, at rates with which adaptation by natural selection would be hard put to keep up. When such change occurs, the quality of your adaptation to your old habitat is irrelevant, and any competitive advantage you might have had may be eliminated at a stroke.

Ian Tattersall, Becoming Human, 1998

...[T]he natural history of the rat is tragically similar to that of man ... some of the more obvious qualities in which rats resemble men — ferocity, omnivorousness, and adaptability to all climates ... the irresponsible fecundity with which both species breed at all seasons of the year with a heedlessness of consequences, which subjects them to wholesale disaster on the inevitable, occasional failure of the food supply.... [G]radually, these two have spread across the earth, keeping pace with each other and unable to destroy each other, though continually hostile. They have wandered from East to West, driven by their physical needs, and — unlike any other species of living things — have made war upon their own kind. The gradual, relentless, progressive extermination of the black rat by the brown has no parallel in nature so close as that of the similar extermination of one race of man by another...

Hans Zinsser

A superficial knowledge of mathematics may lead to the belief that this subject can be taught incidentally, and that exercises akin to counting the petals of flowers or the legs of a grasshopper are mathematical. Such work ignores the fundamental idea out of which quantitative reasoning grows—the equality of magnitudes. It leaves the pupil unaware of that relativity which is the essence of mathematical science. Numerical statements are frequently required in the study of natural history, but to repeat these as a drill upon numbers will scarcely lend charm to these studies, and certainly will not result in mathematical knowledge.

William W. Speer

Exposure → Host → Disease

- Death
- Disability
- Recovery

Empirical research

Theory ⇄ Reality

Exploratory research

Hypothesis	Theory	Law
Proposed explanation that predicts what happens but does not explain how	Explanation that has been tested and verified	Untested explanation based upon on observation or known facts

Carl Linnaeus's System of classification:

Eukaryotes
Animalia
Chordata
Mammalia
Primates
Hominidae
Homo
Homosapiens

Domain
Kingdom
Phylum
Class
Order
Family
Genus
Species

Kingdom:

- Animals
- Plants
- Fungi
- Protists (**very simple organisms**)
- Monera (**bacteria**)

In natural science the principles of truth ought to be confirmed by observation.

Carl Linnaeus

The Five Types of Bones:

Flat Bones	Protect Internal Organs
Long Bones	Support Weight and Facilitate Movement
Short Bones	Provide stability and some movement
Irregular Bones	Helps protect internal organs
Sesamoid Bones	Protect tendons from stress and wear

Put briefly, genetic engineering is a "cut, paste, and copy" operation.

SUSAN ALDRIDGE

Modern genetics is on the verge of some truly fantastic ways of "improving" the human race, but let me emphasize at the onset that this technical know-how does not automatically bring with it the criteria for its use. This, I believe, is the most important fact that scientists and citizens alike must keep in mind as our technology progresses. It may be true that man has tremendous genetic potential for significant improvement, but in what direction? It is tempting to point to the great success animal breeders have had in "improving" their stocks and say that the same can be done in man, but we must remember that animal breeding was successful only because the breeders had a Platonic "ideal" and selected ruthlessly for uniformity to achieve it. It seems certain that the improvement of man does not lie in some simple uniform ideal analogous to the ideal dairy cow with her "opulent udder."

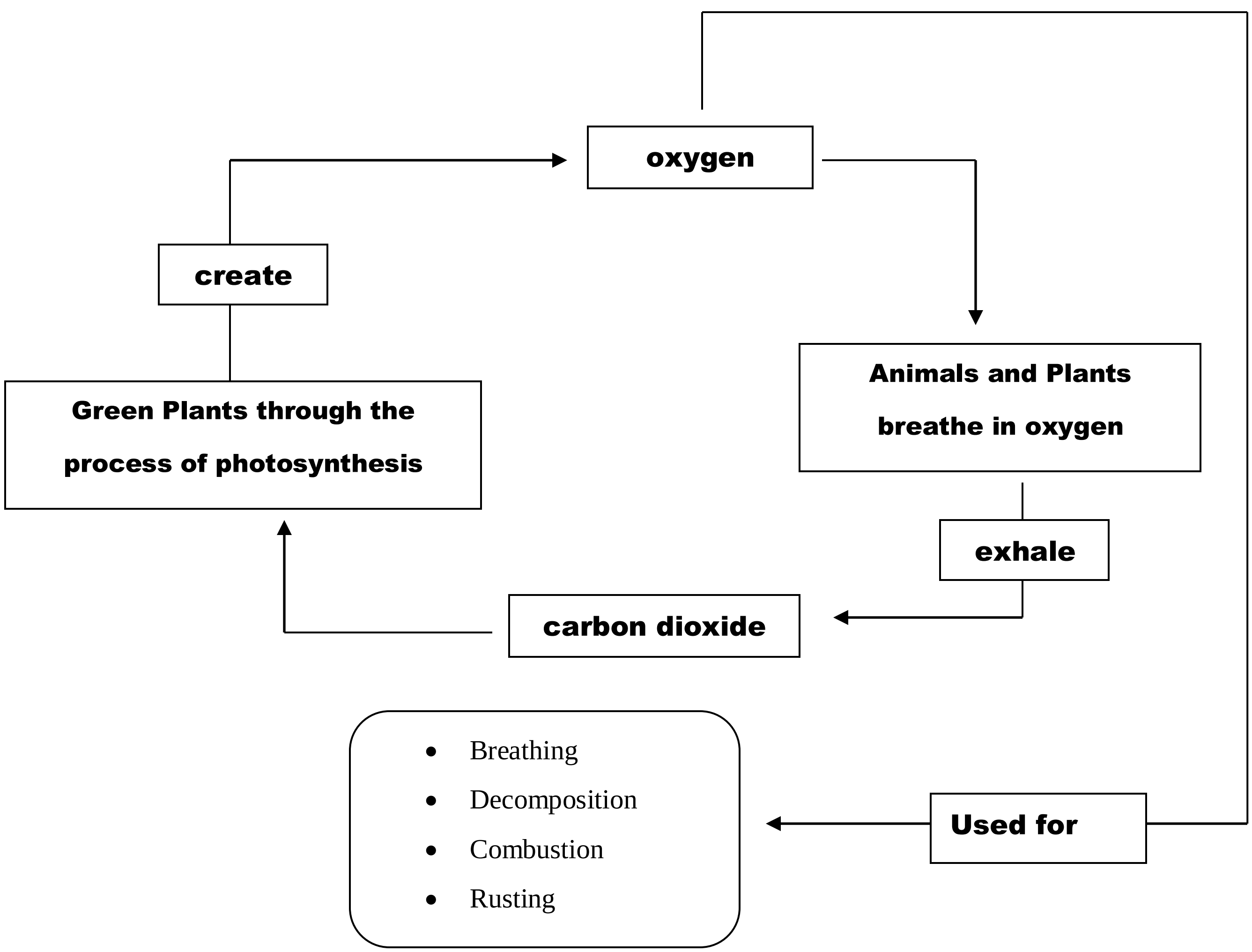
James J. Nagle

Saponification:

Triglyceride + Alkali → Soap + water + glycerine

Fatty acid + Alkali → Soap + water

Soaps	Detergents
They are sodium or potassium salts of fatty acids	They are sodium or potassium salts of sulphonic acids
They have –COONa group	They have $–SO_3Na$ group



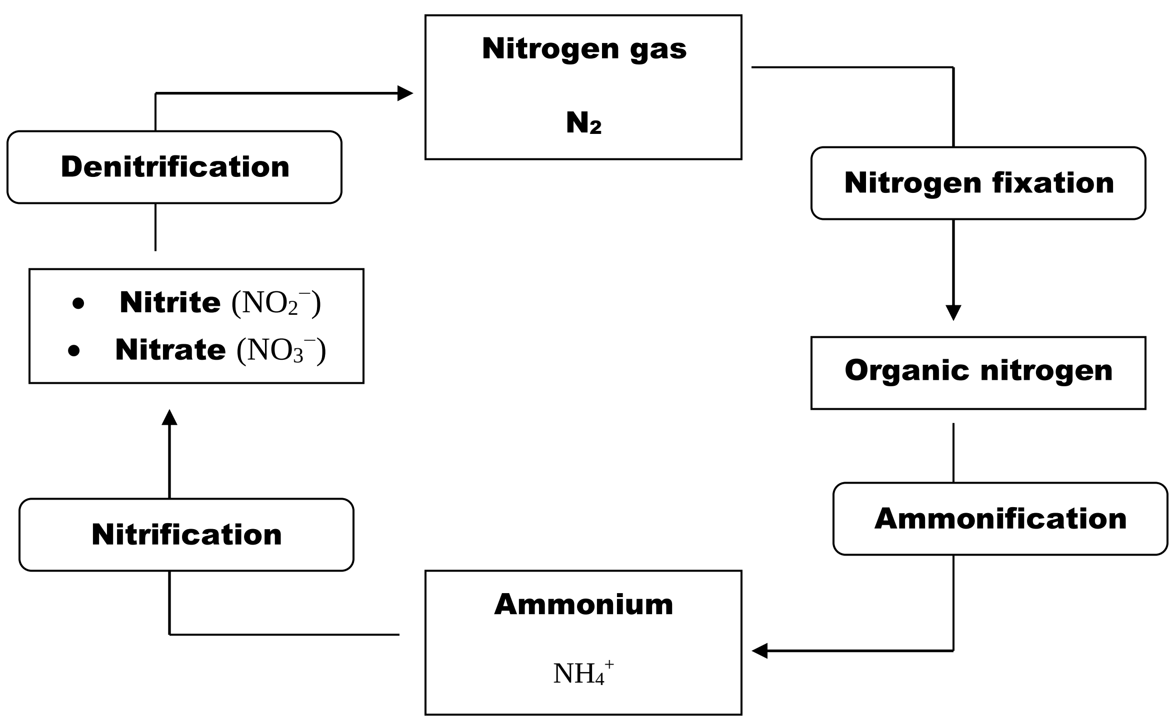
In atmosphere:

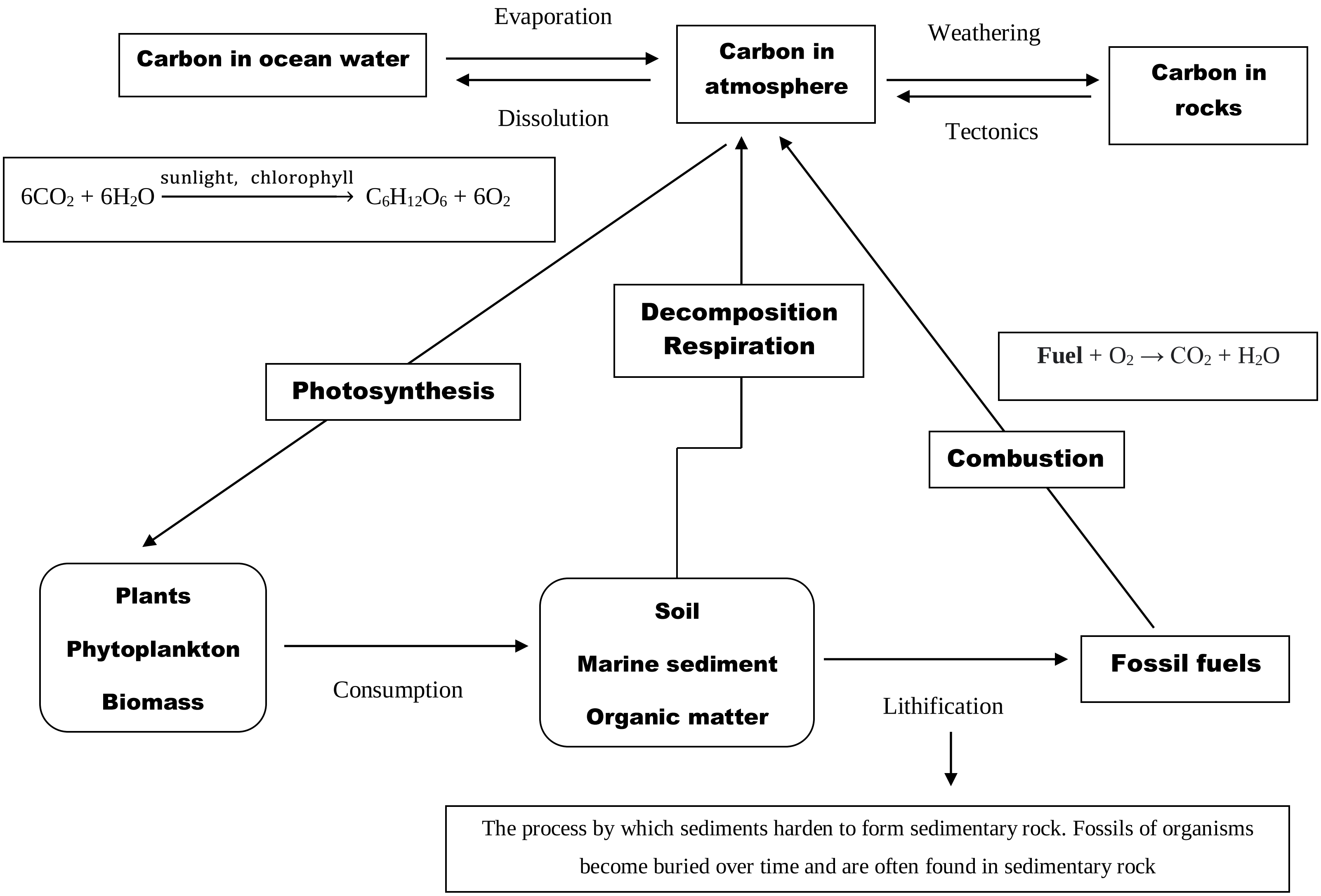
$$H_2O \xrightarrow{\text{sunlight}} H + OH$$

$$CO_2 \xrightarrow{\text{sunlight}} CO + O$$

$$\boxed{O + OH \rightarrow O_2 + H}$$

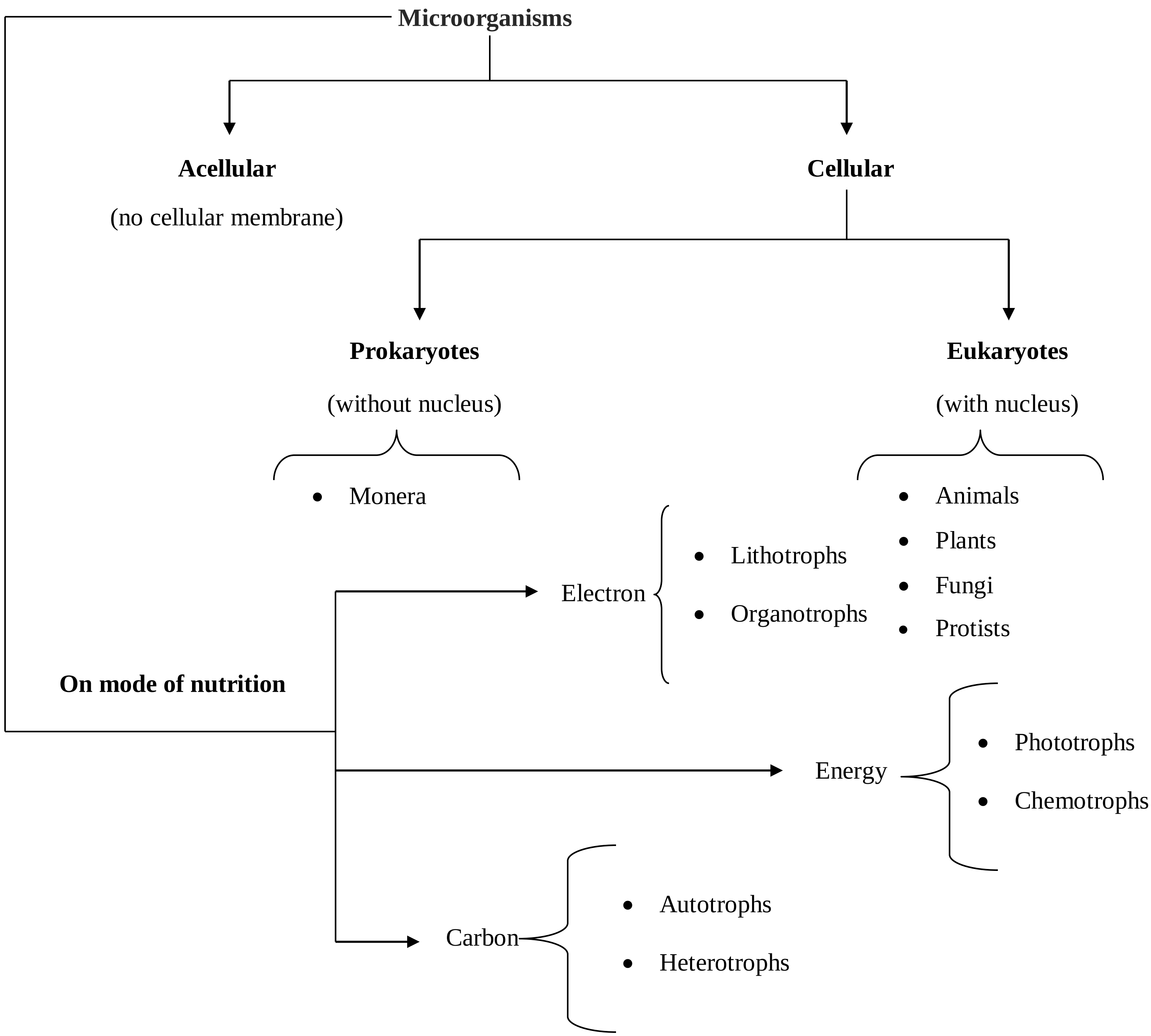
> About two-thirds of the oxygen in our atmosphere is produced in the surface waters of the sea by phytoplankton, the minute forms of algae that give the sea its slightly green hue, and which initiate the entire food web of the ocean.
>
> **— Jacques-Yves Cousteau**





Borel makes the amusing supposition of a million monkeys allowed to play upon the keys of a million typewriters. What is the chance that this wanton activity should reproduce exactly all of the volumes which are contained in the library of the British Museum? It certainly is not a large chance, but it may be roughly calculated, and proves in fact to be considerably larger than the chance that a mixture of oxygen and nitrogen will separate into the two pure constituents. After we have learned to estimate such minute chances, and after we have overcome our fear of numbers which are very much larger or very much smaller than those ordinarily employed, we might proceed to calculate the chance of still more extraordinary occurrences, and even have the boldness to regard the living cell as a result of random arrangement and rearrangement of its atoms. However, we cannot but feel that this would be carrying extrapolation too far. This feeling is due not merely to a recognition of the enormous complexity of living tissue but to the conviction that the whole trend of life, the whole process of building up more and more diverse and complex structures, which we call evolution, is the very opposite of that which we might expect from the laws of chance.

— Gilbert Newton Lewis



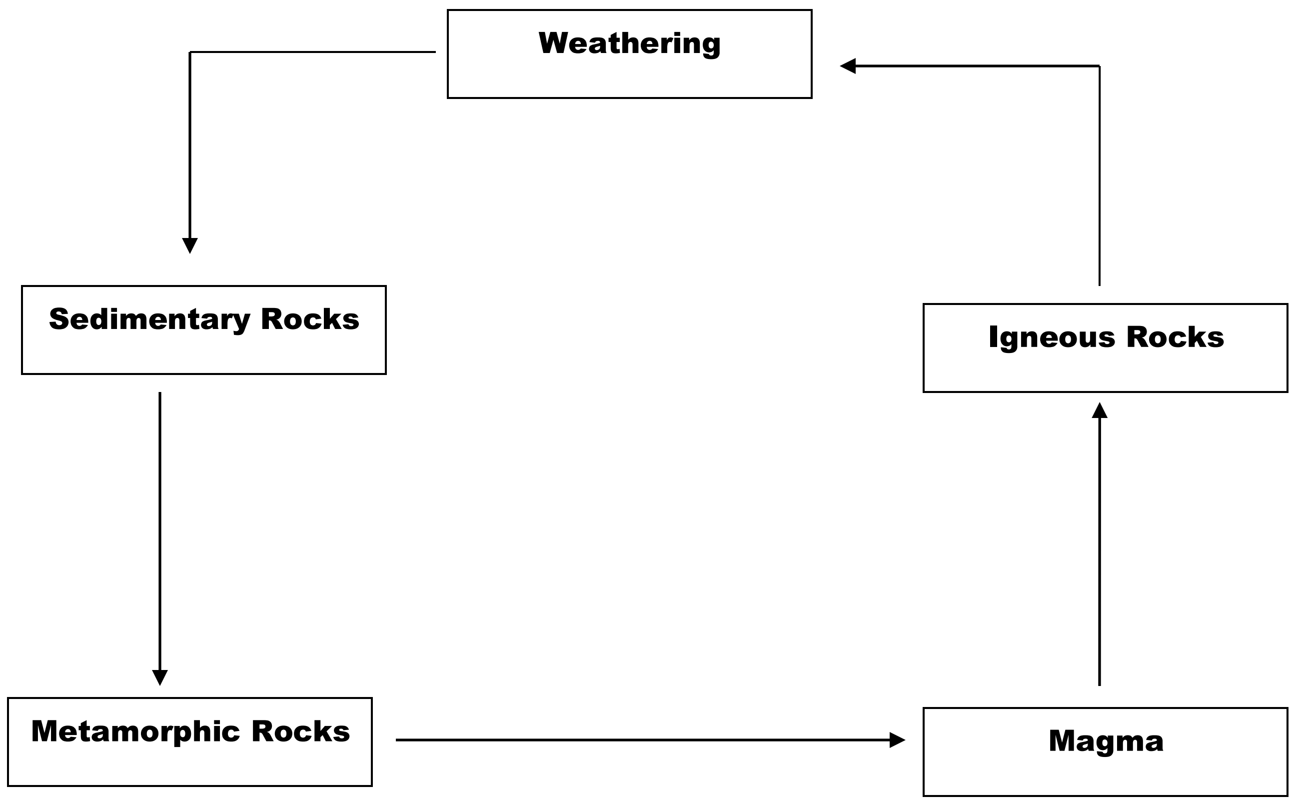
In natural history, great discovery often requires a map to a hidden mine filled with gems then easily gathered by conventional tools, not a shiny new space-age machine for penetrating previously inaccessible worlds.

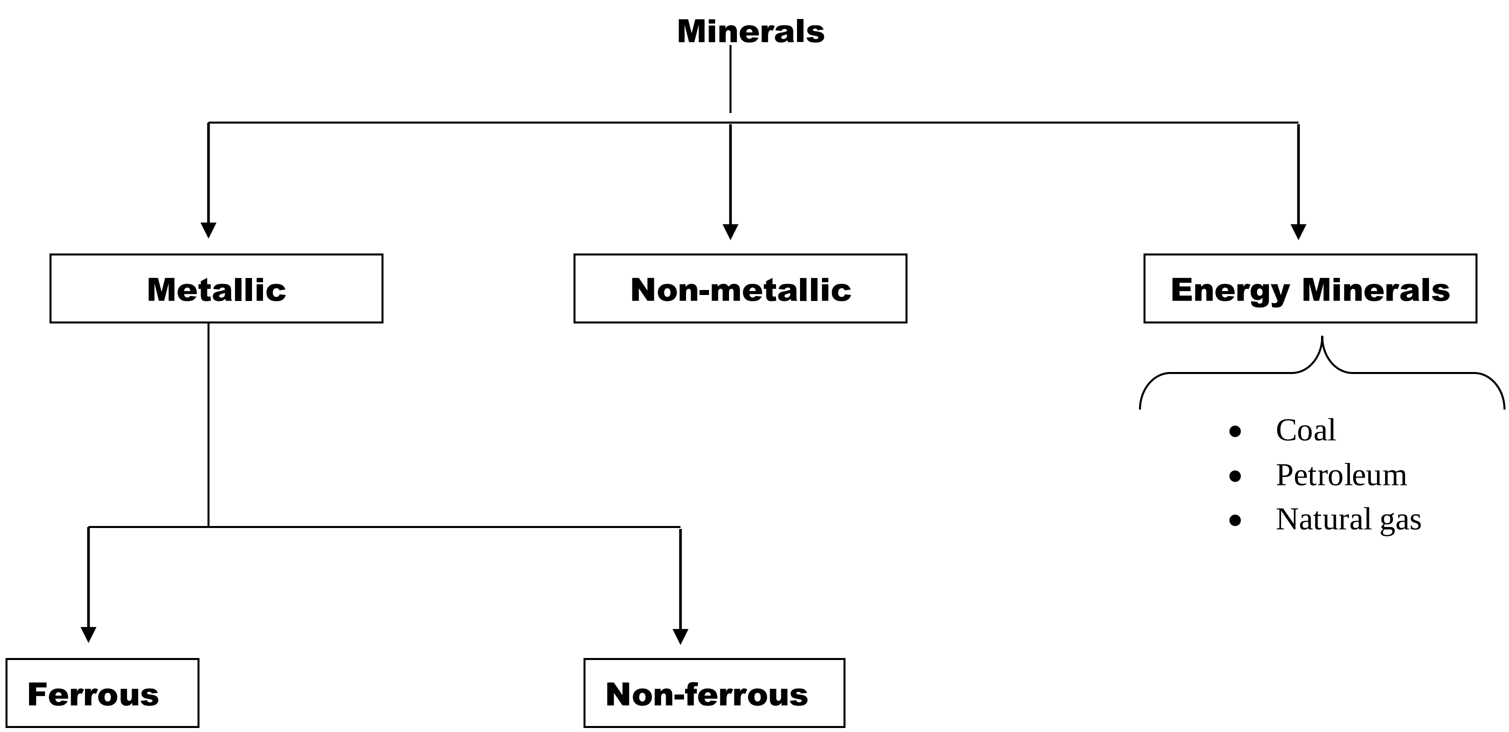
Stephen Jay Gould

Rocks

- Igneous
  - **Intrusive**
    - Gabbro
    - Diorite
    - Granodiorite
    - Granite
  - **Extrusive**
    - Basalt
    - Andesite
    - Dacite
    - Rhyolite
- Sedimentary
  - **Clastic**
    - Conglomerate
    - Breccia
    - Sandstone
    - Siltstone
    - Shale
    - Mustone
  - **Biological**
    - Coal
    - Chert
  - **Chemical**
    - Limestone
    - Dolostoone
- Metamorphic
  - **Foliated**
    - Slate
    - Schist
    - Gneiss
  - **Non-foliated**
    - Quarzite
    - Marble

> Natural history is not equivalent to biology. Biology is the study of life. Natural history is the study of animals and plants—of organisms. Biology thus includes natural history, and much else besides.
>
> **Marston Bates**


Weathering
Sedimentary Rocks
Igneous Rocks
Metamorphic Rocks
Magma


Minerals
Metallic
Non-metallic
Energy Minerals
Coal
Petroleum
Natural gas
Ferrous
Non-ferrous

If we ascribe the ejection of the proton to a Compton recoil from a quantum of 52×10^6 electron volts, then the nitrogen recoil atom arising by a similar process should have an energy not greater than about 400,000 volts, should produce not more than about 10,000 ions, and have a range in the air at N.T.P. of about 1-3mm. Actually, some of the recoil atoms in nitrogen produce at least 30,000 ions. In collaboration with Dr. Feather, I have observed the recoil atoms in an expansion chamber, and their range, estimated visually, was sometimes as much as 3mm. at N.T.P.

These results, and others I have obtained in the course of the work, are very difficult to explain on the assumption that the radiation from beryllium is a quantum radiation, if energy and momentum are to be conserved in the collisions. The difficulties disappear, however, if it be assumed that the radiation consists of particles of mass 1 and charge 0, or neutrons. The capture of the a-particle by the Be^9 nucleus may be supposed to result in the formation of a C^{12} nucleus and the emission of the neutron. From the energy relations of this process the velocity of the neutron emitted in the forward direction may well be about 3×10^9 cm. per sec. The collisions of this neutron with the atoms through which it passes give rise to the recoil atoms, and the observed energies of the recoil atoms are in fair agreement with this view. Moreover, I have observed that the protons ejected from hydrogen by the radiation emitted in the opposite direction to that of the exciting a-particle appear to have a much smaller range than those ejected by the forward radiation.

This again receives a simple explanation on the neutron hypothesis.

Sir James Chadwick

Letter From James Chadwick to German-British physicist Rudolf Peierls

July 14, 1944

Dear Peierls,

I have now had talks with both Kearton and Fuchs about the future of the New York section and in particular about their own positions. As a result, Kearton will approach Keith and Benedict with the object of getting a letter by one or both of them to Groves to say that the services of Fuchs and Skyrme are no longer required. It is possible that this matter was raised by Groves on a visit to New York earlier in the week, but I have had no news from him so far.

The position of Skyrme is quite clear. Bethe or Oppenheimer should write to Groves asking for his services in Y. Groves has provisionally agreed and there should be little delay over his transfer.

Fuchs' future is not so clear. I gave you the gist of a cable from Akers in my letter of July 11. I did not agree with the suggestion made in this cable that Fuchs was not required in England, but I wished to discuss the question with Kearton before I made up my mind. Kearton was very strongly of the opinion that Fuchs was quite necessary in England if work on any kind of diffusion plant is to continue...

I have now had a talk with Fuchs himself. He feels that he has a special contribution to make in England, whereas in Y he would be one of a number and can make no really significant difference to the work

I agree completely with these views of Kearton and Fuchs, and I feel sure you also agree at least in principle.

I come now to the point of this letter It would put me in a very awkward position if a request for Fuchs' services in Y were to be sent to Groves. If Groves were to agree I also should have to consent, for the consequences of refusing, on the grounds that he was needed in England for work which can have no significance for the war, might be quite serious. It would certainly cause great resentment in some quarters and our relations with the U.S. on this project would be impaired. I should attempt to justify his return as being useful for the New York project, for after his experience here he could interpret their requests and help to direct U.K. work into directions of immediate interest to them. This argument would of course not be valid if a low-separation diffucison plant were to be started in England.

I therefore do not want Bethe to ask for Fuchs. Further than that, I want Bethe to say that Fuchs would not be specially useful in Y, if Groves asks if they want him, as he may. This means some

tactful work on your part and I hope you will be able to do what is necessary by suggestion rather than direct action.

I have prepared the ground here and I think the matter can be arranged. I have stated that Fuchs could be useful in Y but that his special qualifications are not on the nuclear side but on the diffusion plant.

Until I know something of what is happening in London I want to keep the New York psotion as fluid as possible.

Yours sincerely,

J. Chadwick

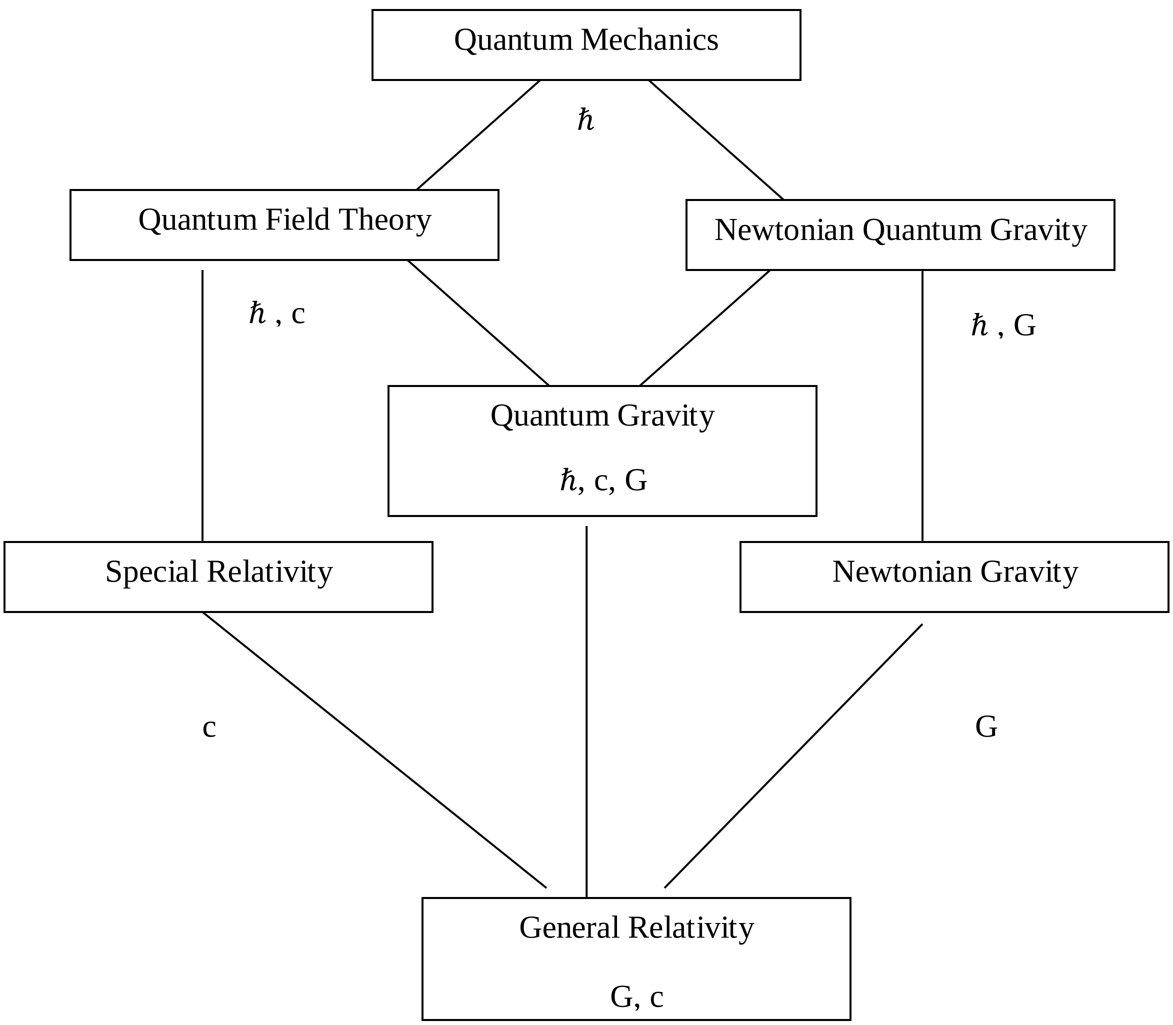
I am glad that Dr. Chadwick has stuck to the view that it [the neutron] is a combination of a proton and electron. Some people have said it was a new kind of ultimate particle. It was really too much to believe—that a new ultimate particle should exist with its mass so conveniently close to that of the proton and electron combined. It was nothing but a bad joke played on its creator and on the rest of us. Still, there is no doubt this neutron business is going to have many developments.

Sir Owen Willans Richardson

In Flat Universe: Expansion slows until the rate approaches zero.

$$E = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Tachyons (if they exist) have v > c. This means that $E = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$ is imaginary!



Philosophy

- Metaphysics
  - Special
    - Cosmology
    - Theodicy
    - Psychology
  - General
    - Ontology
- Epistemology
- Logic
- Ethics

> Nothing happens until something moves.
>
> **Albert Einstein**

Galilean Newtonian Relativity

The basic laws of physics are the same in all inertial reference frames

Einstein's Equivalence principle:

inertial mass = gravitational mass

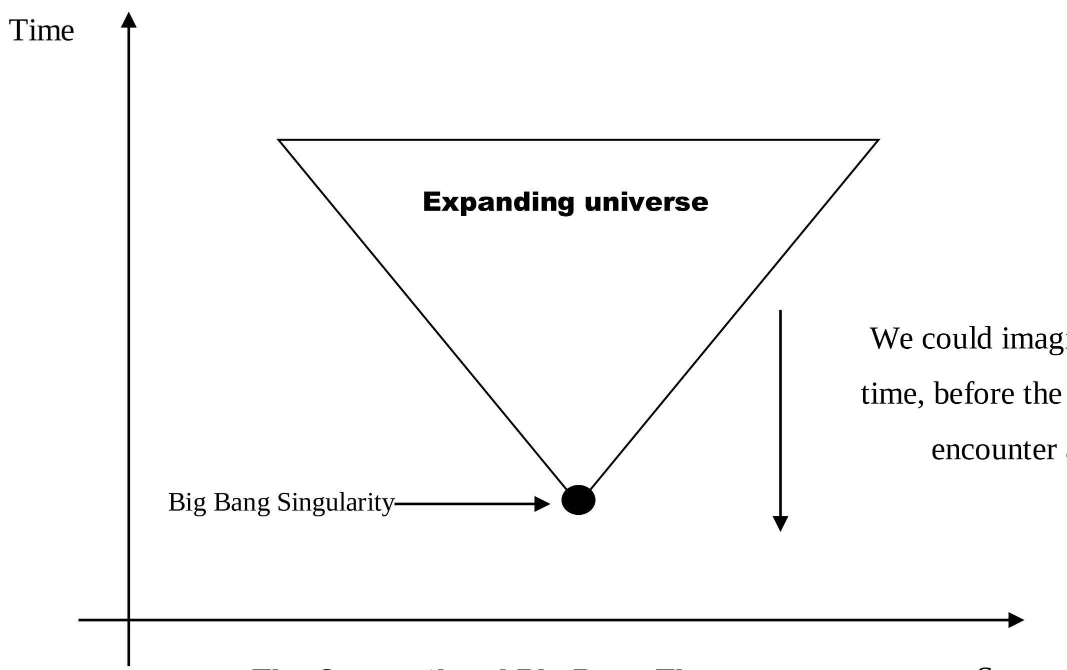
acceleration = intensity of the gravitational field

- **Mach's Principle** → geometry from matter
- **Wheeler's Geometrodynamics** → matter from (pre) geometry

Einstein's static universe is closed and contains a positive cosmological constant with value precisely $\Lambda = \frac{4\pi G\rho}{c^2}$, where G is Newtonian gravitational constant, ρ is the energy density of the matter in the universe and c is the speed of light. The radius of curvature of space of the Einstein universe is equal to $\frac{1}{\sqrt{\Lambda}} = \frac{c}{\sqrt{4\pi G\rho}} = \frac{1}{c} \times \sqrt{\frac{\text{Planck force}}{4\pi\rho}}$

If determinism — the predictability of the universe — breaks down in black holes, it could break down in other situations. Even worse, if determinism breaks down, we can't be sure of our past history either. The history books and our memories could just be illusions. It is the past that tells us who we are. Without it, we lose our identity.

Stephen Hawking



The Conventional Big Bang Theory

Schwarzschild Cosmology:

In this model:

$$\frac{c}{H} = \frac{2GM}{c^2}$$

$\frac{c}{H}$ → Hubble radius of the observable universe

$\frac{2GM}{c^2}$ → Schwarzschild radius of the observable universe

de Sitter universe:

$$H \propto \sqrt{\Lambda}$$

$$E = \frac{\text{Planck power}}{2H}$$

Borde–Guth–Vilenkin theorem:

spacetime had a singularity in the past

Conformal cyclic cosmology:

The Universe goes through infinite cycles. Each cycle begins with an event such as the Big Bang that birthed our own universe

Hot dark matter
- travel with ultrarelativistic speed
- neither emits nor absorbs light

- **Relativity** → deterministic

  explains →
  - Spacetime
  - Gravity

- **Quantum mechanics** → probabilistic

  explains →
  - Atoms
  - Nuclei

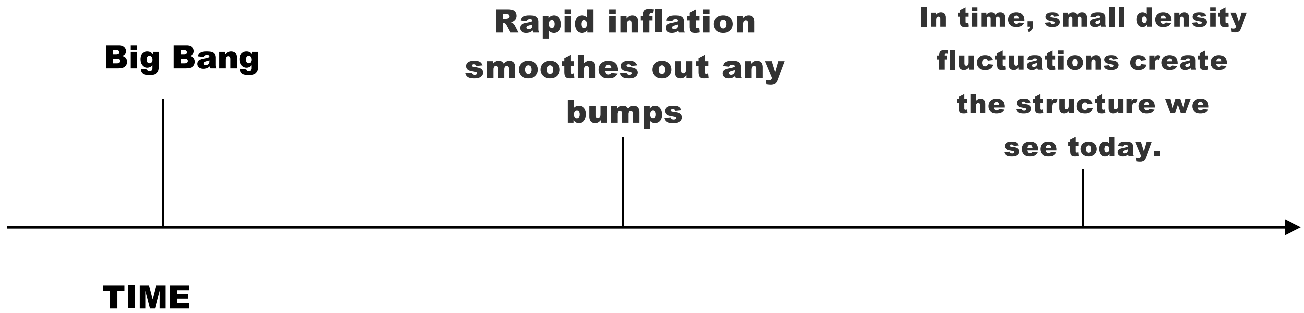
Inflation

The baby universe expands rapidly, smoothing out any lumps in its large-scale structure.

Inflation → Expansion

We are an impossibility in an impossible universe.

— Ray Bradbury



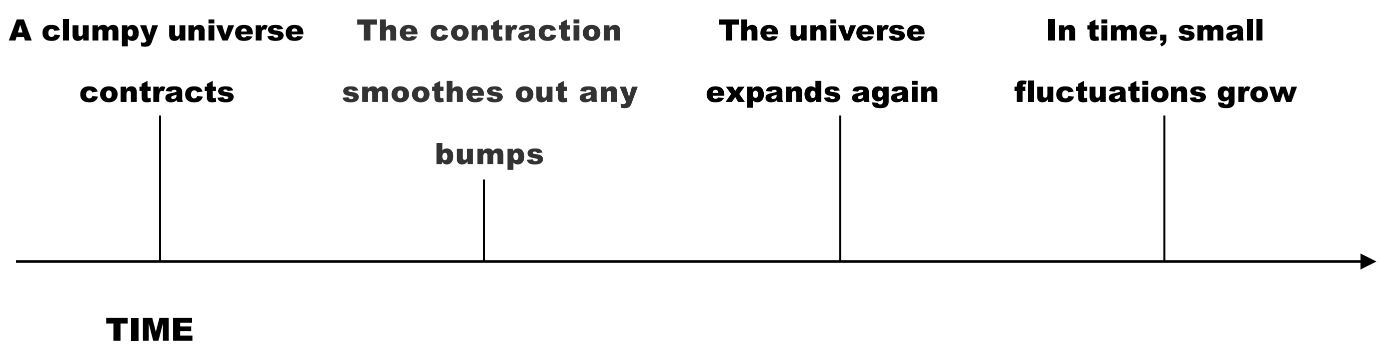
Cyclic Universe

The universe has no beginning and no end. Periodic contractions smooth out its structure.

Contraction → Expansion

The beauty of a living thing is not the atoms that go into it, but the way those atoms are put together.

— **Carl Sagan**



The World's 10 Oldest Ancient Civilizations

- **Mesopotamian Civilization**

Era: 3500 BC–500 BC

Location: Ancient Mesopotamia (modern-day Iraq)

Notable Achievements: Invention of the wheel

> It is childish to assume that science began in Greece; the Greek "miracle" was prepared by millenia of work in Egypt, Mesopotamia and possibly in other regions. Greek science was less an invention than a revival.
>
> **George Sarton**

- **Indus Valley Civilization**

Era: 3300 BC–1900 BC

Location: South Asia (modern-day Pakistan and northwest India)

Notable Achievements: The first people to domesticate Cotton

By the fourth millennium BC, the Fertile Crescent was not the only region of coalesced communities; organized agricultural, military, religious, and administrative activity had also begun to appear in the Indus Valley, in what is now Pakistan. Even before written records, there is evidence of trade between these two regions. Archaeologists have discovered lamps and cups in Mesopotamia dating from the late fourth millennium BC and made from conch shells found only in the Indian Ocean and the Gulf of Oman.

William J. Bernstein

- **Egyptian Civilization**

Era: 3150 BC–30 BC

Location: Nile River Valley of Egypt

Notable Achievements: The Great Pyramids

Less than 1 percent of ancient Egypt has been discovered and excavated. With population pressures, urbanization, and modernization encroaching, we're in a race against time. Why not use the most advanced tools we have to map, quantify, and protect our past?

Sarah Parcak

- **Mayan Civilization**

Era: 2600 BC–900 AD

Location: Central America

Notable Achievements: science of astronomy, calendar systems and hieroglyphic writing

Evidence indicates that cats were first tamed in Egypt. The Egyptians stored grain, which attracted rodents, which attracted cats. (No evidence that such a thing happened with the Mayans, though a number of wild cats are native to the area.) I don't think this is accurate. It is certainly not the whole story. Cats didn't start as mousers. Weasels and snakes and dogs are more efficient as rodent-control agents. I postulate that cats started as psychic companions, as Familiars, and have never deviated from this function.

William S. Burroughs

- **Chinese Civilization**

Era: 1600 BC–1046 BC

Location: Yellow River region of northern China

Notable Achievements: Invention of paper and silk

If you look at ancient Chinese culture, and depictions of it, the relationship between people and nature was very different. It almost felt as though feelings were always attached to a certain landscape.

Jia Zhangke

The Chinese culture belongs not only to the Chinese but also to the whole world.

Hu Jintao

- **Greek Civilization**

Era: 2700 BC– 479 BC

Location: Greece

Notable Achievements: Concepts of democracy and the Senate, the Olympics

Greek customs such as wine drinking were regarded as worthy of imitation by other cultures. So the ships that carried Greek wine were carrying Greek civilization, distributing it around the Mediterranean and beyond, one amphora at a time. Wine displaced beer to become the most civilized and sophisticated of drinks-a status it has maintained ever since, thanks to its association with the intellectual achievements of Ancient Greece.

Tom Standage

- **Persian Civilization**

Era: 550 BC – 331 BC

Location: Modern-day Iran

Notable Achievements: The world's first postal service

What has history said of eminence without honor, wealth without wisdom, power and possessions without principle? The answer is reiterated in the overthrow of the mightiest empires of ancient times. Babylon, Persia, Greece, Rome! The four successive, universal powers of the past. What and where are they?

Orson F. Whitney

- **Roman Civilization**

Era: 550 BC– 465 AD

Location: Rome

Notable Achievements: Roman Numerals

I have a long view of history - my orientation is archaeological because I'm always thinking in terms of ancient Greece and Rome, ancient Persia and Egypt.

Camille Paglia

- **Aztec Civilization**

Era: 1345 AD –1521 AD

Location: Mexico

Notable Achievements: Floating Gardens

The Sun Stone, the famous Aztec calendar, is unquestionably a perfect summary of science, philosophy, art and religion.

Samael Aun Weor

Everything that is really Mexican is either Aztec or Spanish.

Edward Burnett Tylor

- **Incan Civilization**

Era: 1438 AD–1532 AD

Location: modern-day southern Peru

Notable Achievements: Machu Picchu (one of the New 7 Wonders of the Modern World)

"Your emperor may be a great prince; I do not doubt it, seeing that he has sent his subjects so far across the waters; and I am willing to treat him as a brother.

As for your pope of whom you speak, he must be mad to speak of giving away countries that do not belong to him.

As for my faith, I will not change it.

Your own God, as you tell me, was put to death by the very men He created. But my God still looks down on His children."

Atahualpa, Inca Chief (On hearing Pope Alexander VI had declared Peru to be a possession of Spain)

Top 10 Ancient Roman Inventions

- Arches
- Grid-based cities
- Sewers and Sanitation
- Roads and Highways
- Aqueducts
- Roman Numerals
- Surgery Tools and Techniques
- Julian Calendar
- Newspapers
- Concrete

The war of ideas is a Greek invention. It is one of the most important inventions ever made. Indeed, the possibility of fighting with with words and ideas instead of fighting with swords is the very basis of our civilization, and especially of all its legal and parliamentary institutions.

Karl Popper

Top 10 Inventions of the Maya Civilization

- Astronomy
- Ball Courts
- Chocolate
- Hallucinogenic Drugs
- Law and Order
- Mathematics
- Maya Art
- The Maya Calendar
- Mayan Writing System
- Rubber

The Jews had a love-hate relationship with the Greek culture. They craved its civilization but resented its dominance. Josephus says they regarded Greeks as feckless, promiscuous, modernizing lightweights, yet many Jerusalemites were already living the fashionable lifestyle using Greek and Jewish names to show they could be both. Jewish conservatives disagreed; for them, the Greeks were simply idolaters.

Simon Sebag-Montefiore

Top 10 Inventions and Discoveries of Ancient Greece:

• The Water Mill • The Odometer • The Alarm Clock	• Cartography • Olympics • Basis of Geometry

• Earliest Practice of Medicine • Modern Philosophy	• Concept of Democracy • Discoveries in Modern Science

To put it in a nutshell, the Central and South American high cultures of antiquity were entirely worthy of comparison with what the Old World had achieved by the time of the Han, the Gupta, and the Hellenistic age. The fact is that the Amerindian high cultures were a human modality of their own, and those Spaniards who came among them first would have had the sensation, if they had ever heard of such literature, of treading in a world of imaginative science fiction. But it was real, and the Amerindian achievements deserve all our sympathy and praise.

Joseph Needham

Top 10 Ancient Egyptian Inventions

- Bowling
- Paper and Ink
- Make-Up and Wigs
- Barbers
- The Calendar and Timekeeping
- Tables (and other Furniture)
- Toothpaste and Breath Mints
- The Police
- The Lock
- Medicines

The Chinese had first learned of the Roman Empire in 139 B.C., when the emperor Wudi had sent an envoy, Zhang Qian, past the deserts to seek allies to the west. Zhang Qian traveled for twelve years to what is now Turkistan and back and reported on the astounding discovery that there was a fairly advanced civilization to the west. In 104 B.C. and 102 B.C., Chinese armies reached the area, a former Greek kingdom called Sogdiana with its capital in Samarkand, where they met and defeated a force partly composed of captive Roman soldiers.

Mark Kurlansky

Top 10 inventions of Indus Valley Civilization:

- The invention of the Ruler
- Demonstration of World's first-known urban sanitation systems
- Start of a well-structured living area and housing
- The innovation of Seal and Trade
- Creation of typical scripts and Gods
- Discovery of Artefacts
- Discovery of various cooking methods
- The invention of standardized weights
- Ornamental buttons made from seashell
- Origination of Stepwell

Epic literature is not history but is again a way of looking at the past.

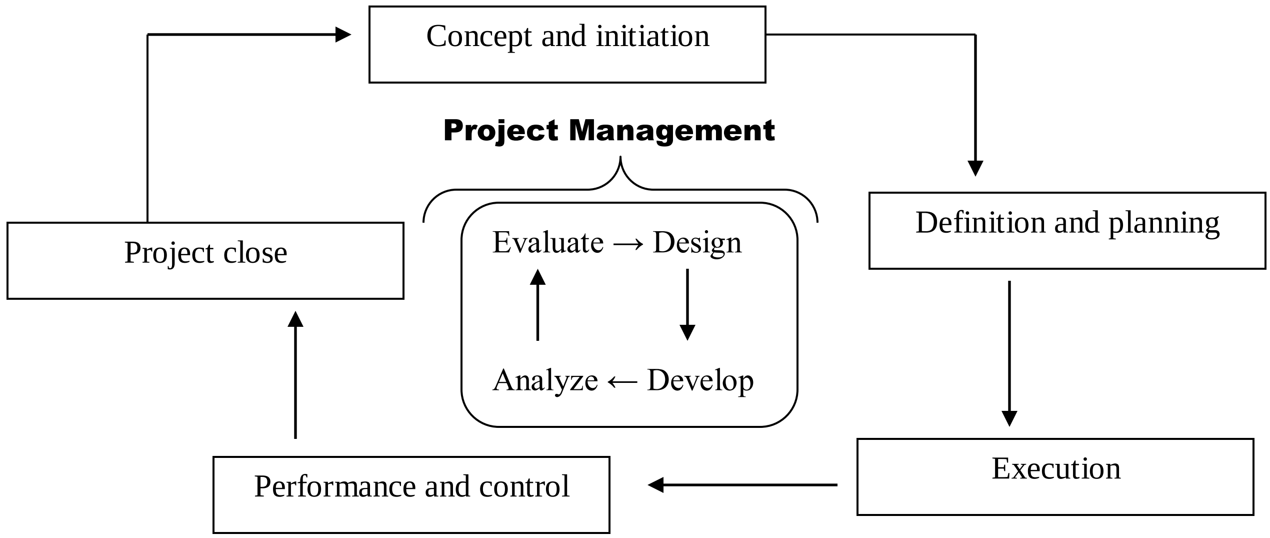
— Romila Thapar

Top 11 inventions and discoveries of Mesopotamian Civilization

- The Wheel
- The Chariot
- The Sailboat
- The Plow
- Time
- Astronomy and Astrology
- The Map
- Mathematics
- Urban Civilization
- The First Form of Writing: Cuneiform
- Agriculture and Irrigation

Top 20 Ancient Chinese Inventions

• Seismographs	• Porcelain
• The Waterwheel	• Noodles
• The Crossbow	• The Compass
• Iron and Steel Smelting	• Acupuncture
• Tuned Chime Bells	• Alcoholic Beverages
• Papermaking	• The Great Wall
• Tea Production	• The Silk Road
• Kites	• Gunpowder
• The Seed Drill	• Movable Type Printing
• Deep Drilling	• Lacquer: A Natural Shapable Plastic



Popular Project Management Methodologies:

Agile — collaborating to iteratively deliver whatever works
Scrum — enabling a small, cross-functional, self-managing team to deliver fast
Kanban — improving speed and quality of delivery by increasing visibility of work in progress and limiting multi-tasking
Scrumban — limiting work in progress like Kanban, with a daily stand up like Scrum
Lean — streamlining and eliminating waste to deliver more with less
eXtreme Programming (XP) — doing development robustly to ensure quality
Waterfall — planning projects fully, then executing through phases
PRINCE2 — controlled project management that leaves nothing to chance
PMI's PMBOK — applying universal standards to Waterfall project management

Waterfall methodology:

Requirements → Analysis → Design → Implementation → Testing → Deployment → Maintenance

7 principles of PRINCE2:

- Continued business justification
- Learn from experience
- Defined roles and responsibilities
- Manage by stages
- Manage by Exception
- Focus on products
- Tailor to suit the project environment

Agile methodology:

Requirements → Design → Develop → Test → Deploy

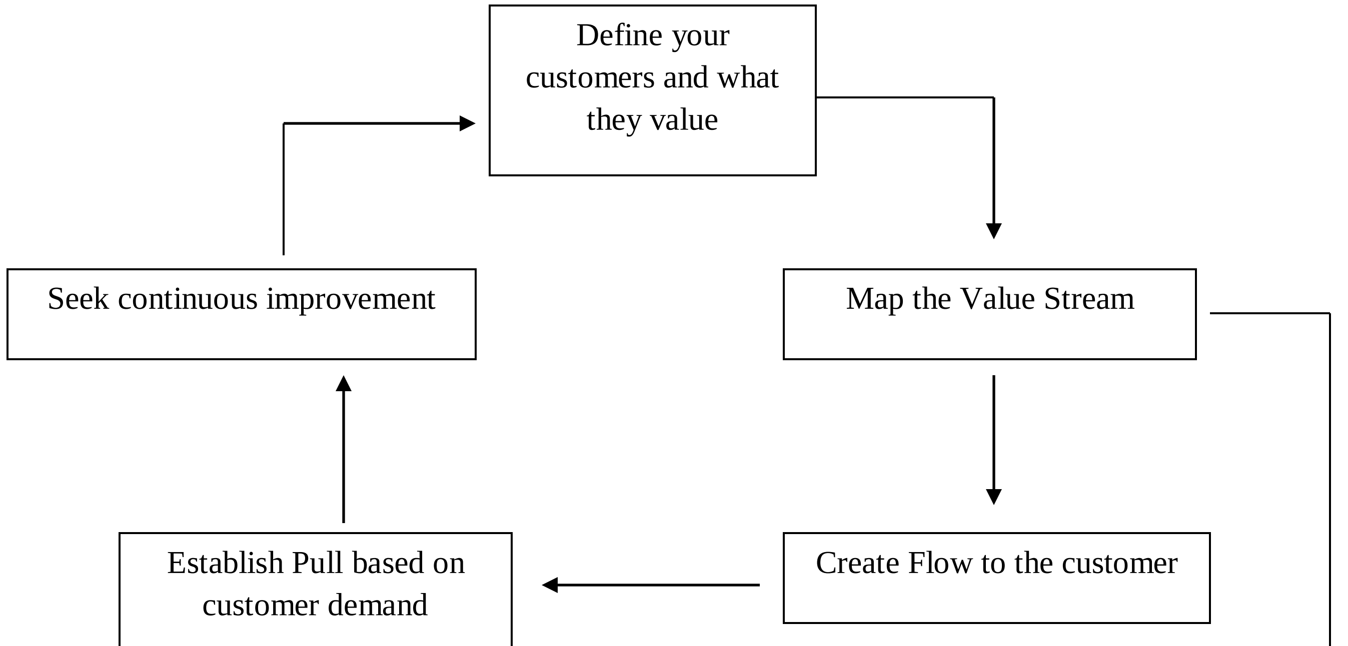
Scrum methodology:

Envision → Speculate → Explore → Adapt → Speculate
Adapt → Close

Operations keeps the lights on, strategy provides a light at the end of the tunnel, but project management is the train engine that moves the organization forward.

~ Joy Gumz

Lean methodology:

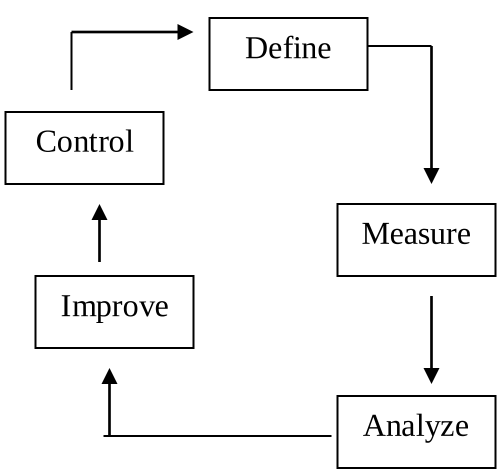


Flowchart method to illustrate, analyze and improve the steps required to deliver value from start to finish

Things to consider when evaluating the project:

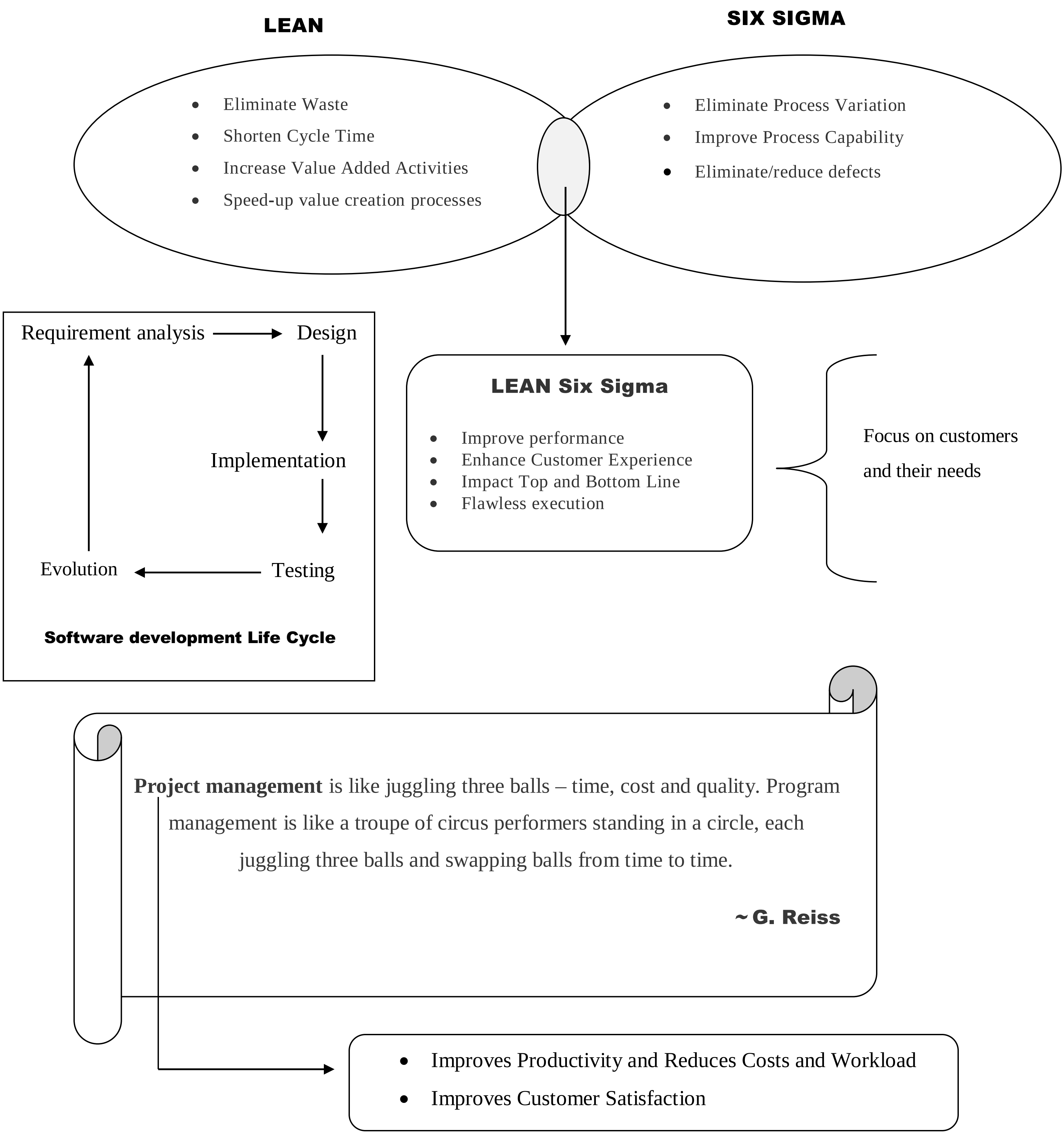
- Project budget
- Timeline
- Size and complexity
- Stakeholder expectations
- Project type and industry

Six Sigma methodology:



Project management can be defined as a way of developing structure in a complex project, where the independent variables of time, cost, resources and human behavior come together.

~ Rory Burke


LEAN
SIX SIGMA
Eliminate Waste
Shorten Cycle Time
Increase Value Added Activities
Speed-up value creation processes
Eliminate Process Variation
Improve Process Capability
Eliminate/reduce defects
Requirement analysis
Design
Implementation
Testing
Evolution
Software development Life Cycle
LEAN Six Sigma
Improve performance
Enhance Customer Experience
Impact Top and Bottom Line
Flawless execution
Focus on customers and their needs
Project management is like juggling three balls – time, cost and quality. Program management is like a troupe of circus performers standing in a circle, each juggling three balls and swapping balls from time to time.
~ G. Reiss
Improves Productivity and Reduces Costs and Workload
Improves Customer Satisfaction

Christiaan Huygens (1629 – 1695) was a Dutch physicist, astronomer, mathematician and the founder of the wave theory of light. His book, **Treatise on light**, makes fascinating reading even today. He brilliantly explained the double refraction shown by the mineral calcite in this work in addition to reflection and refraction. He was the first to analyze circular and simple harmonic motion and designed and built improved clocks and telescopes. He discovered the true geometry of Saturn's rings.

Electron Emission

Thermionic emission

Occurs in metals that are heated to a very high temperature

Field emission

Emission of electrons induced by an electrostatic field (of the order of 10^8 Vm^{-1})

Photoelectric emission

Electrons are ejected from the surface of the metal when it absorbs electromagnetic radiation of the appropriate frequency

3 types of radioactive decay occur in nature:

- α-decay in which a helium nucleus ${}^4_2He$ is emitted.
- β-decay in which electrons or positrons (particles with the same mass as electrons, but with a charge exactly opposite to that of electron) are emitted
- γ-decay in which high energy (hundreds of keV or more) photons are emitted

Current

Direct current

(Electrons move in one direction)

Alternate current

(Electrons flow in both directions)

The Wöhler Synthesis of Urea (1828)

Friedrich Wöhler (1800 −1882) carried out several reactions that resulted in the production of Urea $[(NH_2)_2CO]$**, an organic component of urine. One such reaction used Lead Cyanate and ammonia in aqueous solution:**

$$Pb(CNO)_2 + 2NH_3 + 2H_2O \rightarrow Pb(OH)_2 + 2NH_4(CNO)$$

Ammonium Cyanate decomposes to Ammonia and Cyanic acid, which react reversibly to produce Urea:

$$NH_4(CNO) \rightarrow NH_3 + HCNO \leftrightarrow (NH_2)_2CO$$

Letter from Wöhler to Berzelius

> "Organic chemistry just now is enough to drive one mad. It gives me an impression of a primeval tropical forest, full of the most remarkable things, a monstrous and boundless thicket, with no way to escape, into which one may well dread to enter "
>
> **"**I cannot, so to say, hold my chemical water and must tell you that I can make urea without thereby needing to have kidneys, or anyhow, an animal, be it human or dog**"**

Bertrand Russell had given a talk on the then new quantum mechanics, of whose wonders he was most appreciative. He spoke hard and earnestly in the New Lecture Hall. And when he was done, Professor Whitehead, who presided, thanked him for his efforts, and not least for "leaving the vast darkness of the subject unobscured."

J. Robert Oppenheimer

Science is not a system of certain, or -established, statements; nor is it a system which steadily advances towards a state of finality... And our guesses are guided by the unscientific, the metaphysical (though biologically explicable) faith in laws, in regularities which we can uncover—discover. Like Bacon, we might describe our own contemporary science—'the method of reasoning which men now ordinarily apply to nature'—as consisting of 'anticipations, rash and premature' and as 'prejudices'.

Karl Raimund Popper

All is born of water; all is sustained by water.

— Johann Wolfgang von Goethe

Elements of Scientific Thought

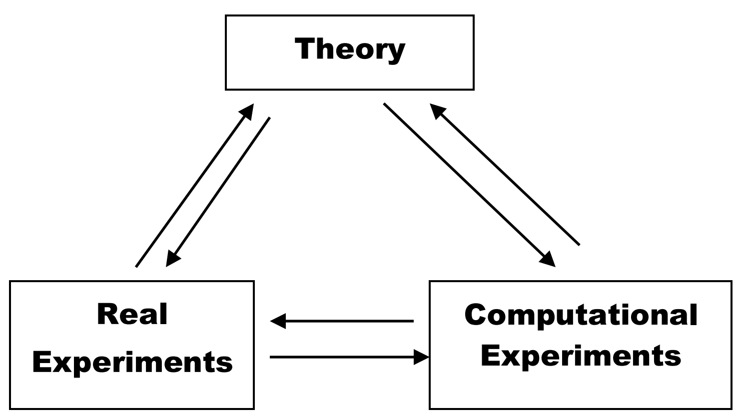
- Implications and Consequences
- Assumptions
- Concepts, Theories and models
- Interpretation
- Information, Facts, data and observations
- Problem and Issue
- Purpose and objective
- Perspective

In scientific thinking are always present elements of poetry. Science and music requires a thought homogeneous.

Albert Einstein

Science

- Information
- Computation
- Theory and models
- Experiment + observation



7 Philosophical Pillars for Peace within Humanity:

- Interdependence
- Humanity
- Sustainability
- Education
- Equity
- Justice and Compassion
- Science and Technology

For a start, how is the existence of the other universes to be tested? To be sure, all cosmologists accept that there are some regions of the universe that lie beyond the reach of our telescopes, but somewhere on the slippery slope between that and the idea that there is an infinite number of universes, credibility reaches a limit. As one slips down that slope, more and more must be accepted on faith, and less and less is open to scientific verification. Extreme multiverse explanations are therefore reminiscent of theological discussions. Indeed, invoking an infinity of unseen universes to explain the unusual features of the one we do see is just as ad hoc as invoking an unseen Creator. The multiverse theory may be dressed up in scientific language, but in essence, it requires the same leap of faith.

Paul Davies

Biomolecules

- Carbohydrates
- Proteins
- Nucleic Acids
- Lipids

Life is not found in atoms or molecules or genes as such, but in organization; not in symbiosis but in synthesis.

Edwin Grant Conklin

Simple Sugars

Complex Non-sugars

Polysaccharides

Homo

eg. Starch

Hetero

eg. Heparin

Monosaccharides

(does not undergo hydrolysis)

Disaccharides

(on hydrolysis yield two Monosaccharides)

Oligosaccharides

(on hydrolysis yield 3 − 10 Monosaccharides)

Reducing sugar

eg. Lactose

Non-reducing sugar

eg. Sucrose

Aldose

eg. Glucose

Ketose

eg. Fructose

The same few dozen organic molecules are used over and over again in biology for the widest variety of functions.

Carl Sagan

Proteins

Based on structure:

- Fibrous proteins
- Globular proteins
- Intermediate proteins

Based on composition:

- Simple proteins
- Conjugated proteins

Based on function:

- Structural proteins
- Enzymes
- Hormones
- Pigments
- Transport proteins
- Contractile proteins
- Storage proteins
- Toxins

Few scientists acquainted with the chemistry of biological systems at the molecular level can avoid being inspired. Evolution has produced chemical compounds exquisitely organized to accomplish the most complicated and delicate of tasks. Many organic chemists viewing crystal structures of enzyme systems or nucleic acids and knowing the marvels of specificity of the immune systems must dream of designing and synthesizing simpler organic compounds that imitate working features of these naturally occurring compounds.

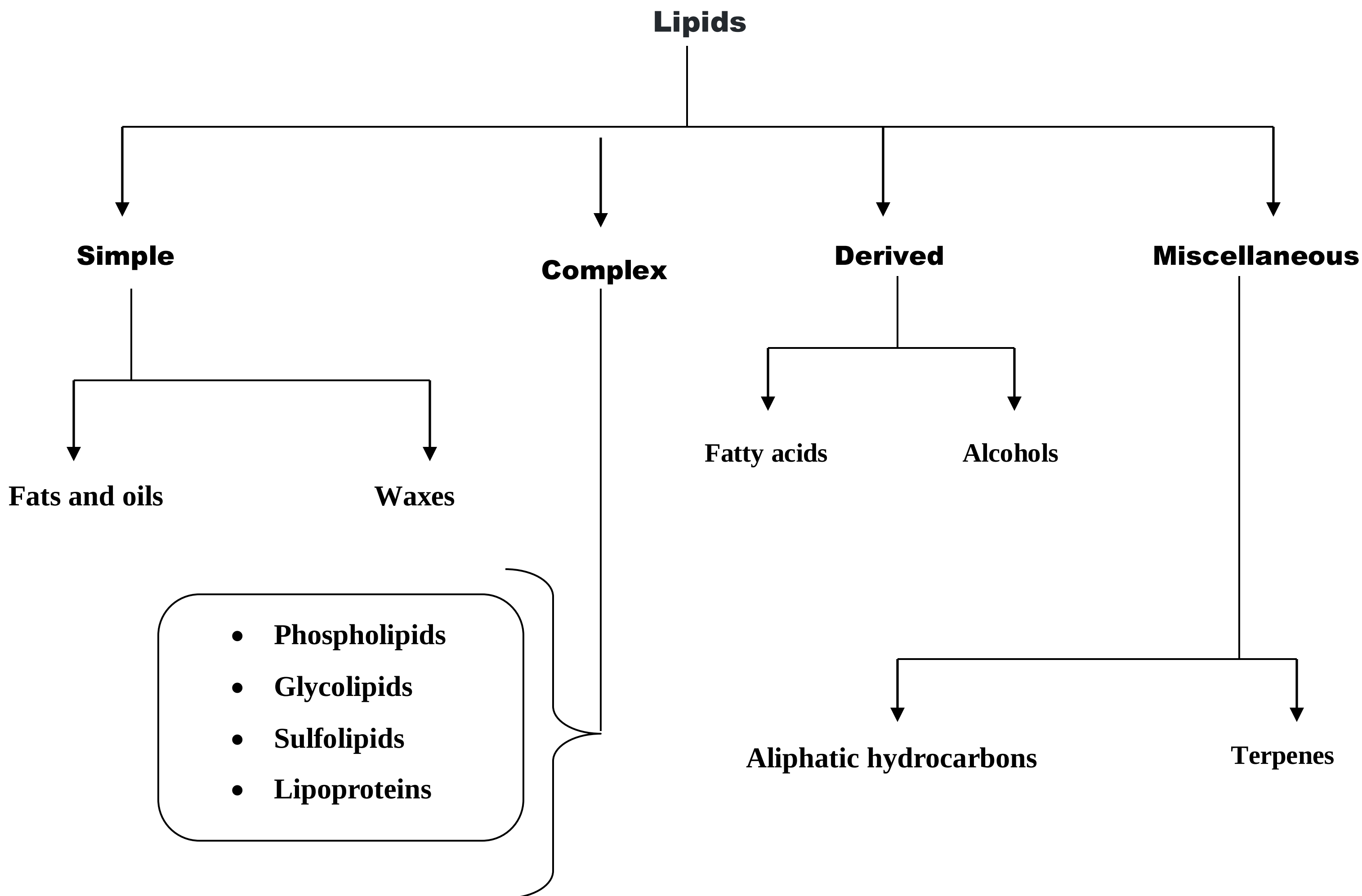
Donald J. Cram

Nucleic acid

- **Nucleotides**
  - **Nucleosides**
    - **Nitrogenous bases**
      - **Purines**
        - Adenine
        - Guanine
      - **Pyrimidines**
        - Cytosine
        - Uracil
        - Thymine
    - **Sugar**
      - **Ribose**
      - **Deoxyribose**
  - **Phosphoric acid**

Mathematics is the art of giving the same name to different things.

Henri Poincare



> The cause of nutrition and growth resides not in the organism as a whole but in the separate elementary parts—the cells.
>
> **Theodor Schwann**

3 Principles of Cell Theory:

- All living things are made up of cells.
- Cells are the basic building blocks of life.
- All cells come from preexisting cells created through the process of cell division.

Bacteria

Shape

- **spherical** (cocci)
- **rod** (bacilli)
- **spiral** (spirilla)

Gram stain

- **Gram positive**
- **Gram negative**

Oxygen demand

- **Aerobic**
- **Anaerobic**

For the first half of geological time our ancestors were bacteria. Most creatures still are bacteria, and each one of our trillions of cells is a colony of bacteria.

Richard Dawkins

4 ways antibiotics affect bacterial cells:

- Disrupt cell wall synthesis
- Inhibit RNA synthesis
- Inhibit protein synthesis
- Inhibit DNA replication

Through the process of **cell replication**, some bacteria develop mutations that make them resistant to drug. Bacteria with the resistant mutation have a better chance of survival against drugs. Resistant bacteria continue to multiply, even when exposed to drugs.

Exposure to bacteria → infection occurs and the bacteria spreads → Drug treatment is used

Non-resistant bacteria	Drug resistant bacteria
• The bacteria multiply • The bacteria die. • The person is healthy again	• The bacteria multiply • The bacteria continue to spread • The person remains sick

Virus

- **Presence of envelope** → Enveloped virus (**Influenza virus**)
- **Absence of envelope** → Non enveloped virus (**Adeno virus**)

Genome:

- DNA viruses (**Adeno virus**)
- RNA virus (**Corona virus**)

Strand of nucleic acid:

- Double stranded DNA viruses
- Single stranded DNA viruses
- Double stranded RNA viruses
- Single stranded RNA viruses

5 steps of viral infection:

- Attachment
- Penetration
- **Uncoating** (viral contents are released)
- Biosynthesis
- Maturation
- Release

If Charles Darwin reappeared today, he might be surprised to learn that humans are descended from viruses as well as from apes.

Robin Weiss

Microorganisms

- **Useful**
  - **Mankind**
    - **Food**
    - **Medicine**
  - **Ecosystem**
    - **Decomposing**
      - **Recycle nutrients**

3 helpful microorganisms:

- **E. Coli** is found in the intestines of humans and aid in digestion.
- **Streptomyces** is used in making antibiotics.
- **Rhizobium** is helpful bacteria found in the soil that helps in fixing nitrogen in leguminous plants.

Lots of people think, well, we're humans; we're the most intelligent and accomplished species; we're in charge. Bacteria may have a different outlook: more bacteria live and work in one linear centimeter of your lower colon than all the humans who have ever lived. That's what's going on in your digestive tract right now. Are we in charge, or are we simply hosts for bacteria? It all depends on your outlook.

Neil deGrasse Tyson

Fungi

- **Phycomycetes** (lower fungi)
- **Ascomycetes** (The sac fungi)
- **Basidiomycetes** (The club fungi)
- **Deuteromycetes** (The fungi imperfect)

Mode of nutrition

- saprophytic
- parasitic
- symbiotic

Reproduction

- **vegetative** (fragmentation, fission or budding)
- **asexual** (conidia, sporangiospores or zoospores)
- **sexual reproduction** by oospores, ascospore and basidiospores

> We inherit every one of our genes, but we leave the womb without a single microbe. As we pass through our mother's birth canal, we begin to attract entire colonies of bacteria. By the time a child can crawl, he has been blanketed by an enormous, unseen cloud of microorganisms--a hundred trillion or more. They are bacteria, mostly, but also viruses and fungi (including a variety of yeasts), and they come at us from all directions: other people, food, furniture, clothing, cars, buildings, trees, pets, even the air we breathe. They congregate in our digestive systems and our mouths, fill the space between our teeth, cover our skin, and line our throats. We are inhabited by as many as ten thousand bacterial species; those cells outnumber those which we consider our own by ten to one, and weigh, all told, about three pounds--the same as our brain. Together, they are referred to as our microbiome--and they play such a crucial role in our lives that scientists like [Martin J.] Blaser have begun to reconsider what it means to be human.
>
> **Michael Specter**

Algae

Macroalgae

- **Green algae** (Chlorophyta)
- **Red algae** (Rhodophyta)
- **Brown algae** (Phaeophyta)

Microalgae

- **Microscopic Green algae** (Chlorophyta)
- **Diatoms and Golden brown algae** (Chrysophyta)
- **Dinoflagellates** (Pyrrophyta or fire algae)
- **Blue-green algae** (Cyanophyta)

> Algae is the perfect food plant. It doubles cell mass every twelve hours, depending on the strain.
>
> **Homaro Cantu**

Uses

- Algae is used to create biofuel and vegetable oil
- Algae is a Great Human Food Supplement
- Algae
  - function as an Energy Source
  - used for Animal Feed
  - used to create plastics
- Algae is a Productive CO_2 Emissions Cleaner and can be an efficient component when it comes to wastewater treatment.

> Large, centralized organizations foster alienation like stagnant ponds breed algae.
>
> **Ricardo Semler**

But we have not used our waters well. Our major rivers are defiled by noxious debris. Pollutants from cities and industries kill the fish in our streams. Many waterways are covered with oil slicks and contain growths of algae that destroy productive life and make the water unfit for recreation. "Polluted Water-No Swimming" has become a familiar sign on too many beaches and rivers. A lake that has served many generations of men now can be destroyed by man in less than one generation.

Lyndon B. Johnson

3 main functions

- sensory
- integration
- motor

Nervous system

Central nervous system

- brain
- spinal cord

The forward bend really relaxes the nervous system and brings blood flow back to the brain.

Mandy Ingber

Peripheral nervous system

- spinal nerves
- cranial nerves

Satellite → Used for imaging, communications, navigation, exploration of the solar system and human habitation.

Natural satellite

(Earth's Moon)

Artificial satellite

(Sputnik 1)

The world's first artificial satellite launched by Soviet Union on 4 October 1957

The Earth has no business possessing such a Moon. It is too huge—over a quarter Earth's diameter and about 1/81 of its mass. No other planet in the Solar System has even nearly so large a satellite.

— Isaac Asimov

It will be possible in a few more years to build radio controlled rockets which can be steered into such orbits beyond the limits of the atmosphere and left to broadcast scientific information back to the Earth. A little later, manned rockets will be able to make similar flights with sufficient excess power to break the orbit and return to Earth. (1945) [Predicting communications satellites.]

— Arthur C. Clarke

6 forms of energy

- Sound Energy
- Chemical Energy
- Radiant Energy
- Electrical Energy
- Atomic Energy
- Mechanical Energy

We can allow satellites, planets, suns, universe, nay whole systems of universe, to be governed by laws, but the smallest insect, we wish to be created at once by special act

Charles Darwin

Laws of reflection:

- The incident ray, the reflected ray and the normal ray at the point of incidence, lie in the same plane.
- The angle of incidence is equal to the angle of reflection

Laws of refraction:

- The incident ray refracted ray, and the normal to the interface of two media at the point of incidence all lie on the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. This is also known as Snell's law of refraction.

The totality of life, known as the biosphere to scientists and creation to theologians, is a membrane of organisms wrapped around Earth so thin it cannot be seen edgewise from a space shuttle, yet so internally complex that most species composing it remain undiscovered. The membrane is seamless. From Everest's peak to the floor of the Mariana Trench, creatures of one kind or another inhabit virtually every square inch of the planetary surface.

— Edward O. Wilson

Carbon Compounds

Organic compounds

From living things

- Sugar
- Protein
- Starch

Contain carbon

Inorganic compounds

Not from living things

- Aluminum arsenate
- Ammonium chromate
- Barium bromide

Do not contain carbon

> This remarkable [nuclear] energy is spreading its tentacles to almost all walks of life - be it power, agriculture, medicine, laser systems, satellite imagery or environment protection.
>
> **— Raja Ramanna**

Phenomenon	Can be explained in terms of waves	Can be explained in terms of particles
Reflection	✔	✔
Refraction	✔	✔
Interference	✔	✖
Diffraction	✔	✖
Polarization	✔	✖
Photoelectric effect	✖	✔

Enzymes

Biological catalysts that speed up reactions although they are not changed in the reaction

Oxidoreductases	Catalyze oxidoreduction reactions.
Transferases	Catalyze the transfer of a functional group from one molecule to another.
Hydrolases	Catalyze the cleavage of a covalent bond using water.
Lyases	Catalyses the joining of specified molecules or groups by a double bond.
Isomerases	Catalyze reactions involving a structural rearrangement of a molecule.
Ligases	Catalyze the binding of two molecules.

$$\textbf{Enzyme + substrate} \underbrace{\leftrightarrow}_{\text{Substrate binding}} \textbf{Enzyme–substrate complex} \underbrace{\rightarrow}_{\text{Catalytic step}} \textbf{Product + Enzyme}$$

Our cells engage in protein production, and many of those proteins are enzymes responsible for the chemistry of life.

Randy Schekman

14 methods of food preservation:

- Chilling
- Salting
- Vacuum Packing
- Refrigeration
- Sugaring
- Fermentation
- Bottling
- Sterilization
- Dehydration
- Lypophilization
- Canning
- Pasteurization
- Irradiation
- Addition of chemicals

Prevent food spoilage until it can be consumed

Rapid freezing and dehydration of frozen product under vacuum

In your cells right now, an enzyme is making a copy of your DNA in less than two hours, right in the nucleus.

Hugh Martin

Producing Ethanol by Fermentation:

Glucose $\xrightarrow{\text{yeast}}$ ethanol + carbon dioxide

Fishes

- jawless fishes
- cartilaginous fishes
- bony fishes

4 main traits

- Live in water
- Have gills to filter oxygen from their water environment
- Have fins to help them move through the water
- Have backbones (vertebrae) for support and movement

Nuclear DNA encodes all the proteins and enzymes that make you you, basically.

Hendrik Poinar

Plant Cell	**Animal Cell**
Cell Shape	
Square or rectangular in shape	Irregular or round in shape
Cell Wall	
Present	Absent
Cell Membrane	
Present	Present
Endoplasmic Reticulum	
Present	Present
Nucleus	
Present and lies on one side of the cell	Present and lies in the centre of the cell
Lysosomes	
Present but are very rare	Present
Centrosomes	
Absent	Present
Golgi Apparatus	
Present	Present
Cytoplasm	
Present	Present
Ribosomes	
Present	Present
Plastids	
Present	Absent
Vacuoles	
Few large or a single, centrally positioned vacuole	Usually small and numerous
Cilia	
Absent	Present in most of the animal cells
Mitochondria	
Present but fewer in number	Present and are numerous
Mode of Nutrition	
Primarily autotrophic	Heterotrophic

A cell has a history; its structure is inherited, it grows, divides, and, as in the embryo of higher animals, the products of division differentiate on complex lines. Living cells, moreover, transmit all that is involved in their complex heredity. I am far from maintaining that these fundamental properties may not depend upon organisation at levels above any chemical level; to understand them may even call for different methods of thought; I do not pretend to know. But if there be a hierarchy of levels we must recognise each one, and the physical and chemical level which, I would again say, may be the level of self-maintenance, must always have a place in any ultimate complete description.

Sir Frederick Gowland Hopkins

Three types of DNA **Mutation**s:

- base substitutions
- deletions
- insertions

A change in the sequence of bases in DNA or RNA

Types of Mutations:

- Somatic mutations
- Germline mutations
- Chromosomal alterations
- Point Mutations
- Frameshift Mutations

DNA (Deoxyribonucleic acid)	**RNA (Ribonucleic acid)**
Definition	
It is a long polymer with a deoxyribose and phosphate backbone with four nitrogenous bases: • **thymine** • cytosine • adenine • guanine	It is a polymer with a ribose and phosphate backbone with four nitrogenous bases: • **uracil** • cytosine • adenine • guanine
Location	
It is located in the nucleus of a cell and in the mitochondria.	It is found in the cytoplasm, nucleus and in the ribosome.
Sugar	
It has 2-deoxyribose.	It has Ribose.
Function	
DNA is functional is the transmission of genetic information. It forms as a media for long-term storage.	RNA is functional is the transmission of the genetic code that is necessary for the protein creation from the nucleus to the ribosome.
Structure	
The DNA is a double-stranded molecule that has a long chain of nucleotides.	The RNA is a single-stranded molecule which has a shorter chain of nucleotides.
Replication	
DNA replicates on its own – it is self-replicating.	• RNA does not replicate on its own • It is synthesized from DNA when required

Base Pairing	
The base pairing is as follows: • Guanine pairs with Cytosine • Adenine pairs with Thymine	The base pairing is as follows: • Guanine pairs with Cytosine • Adenine pairs with Uracil
UV Sensitivity	
DNA is vulnerable to damage by UV light.	RNA is more resistant to damage from UV light than DNA

> If Watson and I had not discovered the [DNA] structure, instead of being revealed with a flourish it would have trickled out and that its impact would have been far less. For this sort of reason Stent had argued that a scientific discovery is more akin to a work of art than is generally admitted. Style, he argues, is as important as content. I am not completely convinced by this argument, at least in this case.
>
> **Francis Crick**

Surgery

Emergency

(Surgery is required within 2 to 3 hours)

Urgent

(Surgery is required within 24 hours)

Scheduled

(Surgery is required within 2 to 3 weeks)

Elective

(Surgery is done at the convenience of patient)

A physician ought to have his shop provided with plenty of all necessary things, as lint, rollers, splinters: let there be likewise in readiness at all times another small cabinet of such things as may serve for occasions of going far from home; let him have also all sorts of plasters, potions, and purging medicines, so contrived that they may keep some considerable time, and likewise such as may be had and used whilst they are fresh.

— Hippocrates

Crops

Food crops

Cereals

Legumes

Cash crops

Fiber crops

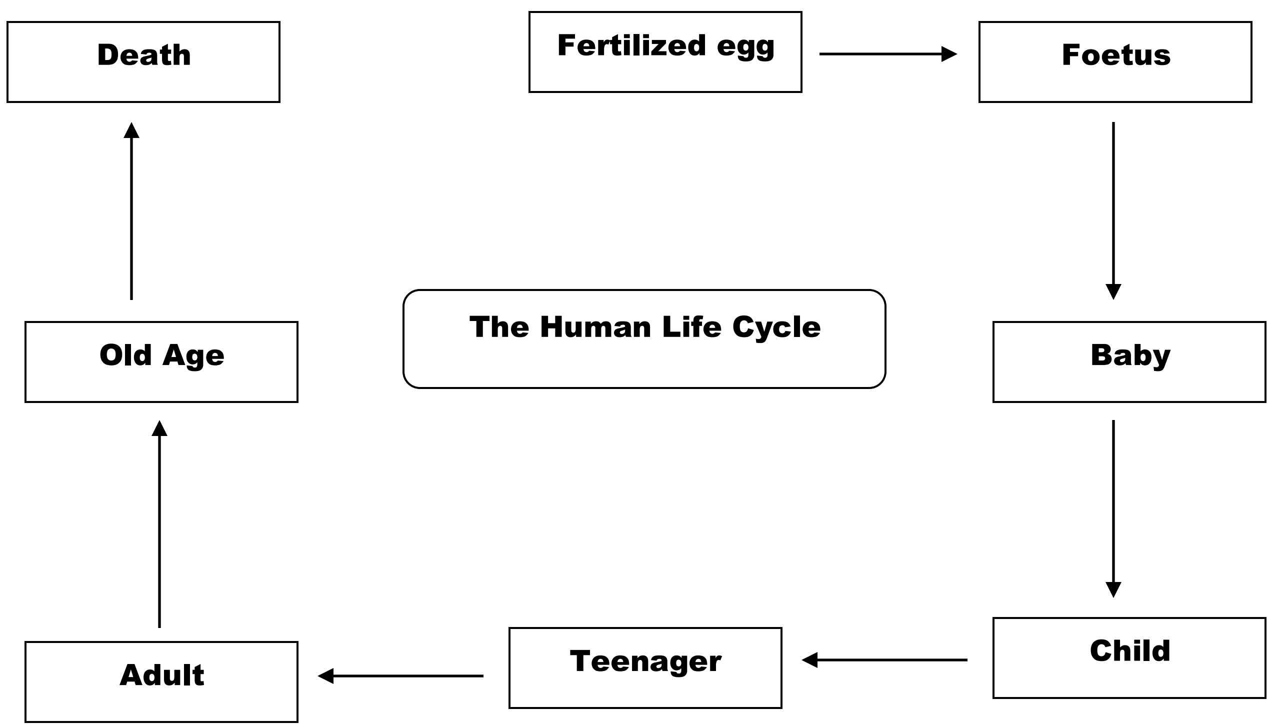
Oil crops

7 principal cereals grown in the world:

- Wheat
- Maize
- Rice
- Barley
- Oats
- Rye
- Sorghum

What is tolerance? It is the consequence of humanity. We are all formed of frailty and error; let us pardon reciprocally each other's folly – that is the first law of nature.

– Voltaire



After the birth of printing books became widespread. Hence everyone throughout Europe devoted himself to the study of literature... Every year, especially since 1563, the number of writings published in every field is greater than all those produced in the past thousand years. Through them there has today been created a new theology and a new jurisprudence; the Paracelsians have created medicine anew and the Copernicans have created astronomy anew. I really believe that at last the world is alive, indeed seething, and that the stimuli of these remarkable conjunctions did not act in vain.

— Johannes Kepler

Letter from Alexander Graham Bell to his wife Mabel Hubbard Bell

June 26, 1906

Beinn Bhreagh,

Victoria County,

Cape Breton, N.S.

Dear Mabel,

The French Journal L'Aerophile for January 1906 contains some interesting details concerning the flying machine of the Wright Brothers of Dayton Ohio. It seems strange that our enterprising American newspapers have failed to keep tract of the experiments in Dayton Ohio for the machine is so large that it must be visible over a considerable extent of country and an electrical tramway runs right by the field where the experiments were made. Numerous persons residing in the neighborhood of Dayton have witnessed the experiments and yet hardly any details of the apparatus employed have appeared in print in America.

This seems to be due to the desire of secrecy. The Wright Brothers have made their experiments at a time when few people excepting the surrounding farmers have been out. They have declined to give the newspapers any information and when they discovered that the Dayton Daily News contained an article describing their apparatus they made arrangements with the Editor to have the edition suppressed.

It seems however that a French Journal L'Auto sent to Dayton Ohio one of their correspondents, M. Robert Coquelle who interviewed various witnesses and although he could get no details from the Wright Brothers themselves he succeeded in obtaining for a price a copy of the suppressed number of the Dayton Daily News. He sent this to France and a French translation of it has appeared in L'Auto. L'Aerophile also gives extracts from it in the number published January 1906, Pages 18 and 19. Considering the fact that this information was published as long ago as the first of January 1906, it seems strange that no American journal has yet got ahold of the information.

The January number of L'Aerophile also contains a letter from the Wright Brothers to the Editor of the Journal giving such information as they care to make public, but the information has not so far as I am aware yet appeared in the English Language. The same number of L'Aerophile contains a French translation of an interesting letter from a Mr. Weaver (who seems to be an American) addressed to M. Frank S. Lahm, but this letter too has not appeared in English. Mr. Weaver gives a plan sketch of the field where the experiments were made with its surroundings, and the results of interviews with the farmers who witnessed the experiments.

The same number of L'Aerophile contains a French translation of a letter signed by Wilbur and Orville Wright, dated 3rd of January 1906, and addressed to M. Frank S. Lahm relating to the purchase of his machine by the French. The number of L'Aerophile published December 1905, pages 265 to 272 contains an account of the negotiations of the Wright Brothers with the French government, with pictures of the two brothers. Several letters are published from the Wright Brothers to persons in France with the object of inducing the French Government to purchase their machine. The price asked being one million francs. Cablegrams backwards and forwards across the Atlantic are also given.

I do not understand how it is that so little attention has been paid to this matter by the American press. I am now studying carefully the details published. I wonder whether Bert would like me to ask Mr. Largelamb to send him some account of the matter.

Your loving husband,
Alec
Mr. A. Graham Bell
Twin Oaks, Woodley Lane,
Washington, D. C.

Letter from Wilbur Wright to Smithsonian

The Smithsonian Institution, Washington:
Dear Sirs:

"I am an enthusiast, but not a crank in the sense that I have some pet theories as to the proper construction of a flying machine. I wish to avail myself of all that is already known and then if possible add my mite to help on the future worker who will attain final success."

Wilbur Wright

Benjamin Franklin, Advice to a Young Man on the Choice of a Mistress (1745).

June 25, 1745

My dear Friend,

I know of no Medicine fit to diminish the violent natural Inclinations you mention; and if I did, I think I should not communicate it to you. Marriage is the proper Remedy. It is the most natural State of Man, and therefore the State in which you are most likely to find solid Happiness. Your Reasons against entering into it at present, appear to me not well-founded. The circumstantial Advantages you have in View by postponing it, are not only uncertain, but they are small in comparison with that of the Thing itself, the being married and settled. It is the Man and Woman united that make the compleat human Being. Separate, she wants his Force of Body and Strength of Reason; he, her Softness, Sensibility and acute Discernment. Together they are more likely to succeed in the World. A single Man has not nearly the Value he would have in that State of Union. He is an incomplete Animal. He resembles the odd Half of a Pair of Scissars. If you get a prudent healthy Wife, your Industry in your Profession, with her good Economy, will be a Fortune sufficient.

But if you will not take this Counsel, and persist in thinking a Commerce with the Sex inevitable, then I repeat my former Advice, that in all your Amours you should prefer old Women to young ones. You call this a Paradox, and demand my Reasons. They are these:

1. Because as they have more Knowledge of the World and their Minds are better stor'd with Observations, their Conversation is more improving and more lastingly agreable.
2. Because when Women cease to be handsome, they study to be good. To maintain their Influence over Men, they supply the Diminution of Beauty by an Augmentation of Utility. They learn to do a 1000 Services small and great, and are the most tender and useful of all Friends when you are sick. Thus they continue amiable. And hence there is hardly such a thing to be found as an old Woman who is not a good Woman.
3. Because there is no hazard of Children, which irregularly produc'd may be attended with much Inconvenience.
4. Because thro' more Experience, they are more prudent and discreet in conducting an Intrigue to prevent Suspicion. The Commerce with them is therefore safer with regard to your Reputation. And with regard to theirs, if the Affair should happen to be known, considerate People might be rather inclin'd to excuse an old Woman who would kindly take care of a young Man, form his Manners by her good Counsels, and prevent his ruining his Health and Fortune among mercenary Prostitutes.
5. Because in every Animal that walks upright, the Deficiency of the Fluids that fill the Muscles appears first in the highest Part: The Face first grows lank and wrinkled; then the Neck; then the Breast and Arms; the lower Parts continuing to the last as plump as ever: So that covering all above with a Basket, and regarding only what is below the Girdle, it is impossible of two Women to know an old from a young one. And as in the dark all Cats are grey, the Pleasure of corporal Enjoyment with an old Woman is at least equal, and frequently superior, every Knack being by Practice capable of Improvement.

6. Because the Sin is less. The debauching a Virgin may be her Ruin, and make her for Life unhappy.

7. Because the Compunction is less. The having made a young Girl miserable may give you frequent bitter Reflections; none of which can attend the making an old Woman happy.

8thly and Lastly They are so grateful!!

Thus much for my Paradox. But still I advise you to marry directly; being sincerely

Your affectionate Friend.

Letter from Francis Crick to William Shockley

Dr. W. Shockley
Stanford Electronics Laboratories

Stanford, California 94305

U.S.A.

2 April 1969

Thank you for your letter of the 17th March, and the enclosures, all of which I have read. The UPI story about my talk was slightly garbled; but was essentially correct. I certainly think these problems are important and that they should be dealt with objectively. Your experience clearly shows that this is not easy.

At the moment we have a large new extension to our laboratory, and are, taking up research in scientific areas which are new to us. Consequently I have decided not to speak or write on these social problems until our new work is will launched. In a year or so I hope to take up these issues again.

Yours sincerely
F.H.C. Crick

	Major contribution
Archimedes	Principle of buoyancy; Principle of the lever
Galileo Galilei	Law of inertia
Christiaan Huygens	Wave theory of light
Isaac Newton	Universal law of gravitation; Laws of motion; Reflecting telescope
Michael Faraday	Laws of electromagnetic induction
James Clerk Maxwell	Electromagnetic theory; Light-an electromagnetic wave
Heinrich Rudolf Hertz	Generation of electromagnetic waves
J.C. Bose	Ultra short radio waves
W.K. Roentgen	X-rays
J.J. Thomson	Electron
Marie Sklodowska Curie	Discovery of radium and polonium; Studies on natural radioactivity
Albert Einstein	Explanation of photoelectric effect; Theory of relativity
Victor Francis Hess	Cosmic radiation
R.A. Millikan	Measurement of electronic charge
Ernest Rutherford	Nuclear model of atom
Niels Bohr	Quantum model of hydrogen atom
C.V. Raman	Inelastic scattering of light by molecules
Louis Victor de Broglie	Wave nature of matter
M.N. Saha	Thermal ionization
S.N. Bose	Quantum statistics
Wolfgang Pauli	Exclusion principle
Enrico Fermi	Controlled nuclear fission
Werner Heisenberg	Quantum mechanics; Uncertainty principle

Paul Dirac	Relativistic theory of electron; Quantum statistics
Edwin Hubble	Expanding universe
Ernest Orlando Lawrence	Cyclotron
James Chadwick	Neutron
Hideki Yukawa	Theory of nuclear forces
Homi Jehangir Bhabha	Cascade process of cosmic radiation
Lev Davidovich Landau	Theory of condensed matter; Liquid helium
S. Chandrasekhar	Chandrasekhar limit, structure and evolution of stars
John Bardeen	Transistors; Theory of super conductivity
C.H. Townes	Maser; Laser
Abdus Salam	Unification of weak and electromagnetic interactions

If I had a time machine, I'd visit Marilyn Monroe in her prime or drop in on Galileo as he turned his telescope to the heavens.

Stephen Hawking

Science sent the Hubble telescope out into space, so it could capture light and the absence thereof, from the very beginning of time. And the telescope really did that. So now we know that there was once absolutely nothing, such a perfect nothing that there wasn't even nothing or once.

Kurt Vonnegut

Thermodynamics

Deals with the transfer of energy from one from one form to another

- **Classical Thermodynamics**
- **Statistical Thermodynamics**
- **Chemical Thermodynamics**
- **Equilibrium Thermodynamics**

Classical thermodynamics ... is the only physical theory of universal content which I am convinced ... will never be overthrown.

Albert Einstein

Evolution in the biosphere is therefore a necessarily irreversible process defining a direction in time; a direction which is the same as that enjoined by the law of increasing entropy, that is to say, the second law of thermodynamics. This is far more than a mere comparison: the second law is founded upon considerations identical to those which establish the irreversibility of evolution. Indeed, it is legitimate to view the irreversibility of evolution as an expression of the second law in the biosphere.

Jacques Monod

Cell genetics led us to investigate cell mechanics. Cell mechanics now compels us to infer the structures underlying it. In seeking the mechanism of heredity and variation we are thus discovering the molecular basis of growth and reproduction. The theory of the cell revealed the unity of living processes; the study of the cell is beginning to reveal their physical foundations.

— Cyril Dean Darlington

- **Mendelian Disorders (**due to the changes in the DNA of an organism**):**
    - Haemophilia
    - Colour Blindness
    - Sickle-cell Anaemia
- **Chromosomal Disorders (**due to the changes in structure or number of the chromosomes of an organism**):**
    - Down's Syndrome
    - Klinefelter's Syndrome
    - Turner's Syndrome

Genetic Disorder

Monogenic Disorder

Variance in one particular gene only

- Sickle cell anemia
- Cystic fibrosis

Polygenic Disorder

Variance in multiple genes at the same time

- Diabetes
- Obesity and heart diseases

Fossil bones and footsteps and ruined homes are the solid facts of history, but the surest hints, the most enduring signs, lie in those miniscule genes. For a moment we protect them with our lives, then like relay runners with a baton, we pass them on to be carried by our descendents. There is a poetry in genetics which is more difficult to discern in broken bones, and genes are the only unbroken living thread that weaves back and forth through all those boneyards.

— Jonathan Kingdon

Warfare

Chemical warfare

Use of chemicals to inflict death or injury

Biological warfare

Use of pathogens to inflict death or disease

Nuclear warfare

Use of nuclear weapons to produce mass destruction in a much shorter time and have a long-lasting radiological result

The power of biological weapons is ten times more than the nuclear power. Unless we act fast with an open mind, any one of them can extinct the human race.

Amit Ray

Although chemical weapons killed proportionally few soldiers in World War I (1914–1918), the psychological damage from gas fright and the exposure of large numbers of soldiers, munitions workers, and civilians to chemical agents had significant public health consequences.

Charles-Augustin de Coulomb, a French military engineer and physicist, began his career as a military engineer in the West Indies. In 1776, he returned to Paris and retired to a small estate to do his scientific research. He invented a torsion balance to measure the quantity of a force and used it for determination of forces of electric attraction or repulsion between small charged spheres. He thus arrived in 1785 at the inverse square law relation, now known as Coulomb's law: $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$. The law had been anticipated by Priestley and also by Cavendish earlier, though Cavendish never published his results. Coulomb also found the inverse square law of force between unlike and like magnetic poles.

1 Ampere-second = 1 coulomb

Total internal reflection

↓

The complete reflection of a light ray moving from a more dense medium to a less dense medium when the angle of incidence exceeds the critical angle

Some **examples of total internal reflection in daily life** are the formation of a mirage, shining of empty test-tube in water, shining of crack in a glass-vessel, sparkling of a diamond, transmission of light rays in an optical fiber, etc.

Reflection

Regular Reflection

Reflected rays are parallel to each other

Diffused Reflection

Reflected rays are not parallel to each other

Multiple Reflection

Reflection of light back and forth several times between reflecting surfaces

The scattering of light by molecules was intensively investigated by **Indian physicist C.V. Raman** and his collaborators in Kolkata in the 1920s. Raman was awarded the Nobel Prize for Physics in 1930 for this work.

Interference	Diffraction
The phenomenon where two waves of the same kind overlap to produce a resultant wave of greater, lower, or the same amplitude	The bending of a wave around the corners of an obstacle or aperture

Fission Chain Reaction

Controlled chain reaction

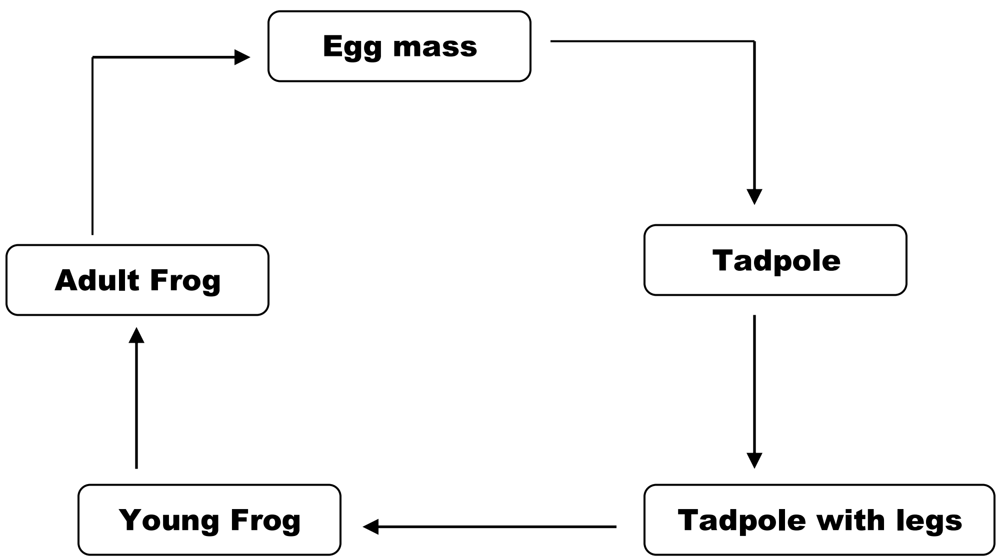
Chain of nuclear reactions that take place subsequently under controlled conditions and in the presence moderators to generate electricity

Uncontrolled chain reaction

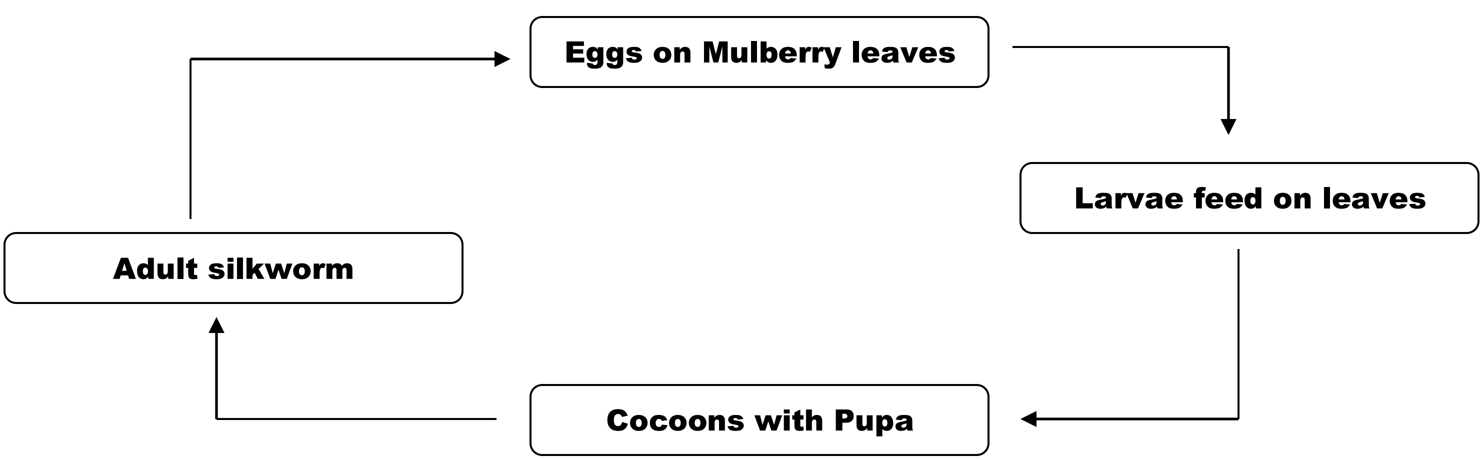
Chain of nuclear reactions that take place subsequently but not under controlled conditions and in the absence moderators to generate nuclear bombs

Tides	Waves
Produced due to the interaction of gravitational effects between the Earth, the moon, and the sun.	Produced due to the extreme raging force exerted on the surface of the water by the wind.

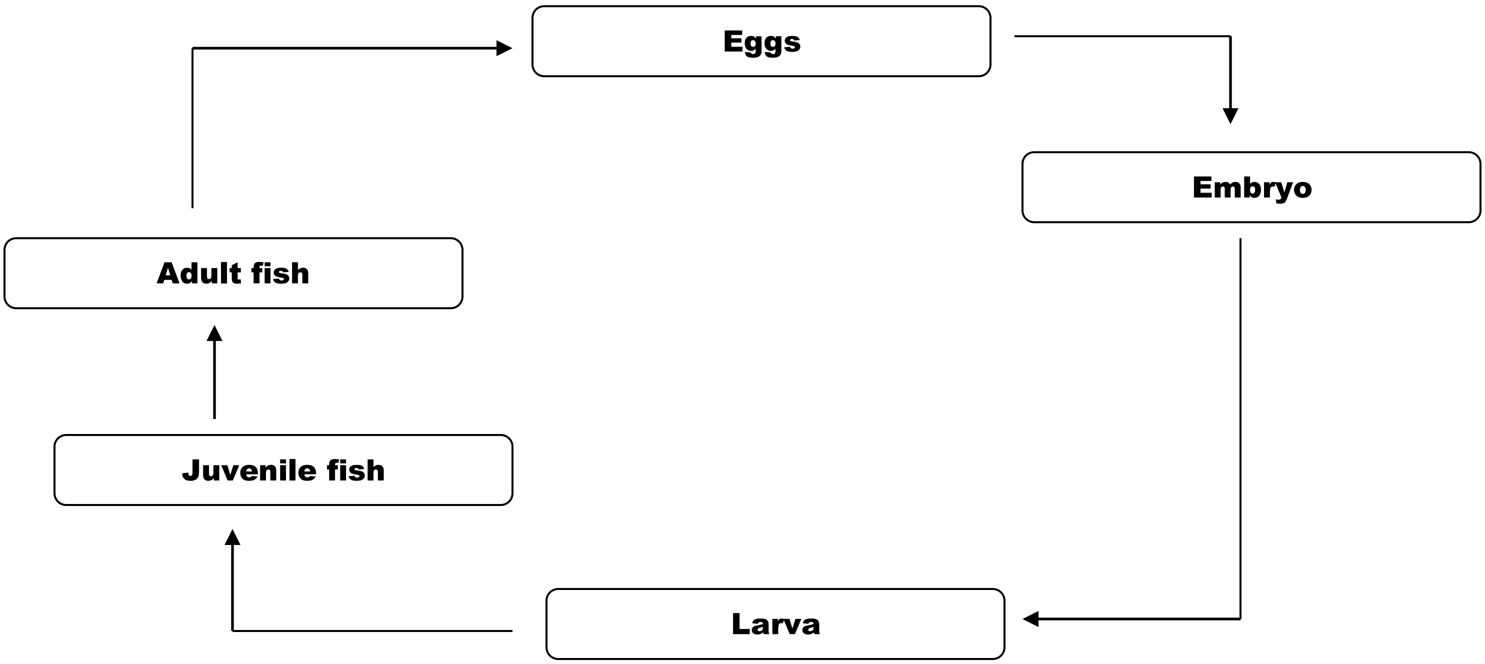
Life Cycle of a Frog:



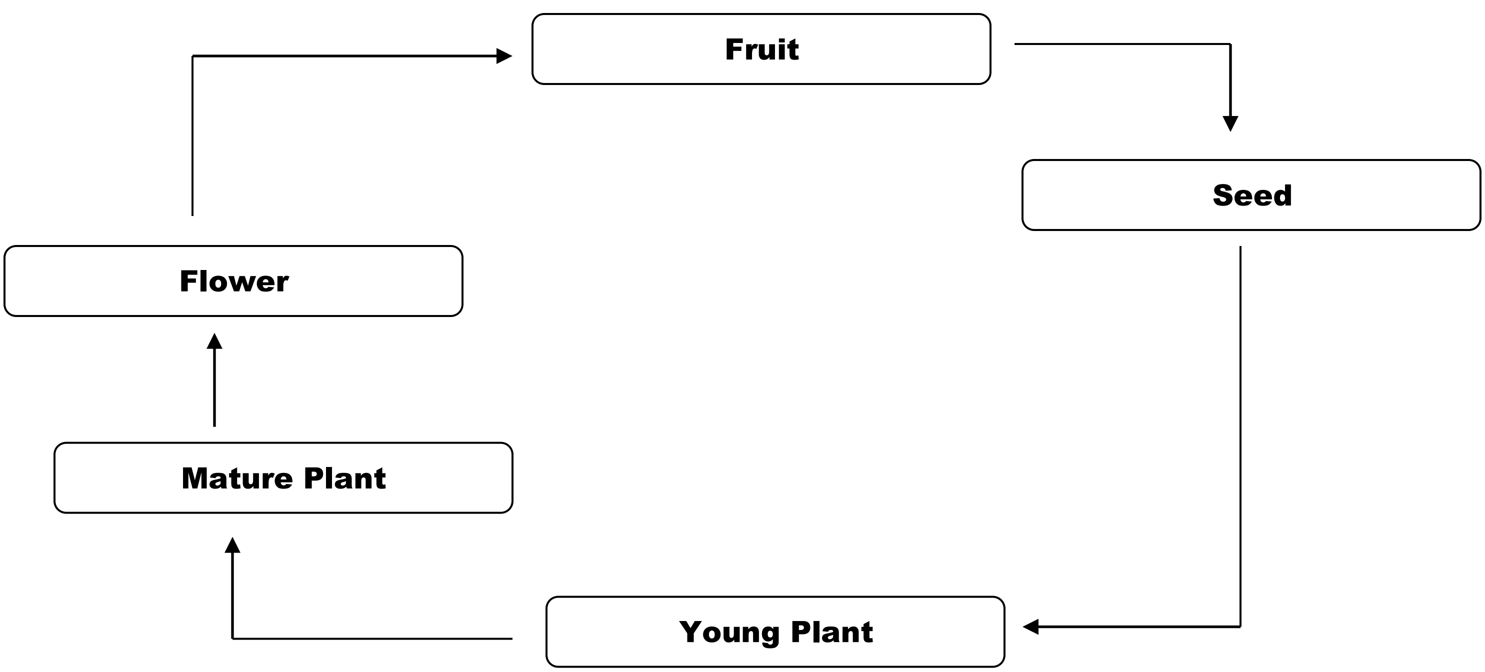
Life Cycle of a Silkworm:



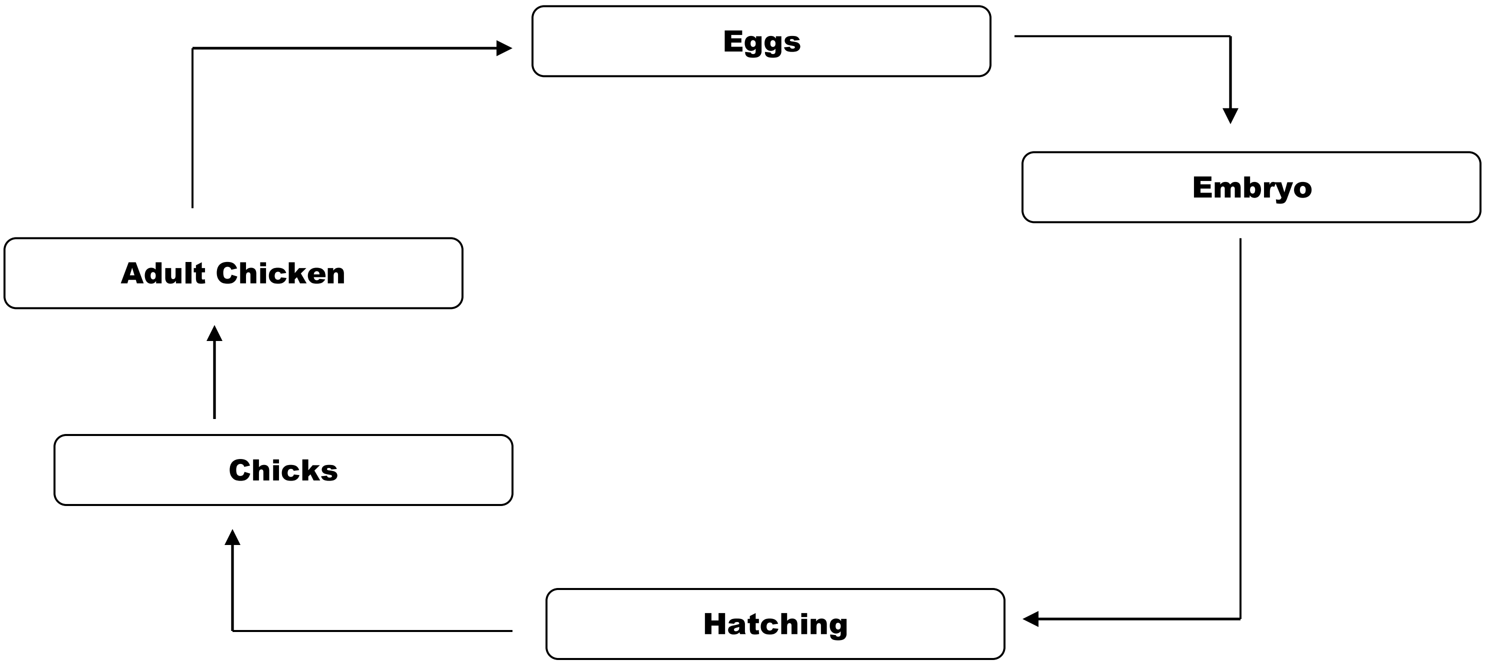
Life Cycle of a Fish:



Life Cycle of a Plant:



Life Cycle of a Chicken:



Francois-Marie Raoult was a French chemist who conducted research into the behavior of solutions, especially their physical properties.

Raoult's Law:

vapor pressure of the solution = mole fraction of the solvent × vapor pressure of the pure solvent

Ideal Solution	Non-ideal Solution
Obey Raoult 's law	Do not obey Raoult's law

5 Causes of Nuclear Pollution:

- Nuclear attacks
- Weapon testing
- Nuclear disasters
- Radioisotopes
- Nuclear Waste disposal

7 metals of alchemy:

- Gold
- Silver
- Mercury
- Copper
- Lead
- Iron

3 main goals of alchemy:

- To find the Stone of Knowledge (The Philosophers' Stone)
- To discover the medium of Eternal Youth and Health
- To discover the transmutation of metals

I prefer the spagyric chemical physicians, for they do not consort with loafers or go about gorgeous in satins, silks and velvets, gold rings on their fingers, silver daggers hanging at their sides and white gloves on their hands, but they tend their work at the fire patiently day and night. They do not go promenading, but seek their recreation in the laboratory, wear plain learthern dress and aprons of hide upon which to wipe their hands, thrust their fingers amongst the coals, into dirt and rubbish and not into golden rings. They are sooty and dirty like the smiths and charcoal burners, and hence make little show, make not many words and gossip with their patients, do not highly praise their own remedies, for they well know that the work must praise the master, not the master praise his work. They well know that words and chatter do not help the sick nor cure them... Therefore they let such things alone and busy themselves with working with their fires and learning the steps of alchemy. These are distillation, solution, putrefaction, extraction, calcination, reverberation, sublimination, fixation, separation, reduction, coagulation, tinction, etc.

— Philippus Aureolus Paracelsus

A school of thought that flourished in Greek and Roman antiquity

4 virtues of stoicism:

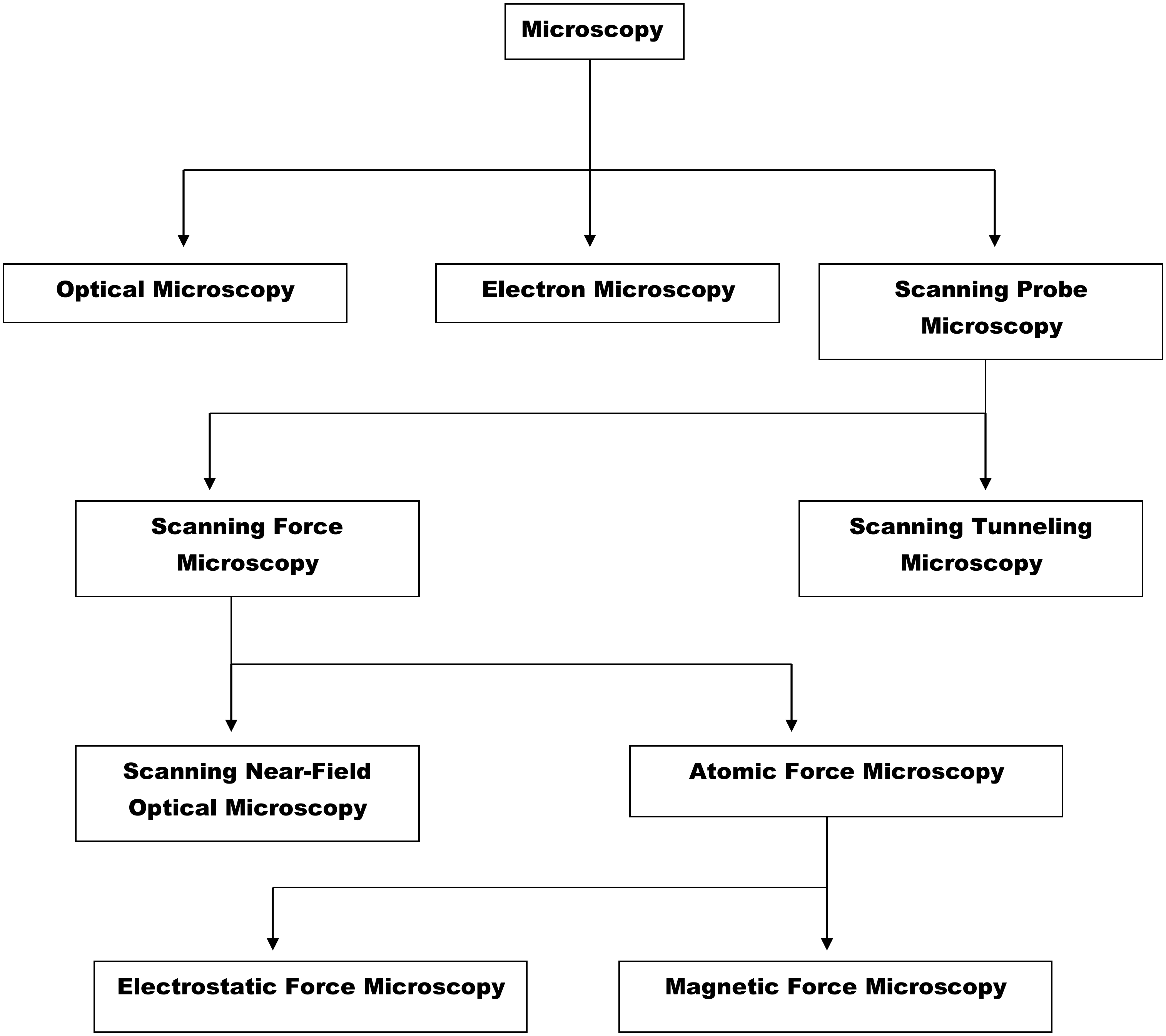
- Wisdom
- Justice
- Courage
- Moderation

8 Principles of Stoicism:

- **Nature:** Nature is rational.
- **Law of Reason:** The universe is governed by the law of reason. Humans can't actually escape its inexorable force, but they can, uniquely, follow the law deliberately.
- **Virtue:** A life led according to rational nature is virtuous.
- **Wisdom:** Wisdom is the root virtue. From it spring the cardinal virtues: insight, bravery, self-control, and justice.
- **Apathea:** Since passion is irrational, life should be waged as a battle against it. Intense feeling should be avoided.
- **Pleasure:** Pleasure is neither good nor bad. It is only acceptable if it doesn't interfere with the quest for virtue.
- **Evil:** Poverty, illness, and death are not evil.
- **Duty:** Virtue should be sought, not for the sake of pleasure, but for duty.

I feel that I have at last struck the solution of a great problem—and the day is coming when telegraph wires will be laid on to houses just like water or gas—and friends converse with each other without leaving home.

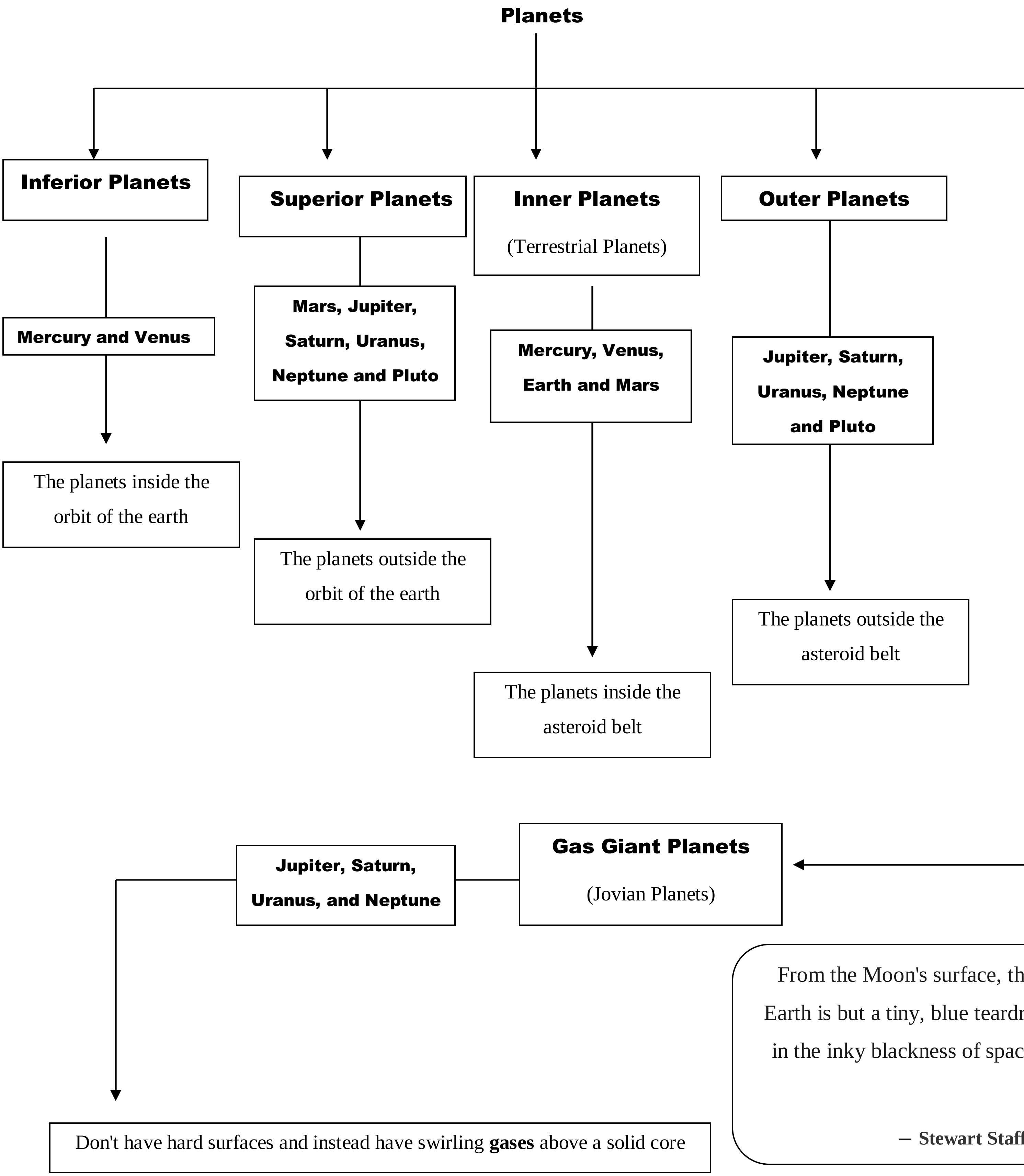
— Alexander Graham Bell



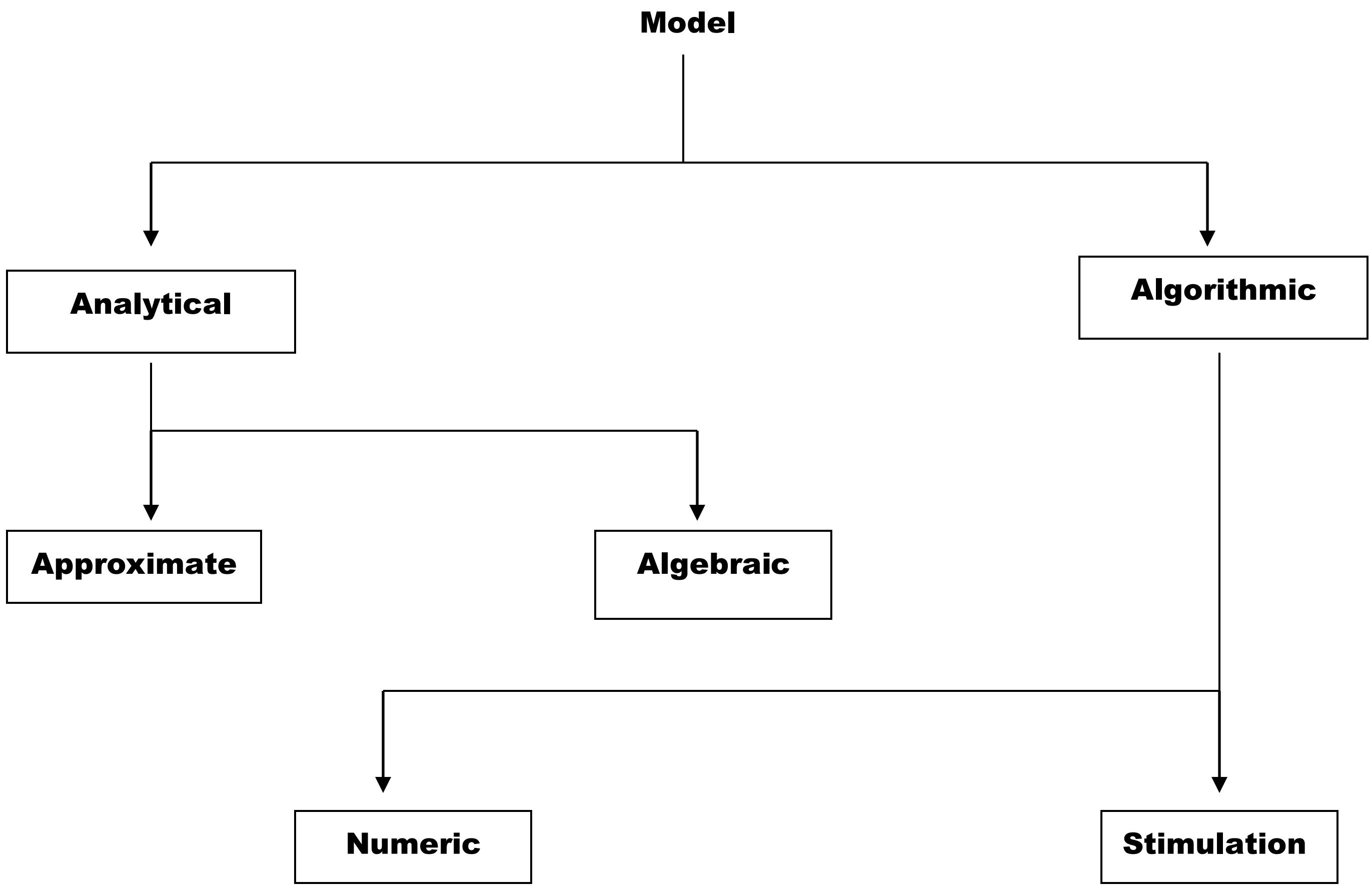
Two important features of microscopy:

- Magnification
- Resolution

> The eye of a human being is a microscope, which makes the world seem bigger than it really is.
>
> **Khalil Gibran**



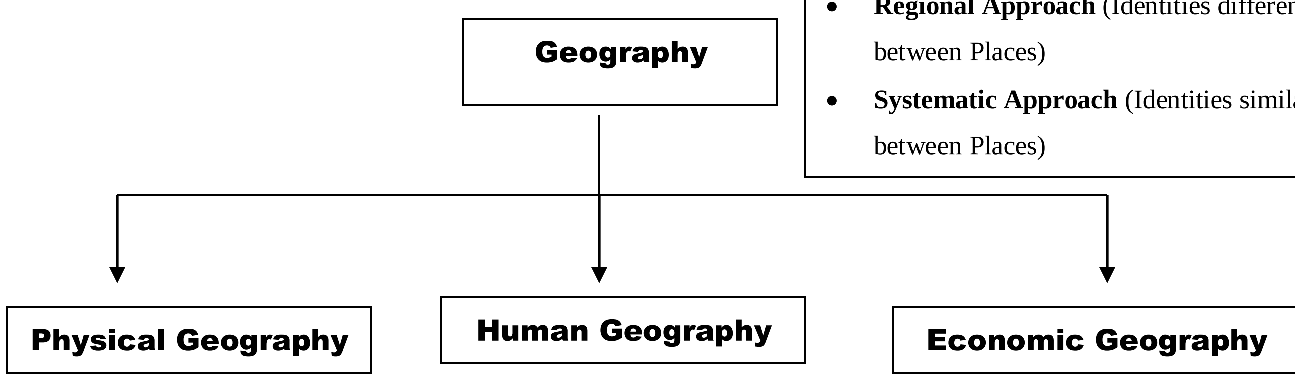
> From the Moon's surface, the Earth is but a tiny, blue teardrop in the inky blackness of space.
>
> — **Stewart Stafford**



- **Scalene Triangle:** All sides are unequal
- **Isosceles Triangle:** Two sides are equal
- **Equilateral Triangle:** All the three sides are equal and all angles measures to 60 degrees.

Approaches for studying geography:

- **Regional Approach** (Identities differences between Places)
- **Systematic Approach** (Identities similarities between Places)



Asteroids → Small, rocky objects that orbit the Sun

- **C-type (Carbon rich)**
- **S-type (Stony)**
- **M-type (Metallic)**

If one small and odd lineage of fishes had not evolved fins capable of bearing weight on land (though evolved for different reasons in lakes and seas,) terrestrial vertebrates would never have arisen. If a large extraterrestrial object—the ultimate random bolt from the blue—had not triggered the extinction of dinosaurs 65 million years ago, mammals would still be small creatures, confined to the nooks and crannies of a dinosaur's world, and incapable of evolving the larger size that brains big enough for self-consciousness require. If a small and tenuous population of protohumans had not survived a hundred slings and arrows of outrageous fortune (and potential extinction) on the savannas of Africa, then Homo sapiens would never have emerged to spread throughout the globe. We are glorious accidents of an unpredictable process with no drive to complexity, not the expected results of evolutionary principles that yearn to produce a creature capable of understanding the mode of its own necessary construction.

Stephen Jay Gould

Comets

Cosmic snowballs of frozen gases, rock and dust that orbit the Sun

Periodic comets

(Halley's Comet)

Non-periodic comets

(Comet Hale–Bopp)

Comets with no meaningful orbit

(The Great Comet of 1106)

Lost comets

(Brorsen's Comet)

Edmond Halley was an English astronomer who calculated the orbit of the comet now called Halley's Comet. He was a supporter of Newton.

Nikola Tesla Inventions:

- AC Power (alternating current)
- Tesla Coil
- Magnifying Transmitter
- Tesla Turbine
- Shadowgraph
- Radio
- Neon Lamp
- Hydroelectric Power
- Induction Motor
- Radio Controlled Boat

Of the 10,000 or so meteorites that have been collected and analyzed, eight are particularly unusual. They are so unusual, in fact, that since 1979 some investigators have thought they might have originated not in asteroids, as most meteorites did, but on the surface of Mars.

— Lawrence M. Krauss

Knowledge Acquisition

- Remembering
- Understanding

↓

Knowledge Deepening

- Applying
- Analyzing

↓

Knowledge Creation

- Evaluating
- Creating

- Preparation
- Incubation
- Illumination
- Evaluation
- Revision

5 Stages of Creativity

Every person on this earth is full of great possibilities that can be realized through imagination, effort, and perseverance.

Scott Barry Kaufmann

Motivation

Internal motives

External motives

Needs

Cognitions

Emotions

Metabolites

Primary Metabolites

Compounds that are directly involved in the metabolic pathways of an organism necessary for its growth, development and reproduction

Secondary Metabolites

Compounds that are produced by various organisms that are not directly involved in the growth, development, or reproduction of the organism but are essential in the ecological and other activities

There is not perhaps another object in the heavens that presents us with such a variety of extraordinary phenomena as the planet Saturn: a magnificent globe, encompassed by a stupendous double ring: attended by seven satellites: ornamented with equatorial belts: compressed at the poles: turning upon its axis: mutually eclipsing its ring and satellites, and eclipsed by them: the most distant of the rings also turning upon its axis, and the same taking place with the farthest of the satellites: all the parts of the system of Saturn occasionally reflecting light to each other: the rings and moons illuminating the nights of the Saturnian: the globe and satellites enlightening the dark parts of the rings: and the planet and rings throwing back the sun's beams upon the moons, when they are deprived of them at the time of their conjunctions.

— Sir William Herschel

Organic chemistry

Restricted to carbon compounds

Inorganic chemistry

Restricted to non-covalent carbon components

Biochemistry

Restricted to chemical components of living systems

Bioinorganic chemistry

Restricted to biochemical function of inorganic elements

Nutrients

Macronutrients

The nutrients the human body needs in larger amounts

↓

carbohydrates, protein and fat

Micronutrients

The nutrients the human body needs in smaller amounts

↓

vitamins and minerals

Protein	Fat	Carbohydrates
build, repair and maintain human body	carrier of vitamins	provide energy to the human body

Victor Grignard had a strange start in academic life for a chemist – he took a maths degree. When he eventually switched to chemistry, it was not to the mathematical province of physical chemistry but to organic chemistry. While attempting to find an efficient catalyst for the process of methylation, he noted that Zn in diethyl ether had been used for this purpose and wondered whether the Mg/ether combination might be successful. Grignard reagents were first reported in 1900 and Grignard used this work for his doctoral thesis in 1901. In 1910, Grignard obtained a professorship at the University of Nancy and in 1912, he was awarded the **Nobel prize for Chemistry** which he shared with Paul Sabatier who had made advances in nickel catalyzed hydrogenation.

Structure	**Common name**	**IUPAC name**
$HCOOH$	Formic acid	Methanoic acid
CH_3COOH	Acetic acid	Ethanoic acid
CH_3CH_2COOH	Propionic acid	Propanoic acid
$CH_3CH_2CH_2COOH$	Butyric acid	Butanoic acid

Amino acids

The building blocks of proteins

Nonessential amino acids

Synthesized in the body

Essential amino acids

Cannot be synthesized in the body and must be obtained through diet

11 nonessential amino acids: arginine, glutamine, tyrosine, cysteine, glycine, proline, serine, ornithine, alanine, asparagine and aspartate.

Gentlemen and ladies, this is ordinary alcohol, sometimes called ethanol; it is found in all fermented beverages. As you well know, it is considered by many to be poisonous, a belief in which I do not concur. If we subtract from it one CH_2-group we arrive at this colorless liquid, which you see in this bottle. It is sometimes called methanol or wood alcohol. It is certainly more toxic than the ethanol we have just seen. Its formula is CH_3OH. If, from this, we subtract the CH_2-group, we arrive at a third colorless liquid, the final member of this homologous series. This compound is hydrogen hydroxide, best known as water. It is the most poisonous of all.

Alfred Werner

Born in Chicago, Illinois, in 1928, **Dr Watson** received his Ph.D. (1950) from Indiana University in Zoology. He is best known for his discovery of the structure of DNA for which he shared with **Francis Crick** and **Maurice Wilkins** the 1962 Nobel prize in Physiology and Medicine. They proposed that DNA molecule takes the shape of a double helix, an elegantly simple structure that resembles a gently twisted ladder. The rails of the ladder are made of alternating units of phosphate and the sugar deoxyribose; the rungs are each composed of a pair of purine/ pyrimidine bases. This research laid the foundation for the emerging field of molecular biology. The complementary pairing of nucleotide bases explains how identical copies of parental DNA pass on to two daughter cells. This research launched a revolution in biology that led to modern recombinant DNA techniques.

Vitamins	**Deficiency Disease**
Vitamin A (**Retinol**)	Night blindness
Vitamin B1 (**Thiamine**)	Beri-beri
Vitamin B2 (**Riboflavin**)	Retarded growth, bad skin
Vitamin B12 (**Cyanocobalamin**)	Anemia
Vitamin C (**Ascorbic acid**)	Scurvy
Vitamin D (**Calciferol**)	Rickets
Vitamin K (**Phylloquinone**)	Excessive bleeding due to injury
Minerals	**Deficiency Disease**
Calcium	Brittle bones, excessive bleeding
Phosphorus	Bad teeth and bones
Iron	Anemia
Iodine	Goiter, enlarged thyroid gland
Copper	Low appetite, retarded growth

Green revolution

The renovation of agricultural practices

- Rapid increase in agricultural production
- Maintenance of high level of agricultural production

We need a new vision for agriculture … to spread happiness among farm and rural families. Bio-happiness through the conversion of our bio-resources into wealth meaningful to our rural families should be the goal of our national policy for farmers.

We should look upon agriculture not just as a food-producing machine for the urban population, but as the major source of skilled and remunerative employment and a hub for global outsourcing.

The importance of rice will grow in the coming decades because of potential changes in temperature, precipitation, and sea-level rise, as a result of global warming. Rice grows under a wide range of latitudes and altitudes and can become the anchor of food security in a world confronted with the challenge of climate change.

M. S. Swaminathan

Digital Computer

Usage-Wise

- Special Purpose
- General Purpose

Size-Wise

- Microcomputer
- Mini computer
- Mainframe computer
- Super computer

> A multidisciplinary study group ... estimated that it would be 1980 before developments in artificial intelligence make it possible for machines alone to do much thinking or problem solving of military significance. That would leave, say, five years to develop man-computer symbiosis and 15 years to use it. The 15 may be 10 or 500, but those years should be intellectually the most creative and exciting in the history of mankind.
>
> **J.C.R. Licklider**

Network

Local Area Network	**Metropolitan Area Network**	**Wide Area Network**
(LAN)	(MAN)	(LAN)
Lowest in distance and complexity	Medium in distance and complexity	Longest in distance and complexity

- microchips and self-driving cars
- 3D printing machines
- calculators, solar plates, computers and other electronic devices

The next major explosion is going to be when genetics and computers come together. I'm talking about an organic computer - about biological substances that can function like a semiconductor.

Alvin Toffler

Used in

Semiconductor

The materials whose conductivity lies between insulator and conductors

Intrinsic semiconductors

- Pure semiconductor
- Electrical conductivity is low

Extrinsic semiconductors

- Impure semiconductor
- Electrical conductivity is high

N-Type Semiconductor

Free electrons > positive holes

P-Type Semiconductor

Free electrons < positive holes

They were the largest semiconductor maker in the world up until about 1980. I'm not sure that that can be re-gained again, but their progress in the last few years has been very impressive.

– Jack Kilby

Lens

A tool used to bring light to a fixed focal point

Convex Lens (Converging)

Concave Lens (Diverging)

The working principle of the **mirror** is the law of reflection	The working principle of the **lens** is the law of refraction

Meiosis + Fertilization → Sexual Reproduction

Gametes

An organism's reproductive cells

Male gametes

(sperm)

Female gametes

(ova or egg cells)

Pollination

Biological process in which the pollen grains are transferred from an **anther** (male part of a flower) to the **stigma** (female part of a flower)

Self-Pollination

Transfer pollen grains from the anther to the stigma of the same flower

causes

Inbreeding

Cross-Pollination

Transfer pollen grains from the anther to the stigma of a different flower

causes

Outbreeding

External pollinating agents are required for this type of pollination (water, wind, insects etc)

If the bee disappeared off the surface of the globe, then man would have only four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man.

Albert Einstein

We are developing all sorts of technologies based on what we have learnt from birds, animals and soils. Pollination is worth £billions. But it also highlights how nature is so interconnected.

Tony Juniper

Water

Plays a critical role in regulating the body temperature and carrying nutrients throughout human body

Hard water

- Contains dissolved salts of Ca^{2+} and Mg^{2+}
- Does not form lather with soap

Soft water

- Does not contain dissolved salts
- Forms lather with soap

Man … begins life as an ambiguous speck of matter which can in no way be distinguished from the original form of the lowest animal or plant. He next becomes a cell; his life is precisely that of the animalcule. Cells cluster round this primordial cell, and the man is so far advanced that he might be mistaken for an undeveloped oyster; he grows still more, and it is clear that he might even be a fish; he then passes into a stage which is common to all quadrupeds, and next assumes a form which can only belong to quadrupeds of the higher type. At last the hour of birth approaches; coiled within the dark womb he sits, the image of an ape; a caricature of the man that is to be. He is born, and for some time he walks only on all fours; he utters only inarticulate sounds; and even in his boyhood his fondness for climbing trees would seem to be a relic of the old arboreal life.

Winwood Reade

6 main types of soil:

- Clay
- Sandy
- Silty
- Peaty
- Chalky
- Loamy

The three main stages of soil cultivation:

- ploughing
- tilling
- levelling

Weathering

Breakdown of rocks

Physical

Breakdown of rocks by the action of rainwater and extremes of temperature

Chemical

Breakdown of rocks through a series of chemical processes such as acidification, dissolution and oxidation

Biological

Breakdown of rocks by the action of biological activity

Surely the mitochondrion that first entered another cell was not thinking about the future benefits of cooperation and integration; it was merely trying to make its own living in a tough Darwinian world

— Stephen Jay Gould

Causes of Soil Erosion:

- Rainfall and Flooding
- Deforestation and Farming
- Overgrazing
- Construction and Recreational Activities

Essentially, all life depends upon the soil ... There can be no life without soil and no soil without life; they have evolved together.

Charles Kellogg

Methods to prevent soil erosion**:**

- Crop Rotation
- Conservation Tillage
- Contour Farming
- Strip Farming
- Mulch matting
- Terrace Farming
- Grass Waterways
- Diversion Structures
- Reduce watering
- Social Forestry

Geological process in which earthen materials are worn away and transported by natural forces such as wind or water

7 Reasons for Loss of Biodiversity:

- deforestation
- overpopulation
- pollution
- global warming and climate change
- over-harvesting and natural calamities
- over-exploitation of species
- genetic pollution and habitat destruction

Biodiversity

The richness and variety of life on earth

Genetic diversity

(Diversity within species)

Species diversity

(Diversity between species)

Ecosystem diversity

(Diversity between ecosystems)

The 3 main causes of climate change:

- Increased use of fossil fuels
- Deforestation
- Increasingly intensive agriculture

History is largely a record of human struggle to wrest the land from nature, because man relies for sustenance on the products of the soil. So direct, is the relationship between soil erosion, the productivity of the land, and the prosperity of people, that the history of mankind, to a considerable degree at least, may be interpreted in terms of the soil and what has happened to it as the result of human use.

Hugh Hammond Bennett

Antigen-Antibody Reaction:

Antigen + Antibody ↔ Antigen-Antibody complex

↓

Stimulate the production of antibody

$$K = \frac{[\text{Antigen}-\text{Antibody complex}]}{[\text{Antigen}][\text{Antibody}]}$$

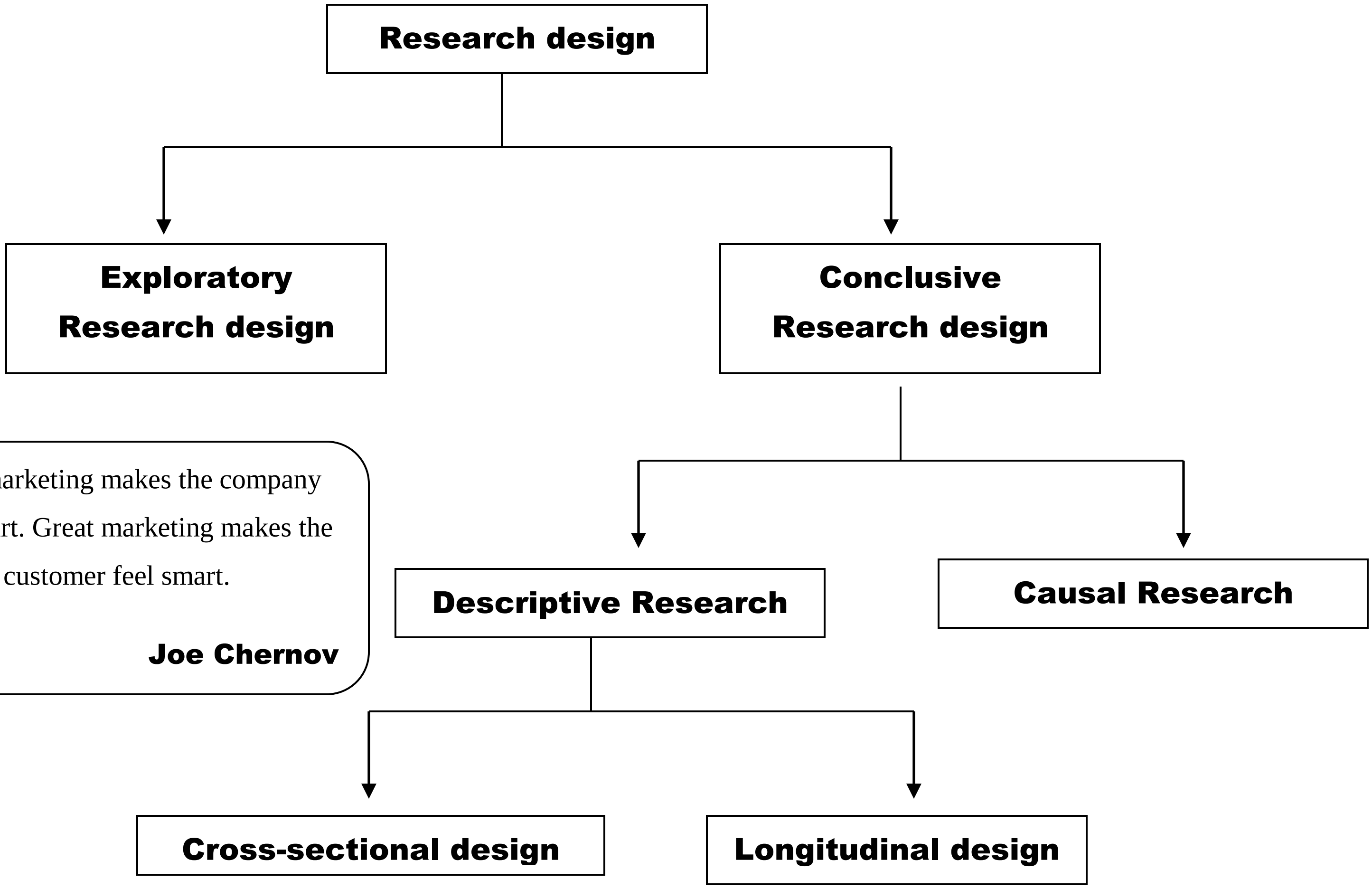
The larger the K value the greater the affinity of the antibody for the antigen.

Landsteiner Rule:

If an antigen is present on patient's red blood cells (RBCs) the corresponding antibody will NOT be present in the patient's plasma – under 'normal conditions'.

The 4 main components of blood:

red blood cells	carry oxygen around the body
white blood cells	play a crucial role in the immune system
plasma	yellowish liquid that contains proteins and salts
platelets	enable clotting

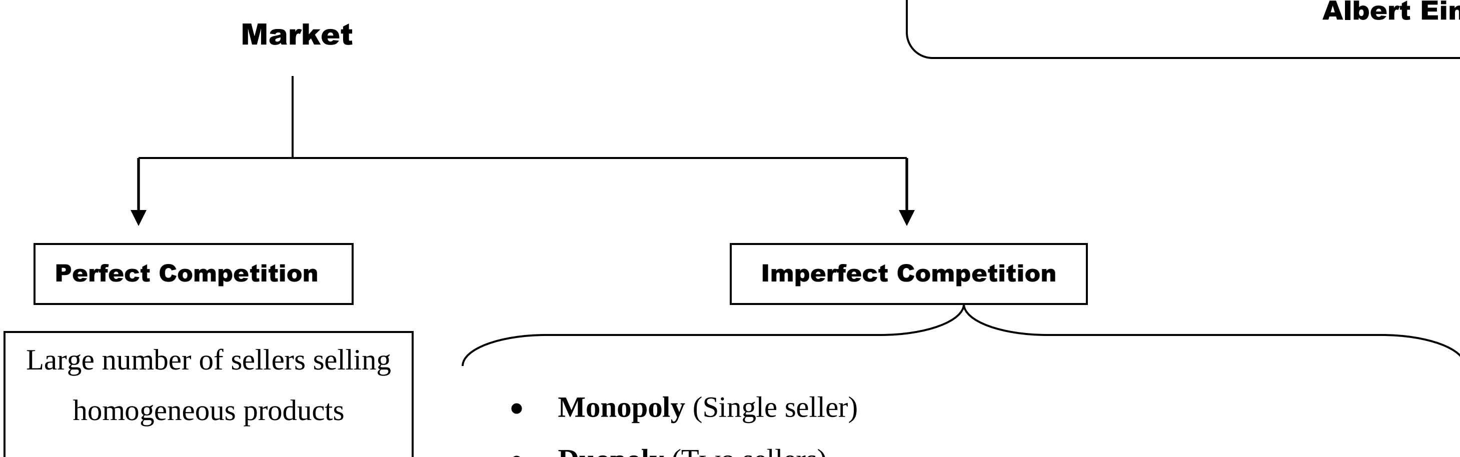


Good marketing makes the company look smart. Great marketing makes the customer feel smart.

Joe Chernov

Creativity is intelligence having fun.

Albert Einstein



- **Monopoly** (Single seller)
- **Duopoly** (Two sellers)
- **Oligopoly** (A few sellers selling homogeneous or differentiated products)
- **Monopolistic** (Large number of sellers selling differentiated products)

Walther Nernst was a German scientist who was one of the founders of modern physical chemistry. His theoretical and experimental work in chemistry, including his formulation of the heat theorem, known as the third law of thermodynamics, gained him the 1920 Nobel Prize for Chemistry.

Nernst equation:

$$E_{cell} = E^0 - \frac{RT}{nF} \ln Q$$

- E_{cell} = cell potential of the cell
- E^0 = cell potential under standard conditions
- R = universal gas constant
- T = temperature in Kelvin
- n = number of electrons transferred in the redox reaction
- F = Faraday constant
- Q = reaction quotient

Knowledge is the death of research.

No effect that requires more than 10 percent accuracy in measurement is worth investigating.

One should avoid carrying out an experiment requiring more than 10 per cent accuracy.

Walther Nernst

Disorders of Circulatory System:

- High Blood Pressure (**Hypertension**)
- Coronary Artery Disease
- Angina (**chest pain**)
- Heart Failure

In 1673, English scientist **Robert Hooke** built the earliest Gregorian telescope, and observed the rotations of the planets Mars and Jupiter

Cellular movements

Amoeboid **Ciliary** **Muscular**

Isothermal process	Temperature constant
Isobaric process	Pressure constant
Isochoric process	Volume constant
Adiabatic process	No heat flow between the system and the surroundings

Rudolf Clausius (1822−1888), born in Poland, is generally regarded as the discoverer of the Second Law of Thermodynamics. Based on the work of Carnot and Thomson, Clausius arrived at the important notion of entropy that led him to a fundamental version of the Second Law of Thermodynamics that states that the entropy of an isolated system can never decrease. Clausius also worked on the kinetic theory of gases and obtained the first reliable estimates of molecular size, speed, mean free path, etc

erg	10^{-7} J
electron volt	1.6×10^{-19} J
calorie	4.186 J
kilowatt hour	3.6×10^{6} J

	Based on the principle
Steam engine	Laws of thermodynamics
Nuclear reactor	Controlled nuclear fission
Radio and Television	Generation, propagation and detection of electromagnetic waves
Computers	Digital logic
Lasers	Light amplification by stimulated emission of radiation
Production of ultra high magnetic fields	Superconductivity
Rocket propulsion	Newton's laws of motion
Electric generator	Faraday's laws of electromagnetic induction
Hydroelectric power	Conversion of gravitational potential energy into electrical energy
Aeroplane	Bernoulli's principle in fluid dynamics
Particle accelerators	Motion of charged particles in electromagnetic fields
Sonar	Reflection of ultrasonic waves
Optical fibers	Total internal reflection of light
Non-reflecting coatings	Thin film optical interference
Electron microscope	Wave nature of electrons
Photocell	Photoelectric effect
Fusion test reactor (**Tokamak**)	Magnetic confinement of plasma
Giant Metrewave Radio Telescope (**GMRT**)	Detection of cosmic radio waves
Bose-Einstein condensate	Trapping and cooling of atoms by laser beams and magnetic fields

One of the things that always fascinated me about the Renaissance was that it was a time both of great scientific discovery and also of superstition and belief in magic. And so it was a period in which Galileo invented the telescope, but also a time when hundreds were burned at the stake because people thought they were witches.

Marie Rutkoski

Adsorption

The deposition of molecular species onto the surface

Physical adsorption

Due to weak Van der Waals forces between adsorbate and adsorbent

Chemical adsorption

Due to strong chemical forces of bonding between adsorbate and adsorbent

- **Adsorbate:** Substance that is deposited on the surface of another substance
- **Adsorbent:** Surface of a substance on which adsorbate adsorbs

In 1905, a physicist measuring the thermal conductivity of copper would have faced, unknowingly, a very small systematic error due to the heating of his equipment and sample by the absorption of cosmic rays, then unknown to physics. In early 1946, an opinion poller, studying Japanese opinion as to who won the war, would have faced a very small systematic error due to the neglect of the 17 Japanese holdouts, who were discovered later north of Saipan. These cases are entirely parallel. Social, biological and physical scientists all need to remember that they have the same problems, the main difference being the decimal place in which they appear.

— William Gemmell Cochran

Catalysis

Homogeneous

(The catalyst and reactants are in same phase)

Heterogeneous

(The catalyst and reactants are in different phase)

Enzymatic

(catalyst is an enzyme)

Enzyme	**Enzymatic reaction**
Invertase	Sucrose → Glucose and fructose
Zymase	Glucose → Ethyl alcohol and carbon dioxide
Diastase	Starch → Maltose
Maltase	Maltose → Glucose
Urease	Urea → Ammonia and carbon dioxide
Pepsin	Proteins → Amino acids

Our knowledge of stars and interstellar matter must be based primarily on the electromagnetic radiation which reaches us. Nature has thoughtfully provided us with a universe in which radiant energy of almost all wave lengths travels in straight lines over enormous distances with usually rather negligible absorption.

— Lyman Spitzer, Jr.

Haber's process for the manufacture of ammonia:

$$N_2\,(g) + 3H_2\,(g) \rightarrow 2NH_3\,(g)$$

- Finely divided iron as catalyst, molybdenum as promoter
- **Conditions:** 200 bar pressure and 723-773K temperature

Noble gases being monoatomic have no interatomic forces except weak dispersion forces and therefore, they are liquefied at very low temperatures. Hence, they have low boiling points.

The absorption of oxygen and the elimination of carbon dioxide in the lungs take place by diffusion alone. There is no trustworthy evidence of any regulation of this process on the part of the organism.

— August Krogh

Colloids

Any substance consisting of particles substantially larger than atoms or ordinary molecules but too small to be visible to the unaided eye

Lyophilic colloids

(Solvent attracting)

Lyophobic colloids

(Solvent repelling)

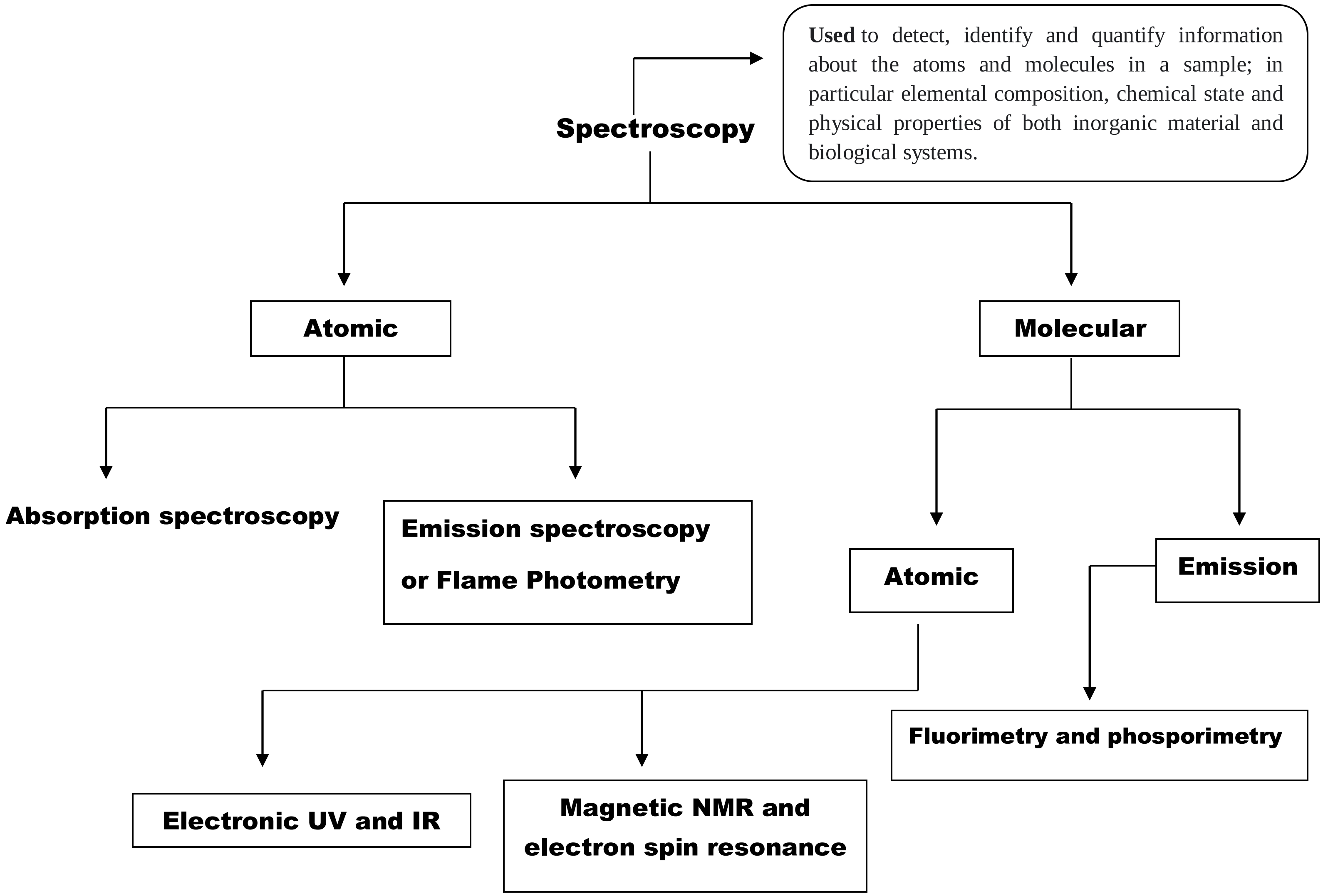
Colloids in everyday life: whipped cream, mayonnaise, milk, butter, gelatin, jelly, muddy water, plaster, colored glass, and paper.

Alfred Werner was born on December 12, 1866, in Mülhouse, a small community in the French province of Alsace. His study of chemistry began in Karlsruhe (Germany) and continued in Zurich (Switzerland), where in his doctoral thesis in 1890, he explained the difference in properties of certain nitrogen containing organic substances on the basis of isomerism. He extended **van't Hoff 's theory** of tetrahedral carbon atom and modified it for nitrogen. Werner showed optical and electrical differences between complex compounds based on physical measurements. In fact, Werner was the first to discover optical activity in certain coordination compounds. He, at the age of 29 years became a full professor at Technische Hochschule in Zurich in 1895. Alfred Werner was a chemist and educationist. His accomplishments included the development of the theory of coordination compounds. This theory, in which Werner proposed revolutionary ideas about how atoms and molecules are linked together, was formulated in a span of only three years, from 1890 to 1893. The remainder of his career was spent gathering the experimental support required to validate his new ideas. Werner became the first Swiss chemist to win the **Nobel Prize** in 1913 for his work on the linkage of atoms and the coordination theory.

Chemistry must become the astronomy of the molecular world.

— Alfred Werner

Coordination number	**Type of hybridization**	**Shape**
4	sp^3	Tetrahedral
4	dsp^2	Square planar
5	sp^3d	Trigonal bipyramidal
6	sp^3d^2	Octahedral



An attempt to study the evolution of living organisms without reference to cytology would be as futile as an account of stellar evolution which ignored spectroscopy.

— J.B.S. Haldane

Beer–Lambert law:

Absorbance ∝ (length of light path × concentration of the absorbing species)

Absorbance = molar absorptivity × (length of light path × concentration of the absorbing species)

The whole subject of the X rays is opening out wonderfully, Bragg has of course got in ahead of us, and so the credit all belongs to him, but that does not make it less interesting. We find that an X ray bulb with a platinum target gives out a sharp line spectrum of five wavelengths which the crystal separates out as if it were a diffraction grating. In this way one can get pure monochromatic X rays. Tomorrow we search for the spectra of other elements. There is here a whole new branch of spectroscopy, which is sure to tell one much about the nature of an atom.

Henry Moseley

Moseley's Law:

The frequency υ of a characteristic X-ray of an element is related to its atomic number Z by $\sqrt{\upsilon} = a\,(Z - b)$, where a and b are constants that depend on the type of line (that is, K, L, etc. in X-ray notation).

[W]e pity our fathers for dying before steam and galvanism, sulphuric ether and ocean telegraphs, photograph and spectrograph arrived, as cheated out of their human estate.

— Ralph Waldo Emerson

Biological Oxygen Demand (BOD)	**Chemical Oxygen Demand (COD)**
Biological oxidation process performed by aerobic organisms	Chemical oxidation process performed by chemical reagents
Determined by incubating sealed water for a period of 5 days at 20 degree Celsius. The reduction in dissolved oxygen gives the amount of oxygen consumed by the aerobic organisms.	Determined by incubating a closed water sample with a strong oxidant like potassium dichromate in combination with boiling sulfuric acid for a specific period of time and temperature.
BOD value is lower than COD	COD value is always greater than BOD
BOD measure the amount of oxygen that will be consumed by bacteria or other aerobic microorganisms while decomposing organic matter under aerobic conditions.	COD measure the amount of oxygen that will be consumed by the chemical breakdown, or oxidation of organic pollutants in water.

I have procured air [oxygen] ... between five and six times as good as the best common air that I have ever met with.

— Joseph Priestley

As mineralogy constitutes a part of chemistry, it is clear that this arrangement [of minerals] must derive its principles from chemistry. The most perfect mode of arrangement would certainly be to allow bodies to follow each other according to the order of their electro-chemical properties, from the most electro-negative, oxygen, to the most electro-positive, potassium; and to place every compound body according to its most electro-positive ingredient.

Jöns Jacob Berzelius

Natural vegetation

Forests

- Tropical Rain Forest
- Tropical Deciduous Forest
- Temperate Deciduous Forest
- Temperate Evergreen Forest
- Mediterranean Forest
- Coniferous Forest

Grasslands

- Tropical Grasslands
- Temperate Grasslands

Desertic Scrubs

- Tropical Deserts
- Tundra Regions

Lymph	**Blood**
colorless fluid ↓ Helps in body defence and is a part of the immune system	reddish colored fluid ↓ Involved in the circulation of nutrients, hormones, oxygen and carbon dioxide, wastes and other toxins

- A **heart rate** is the number of times your heart beats in the span of a minute.
- A **pulse rate** is the number of times your arteries create a noticeable "**pulse**" due to increase in blood pressure as a result of your heart contracting.

Category of rainfall	Intensity (mm)
Trace	≤ 3
Light rain	4.57 − 9.64
Moderate rain	9.65 − 22.34
Moderately heavy rain	22.35 − 44.19
Heavy rain	44.20 – 88.90
Very heavy rain	≥ 89

In every combustion there is disengagement of the matter of fire or of light. A body can burn only in pure air [oxygen]. There is no destruction or decomposition of pure air and the increase in weight of the body burnt is exactly equal to the weight of air destroyed or decomposed. The body burnt changes into an acid by addition of the substance that increases its weight. Pure air is a compound of the matter of fire or of light with a base. In combustion the burning body removes the base, which it attracts more strongly than does the matter of heat, which appears as flame, heat and light.

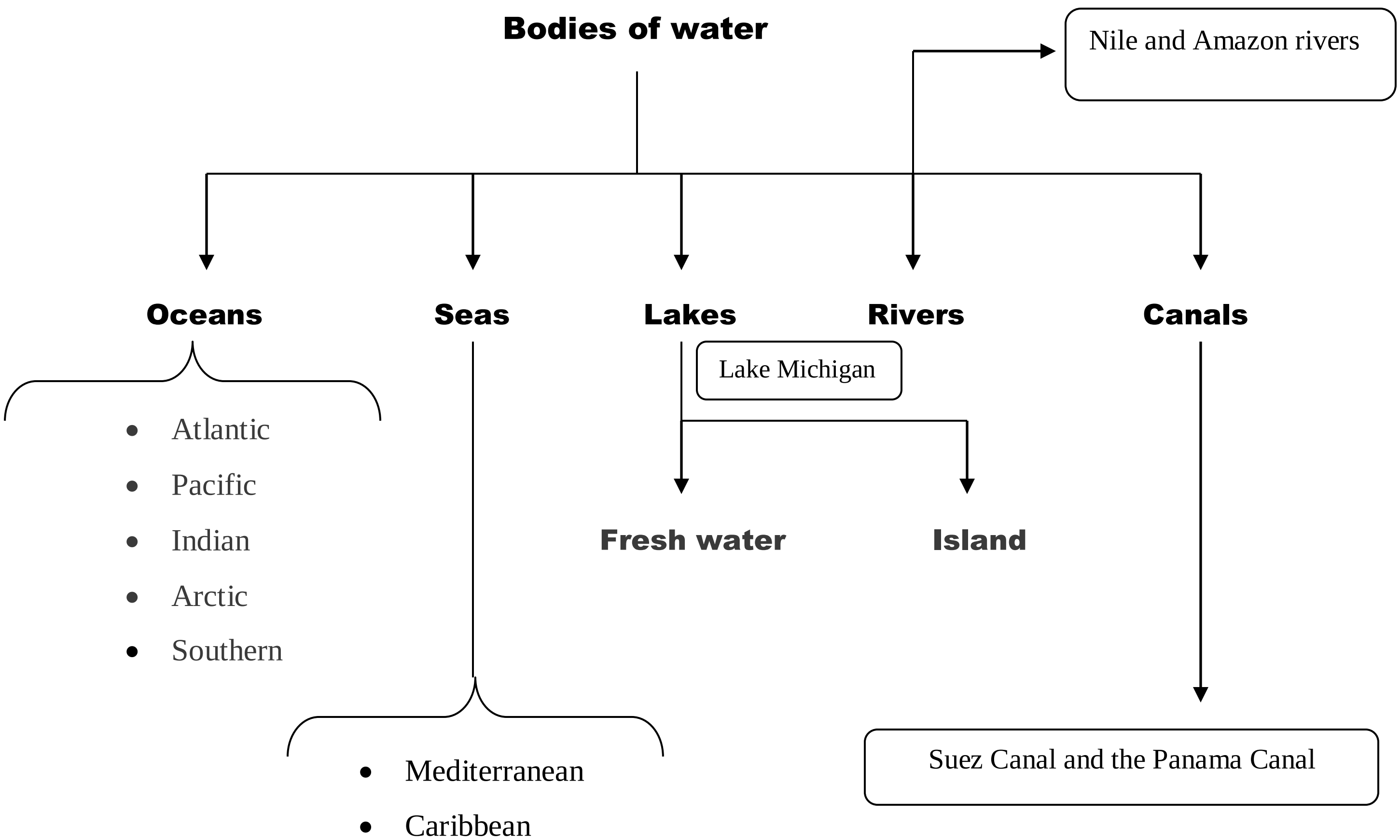
— Antoine-Laurent Lavoisier

Metal + Oxygen → Metal oxide

Metal + Sulfur → Metal Sulfide

Metal oxide + water → Metal Hydroxide

Incandescent Bulb	**Fluorescent Bulb**
Light produced by a heating a metallic filament	Light produced by electricity flowing through a tube filled with ionized gas



Top 10 Most Dangerous Lakes in the World:

- Boiling Lake
- Lake Natron
- Jacob's Well
- Rio Tinto
- Horseshoe Lake
- Lake Champlain
- Lake Kivu
- Blue Hole
- Lake Michigan
- Drake Passage

- Extremely dangerous
- Spending time in or by can even be fatal

Hans Christian Oersted (1777–1851) was a Danish physicist and chemist, professor at Copenhagen. He observed that a compass needle suffers a deflection when placed near a wire carrying an electric current. This discovery gave the first empirical evidence of a connection between electric and magnetic phenomena.

Hendrik Antoon Lorentz (1853 – 1928) was a Dutch theoretical physicist, professor at Leiden. He investigated the relationship between electricity, magnetism, and mechanics. In order to explain the observed effect of magnetic fields on emitters of light (**Zeeman Effect**), he postulated the existence of electric charges in the atom, for which he was awarded the Nobel Prize in 1902. He derived a set of transformation equations (known after him, as Lorentz transformation equations) by some tangled mathematical arguments, but he was not aware that these equations hinge on a new concept of space and time.

Circuits

Series Circuits

$$R_{tot} = R_1 + R_2 + R_3 + \ldots$$

Parallel Circuits

$$\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

2 basic laws of magnets:

- Like poles (North-North, South-South) will repel each other
- Unlike poles (North-South) will attract each other

The field of scientific abstraction encompasses independent kingdoms of ideas and of experiments and within these, rulers whose fame outlasts the centuries. But they are not the only kings in science. He also is a king who guides the spirit of his contemporaries by knowledge and creative work, by teaching and research in the field of applied science, and who conquers for science provinces which have only been raided by craftsmen.

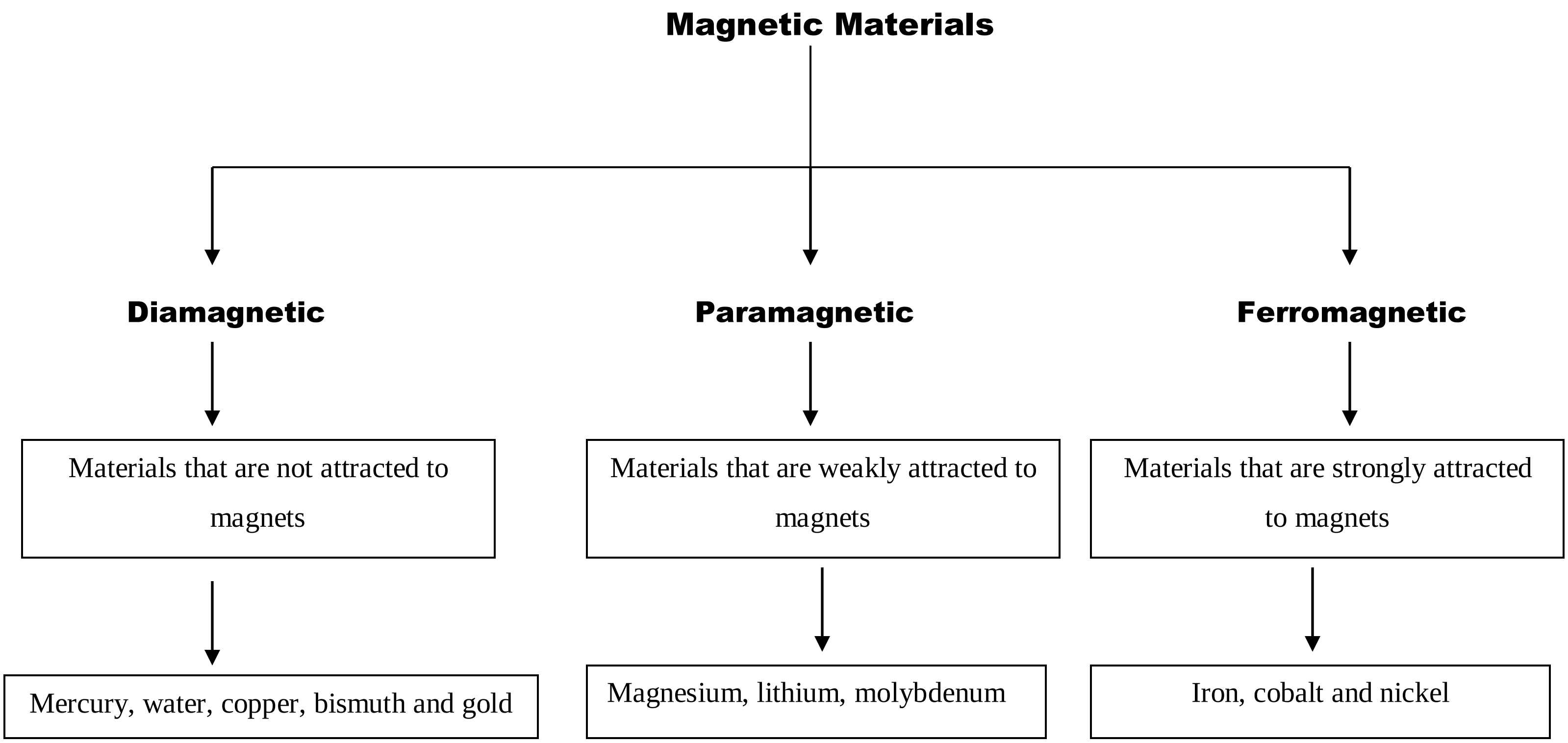
— Fritz Haber

3 properties of waves:

- **Amplitude** – The measure of the displacement of the wave from its rest position.
- **Frequency** – The frequency of a wave is the number of times per second that the wave cycles.
- **Wavelength** – The wavelength of a wave is the distance between two corresponding troughs or crests.

Every teacher certainly should know something of non-euclidean geometry. Thus, it forms one of the few parts of mathematics which, at least in scattered catch-words, is talked about in wide circles, so that any teacher may be asked about it at any moment. … Imagine a teacher of physics who is unable to say anything about Röntgen rays, or about radium. A teacher of mathematics who could give no answer to questions about non-euclidean geometry would not make a better impression. On the other hand, I should like to advise emphatically against bringing non-euclidean into regular school instruction (i.e., beyond occasional suggestions, upon inquiry by interested pupils), as enthusiasts are always recommending. Let us be satisfied if the preceding advice is followed and if the pupils learn to really understand euclidean geometry. After all, it is in order for the teacher to know a little more than the average pupil.

— Felix Klein



Joseph Henry [1797 –1878] was an American experimental physicist, professor at Princeton University and first director of the Smithsonian Institution. He made important improvements in electromagnets by winding coils of insulated wire around iron pole pieces and invented an electromagnetic motor and a new, efficient telegraph. He discovered self-induction and investigated how currents in one circuit induce currents in another.

George Westinghouse (1846 – 1914) was a leading proponent of the use of alternating current over direct current. Thus, he came into conflict with Thomas Alva Edison, an advocate of direct current. Westinghouse was convinced that the technology of alternating current was the key to the electrical future. He founded the famous Company named after him and enlisted the services of Nicola Tesla and other inventors in the development of alternating current motors and apparatus for the transmission of high tension current, pioneering in large scale lighting.

Crystalline solids	Amorphous solids
They have definite characteristic geometrical shape	They have irregular shape
Symmetrical and more rigid	Unsymmetrical and less rigid
They are true solids	They are pseudo solids or super cooled liquids
They have sharp melting points	They do not have sharp melting points
They are anisotropic in nature	They are isotropic in nature
They have definite heat of fusion	They do not have definite heat of fusion
Diamond	Glass

Neumann, to a physicist seeking help with a difficult problem: Simple. This can be solved by using the method of characteristics.

Physicist: I'm afraid I don't understand the method of characteristics.

Neumann: In mathematics you don't understand things. You just get used to them.

— John von Neumann

3 types of Solutions:

- **Gaseous Solutions**

Gas + Gas (Mixture of oxygen and nitrogen gases)

Liquid + Gas (Chloroform mixed with nitrogen gas)

Solid + Gas (Camphor in nitrogen gas)

- **Liquid Solutions**

Gas + Liquid (Oxygen dissolved in water)

Liquid + Liquid (Ethanol dissolved in water)

Solid + Liquid (Glucose dissolved in water)

- **Solid Solutions**

Gas + Solid (Solution of hydrogen in palladium)

Liquid + Solid (Amalgam of mercury with sodium)

Solid + Solid (Copper dissolved in gold)

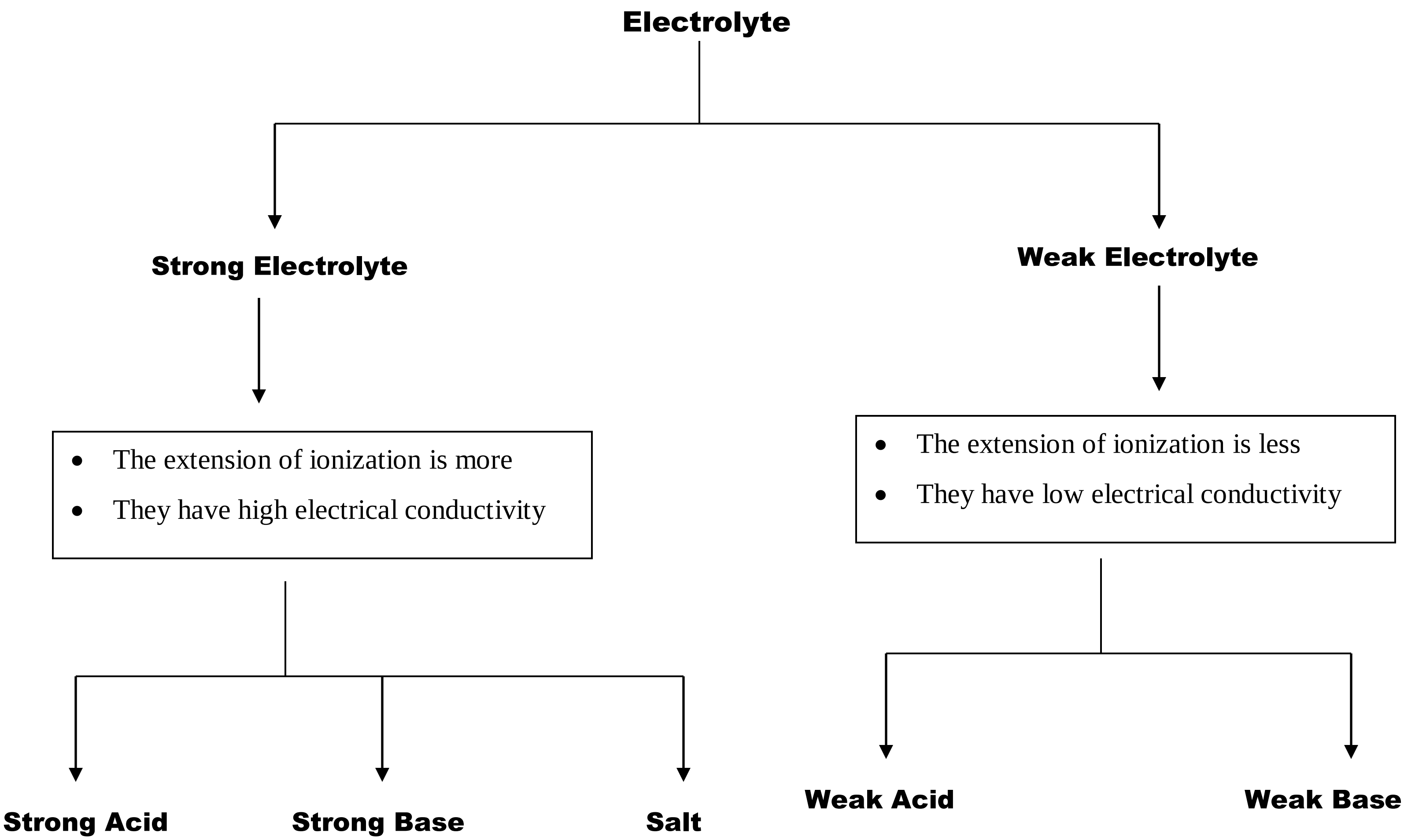
The Annotated Alice, of course, does tie in with math, because Lewis Carroll was, as you know, a professional mathematician. So it wasn't really too far afield from recreational math, because the two books are filled with all kinds of mathematical jokes. I was lucky there in that I really didn't have anything new to say in The Annotated Alice because I just looked over the literature and pulled together everything in the form of footnotes. But it was a lucky idea because that's been the best seller of all my books.

Martin Gardner

OXIDATION	REDUCTION
Losing electrons	Gaining electrons
Increase in oxidation number	Decrease in oxidation number
Losing hydrogen	Gaining hydrogen
Releases energy	Stores energy

A general course in mathematics should be required of all officers for its practical value, but no less for its educational value in training the mind to logical forms of thought, in developing the sense of absolute truthfulness, together with a confidence in the accomplishment of definite results by definite means.

— Charles Echols



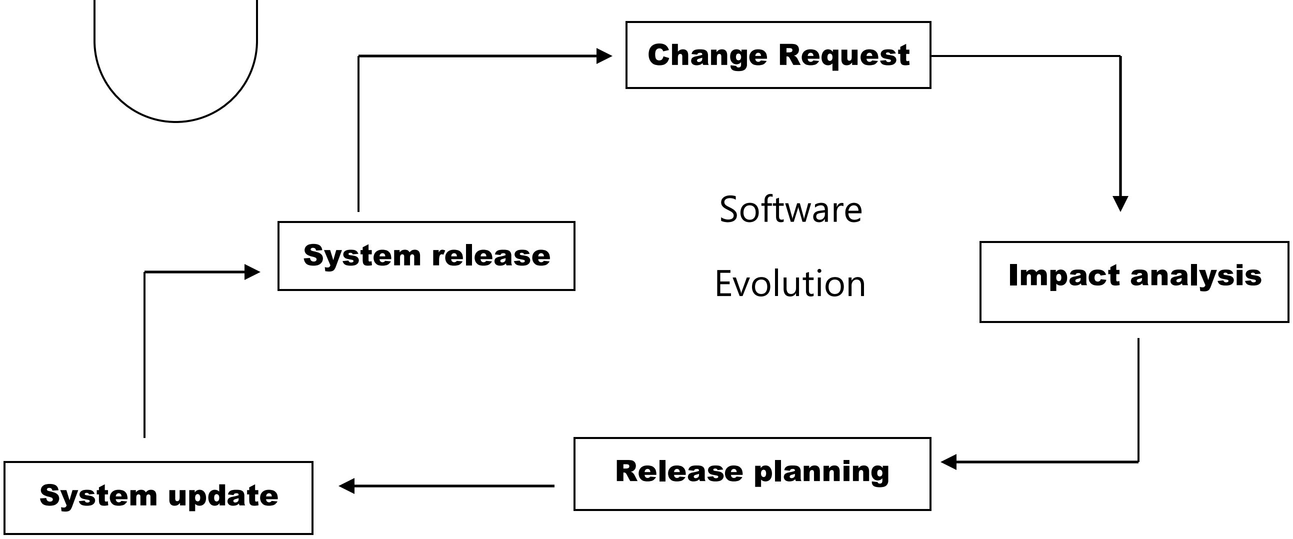
A formal manipulator in mathematics often experiences the discomforting feeling that his pencil surpasses him in intelligence.

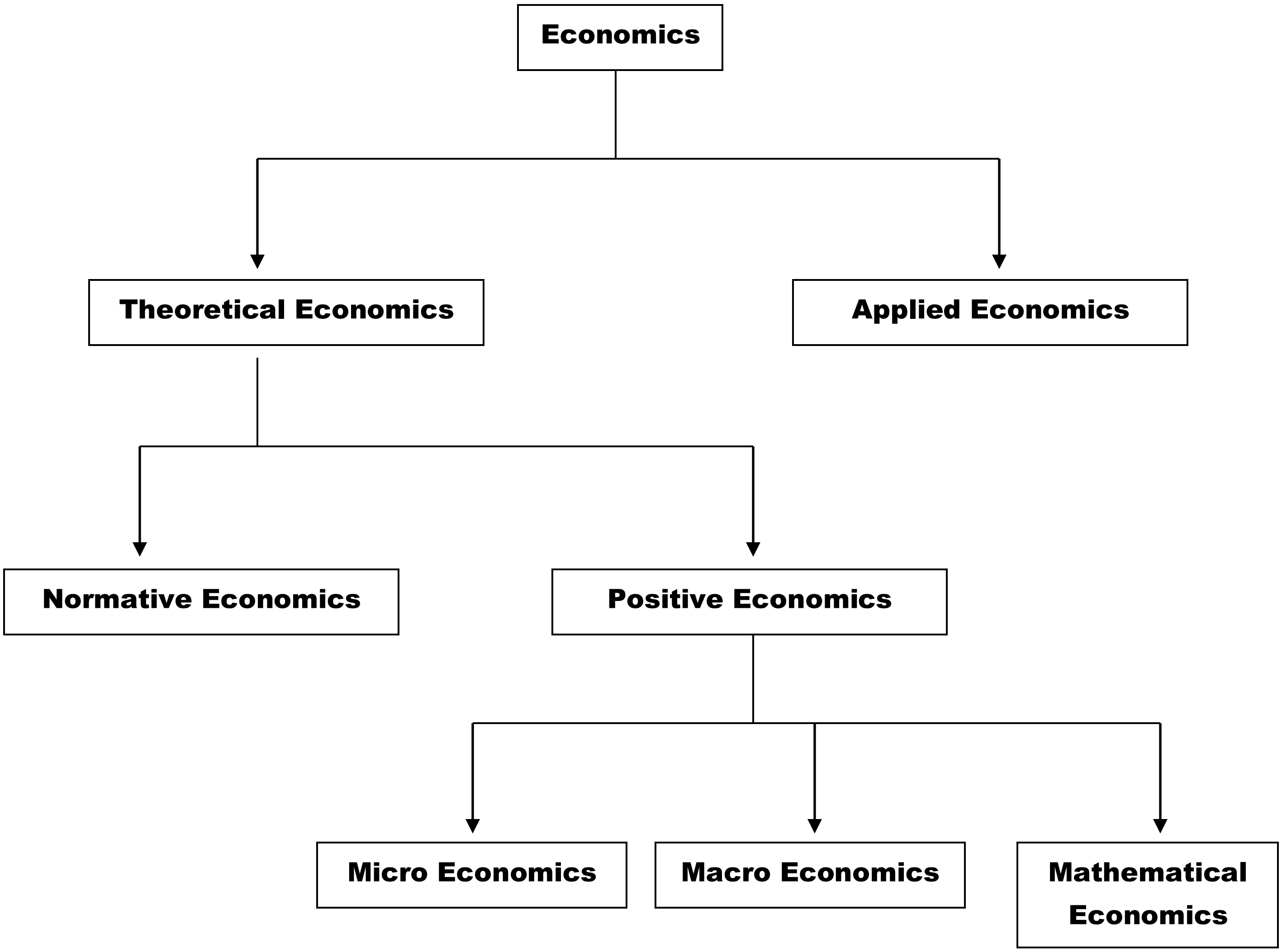
— **Howard Eves**

Strong Electrolytes	**strong acids**	HCl, HBr, HI, HNO_3, $HClO_3$, $HClO_4$ and H_2SO_4
	strong bases	NaOH, KOH, LiOH, $Ba(OH)_2$ and $Ca(OH)_2$
	salts	NaCl, KBr and $MgCl_2$
Weak Electrolytes	**weak acids**	HF, CH_3COOH, H_2CO_3 and H_3PO_4
	weak bases	NH_3 and C_5H_5N

Incandescent carbon particles, by the tens of millions, leap free of the log and wave like banners, as flame. Several hundred significantly different chemical reactions are now going on. For example, a carbon atom and four hydrogen atoms, coming out of the breaking cellulose, may lock together and form methane, natural gas. The methane, burning (combining with oxygen), turns into carbon dioxide and water, which also go up the flue. If two carbon atoms happen to come out of the wood with six hydrogen atoms, they are, agglomerately, ethane, which bums to become, also, carbon dioxide and water. Three carbons and eight hydrogens form propane, and propane is there, too, in the fire. Four carbons and ten hydrogens — butane. Five carbons … pentane. Six … hexane. Seven … heptane. Eight carbons and eighteen hydrogens—octane. All these compounds come away in the breaking of the cellulose molecule, and burn, and go up the chimney as carbon dioxide and water. Pentane, hexane, heptane, and octane have a collective name. Logs burning in a fireplace are making and burning gasoline.

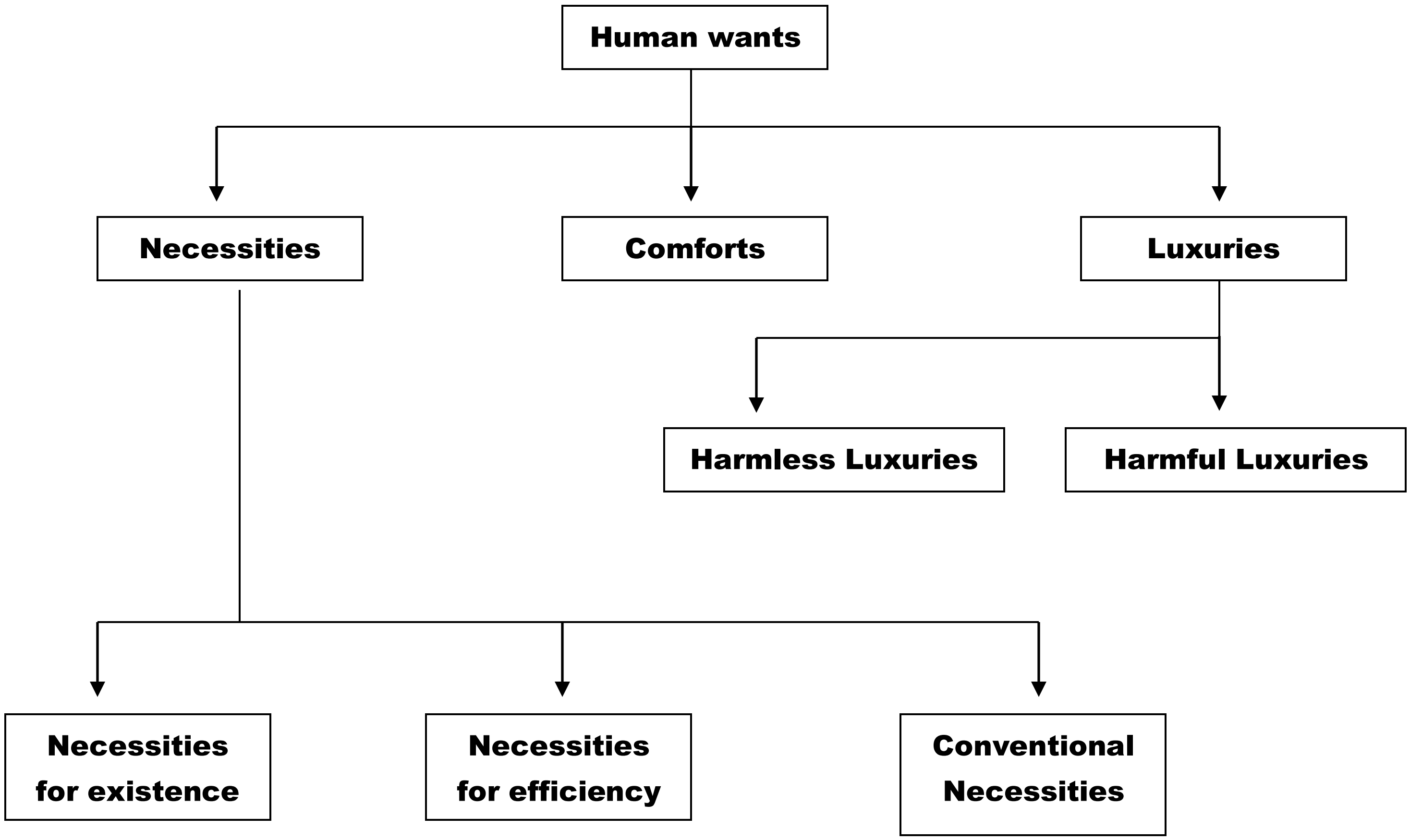
— John McPhee





The climate crisis is both the easiest and the hardest issue we have ever faced. The easiest because we know what we must do. We must stop the emissions of greenhouse gases. The hardest because our current economics are still totally dependent on burning fossil fuels, and thereby destroying ecosystems in order to create everlasting economic growth.

Greta Thunburg



Gregory Mankiw's 10 Principles of Economics:

> Economics is the study of how society manages its scarce resources.
>
> **Greg Mankiw**

- People face trade-offs
- The cost of something is what you give up to get it
- Rational people think at the margin
- People respond to incentives
- Trade can make everyone better off
- Markets are usually a good way to organize economic activity
- Governments can sometimes improve market outcomes
- A country's standard of living depends on its ability to produce goods and services
- Prices rise when the government prints too much money
- Society faces a short-run tradeoff between Inflation and unemployment

4 key elements of economics:

- Description
- Analysis
- Explanation
- Prediction

4 types of population:

- **Finite Population** (countable population)
- **Infinite Population** (uncountable population)
- **Existent Population** (population that exist in reality)
- **Hypothetical Population** (what the population is expected to be)

The first lesson of economics is scarcity: there is never enough of anything to fully satisfy all those who want it. The first lesson of politics is to disregard the first lesson of economics.

Thomas Sowell

Communication

On the basis of relationship

- Formal
- Informal

On the basis of flow

- Vertical
  - Downward
  - Upward
- Horizontal

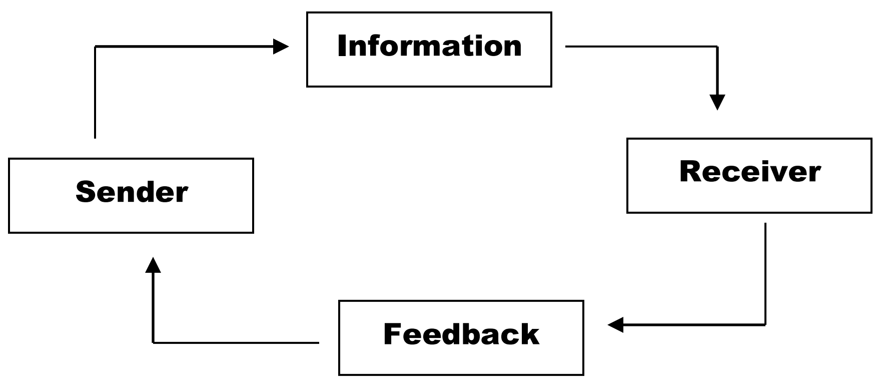
On the basis of expression

- Verbal
  - Oral
  - Written
- Nonverbal

One-way communication process:

Sender → Message → Channel → Receiver

Two-way communication process:



> The human world lives in a framework called global economics. We live in a system based on GDP, which drives consumption. It causes people to compete with each other through trade in a way that they all grow.
>
> **John Sulston**

Communication channels

Based on guided propagation

- Telephone channels
- Coaxial cable
- Optical fiber

Based on free propagation

- Wireless broadcast channels
- Satellite channels
- Mobile radio channels

Properties of metals:

- Shiny metallic appearance
- Solids at room temperature (except mercury)
- High melting points
- High densities
- Large atomic radii
- Low ionization energies

Since scarcity is the basic economic problem, if it does not exist then there is no reason for my economics course. Devoting time to the study of how people use limited resources to fulfill unlimited wants and needs should help us to discover how to best utilize the resources we have at our disposal.

Kurt Bills

Hydrogen gas is produced when metals react with acids. For example, when zinc reacts with hydrochloric acid it produces zinc chloride and hydrogen gas.

$$\mathbf{Zn} + \mathbf{HCl} \rightarrow ZnCl_2 + H_2\uparrow$$

Metal oxides are produced when metals burn in the presence of oxygen.

$$2Mg + O_2 \rightarrow 2\mathbf{MgO}$$

Metal	Ion	Reactivity
Caesium (Cs)	Cs^+	reacts with cold water
Rubidium (Rb)	Rb^+	
Potassium (K)	K^+	
Sodium (Na)	Na^+	
Lithium (Li)	Li^+	
Barium (Ba)	Ba^{2+}	
Strontium (Sr)	Sr^{2+}	
Calcium (Ca)	Ca^{2+}	
Magnesium (Mg)	Mg^{2+}	reacts very slowly with cold water, but rapidly in boiling water, and very vigorously with acids
Beryllium (Be)	Be^{2+}	reacts with acids and steam
Aluminum (Al)	Al^{3+}	
Titanium (Ti)	Ti^{4+}	reacts with concentrated mineral acids

List of Metals:

Atomic Number	Symbol	Metal Element
3	Li	Lithium
4	Be	Beryllium
11	Na	Sodium
12	Mg	Magnesium
13	Al	Aluminum
19	K	Potassium
20	Ca	Calcium
21	Sc	Scandium
22	Ti	Titanium
23	V	Vanadium
24	Cr	Chromium
25	Mn	Manganese
26	Fe	Iron
27	Co	Cobalt
28	Ni	Nickel
29	Cu	Copper
30	Zn	Zinc
31	Ga	Gallium
37	Rb	Rubidium
38	Sr	Strontium
39	Y	Yttrium
40	Zr	Zirconium
41	Nb	Niobium
42	Mo	Molybdenum
43	Tc	Technetium
44	Ru	Ruthenium
45	Rh	Rhodium
46	Pd	Palladium
47	Ag	Silver
48	Cd	Cadmium

Manganese (Mn)	Mn^{2+}	reacts with acids; very poor reaction with steam
Zinc (Zn)	Zn^{2+}	
Chromium (Cr)	Cr^{3+}	
Iron (Fe)	Fe^{2+}	
Cadmium (Cd)	Cd^{2+}	
Cobalt (Co)	Co^{2+}	
Nickel (Ni)	Ni^{2+}	
Tin (Sn)	Sn^{2+}	
Lead (Pb)	Pb^{2+}	
Antimony (Sb)	Sb^{3+}	may react with some strong oxidizing acids
Bismuth (Bi)	Bi^{3+}	
Copper (Cu)	Cu^{2+}	reacts slowly with air
Tungsten (W)	W^{3+}	may react with some strong oxidizing acids
Mercury (Hg)	Hg^{2+}	
Silver (Ag)	Ag^{+}	
Gold (Au)	Au^{3+}	
Platinum (Pt)	Pt^{4+}	

49	In	Indium
50	Sn	Tin
55	Cs	Cesium
56	Ba	Barium
57	La	Lanthanum
58	Ce	Cerium
59	Pr	Praseodymium
60	Nd	Neodymium
61	Pm	Promethium
62	Sm	Samarium
63	Eu	Europium
64	Gd	Gadolinium
65	Tb	Terbium
66	Dy	Dysprosium
67	Ho	Holmium
68	Er	Erbium
69	Tm	Thulium
70	Yb	Ytterbium
71	Lu	Lutetium
72	Hf	Hafnium
73	Ta	Tantalum
74	W	Tungsten
75	Re	Rhenium
76	Os	Osmium
77	Ir	Iridium
78	Pt	Platinum
79	Au	Gold
80	Hg	Mercury
81	Tl	Thallium
82	Pb	Lead
83	Bi	Bismuth
84	Po	Polonium
87	Fr	Francium

Chemistry is one of those branches of human knowledge which has built itself upon methods and instruments by which truth can presumably be determined. It has survived and grown because all its precepts and principles can be re-tested at anytime and anywhere. So long as it remained the mysterious alchemy by which a few devotees, by devious and dubious means, presumed to change baser metals into gold, it did not flourish, but when it dealt with the fact that 56 g. of fine iron, when heated with 32 g. of flowers of sulfur, generated extra heat and gave exactly 88 g. of an entirely new substance, then additional steps could be taken by anyone. Scientific research in chemistry, since the birth of the balance and the thermometer, has been a steady growth of test and observation. It has disclosed a finite number of elementary reagents composing an infinite universe, and it is devoted to their inter-reaction for the benefit of mankind.

Willis R. Whitney

Not all the metals react with bases and when they do react, they produce metal salts and hydrogen gas. For example: When zinc reacts with strong sodium hydroxide it gives sodium zincate and hydrogen gas.

$$Zn + 2\mathbf{NaOH} \rightarrow Na_2ZnO_2 + H_2\uparrow$$

88	Ra	Radium
89	Ac	Actinium
90	Th	Thorium
91	Pa	Protactinium
92	U	Uranium
93	Np	Neptunium
94	Pu	Plutonium
95	Am	Americium
96	Cm	Curium
97	Bk	Berkelium
98	Cf	Californium
99	Es	Einsteinium
100	Fm	Fermium
101	Md	Mendelevium
102	No	Nobelium
103	Lr	Lawrencium
104	Rf	Rutherfordium
105	Db	Dubnium
106	Sg	Seaborgium
107	Bh	Bohrium
108	Hs	Hassium
109	Mt	Meitnerium
110	Ds	Darmstadtium
111	Rg	Roentgenium
112	Cn	Copernicium
113	Nh	Nihonium
114	Fl	Flerovium
115	Mc	Moscovium
116	Lv	Livermorium

Polymer

A substance which has a molecular structure built up chiefly or completely from a large number of similar units bonded together

Natural polymer | **Semi-synthetic polymer** | **Synthetic polymer** (Human-made polymers)

I was working with these very long-chain … extended-chain polymers, where you had a lot of benzene rings in them. … Transforming a polymer solution from a liquid to a fiber requires a process called spinning. … We spun it and it spun beautifully. It [Kevlar] was very strong and very stiff—unlike anything we had made before. I knew that I had made a discovery. I didn't shout "Eureka!" but I was very excited, as was the whole laboratory excited, and management was excited, because we were looking for something new. Something different. And this was it.

Stephanie Kwolek

Bactericidal	Bacteriostatic
A drug that kills bacteria • Penicillin • Aminoglycosides • Ofloxacin	A drug that prevents bacterial growth and reproduction • Erythromycin • Tetracycline • Chloramphenicol

Isomerism

The phenomenon in which more than one compounds have the same chemical formula but different chemical structures

Structural isomerism

- Chain isomerism
- Position isomerism
- Functional group isomerism
- Metamerism

Stereoisomerism

- Geometrical isomerism
- Optical isomerism

[**Mitscherlich Law of Isomerism**] An equal number of atoms, combined in the same way produce the same crystal forms, and the same crystal form does not depend on the nature of the atoms, but only on their number and mode of combination.

— Eilhard Mitscherlich

Methods of Purification of Organic Compounds:

- Sublimation
- Crystallization
- Distillation
- Differential extraction
- Chromatography

Hydrocarbons

Saturated hydrocarbons

Hydrocarbons in which all the carbon-carbon bonds are single bonds

Aromatic compounds

Resonance structures containing single and double bonds

Unsaturated hydrocarbons

Hydrocarbons in which all the carbon-carbon bonds are double or triple bonds

The resulting acid rain reacts with marble, $CaCO_3$ of **Taj Mahal** ($CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$) causing damage to this wonderful monument that has attracted people from around the world.

Yves Chauvin, Institut Français du Pétrole, Rueil-Malmaison France, Robert H. Grubbs California Institute of Technology (Caltech), Pasadena, CA, USA and Richard R. Schrock Massachusetts Institute of Technology (MIT), Cambridge, MA, USA won the 2005 Nobel Prize in chemistry for work that reduces hazardous waste in creating new chemicals. The trio won the award for their development of the metathesis method in organic synthesis – a way to rearrange groups of atoms within molecules that the **Royal Swedish Academy of Sciences** likened to a dance in which couples change partners. The metathesis has tremendous commercial potential in the pharmaceuticals, biotechnology and food stuffs production industries. It is also used in the development of revolutionary environmentally-friendlier polymers. This represents a great step forward for '**green chemistry**', reducing potentially hazardous waste through smarter production. Metathesis is an example of how important application of basic science is for the benefit of man, society and the environment.

Dalton's Atomic Theory:

- All matter is made of atoms. Atoms are indivisible and indestructible.
- All atoms of a given element are identical in mass and properties
- Compounds are formed by a combination of two or more different kinds of atoms
- A chemical reaction is a rearrangement of atoms

The Periodic Table is arguably the most important concept in chemistry, both in principle and in practice. It is the everyday support for students, it suggests new avenues of research to professionals, and it provides a succinct organization of the whole of chemistry. It is a remarkable demonstration of the fact that the chemical elements are not a random cluster of entities but instead display trends and lie together in families. An awareness of the Periodic Table is essential to anyone who wishes to disentangle the world and see how it is built up from the fundamental building blocks of the chemistry, the chemical elements.

Glenn T. Seaborg

Earthquake

Sudden tremor of the earth due to movements within the earth's crust

Tectonic

Occurs when the earth's crust breaks due to geological forces on rocks and adjoining plates that cause physical and chemical changes

Volcanic

Results from tectonic forces which occur in conjunction with volcanic activity

Collapse

Small earthquakes in underground caverns and mines that are caused by seismic waves produced from the explosion of rock on the surface

Explosion

Result from the explosion of nuclear and chemical device

causes

- damage to buildings and infrastructure
- Landslides and rockslides
- Floods
- Tsunamis
- the soil to become saturated and lose its strength

A first step in the study of civilization is to dissect it into details, and to classify these in their proper groups. Thus, in examining weapons, they are to be classed under spear, club, sling, bow and arrow, and so forth; among textile arts are to be ranged matting, netting, and several grades of making and weaving threads; myths are divided under such headings as myths of sunrise and sunset, eclipse-myths, earthquake-myths, local myths which account for the names of places by some fanciful tale, eponymic myths which account for the parentage of a tribe by turning its name into the name of an imaginary ancestor; under rites and ceremonies occur such practices as the various kinds of sacrifice to the ghosts of the dead and to other spiritual beings, the turning to the east in worship, the purification of ceremonial or moral uncleanness by means of water or fire. Such are a few miscellaneous examples from a list of hundreds … To the ethnographer, the bow and arrow is the species, the habit of flattening children's skulls is a species, the practice of reckoning numbers by tens is a species. The geographical distribution of these things, and their transmission from region to region, have to be studied as the naturalist studies the geography of his botanical and zoological species.

— Sir Edward Burnett Tylor

As the Director of the Theoretical Division of Los Alamos, I participated at the most senior level in the World War II Manhattan Project that produced the first atomic weapons.

Now, at age 88, I am one of the few remaining such senior persons alive. Looking back at the half century since that time, I feel the most intense relief that these weapons have not been used since World War II, mixed with the horror that tens of thousands of such weapons have been built since that time—one hundred times more than any of us at Los Alamos could ever have imagined.

Today we are rightly in an era of disarmament and dismantlement of nuclear weapons. But in some countries nuclear weapons development still continues. Whether and when the various Nations of the World can agree to stop this is uncertain. But individual scientists can still influence this process by withholding their skills.

Accordingly, I call on all scientists in all countries to cease and desist from work creating, developing, improving and manufacturing further nuclear weapons - and, for that matter, other weapons of potential mass destruction such as chemical and biological weapons.

[On the occasion of the 50th Anniversary of Hiroshima]

— Hans Albrecht Bethe

Each part of the project had a specific task. These tasks were carefully allocated and supervised so that the sum of their parts would result in the accomplishment of our over-all mission.

I first met J. Robert Oppenheimer on October 8, 1942, at Berkeley, Calif. There we discussed the theoretical research studies he was engaged in with respect to the physics of the bomb. Our discussions confirmed my previous belief that we should bring all of the widely scattered theoretical work together. … He expressed complete agreement, and it was then that the idea of the prompt establishment of a Los Alamos was conceived.

— Leslie Richard Groves

I remember the spring of 1941 to this day. I realized then that a nuclear bomb was not only possible—it was inevitable. … And I had then to start taking sleeping pills. It was the only remedy, I've never stopped since then. It's 28 years, and I don't think I've missed a single night in all those 28 years.

— Sir James Chadwick

Let us sum up the three possible explanations of the decision to drop the bomb and its timing. The first that it was a clever and highly successful move in the field of power politics, is almost certainly correct; the second, that the timing was coincidental, convicts the American government of a hardly credible tactlessness [towards the Soviet Union]; and the third, the Roman holiday theory [a spectacular event to justify the cost of the Manhattan Project], convicts them of an equally incredible irresponsibility.

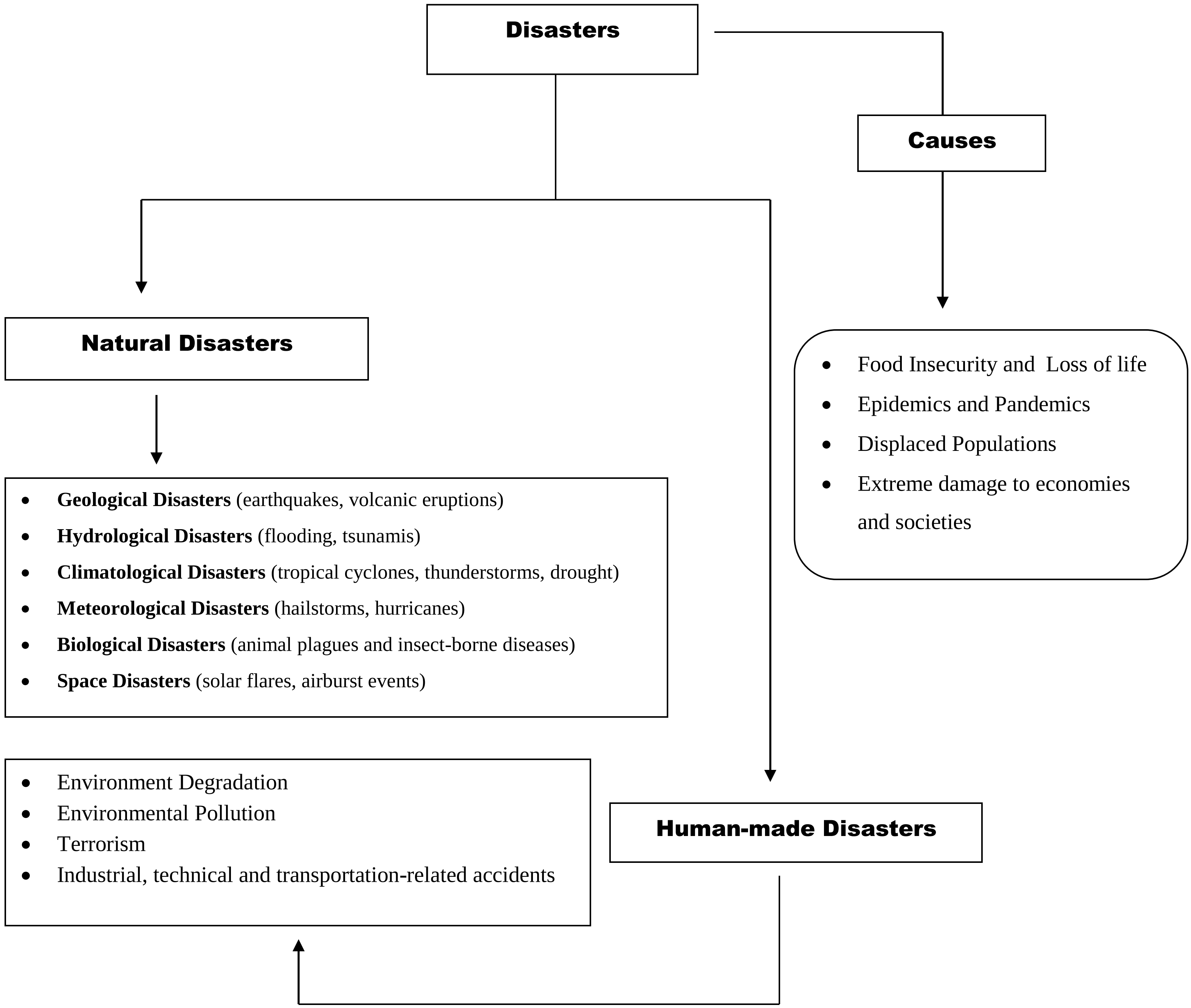
— Patrick M.S. Blackett

Laser → light amplification by the stimulated emission of radiation

Used for

- Cutting
- Engraving
- Drilling
- Marking
- Surface Modification

- Surgery
- Holographic Imaging
- Information Processing



We need to come up with precise, deterministic ways of directly evaluating single-molecule interactions systematically in single cells.

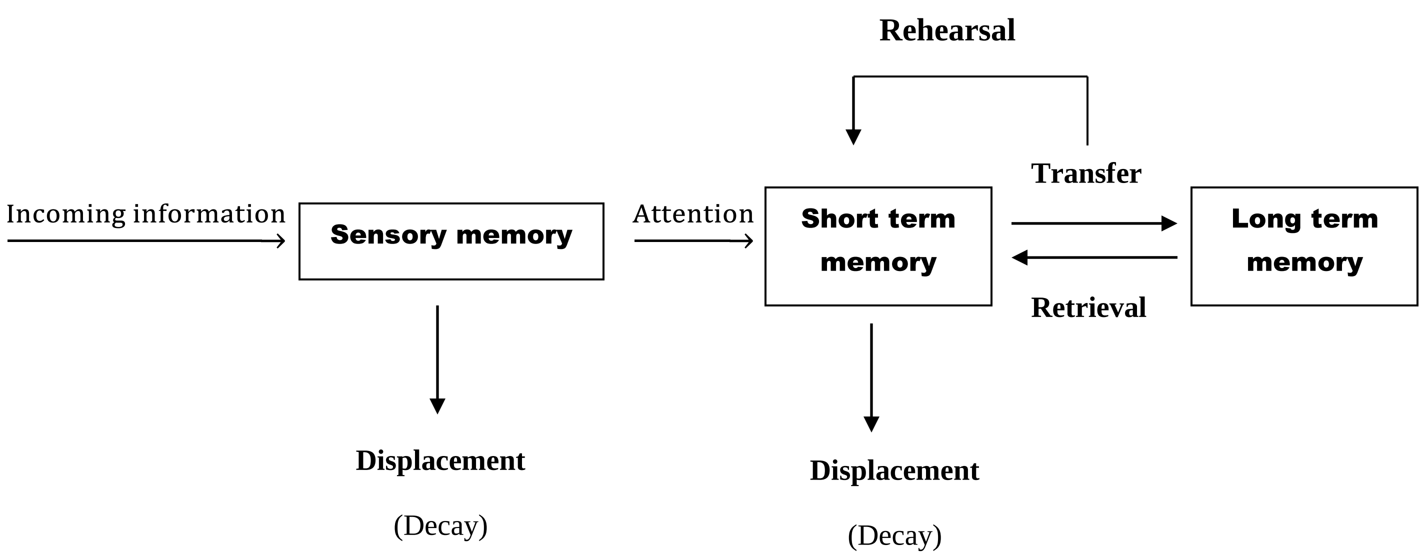
Bradley Bernstein

3 Types of Paradox:

- **Veridical Paradox:** contradict with our intuition but is perfectly logical
- **Falsidical paradox:** seems true but actually is false due to a fallacy in the demonstration
- **Antinomy:** be self-contradictive

Human personality resembles a coral reef: a large hard/dead structure built and inhabited by tiny soft/live animals. The hard/dead part of our personality consists of habits, memories, and compulsions and will probably be explained someday by some sort of extended computer metaphor. The soft/live part of personality consists of moment-to-moment direct experience of being. This aspect of personality is familiar but somewhat ineffable and has eluded all attempts at physical explanation.

— Nick Herbert



Leo Szilard was a Hungarian-American physicist and inventor. He conceived the nuclear chain reaction in 1933, patented the idea of a nuclear fission reactor in 1934, and in late 1939 wrote the letter for Albert Einstein's signature that resulted in the Manhattan Project that built the atomic bomb.

Leo Szilard's Ten Commandments:

- Recognize the connections of things and the laws of conduct of men, so that you may know what you are doing.
- Let your acts be directed towards a worthy goal, but do not ask if they will reach it; they are to be models and examples, not means to an end.
- Speak to all men as you do to yourself, with no concern for the effect you make, so that you do not shut them out from your world; lest in isolation the meaning of life slips out of sight and you lose the belief in the perfection of the creation.
- Do not destroy what you cannot create.
- Touch no dish, except that you are hungry.
- Do not covet what you cannot have.
- Do not lie without need.
- Honor children. Listen reverently to their words and speak to them with infinite love.
- Do your work for six years; but in the seventh, go into solitude or among strangers, so that the memory of your friends does not hinder you from being what you have become.
- Lead your life with a gentle hand and be ready to leave whenever you are called.

Glaciers

Huge masses of ice that moves slowly over land

Continental glaciers

(Enormous glaciers that can cover entire continents)

Alpine glaciers

(Small glaciers that form valleys)

4 types of English sentence:

- **declarative sentence** (statement)
- **interrogative sentence** (question)
- **imperative sentence** (command)
- **exclamative sentence** (exclamation)

Dream analysis stands or falls with [the hypothesis of the unconscious]. Without it the dream appears to be merely a freak of nature, a meaningless conglomerate of memory-fragments left over from the happenings of the day.

— Carl Jung

3 Types of Mass Media:

- **Print media** (newspapers, books, magazines)
- **Broadcast media** (television, radio)
- **Digital media** (internet)

How many discoveries are reserved for the ages to come when our memory shall be no more, for this world of ours contains matter for investigation for all generations.

— Lucius Annaeus Seneca

Vaccines → Trigger human **immune response** to recognize and fight disease-causing organisms

- **Conventional Vaccines**
  - **Live Vaccines**
  - **Inactivated Vaccines**
- **Purified antigen Vaccines**
- **Recombinant Vaccines**
  - **Subunit Vaccines**
    - **Whole protein molecule**
    - **Polypeptide**
  - **DNA Vaccines**

Although our main concern is to treat people with substance use disorder and mental health issues and to ultimately prepare them for reintegration into society, vaccination is crucial in terms of ensuring overall health and well-being.

Susanne Bjelbo

3 main reasons for cell division: → The process by which a parent cell divides into two daughter cells

Making New cells | **Making New DNA**

- Growth
- Reproduction
- Repair

Types of cell division:

Mitosis | Meiosis | Binary Fission

Mitosis	Meiosis
Parent cell $\xrightarrow{\text{DNA replicates}}$ 2 daughter cells	Parent cell $\xrightarrow{\text{DNA replicates}}$ 2 daughter cells → 4 daughter cells

3 main types of joints:

- **Fibrous** (immovable)
- **Cartilaginous** (slightly moveable)
- **Synovial** (freely moveable)

> Not a single visible phenomenon of cell-division gives even a remote suggestion of qualitative division. All the facts, on the contrary, indicate that the division of the chromatin is carried out with the most exact equality.
>
> **Edmund Beecher Wilson**

Healthy cell

Necrosis

- Increase in cell volume
- Loss of plasma membrane integrity
- Leakage of cell contents

Cell death due to unfavorable stressful situations− infections, excessive heat, radiation or lack of blood supply

Apoptosis

- Cell shrinkage
- Plasma membrane blebbing
- Formation of apoptotic bodies

Programmed cell death which eliminates unwanted cells from the body

Unfixable DNA Damage

Apoptosis → No cancer risk

Cell continues dividing → Could lead to Cancer

The development of the nucleoplasm during ontogeny may be to some extent compared to an army composed of corps, which are made up of divisions, and these of brigades, and so on. The whole army may be taken to represent the nucleoplasm of the germ-cell: the earliest cell-division … may be represented by the separation of the two corps, similarly formed but with different duties: and the following cell-divisions by the successive detachment of divisions, brigades, regiments, battalions, companies, etc.; and as the groups become simpler so does their sphere of action become limited.

August Weismann

Fertilization of mammalian eggs is followed by successive cell divisions and progressive differentiation, first into the early embryo and subsequently into all of the cell types that make up the adult animal. Transfer of a single nucleus at a specific stage of development, to an enucleated unfertilized egg, provided an opportunity to investigate whether cellular differentiation to that stage involved irreversible genetic modification. The first offspring to develop from a differentiated cell were born after nuclear transfer from an embryo-derived cell line that had been induced to became quiescent. Using the same procedure, we now report the birth of live lambs from three new cell populations established from adult mammary gland, fetus and embryo. The fact that a lamb was derived from an adult cell confirms that differentiation of that cell did not involve the irreversible modification of genetic material required far development to term. The birth of lambs from differentiated fetal and adult cells also reinforces previous speculation that by inducing donor cells to became quiescent it will be possible to obtain normal development from a wide variety of differentiated cells.

Ian Wilmut

> The nucleic acids, as constituents of living organisms, are comparable in importance to proteins. There is evidence that they are Involved In the processes of cell division and growth, that they participate in the transmission of hereditary characters, and that they are important constituents of viruses. An understanding of the molecular structure of the nucleic acids should be of value in the effort to understand the fundamental phenomena of life.
>
> **Linus Pauling**

Gene Therapy

Gene augmentation

Introduction of new genes into patients' cells − often through adeno-associated viruses, to replace a defective gene

Autologous therapy

Administered to patients' cells outside the body before being reintroduced

Allogeneic therapy

Administered to patients directly

Gene editing

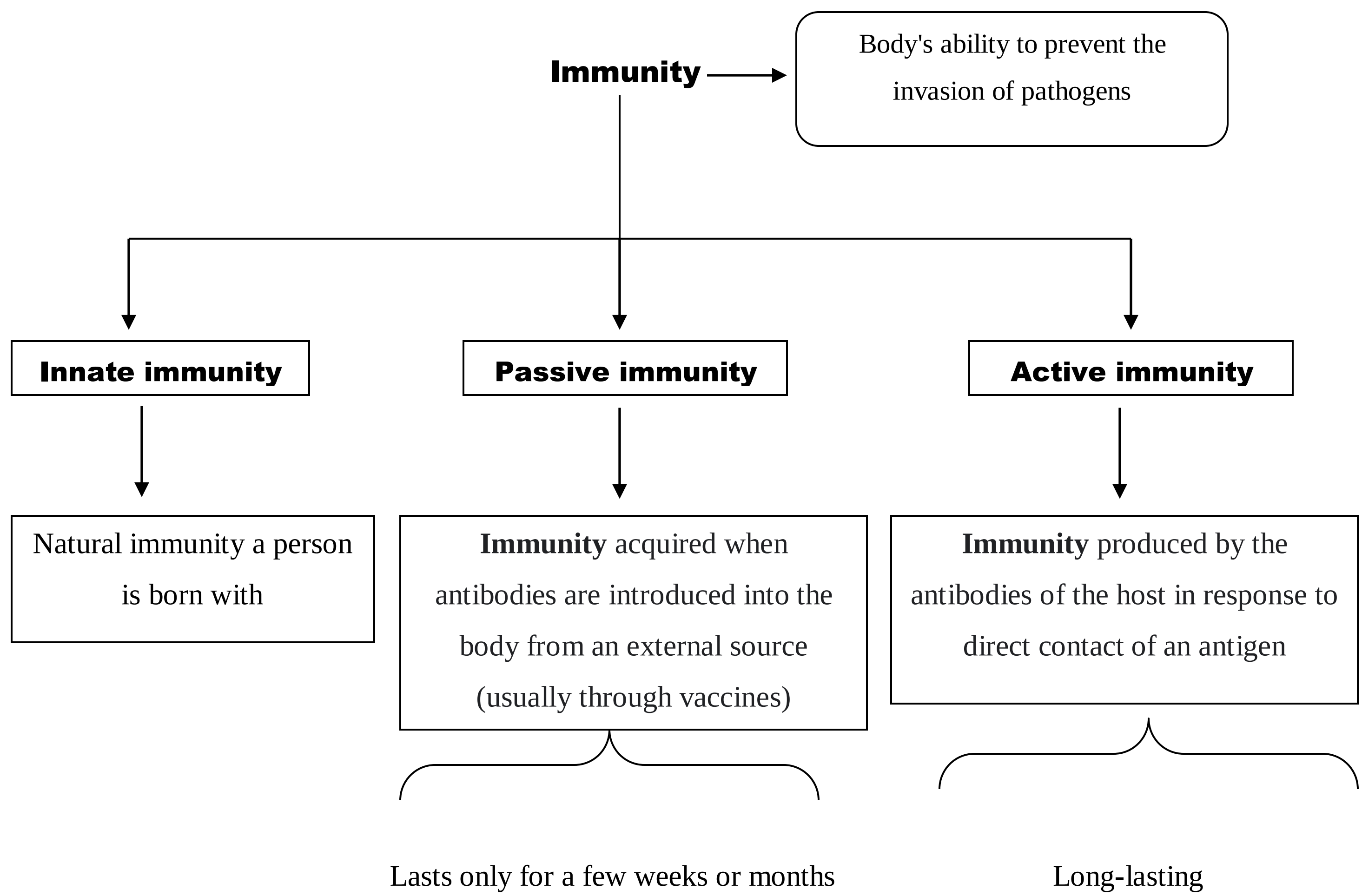
Modification, addition or removal of patients' existing DNA

Chemotherapy drugs

- prevent cell division
- target the cancer cells' food source (the enzymes and hormones they need to grow)
- trigger the suicide of cancer cells

These facts show that mitosis is due to the co-ordinate play of an extremely complex system of forces which are as yet scarcely comprehended. Its purpose is, however, as obvious as its physiological explanation is difficult. It is the end of mitosis to divide every part of the chromatin of the mother-cell equally between the daughter-nuclei. All the other operations are tributary to this. We may therefore regard the mitotic figure as essentially an apparatus for the distribution of the hereditary substance, and in this sense as the especial instrument of inheritance.

Edmund Beecher Wilson



Skin	prevent germs from getting into the body
Mucous membranes	secrete mucus and other substances which trap and fight germs
White blood cells (the cells of the immune system)	protect the human body against both infectious disease and foreign invaders
Organs and tissues of the lymph system	produce, store and carry white blood cells

> Naturally, immunity is a natural physician that fends off all invading bacteria and viruses; whereas, food becomes its medicine or trouble since that appears to increase or decrease your immune system. Thus, choose the right and healthy food, and adopt this proverb: Eat to be alive, not live to eat.
>
> **Ehsan Sehgal**

White blood cells

Phagocytes

Surround and absorb pathogens and break them down − effectively eating them

- Neutrophils
- Monocytes
- Macrophages
- Mast cells

Lymphocytes

Help the human body to remember previous invaders and recognize them if they come back to attack again

- B lymphocytes
- T lymphocytes

replication

DNA $\xrightarrow{\text{transcription}}$ **mRNA** $\xrightarrow{\text{translation}}$ **protein**

Process of Transcription in Bacteria:

- Initiation
- Elongation
- Termination

[Decoding the human genome sequence] is the most significant undertaking that we have mounted so far in an organized way in all of science. I believe that reading our blueprints, cataloguing our own instruction book, will be judged by history as more significant than even splitting the atom or going to the moon.

[Locating, from scratch, the gene related to a disease is like] trying to find a burned-out light bulb in a house located somewhere between the East and West coasts without knowing the state, much less the town or street the house is on.

— Francis S. Collins

BOD (**biochemical oxygen demand**) is a measure of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential.

Gene Cloning

- identification of DNA with desirable genes
- introduction of the identified DNA into the host
- maintenance of introduced DNA in the host and transfer of the DNA to its progeny

The cloning of humans is on most of the lists of things to worry about from Science, along with behaviour control, genetic engineering, transplanted heads, computer poetry and the unrestrained growth of plastic flowers.

— Lewis Thomas

Plant hybridization

- **Intravarietal hybridization** → The cross between the plants of same variety
- **Intervarietal hybridization** →The cross between the plants belonging to two different varieties of the same species
- **Interspecific hybridization** → The cross between the plants belonging to different species belonging to the same genus
- **Intergeneric hybridization** → The cross between the plants belonging to two different genera

[Cloning] can't make you immortal because clearly the clone is a different person. If I take twins and shoot one of them, it will be faint consolation to the dead one that the other one is still running around, even though they are genetically identical. So the road to immortality is not through cloning.

— Arthur L. Caplan

Protozoans

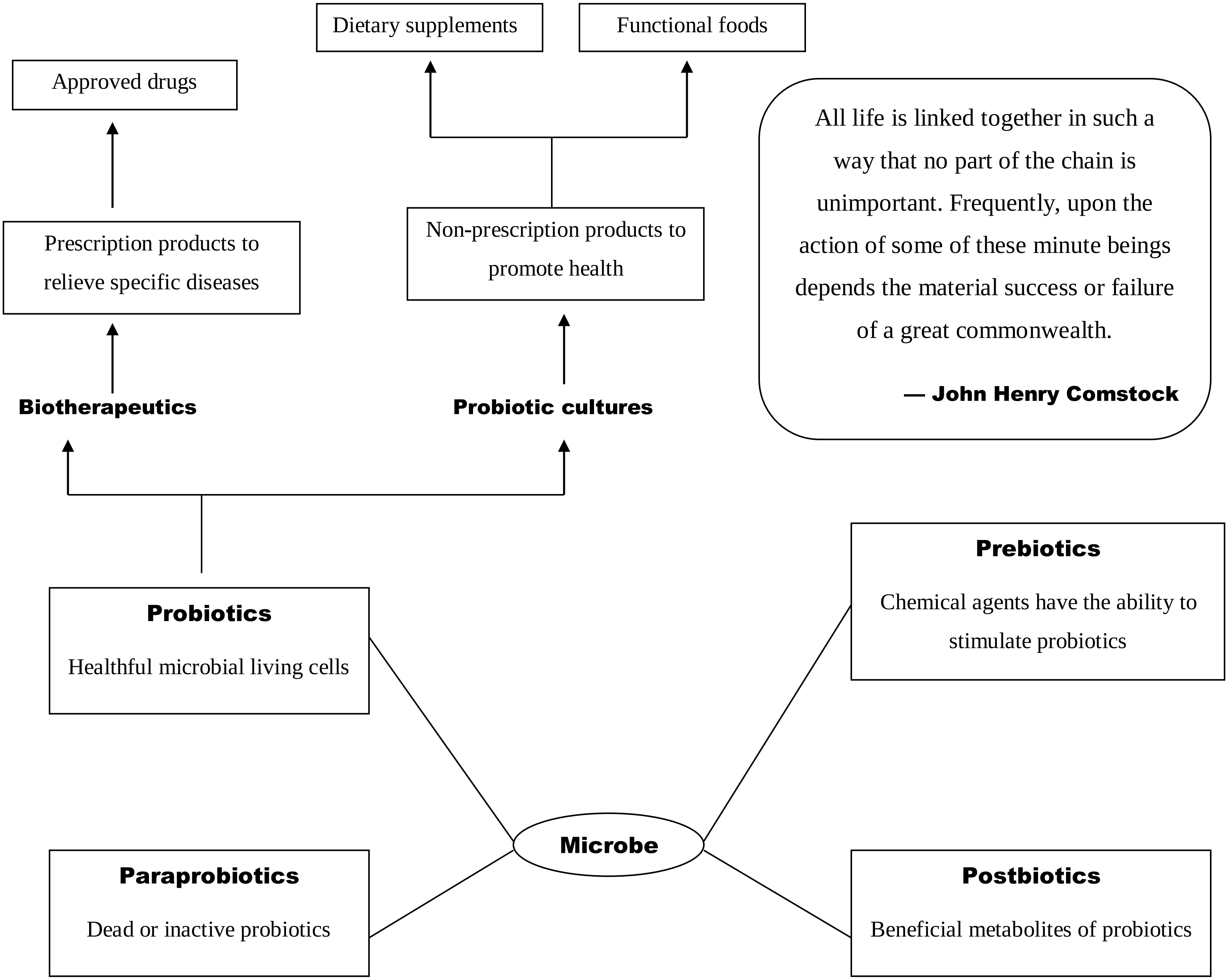
Eukaryotic, unicellular and heterotrophic protists

Amoeboid protozoans | **Flagellated protozoans** | **Ciliated protozoans** | **Sporozoans**

Arthropods

- **Insects**
  - **Winged** (Biting)
    - Flea
    - Mosquito
    - Sandfly
    - Blackfly
    - Tsetse fly
  - **Winged** (Non-biting)
    - Housefly
  - **Wingless** (Biting)
    - Louse
    - Bedbug
- **Arachnids** (Ticks, mites and other copepods)
- **Crustaceans** (Cyclops and other copepods)

> After the planet becomes theirs, many millions of years will have to pass before a beetle particularly loved by God, at the end of its calculations will find written on a sheet of paper in letters of fire that energy is equal to the mass multiplied by the square of the velocity of light. The new kings of the world will live tranquilly for a long time, confining themselves to devouring each other and being parasites among each other on a cottage industry scale.
>
> **— Primo Levi**



All life is linked together in such a way that no part of the chain is unimportant. Frequently, upon the action of some of these minute beings depends the material success or failure of a great commonwealth.

— John Henry Comstock

A working definition of life … could thing in terms of a large molecule made up of carbon compounds that can replicate, or make copies of itself, and metabolize food and energy…: macromolecule, metabolism, replication.

— Cyril Ponnamperuma

Food

- **High acid foods** (pH > 3.7)
- **Low acid foods** (pH > 4.5)
- **Acid foods** (pH of 3.7 to 4.5)

Energy supplying food

(cereals, sugars, roots, tubers, fats and oils)

Body building food

(milk, meat, poultry, eggs, fish, pulses and groundnuts)

Repairing and maintenance food

(vegetables, fruits, milk)

Question: Explain why, in order to cook food by boiling, at the top of a high mountain, you must employ a different method from that used at the sea level.

Answer: It is easy to cook food at the sea level by boiling it, but once you get above the sea level the only plan is to fry it in its own fat. It is, in fact, impossible to boil water above the sea level by any amount of heat. A different method, therefore, would have to be employed to boil food at the top of a high mountain, but what that method is has not yet been discovered. The future may reveal it to a daring experimentalist.

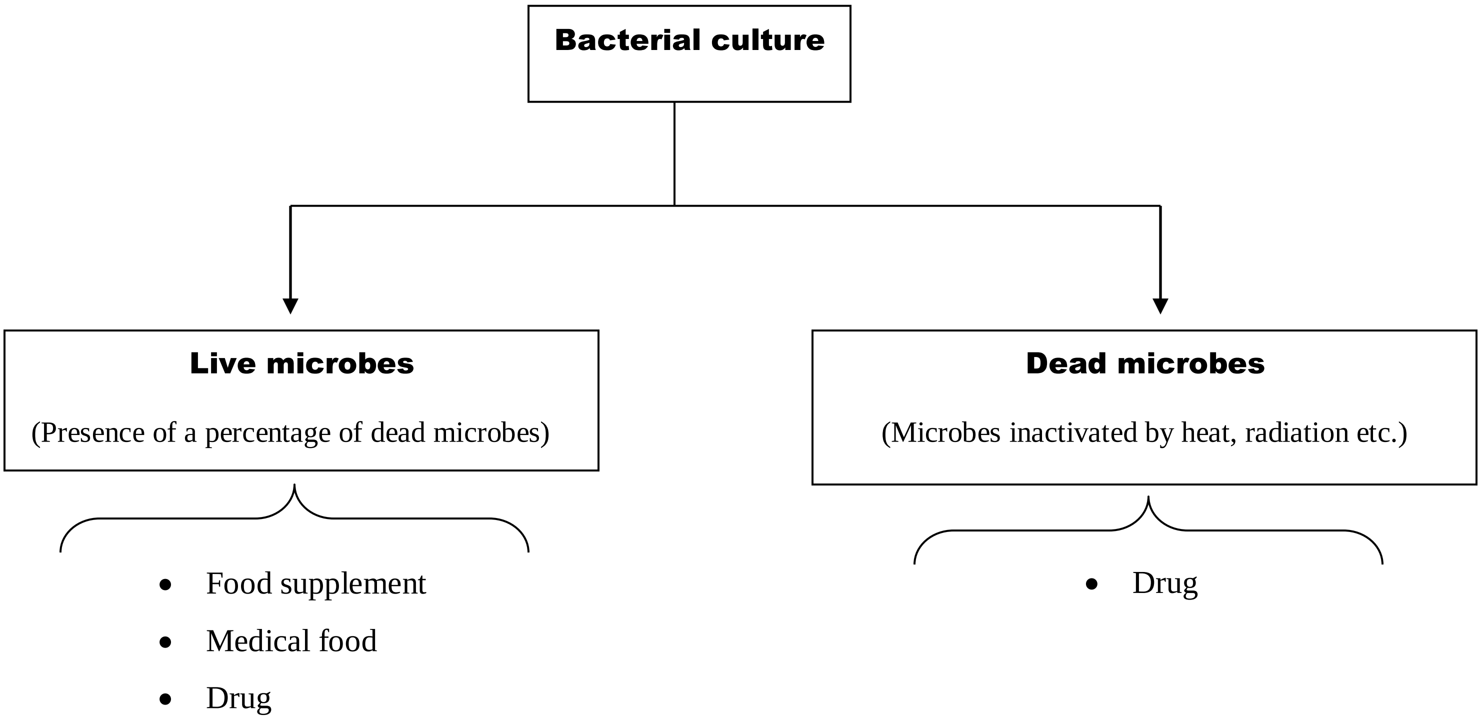
— 19th Century Schoolboy Blunders

Environmental Factors affecting Microbial Growth:

- Moisture
- Oxygen
- Carbon Dioxide
- Temperature
- pH
- Light
- Osmotic Effect
- Mechanical and Sonic Stress

Advocacy of leaf protein as a human food is based on the undisputed fact that forage crops (such as Lucerne) give a greater yield of protein than other types of crops. Even with conventional food crops there is more protein in the leafy parts than in the seeds or tubs that are usually harvested.

— Norman Wingate Pirie



Scalar	Vector
A physical quantity with only magnitude.	A physical quantity with both the magnitude and direction.
• Mass • Speed • Distance • Time • Area • Volume • Density • Temperature	• Linear momentum • Acceleration • Displacement • Momentum • Angular velocity • Force • Electric field • Polarization

> As agonizing a disease as cancer is, I do not think it can be said that our civilization is threatened by it. … But a very plausible case can be made that our civilization is fundamentally threatened by the lack of adequate fertility control. Exponential increases of population will dominate any arithmetic increases, even those brought about by heroic technological initiatives, in the availability of food and resources, as Malthus long ago realized.
>
> **Carl Sagan**

Nutraceuticals

Traditional

- Chemical Constituents
- Probiotic Microorganisms
- Nutraceutical Enzymes

Non-traditional

- Fortified Nutraceuticals
- Recombinant Nutraceuticals

Substances which have a physiological benefit or provides protection against chronic disease

Biology is a science of three dimensions. The first is the study of each species across all levels of biological organization, molecule to cell to organism to population to ecosystem. The second dimension is the diversity of all species in the biosphere. The third dimension is the history of each species in turn, comprising both its genetic evolution and the environmental change that drove the evolution. Biology, by growing in all three dimensions, is progressing toward unification and will continue to do so.

Edward O. Wilson

Transpiration

Stomatal Transpiration | **Lenticular Transpiration** | **Cuticular Transpiration**

- Helps in the exchange of gases
- Helps in sending out excessively absorbed water by plants
- Controls the temperature of the plants
- Allows the movement of minerals from the soil to different parts of the plant

Both biological and cultural diversity are now severely threatened and working for their preservation is a critical task.

— Murray Gell-Mann

Pigments

Organic pigment

Inorganic pigment

Provide colour to materials − whether they are textiles or paints

Darwin was a biological evolutionist, because he was first a uniformitarian geologist. Biology is pre-eminent to-day among the natural sciences, because its younger sister, Geology, gave it the means.

— Charles Lapworth

Top 10 Most Endangered Animals:

- Vaquita
- Amur Leopard
- Kakapo
- Gharial
- Tooth-billed pigeon
- North Atlantic right whale
- Saola
- Sea turtles
- Rhinos
- Gorillas

Very likely to become extinct in the near future

Computer science is no more about computers than astronomy is about telescopes, biology is about microscopes or chemistry is about beakers and test tubes. Science is not about tools. It is about how we use them, and what we find out when we do.

Edsger W. Dijkstra

	MERCURY	VENUS	EARTH	MOON	MARS	JUPITER
Mass (10^{24}kg)	0.330	4.87	5.97	0.073	0.642	1898
Diameter (km)	4879	12,104	12,756	3475	6792	142,984
Density (kg/m^3)	5427	5243	5514	3340	3933	1326
Gravity (m/s^2)	3.7	8.9	9.8	1.6	3.7	23.1
Escape Velocity (km/s)	4.3	10.4	11.2	2.4	5.0	59.5
Rotation Period (hours)	1407.6	-5832.5	23.9	655.7	24.6	9.9
Length of Day (hours)	4222.6	2802.0	24.0	708.7	24.7	9.9
Distance from Sun (10^6 km)	57.9	108.2	149.6	0.384	227.9	778.6
Perihelion (10^6 km)	46.0	107.5	147.1	0.363	206.6	740.5
Aphelion (10^6 km)	69.8	108.9	152.1	0.406	249.2	816.6
Orbital Period (days)	88.0	224.7	365.2	27.3	687.0	4331
Orbital Velocity (km/s)	47.4	35.0	29.8	1.0	24.1	13.1
Orbital Inclination (degrees)	7.0	3.4	0.0	5.1	1.9	1.3
Orbital Eccentricity	0.205	0.007	0.017	0.055	0.094	0.049
Obliquity to Orbit (degrees)	0.034	177.4	23.4	6.7	25.2	3.1
Mean Temperature (C)	167	464	15	-20	-65	-110
Surface Pressure (bars)	0	92	1	0	0.01	Unknown
Number of Moons	0	0	1	0	2	79
Ring System?	No	No	No	No	No	Yes
Global Magnetic Field?	Yes	No	Yes	No	No	Yes

About two million years ago, man appeared. He has become the dominant species on the earth. All other living things, animal and plant, live by his sufferance. He is the custodian of life on earth, and in the solar system. It's a big responsibility.

— George Wald

	SATURN	URANUS	NEPTUNE	PLUTO
Mass (10^{24}kg)	568	86.8	102	0.0146
Diameter (km)	120,536	51,118	49,528	2370
Density (kg/m^3)	687	1271	1638	2095
Gravity (m/s^2)	9.0	8.7	11.0	0.7
Escape Velocity (km/s)	35.5	21.3	23.5	1.3
Rotation Period (hours)	10.7	-17.2	16.1	-153.3
Length of Day (hours)	10.7	17.2	16.1	153.3
Distance from Sun (10^6 km)	1433.5	2872.5	4495.1	5906.4
Perihelion (10^6 km)	1352.6	2741.3	4444.5	4436.8
Aphelion (10^6 km)	1514.5	3003.6	4545.7	7375.9
Orbital Period (days)	10,747	30,589	59,800	90,560
Orbital Velocity (km/s)	9.7	6.8	5.4	4.7
Orbital Inclination (degrees)	2.5	0.8	1.8	17.2
Orbital Eccentricity	0.057	0.046	0.011	0.244
Obliquity to Orbit (degrees)	26.7	97.8	28.3	122.5
Mean Temperature (C)	-140	-195	-200	-225
Surface Pressure (bars)	Unknown	Unknown	Unknown	0.00001
Number of Moons	82	27	14	5
Ring System?	Yes	Yes	Yes	No
Global Magnetic Field?	Yes	Yes	Yes	Unknown

Almost all of the space program's important advances in scientific knowledge have been accomplished by hundreds of robotic spacecraft in orbit about Earth and on missions to the distant planets Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. Robotic exploration of the planets and their satellites as well as of comets and asteroids has truly revolutionized our knowledge of the solar system.

— James Alfred Van Allen

At the planet's very heart lies a solid rocky core, at least five times larger than Earth, seething with the appalling heat generated by the inexorable contraction of the stupendous mass of material pressing down to its centre. For more than four billion years Jupiter’s immense gravitational power has been squeezing the planet slowly, relentlessly, steadily, converting gravitational energy into heat, raising the temperature of that rocky core to thirty thousand degrees, spawning the heat flow that warms the planet from within. That hot, rocky core is the original protoplanet seed from the solar system’s primeval time, the nucleus around which those awesome layers of hydrogen and helium and ammonia, methane, sulphur compounds and water have wrapped themselves.

— Ben Bova

Copernicus ... did not publish his book [on the nature of the solar system] until he was on his deathbed. He knew how dangerous it is to be right when the rest of the world is wrong.

— Thomas Brackett Reed

Chemical analysis and synthesis go no farther than to the separation of particles one from another, and to their reunion. No new creation or destruction of matter is within the reach of chemical agency. We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen.

— John Dalton

Fruits

True Fruit

Formed after fertilization

Contain one or many seeds

- Watermelon
- Lemon
- Cherry
- Blueberries
- Mango
- Kiwi
- Peaches
- Plums

False Fruit

Formed without fertilization

Do not contain seeds

- Strawberry
- Pineapple
- Mulberry
- Gourd
- Cucumber
- Apples
- Pears
- Cashews
- Banana
- Pineapple
- Jack fruit

As soon as we touch the complex processes that go on in a living thing, be it plant or animal, we are at once forced to use the methods of this science [chemistry]. No longer will the microscope, the kymograph, the scalpel avail for the complete solution of the problem. For the further analysis of these phenomena which are in flux and flow, the investigator must associate himself with those who have labored in fields where molecules and atoms, rather than multicellular tissues or even unicellular organisms, are the units of study.

— John Jacob Abel

Roots

Taproot | **Fibrous** | **Adventitious**

- Absorb water and nutrients from the soil
- Anchor the plant firmly
- Help in storing food and nutrients
- Transport water and minerals to the plant

Plant tissue

Meristematic tissue

Cells capable of cell division

- Apical
- Lateral
- Intercalary

Permanent tissue

Mature cells incapable of cell division

Simple

Composed of single type of cells

- Parenchyma
- Collenchyma
- Sclerenchyma

Complex

Composed of more than one type of cells

- Phloem (sieve tubes and companion cells)
- Xylem (Xylem vessels and tracheids)

Leaves

Simple

Single undivided leaf

Compound

Leaf divided into multiple leaflets attached at the stem

Pinnately Compound

Feather-like arrangement of leaflets from midvein

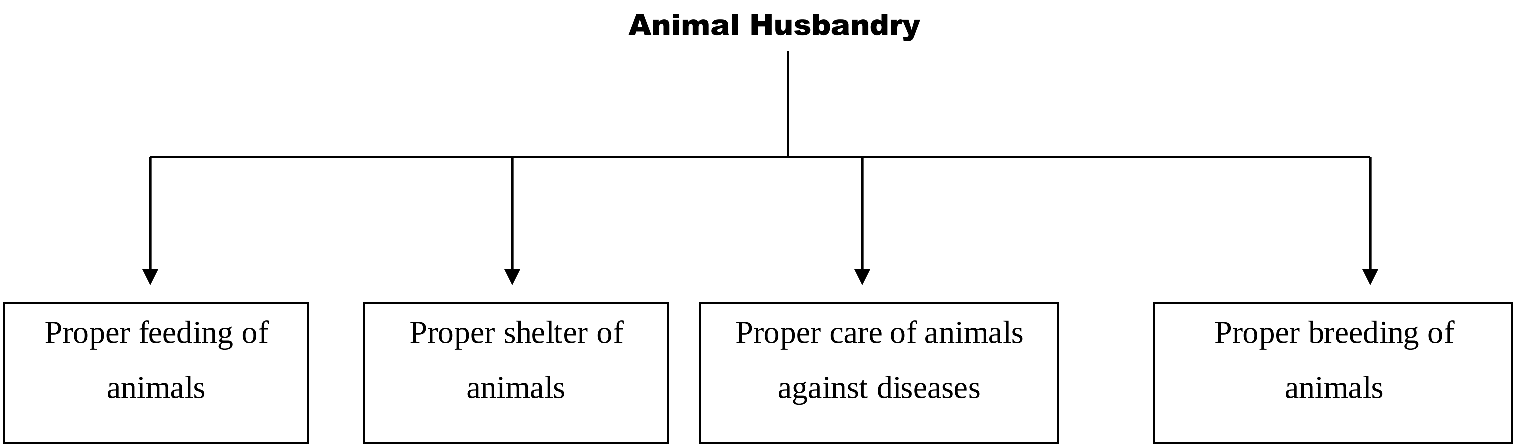
Palmately Compound

Leaflets radiating from a single point

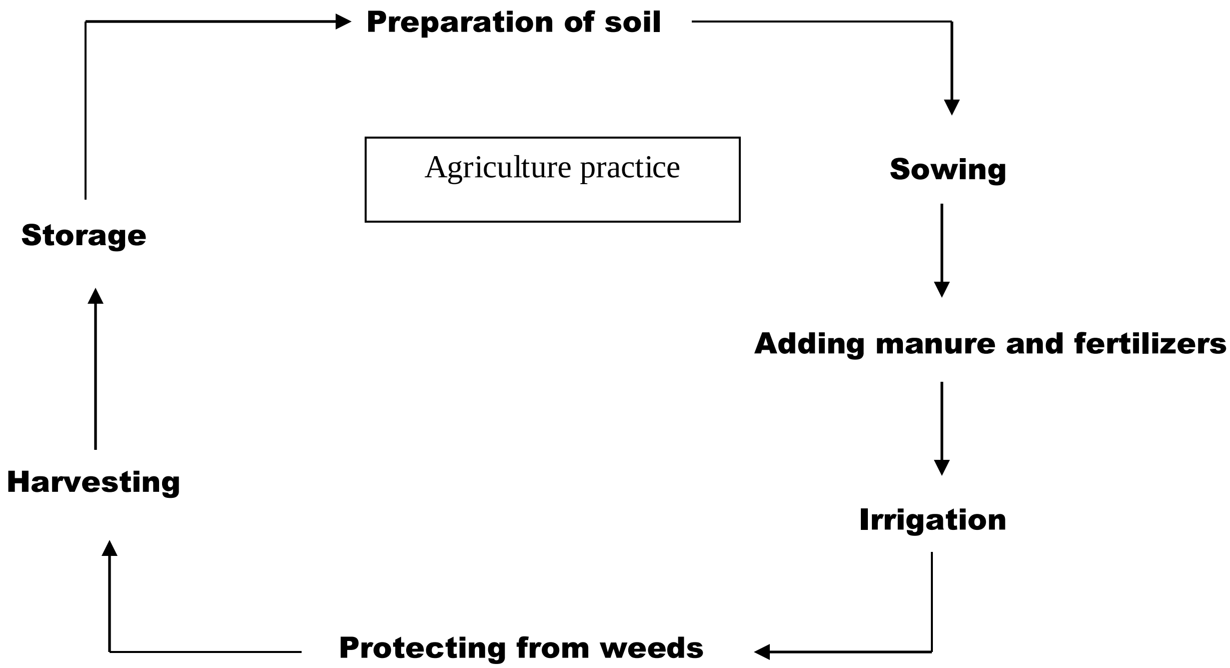
At the beginning of its existence as a science, biology was forced to take cognizance of the seemingly boundless variety of living things, for no exact study of life phenomena was possible until the apparent chaos of the distinct kinds of organisms had been reduced to a rational system. Systematics and morphology, two predominantly descriptive and observational disciplines, took precedence among biological sciences during the eighteenth and nineteenth centuries. More recently physiology has come to the foreground, accompanied by the introduction of quantitative methods and by a shift from the observationalism of the past to a predominance of experimentation.

Theodosius Dobzhansky

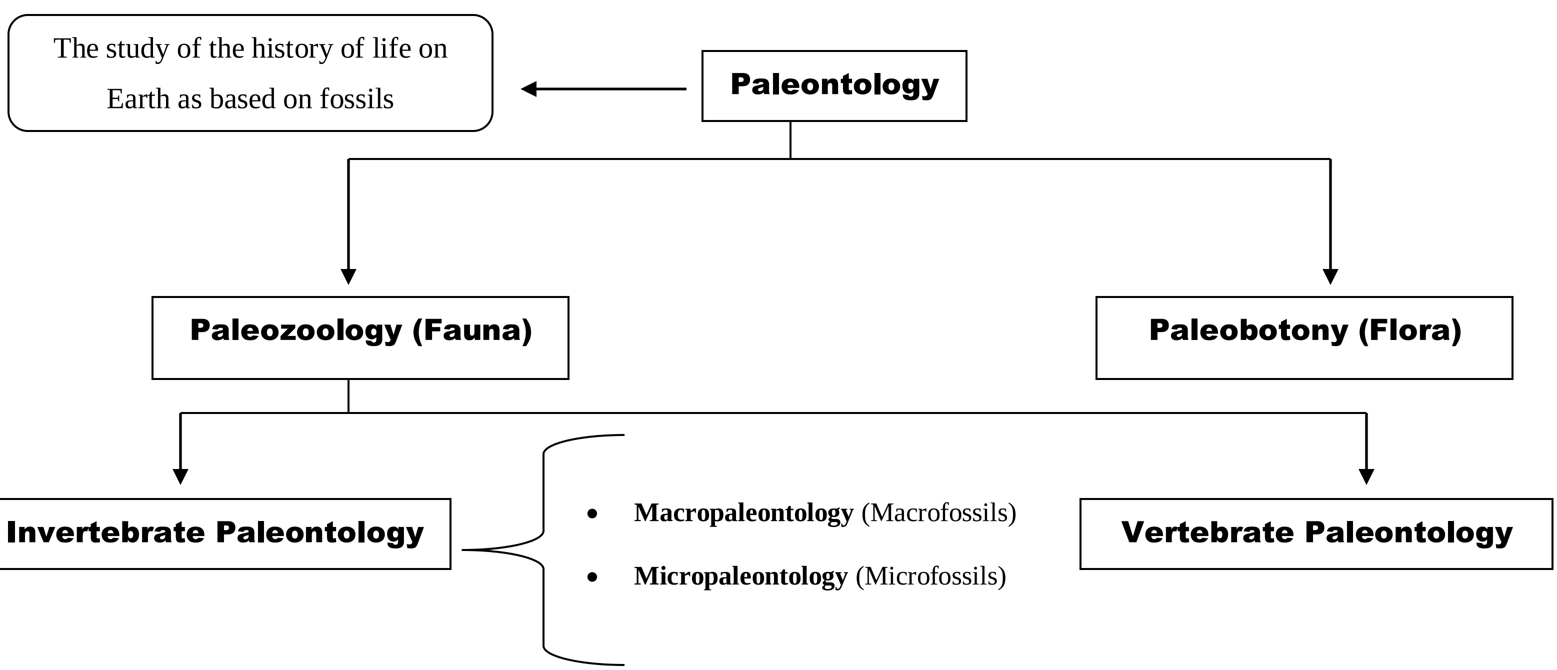
Turtle	Tortoise
Water-dwelling reptiles	Land-dwelling reptiles
Omnivores	Herbivores
Have lighter shells on their backs	Have much heavier and robust shells on their backs
Not all turtles are Tortoises	All tortoises are turtles



> ... the cooperative forces are biologically the more important and vital. The balance between the cooperative and altruistic tendencies and those which are disoperative and egoistic is relatively close. Under many conditions the cooperative forces lose, In the long run, however, the group centered, more altruistic drives are slightly stronger. ... human altruistic drives are as firmly based on an animal ancestry as is man himself. Our tendencies toward goodness... are as innate as our tendencies toward intelligence; we could do well with more of both.
>
> **— Warder Clyde Allee**



> The idea that one can go to the fossil record and expect to empirically recover an ancestor-descendant sequence, be it of species, genera, families, or whatever, has been, and continues to be, a pernicious illusion.
>
> **— Gareth J. Nelson**



Organic Compounds

- **Aliphatic organic compound** (Open chain)
  - **Alkanes**
  - **Alkenes**
  - **Alkynes**
- **Cyclic organic compound** (Closed chain)
  - **Homocyclic Compounds**
    - **Alicyclic compounds**
      - Homocyclic Compounds
      - Heterocyclic Compounds
    - **Aromatic compounds**
      - Benzenoid compounds
      - Non-benzenoid compound
      - Heterocyclic aromatic compounds
  - **Heterocyclic Compounds**

5 branches of modern biotechnology:

Use of living organism to produce the desired product

- Human biotechnology
- Environmental biotechnology
- Industrial Biotechnology
- Animal Biotechnology
- Plant Biotechnology

Help us fight hunger and disease, produce more safely, cleanly and efficiently, reduce our ecological footprint and save energy

We believe that biotechnology has a critical role to play in increasing agricultural productivity, particularly in light of climate change. We also believe it can help to improve the nutritional value of staple foods.

Hillary Clinton

Developing countries can leapfrog several stages in the development process through the application of bio-technology in agriculture.

— M. S. Swaminathan

We are moving rapidly into the post-Darwinian era, when species other than our own will no longer exist, and the rules of Open Source sharing will be extended from the exchange of software to the exchange of genes.

Domesticated biotechnology, once it gets into the hands of housewives and children, will give us an explosion of diversity of new living creatures … New lineages will proliferate to replace those that monoculture farming and deforestation have destroyed. Designing genomes will be a personal thing, a new art form as creative as painting or sculpture. Few of the new creations will be masterpieces, but a great many will bring joy to their creators and variety to our fauna and flora.

Freeman Dyson

Plants

- **Vascular**
  - **Seed bearing** → Flowering
    - **Angiosperms**
      - **Monocots**
      - **Dicots**
    - **Gymnosperms**
      - Plants with **naked seeds** — such as conifers, cycads, and ginkgo
  - **Spore bearing** → Non-flowering
    - no roots (Mosses)
    - with roots (Ferns)
- **Non-vascular**
  - **Algae**

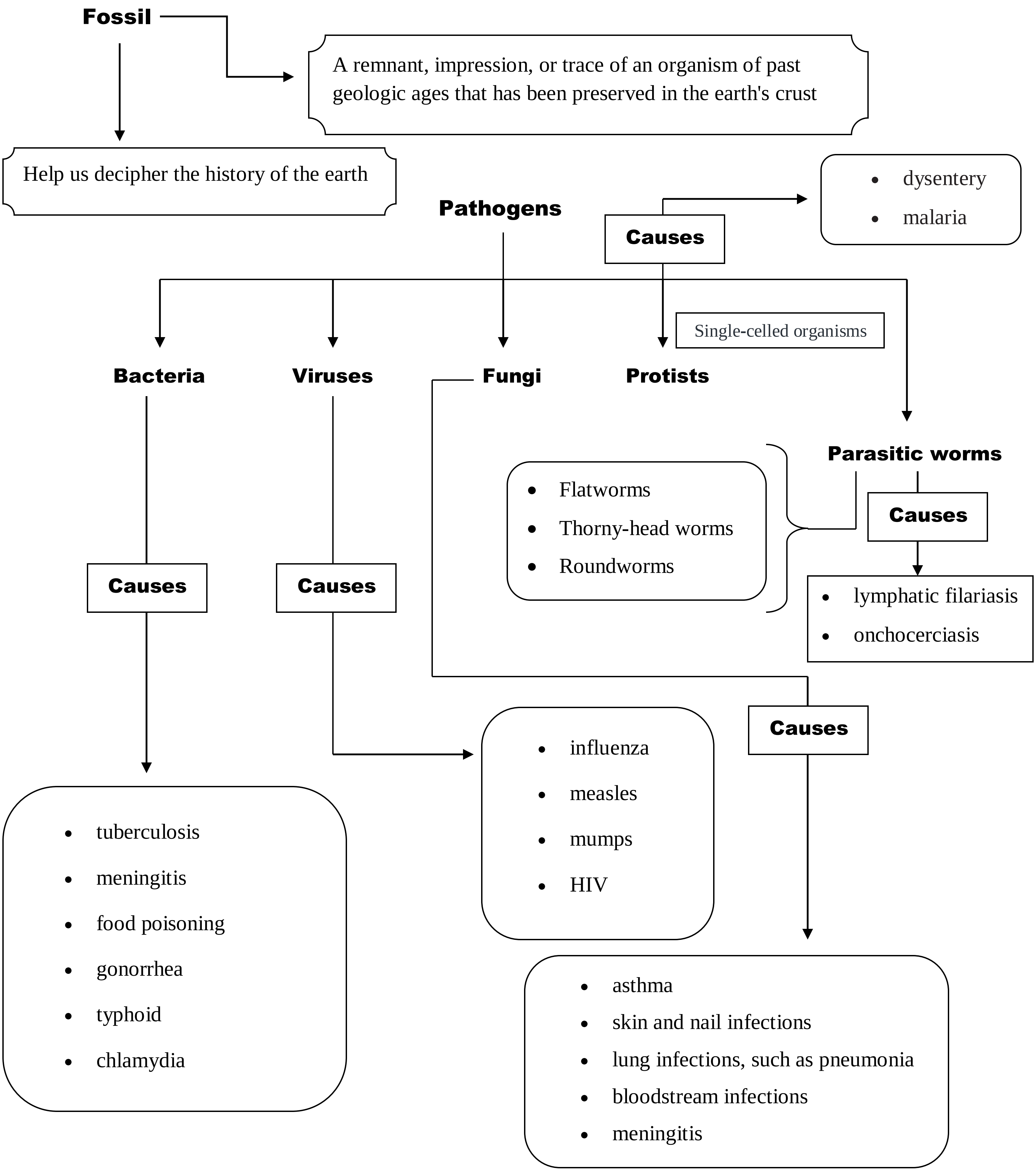
Photosynthesis:

$$\text{Carbon dioxide} + \text{water} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{Glucose} + \text{oxygen}$$

> ...the life of the planet began the long, slow process of modulating and regulating the physical conditions of the planet. The oxygen in today's atmosphere is almost entirely the result of photosynthetic living, which had its start with the appearance of blue-green algae among the microorganisms.
>
> **Lewis Thomas**

Cellular Respiration:

Glucose + oxygen → Carbon dioxide + water + energy


Fossil
A remnant, impression, or trace of an organism of past geologic ages that has been preserved in the earth's crust
Help us decipher the history of the earth
Pathogens
Causes
dysentery
malaria
Single-celled organisms
Bacteria
Viruses
Fungi
Protists
Parasitic worms
Flatworms
Thorny-head worms
Roundworms
Causes
lymphatic filariasis
onchocerciasis
Causes
Causes
Causes
influenza
measles
mumps
HIV
tuberculosis
meningitis
food poisoning
gonorrhea
typhoid
chlamydia
asthma
skin and nail infections
lung infections, such as pneumonia
bloodstream infections
meningitis

Animals

- **With backbone** → **Vertebrates**
  - **Warm Blooded**
    - Mammals
    - Birds
  - **Cold Blooded**
    - Fish
    - Reptiles
    - Amphibians
- **Without backbone** → **Invertebrates**
  - **Without legs**
    - **Worm-like**
    - **Not Worm-like**
  - **With jointed legs**
    - **with 3 pairs of legs** → **Insects**
    - **with more than 3 pairs of legs**

In the deepest places, where physical norms collapse under the crushing water, bodies still fall softly through the dark, days after their vessels have capsized. They decay on their long journey down. Nothing will hit the black sand at the bottom of the world but algae-covered bones.

China Mieville

Three principles of heredity:

- dominance
- segregation
- independent assortment

Birds

- **Flightless Birds** (ostrich, kiwi, rhea, cassowary and moa)
- **Flying Birds** (Bearded vulture, Bar-tailed godwit, shorebirds, parrots and perching birds)

The difference between humans and other mammals is that we know how to accessorize.

Madeleine Albright

Mammalia

(Mammals)

Bats are the only Mammals capable of Flight.

Prototheria

Primitive egg laying mammals

Theria

Metatheria

Pouched mammals

Eutheria

True Placental mammals

Warm-bloodedness is one of the key factors that have enabled mammals to conquer the Earth, and to develop the most complex bodies in the animal kingdom. In this series, we will travel the world to discover just how varied and how astonishing mammals are.

David Attenborough

Geologists are rapidly becoming convinced that the mammals spread from their central Asian point of origin largely because of great variations in climate.

Ellsworth Huntington

Eclipse

Solar Eclipse

Takes place when the Moon comes between the Sun and Earth

Lunar Eclipse

Takes place when the Earth comes between the Sun and the Moon

> As the sun eclipses the stars by his brilliancy, so the man of knowledge will eclipse the fame of others in assemblies of the people if he proposes algebraic problems, and still more if he solves them.
>
> **— Brahmagupta**

As to the position of the earth, then, this is the view which some advance, and the views advanced concerning its rest or motion are similar. For here too there is no general agreement. All who deny that the earth lies at the centre think that it revolves about the centre, and not the earth only but, as we said before, the counter-earth as well. Some of them even consider it possible that there are several bodies so moving, which are invisible to us owing to the interposition of the earth. This, they say, accounts for the fact that eclipses of the moon are more frequent than eclipses of the sun; for in addition to the earth each of these moving bodies can obstruct it.

Aristotle

Scattering

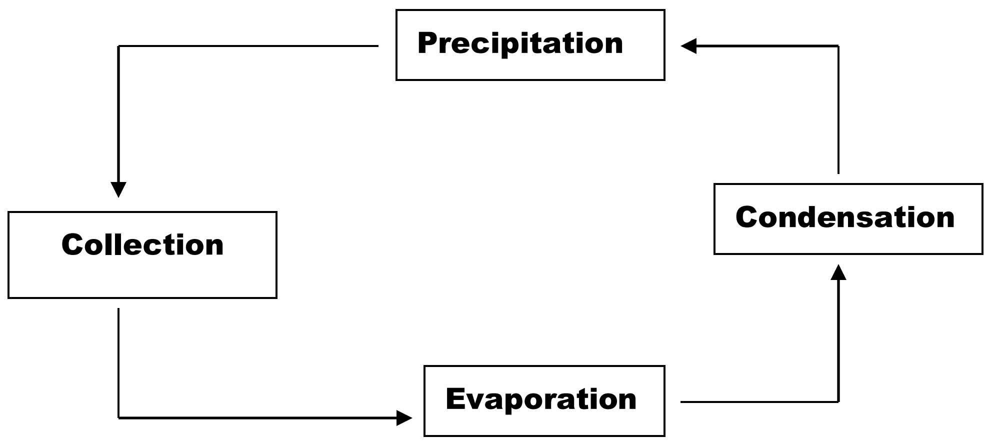
- **Linear**
  - **Rayleigh**
  - **Mie scattering**
- **Non-linear**
  - **Stimulated Brillouin**
  - **Stimulated Raman**

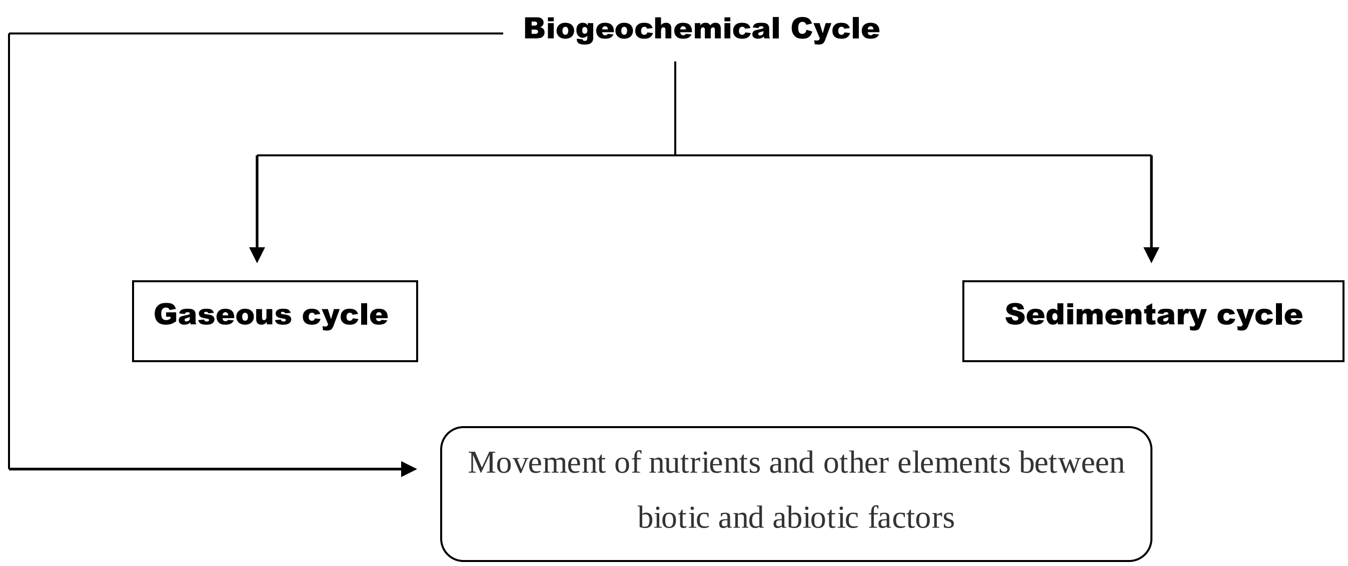
Law of scattering:

The intensity of scattered light is inversely proportional with the fourth power of the wavelength of the incident light when the particle (**scatterer**) is of smaller diameter than the wavelength of light

Over the last century, physicists have used light quanta, electrons, alpha particles, X-rays, gamma-rays, protons, neutrons and exotic sub-nuclear particles for this purpose [scattering experiments]. Much important information about the target atoms or nuclei or their assemblage has been obtained in this way. In witness of this importance one can point to the unusual concentration of scattering enthusiasts among earlier Nobel Laureate physicists. One could say that physicists just love to perform or interpret scattering experiments.

Clifford G. Shull





Astrobiology is the science of life in the universe. It's an attempt to scientifically deal with the question of whether or not we're alone in the universe, looking at the past of life, the present of life, and the future of life. It's an interdisciplinary study incorporating astronomy, biology, and the Earth sciences.

David Grinspoon

Used for treating wounds, skin disorders, respiratory and digestive issues, and obstetric and gynecological concern

Lichens

A complex life form that is a symbiotic partnership of two separate organisms − a fungus and an algae

Based on their growth:

- Crustose Lichens
- Foliose Lichens
- Fruticose Lichens

Based on their internal structure:

- Heteromerous lichens
- Homoiomerous lichens

Based on their fungal partner:

- Ascolichens
- Basidiolichens
- Hymenolichens

Based on their habitat:

- **Lignicolous** (found growing on woods)
- **Corticolous** (found growing on the bark of trees)
- **Saxicolous** (found growing on stones or rocks)
- **Marine** (found growing on the siliceous rocks, near the shores of the sea)
- **Freshwater** (found growing on the hard siliceous rocks, especially around the freshwater)
- **Terricolous** (found growing on the soil − **terrestrial lichens**)

It is difficult to conceive a grander mass of vegetation:—the straight shafts of the timber-trees shooting aloft, some naked and clean, with grey, pale, or brown bark; others literally clothed for yards with a continuous garment of epiphytes, one mass of blossoms, especially the white Orchids Caelogynes, which bloom in a profuse manner, whitening their trunks like snow. More bulky trunks were masses of interlacing climbers, Araliaceae, Leguminosae, Vines, and Menispermeae, Hydrangea, and Peppers, enclosing a hollow, once filled by the now strangled supporting tree, which has long ago decayed away. From the sides and summit of these, supple branches hung forth, either leafy or naked; the latter resembling cables flung from one tree to another, swinging in the breeze, their rocking motion increased by the weight of great bunches of ferns or Orchids, which were perched aloft in the loops. Perpetual moisture nourishes this dripping forest: and pendulous mosses and lichens are met with in profusion.

— Sir Joseph Dalton Hooker

It is easy to overlook this thought that life just is. As humans we are inclined to feel that life must have a point. We have plans and aspirations and desires. We want to take constant advantage of the intoxicating existence we've been endowed with. But what's life to a lichen? Yet its impulse to exist, to be, is every bit as strong as ours-arguably even stronger. If I were told that I had to spend decades being a furry growth on a rock in the woods, I believe I would lose the will to go on. Lichens don't. Like virtually all living things, they will suffer any hardship; endure any insult, for a moment's additions existence. Life, in short just wants to be.

Bill Bryson

Chordates	Non-chordates
Cold or warm-blooded	Cold-blooded
Respiration through gills or lungs	Respiration through body surfece, gills or tracheae
Sexual reproduction is predominant	Asexual reproduction is predominant
Exoskeleton and Endoskeleton are present	Only exoskeleton is present
Post-anal tail is usually present	Post-anal tail is absent
RBC posses Hemoglobin	Hemoglobin is present in plasma or absent
Closed Blood vascular system	**Blood vascular system:** Absent and if present open or closed
Regeneration power is usually poor	Regeneration power is usually good
Central nervous system is dorsal, hollow and single	Central nervous system is ventral, solid and double
Hemichordata, Cyclostomata, Aves, Reptiles, Amphibia and Mammals	Protozoa, Arthropods and Annelids

Modifications of leaf for:

support	tendril
protection	spines
storage	fleshy leaves

Plasmolysis occurs when water moves out of the cell and the cell membrane of a plant cell shrinks away from its cell wall.

$$\textbf{Starch} \xrightarrow[\text{pH 6.8}]{\text{Salivary Amylase}} \textbf{Maltose}$$

- **Pharmacodynamics:** What the drug does to the body.
- **Pharmacokinetics:** What the body does to the drugs.

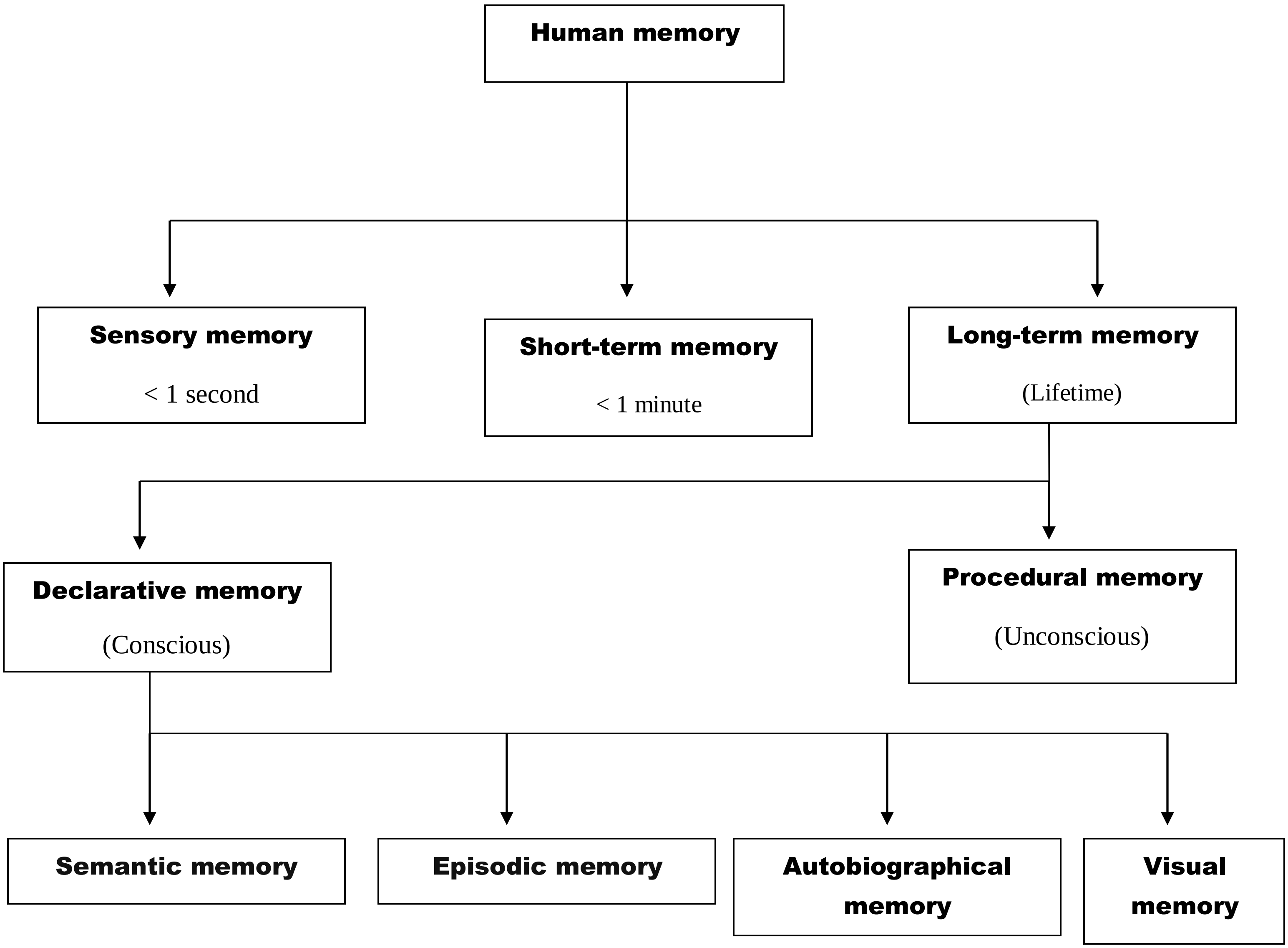
The drug is an exogenous non-nutritive chemical substance which when taken in the solid form by the mouth enter the digestive tract and there it is transformed into a solution and passed on to the liver where it is chemically altered and finally released into the blood stream. And in the blood it exists in two forms: bound and unbound. Depending on its **specific affinity for proteins** in the blood (albumin, globulins), a proportion of the drug may become bound to plasma proteins, with the remainder being unbound. And since the drug-protein binding is reversible, the chemical equilibrium exists between the bound and unbound states, such that: Protein + drug ↔ Protein-drug complex. And the bloodstream carries the drug (free plus bound) to the site of action. Free drug reversibly bind to the target cell surface receptors. And the Bound drug slowly dissociates from the protein and binds reversibly to the target cell surface receptors to produce its **pharmacological effect**.

Drug + Receptor ↔ Drug - Receptor complex → pharmacological effect

And the equilibrium constant for the formation of Drug - Receptor complex is given by:

$$\mathbf{K} = \frac{[\text{Drug} - \text{Receptor complex}]}{[\text{Drug}]\ [\text{Receptor}]}$$

And K is a measure of how tightly a drug binds to the receptor: The higher the K value the drug bind well to the receptor, the action of the drug will be longer. In general, drugs with higher K values will require lower concentrations to achieve sufficient receptor occupancy to exert an effect. And after its **pharmacological effect** drug slowly detaches from the receptor. And then it is sent to the liver. And there it is transformed into a more water soluble compound called **metabolite** and released from the body through urine, sweat, saliva, and excretory products.

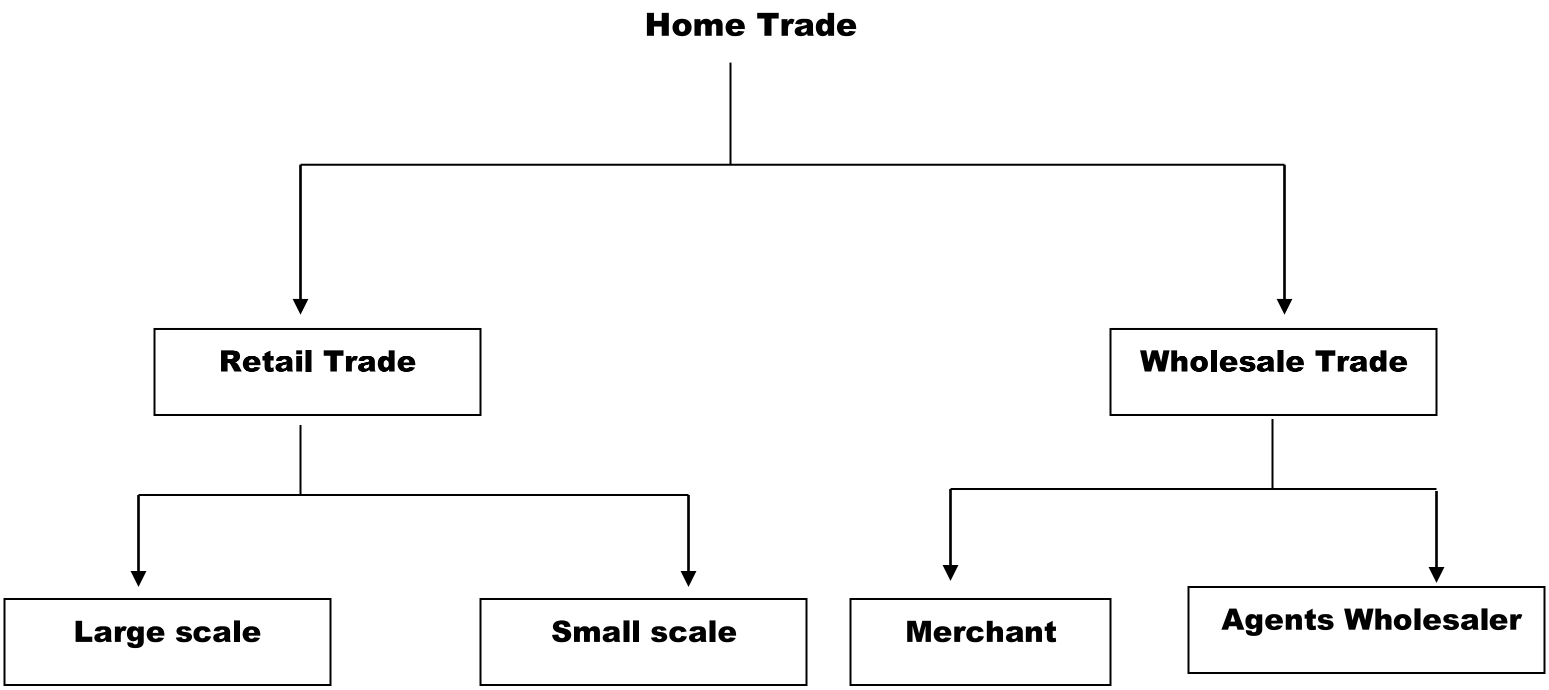


A strict materialist believes that everything depends on the motion of matter. He knows the form of the laws of motion though he does not know all their consequences when applied to systems of unknown complexity.

Now one thing in which the materialist (fortified with dynamical knowledge) believes is that if every motion great & small were accurately reversed, and the world left to itself again, everything would happen backwards the fresh water would collect out of the sea and run up the rivers and finally fly up to the clouds in drops which would extract heat from the air and evaporate and afterwards in condensing would shoot out rays of light to the sun and so on. Of course all living things would regrede from the grave to the cradle and we should have a memory of the future but not of the past.

The reason why we do not expect anything of this kind to take place at any time is our experience of irreversible processes, all of one kind, and this leads to the doctrine of a beginning & an end instead of cyclical progression for ever.

— James Clerk Maxwell

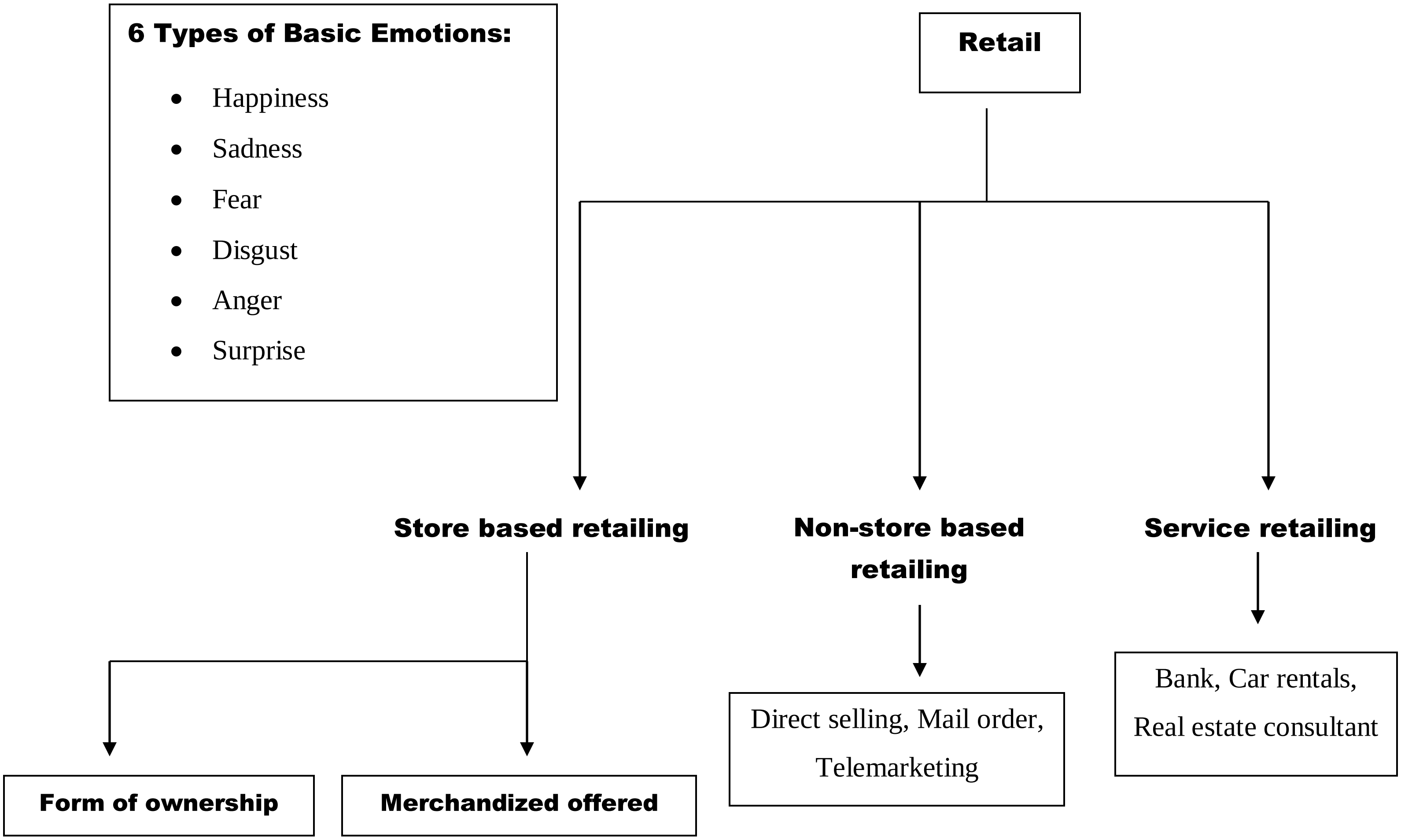


9 types of Vegetables:

Stem Vegetables	Asparagus, Celery, Kohlrabi, Leek
Leaves Vegetables	Spinach, Cabbage, Collard Leaves, Swiss Chard, Mustard Leaves
Flower Vegetables	Cauliflower, Broccoli, Courgette Flowers, Squash Blossoms
Bulb Vegetables	Onion, Garlic, Spring Onion
Seed Vegetables	Fava Beans, Kidney Beans, Green Peas, French Beans
Root Vegetables	Beet, Carrot, Radish, Horseradish, Turnip
Tuber Vegetables	Potato, Cassava, Sweet Potato, Taro
Fruit Vegetables	Tomatoes, Avocado, Bitter Gourd
Fungi Vegetables	Button Mushroom, Enoki, Oyster, Shitake

6 Types of Basic Emotions:

- Happiness
- Sadness
- Fear
- Disgust
- Anger
- Surprise



According to the conclusion of Dr. Hutton, and of many other geologists, our continents are of definite antiquity, they have been peopled we know not how, and mankind are wholly unacquainted with their origin. According to my conclusions drawn from the same source, that of facts, our continents are of such small antiquity, that the memory of the revolution which gave them birth must still be preserved among men; and thus we are led to seek in the book of Genesis the record of the history of the human race from its origin. Can any object of importance superior to this be found throughout the circle of natural science?

— Jean André Deluc

Trees

Exogenous

(Trees with outward growth)

Endogenous

(Trees with inward growth)

Conifers

(**Narrow leaves, Gymnosperms**)

- Pine
- Cedar
- Spruce
- Deodar

Deciduous

(**Broad leaves, dicot Angiosperms**)

- Teak
- Rose
- Oak
- Maple

Soft Wood

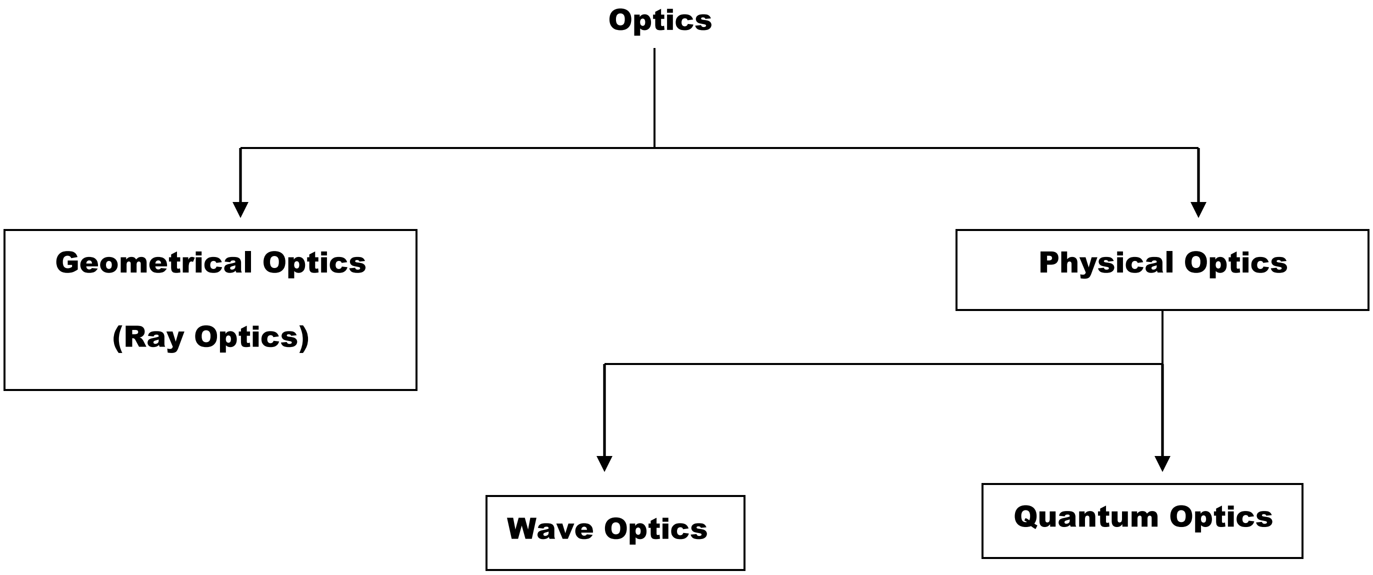
- Wood is soft and light with a fine texture.
- Wood fibers absent.
- Vessels absent.

Hard Wood

- Wood is hard and heavy with a rough texture.
- Wood fibers present.
- Vessels present.

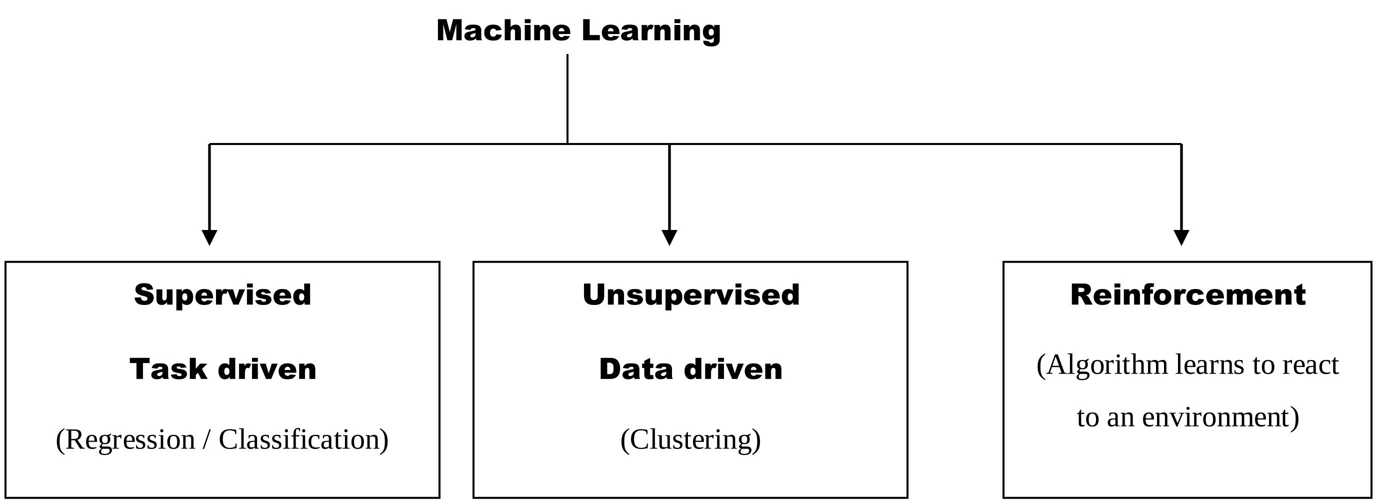
Curiosity is as much the parent of attention, as attention is of memory.

— Richard Whately



In fiber optics, the cable is a light pipe or waveguide, into which you inject light. If a finger presses on the pipe, it disrupts that light within the waveguide.

Jefferson Han



We are entering a new world. The technologies of machine learning, speech recognition, and natural language understanding are reaching a nexus of capability. The end result is that we'll soon have artificially intelligent assistants to help us in every aspect of our lives.

~Amy Stapleton

The food chain consists of four major parts, namely:

- **The Sun** (initial source of energy)
- **Producers** (green plants)
- **Consumers**
  - **Primary consumers** (herbivores)
  - **Secondary consumers** (carnivores)
- **Decomposers**

Get energy from dead or waste organic material

2 Types of food chain:

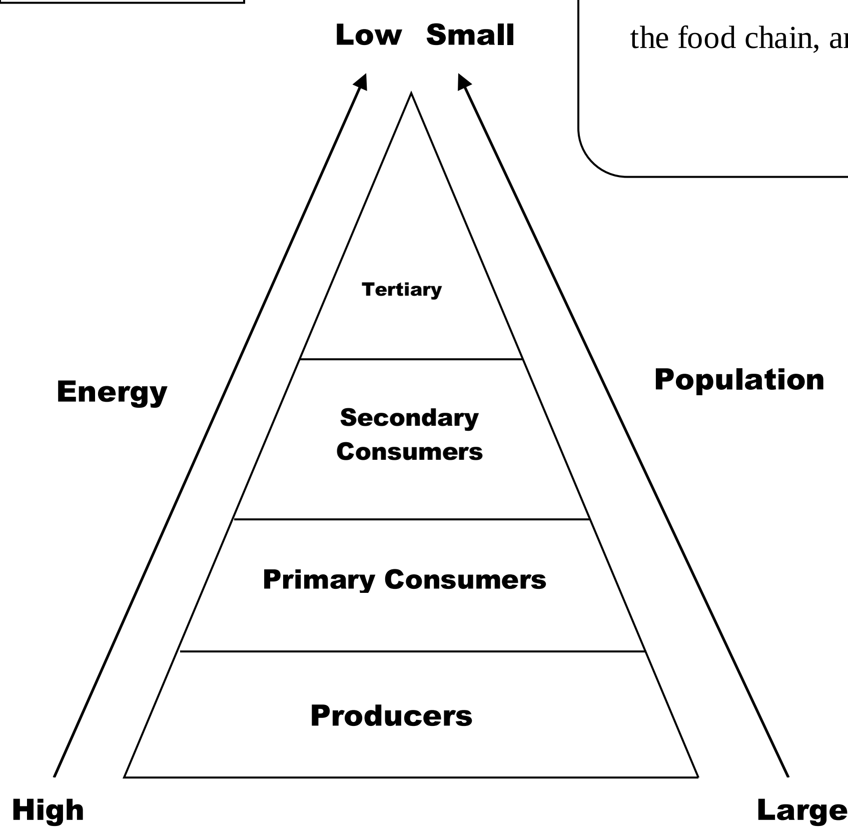
- **Detritus food chain** → food chain that starts with dead organic material
- **Grazing food chain** → food chain that starts with green plants

grass → grasshopper → lizard → snake → owl

Decomposers

It was the Law of the Sea, they said. Civilization ends at the waterline. Beyond that, we all enter the food chain, and not always right at the top.

Hunter S. Thompson



Ecology also teaches that all life on earth can be viewed as a competition among species for the solar energy captured by green plants and stored in the form of complex carbon molecules. A food chain is a system for passing those calories on to species that lack the pant's unique ability to synthesize them from sunlight.

Michael Pollan

4 main types of disease:

- infectious diseases
- deficiency diseases
- hereditary diseases
- physiological diseases

Drugs

Ethical Drugs

(Patented small molecule drugs)

Generics

(Patent expired drugs offered at low prices)

Biologics

(Very expensive biotech drugs)

Drug + Molecular target → **Biological response**

Let food be thy medicine and medicine be thy food.

— Hippocrates

Three phases of drug action:

> Growth for the sake of growth is the ideology of the cancer cell.
>
> **Edward Abbey**

Drug Administration Phase

↓

Dosage from route of administration

↓

Pharmacokinetic Phase

↓

- Absorption
- Distribution
- Metabolism
- Elimination

Metabolism, Elimination → **Clearance**

↓

Pharmacodynamic Phase

↓

Drug + Receptor

↓

Effect →

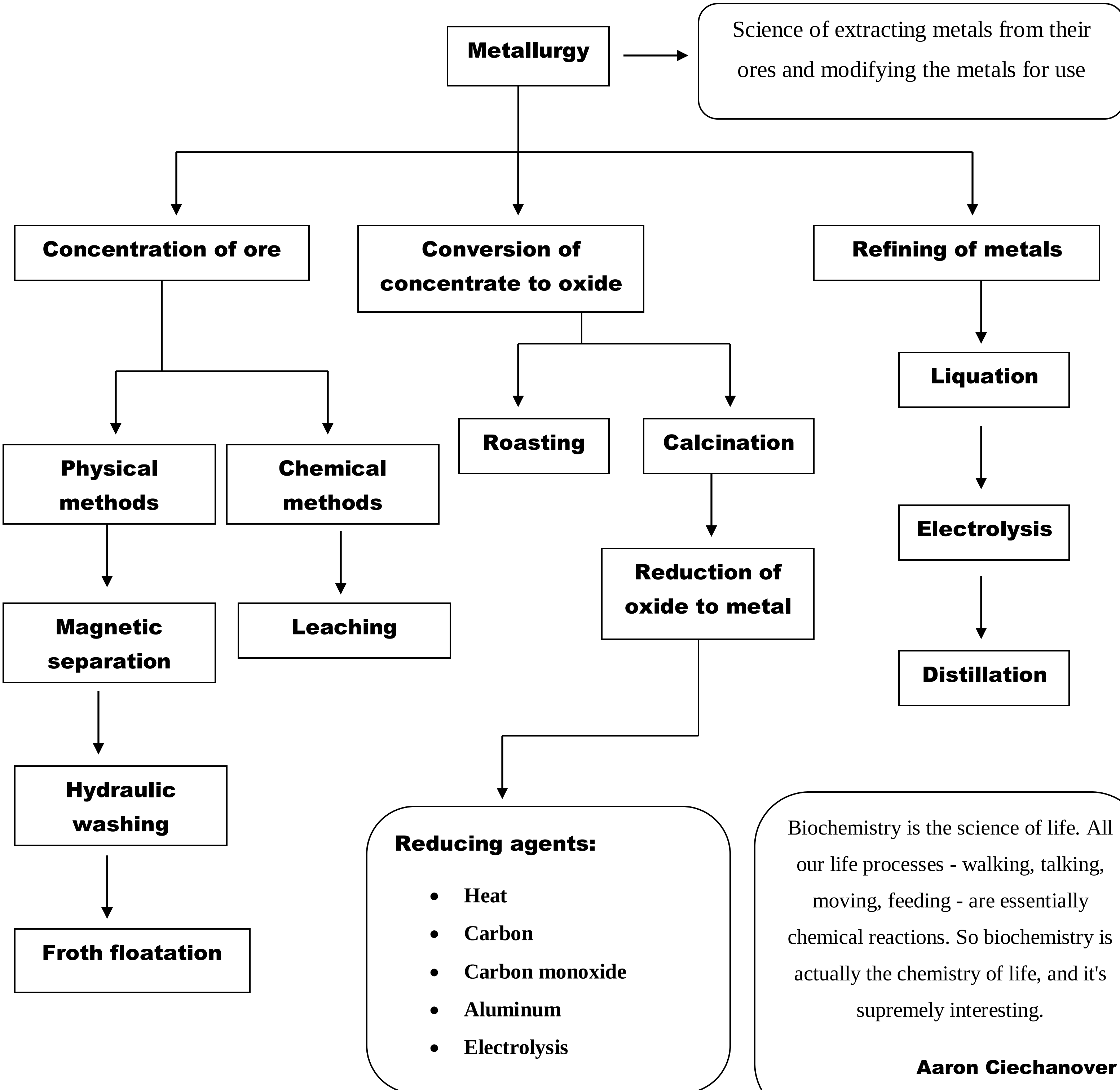
- Metabolism
- Elimination

→ **Clearance**

> Any living cell carries with it the experience of a billion years of experimentation by its ancestors.
>
> **Max Ludwig Henning Delbrück**

> All cell biologists are condemned to suffer an incurable secret sorrow: the size of the objects of their passion. … But those of us enamored of the cell must resign ourselves to the perverse, lonely fascination of a human being for things invisible to the naked human eye.
>
> **L.L. Larison Cudmore**

> Man is a creature composed of countless millions of cells: a microbe is composed of only one, yet throughout the ages the two have been in ceaseless conflict.
>
> **— AB Christie**



> Biochemistry is the science of life. All our life processes - walking, talking, moving, feeding - are essentially chemical reactions. So biochemistry is actually the chemistry of life, and it's supremely interesting.
>
> **Aaron Ciechanover**

Matter

- **Elements** (contains only one kind of atom)
- **Compounds** (contains two or more kind of atoms)
- **Mixtures** (made up of two or more different substances which are not chemically combined)

Chemistry is not a primitive science like geometry and astronomy; it is constructed from the debris of a previous scientific formation; a formation half chimerical and half positive, itself found on the treasure slowly amassed by the practical discoveries of metallurgy, medicine, industry and domestic economy. It has to do with alchemy, which pretended to enrich its adepts by teaching them to manufacture gold and silver, to shield them from diseases by the preparation of the panacea, and, finally, to obtain for them perfect felicity by identifying them with the soul of the world and the universal spirit.

Marcellin Berthelot

Ores of Metals:

Metal	Ore
Aluminium	Bauxite
Beryllium	Beryl
Chromium	Chromite
Cobalt	Cobaltite
Copper	Bornite, Chalcocite
Gold	Quartz
Iron	Magnetite
Lead	Galena
Manganese	Pyrolusite
Mercury	Cinnabar
Nickel	Pentlandite
Tin	Casseterite
Tungsten	Wolframite, Scheelite
Silver	Argentite
Uranium	Uraninite
Zinc	Sphalerite

Important Alloys:

Alloy	Combination of
Duralumin	Aluminium and Copper
Brass	Copper and Zinc
Bronze	Copper and Tin
Invar	Iron and Nickel
Stainless steel	Iron, Chromium and Nickel
German Silver	Copper, Nickel and Zinc
Gunmetal	Copper, Tin and Zinc
Solder	Lead and Tin
Electrum	Gold and Silver
Constantan	Copper and Nickel
Manganin	Copper, Manganese and Nickel

Radiation

Ionizing Radiation

can ionize matter

- X rays
- Gamma rays
- Alpha
- Beta
- Neutron

Non-ionizing Radiation

cannot ionize matter

- Ultraviolet light
- Infrared
- Visible light
- Microwaves
- Radio waves
- Very low frequency
- Extremely low frequency
- Thermal radiation
- Black body radiation

Waves

Longitudinal waves

Need a medium for propagation

Transverse waves

Do not need a medium for propagation

Waste

Hazardous waste

Radioactive waste

- Industrial waste
- Electronic waste
- Medical waste

Non-hazardous waste

Municipal waste:

- Organic waste
- Packing waste
- Glass, plastic and metal

Other non-hazardous industrial waste

Major Dangers of Nuclear Waste disposal:

The nuclear waste has long half lives, which means that it will continue to be radioactive – and therefore hazardous- for many thousands of years

Issue of storage of nuclear waste

The nuclear waste is well stored inside huge steel and concrete containers − sometimes accidents can happen and leaks can occur. Nuclear waste can have drastically bad effects on life causing

- Cancerous tumor growths
- genetic problems for many generations of animal and plants

… just as the astronomer, the physicist, the geologist, or other student of objective science looks about in the world of sense, so, not metaphorically speaking but literally, the mind of the mathematician goes forth in the universe of logic in quest of the things that are there; exploring the heights and depths for facts—ideas, classes, relationships, implications, and the rest; observing the minute and elusive with the powerful microscope of his Infinitesimal Analysis; observing the elusive and vast with the limitless telescope of his Calculus of the Infinite; making guesses regarding the order and internal harmony of the data observed and collocated; testing the hypotheses, not merely by the complete induction peculiar to mathematics, but, like his colleagues of the outer world, resorting also to experimental tests and incomplete induction; frequently finding it necessary, in view of unforeseen disclosures, to abandon one hopeful hypothesis or to transform it by retrenchment or by enlargement:—thus, in his own domain, matching, point for point, the processes, methods and experience familiar to the devotee of natural science.

Cassius Jackson Keyser

Normal Cells	**Tumor Cells**
Normal cells stop growing when enough cells are present	Tumor cells continue to grow after enough cells are present
Normal cells respond to the signals from other cells warning overgrowth and stop growing	Tumor cells do not respond to the signals from other cells warning overgrowth
Normal cells do repair themselves or may even die off if they are not healthy	Tumor cells don't repair themselves when they are old or damaged

[On the practical applications of particle physics research with the Large Hadron Collider.] Sometimes the public says, "What's in it for Numero Uno? Am I going to get better television reception? Am I going to get better Internet reception? " Well, in some sense, yeah. … All the wonders of quantum physics were learned basically from looking at atom-smasher technology. … But let me let you in on a secret: We physicists are not driven to do this because of better color television. … That's a spin-off. We do this because we want to understand our role and our place in the universe.

— Michio Kaku

Nuclear Fission	**Nuclear Fusion**
The nucleus of an atom splits into lighter nuclei	Two or more light nuclei collide with each other to form a heavier nucleus
Tremendous amount of energy is released	The energy released is 3 to 4 times greater than the energy released by fission.
do not occur in nature naturally	occur in stars and the sun
Little energy is needed to split an atom	High energy is needed to bring and fuse two or more atoms together
Atomic bomb works on the principle of nuclear fission reaction	Hydrogen bomb works on the principle of nuclear fusion reaction

HIV (human immunodeficiency virus) $\xrightarrow{\text{causes}}$ **AIDS** (acquired immunodeficiency syndrome)

Transferred from person to person through

- Sexual contact
- IV drug abuse (through sharing needles)
- Mother-to-child transmission during pregnancy, labor (the delivery process)
- Breastfeeding

Symptoms

- Fever
- Headache
- Muscle aches and joint pain
- Rash
- Sore throat and painful mouth sores
- Swollen lymph glands, mainly on the neck
- Diarrhea
- Weight loss
- Cough
- Night sweats

Did you Know?

Nearly 38 million people are living with HIV worldwide. Many of them do not know they are infected and may be spreading the virus to others. In the U.S., 1.1 million people are living with HIV, and almost 39,000 Americans become newly infected with the virus each year.

Elastic Collision	Inelastic Collision
The total kinetic energy is conserved	The total kinetic energy is not conserved
Momentum does not change	Momentum changes

A person who is religiously enlightened appears to me to be one who has, to the best of his ability, liberated himself from the fetters of his selfish desires and is preoccupied with thoughts, feelings, and aspirations to which he clings because of their superpersonal value. It seems to me that what is important is the force of this superpersonal content and the depth of the conviction concerning its overpowering meaningfulness, regardless of whether any attempt is made to unite this content with a divine Being, for otherwise it would not be possible to count Buddha and Spinoza as religious personalities. Accordingly, a religious person is devout in the sense that he has no doubt of the significance and loftiness of those superpersonal objects and goals which neither require nor are capable of rational foundation. They exist with the same necessity and matter-of-factness as he himself. In this sense religion is the age-old endeavor of mankind to become clearly and completely conscious of these values and goals and constantly to strengthen and extend their effect. If one conceives of religion and science according to these definitions then a conflict between them appears impossible. For science can only ascertain what is, but not what should be, and outside of its domain value judgments of all kinds remain necessary.

— Albert Einstein

Fraction	Rational Numbers
Written in the form of $\frac{a}{b}$, where a and b are whole numbers and $b \neq 0$	Written in the form of $\frac{p}{q}$, where p and q are integers and $q \neq 0$
All fractional numbers are rational	All rational numbers are not fractions.

All revolutionary advances in science may consist less of sudden and dramatic revelations than a series of transformations, of which the revolutionary significance may not be seen (except afterwards, by historians) until the last great step. In many cases the full potentiality and force of a most radical step in such a sequence of transformations may not even be manifest to its author.

— I. Bernard Cohen

Osmosis	Diffusion
The movement of solvent particles across a semipermeable membrane from a dilute solution into a concentrated solution	The movement of particles from an area of higher concentration to lower concentration
Example:	
Plant root hairs taking up water	The movement of small molecules across a cell membrane

All things on the earth are the result of chemical combination. The operation by which the commingling of molecules and the interchange of atoms take place we can imitate in our laboratories; but in nature they proceed by slow degrees, and, in general, in our hands they are distinguished by suddenness of action. In nature chemical power is distributed over a long period of time, and the process of change is scarcely to be observed. By acts we concentrate chemical force, and expend it in producing a change which occupies but a few hours at most.

— Robert Hunt

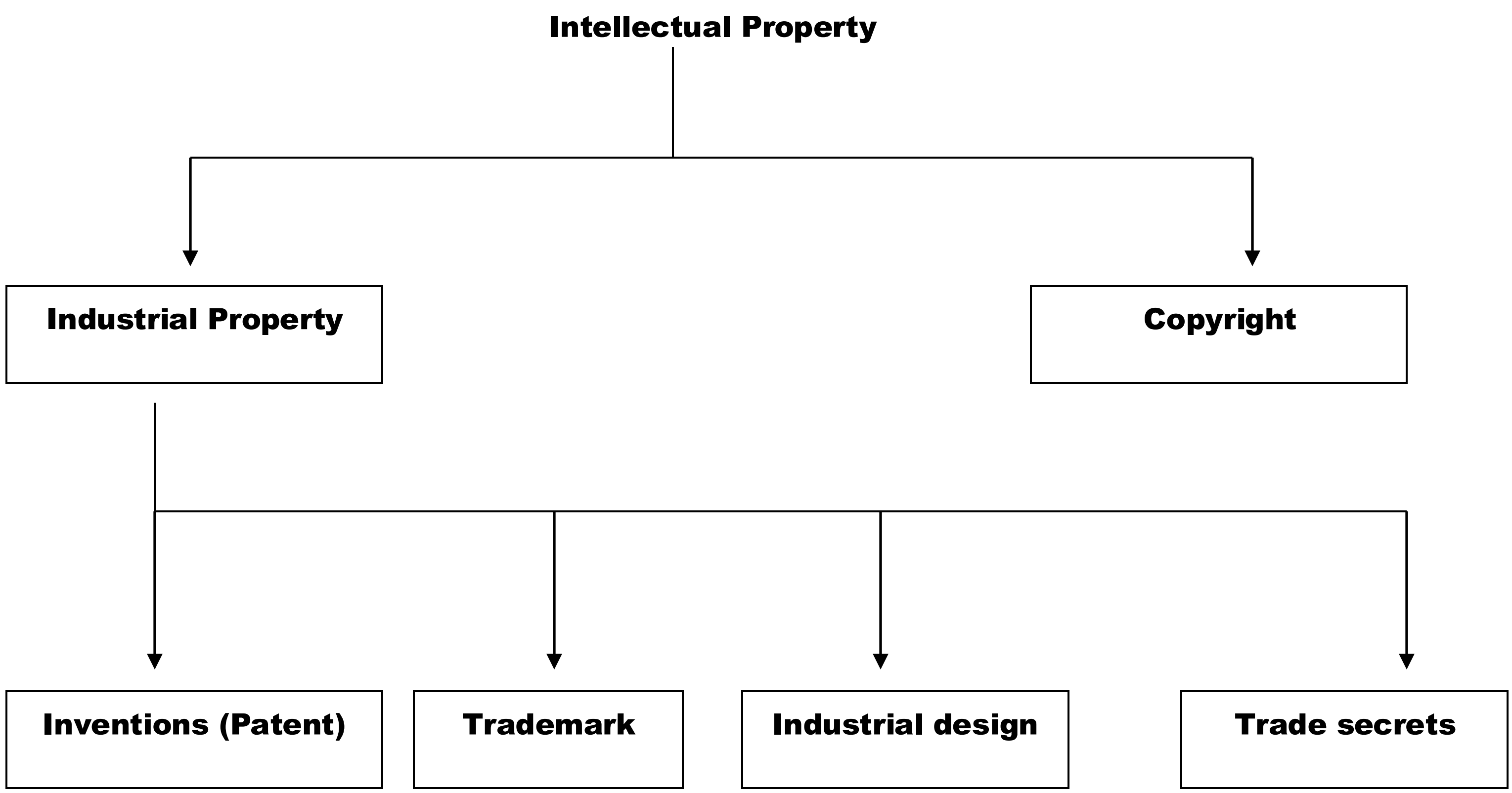
Data doesn't depend on **information**.	**Information** depends on **data**.

Although gravity is by far the weakest force of nature, its insidious and cumulative action serves to determine the ultimate fate not only of individual astronomical objects but of the entire cosmos. The same remorseless attraction that crushes a star operates on a much grander scale on the universe as a whole.

P.C.W. Davies

Heat	Temperature
The amount of energy present in a body	The measure of the heat's intensity
Flows from a hotter object to a cooler object	Rises when we heat and falls when we cool

James Prescott Joule (an English physicist and inventor) studied the nature of heat and established its relationship to mechanical work. He laid the foundation for the theory of conservation of energy, which later influenced the **First Law of Thermodynamics** (which states that Energy can neither be created nor be destroyed; it can only be transferred from one form to another). He also formulated the Joule's law which deals with the transfer of energy.



Creativity

The act of turning new and imaginative ideas into reality

Invention

The creation of a new idea or concept

Innovation

The process of turning a new concept into commercial success or widespread use

4 Types of Intellectual Property:

- **Trade secrets:** Protects secret information
- **Trademarks:** Protects brands
- **Copyrights:** Protects works of authorship
- **Patents:** Protects functional aspects and ornamental features

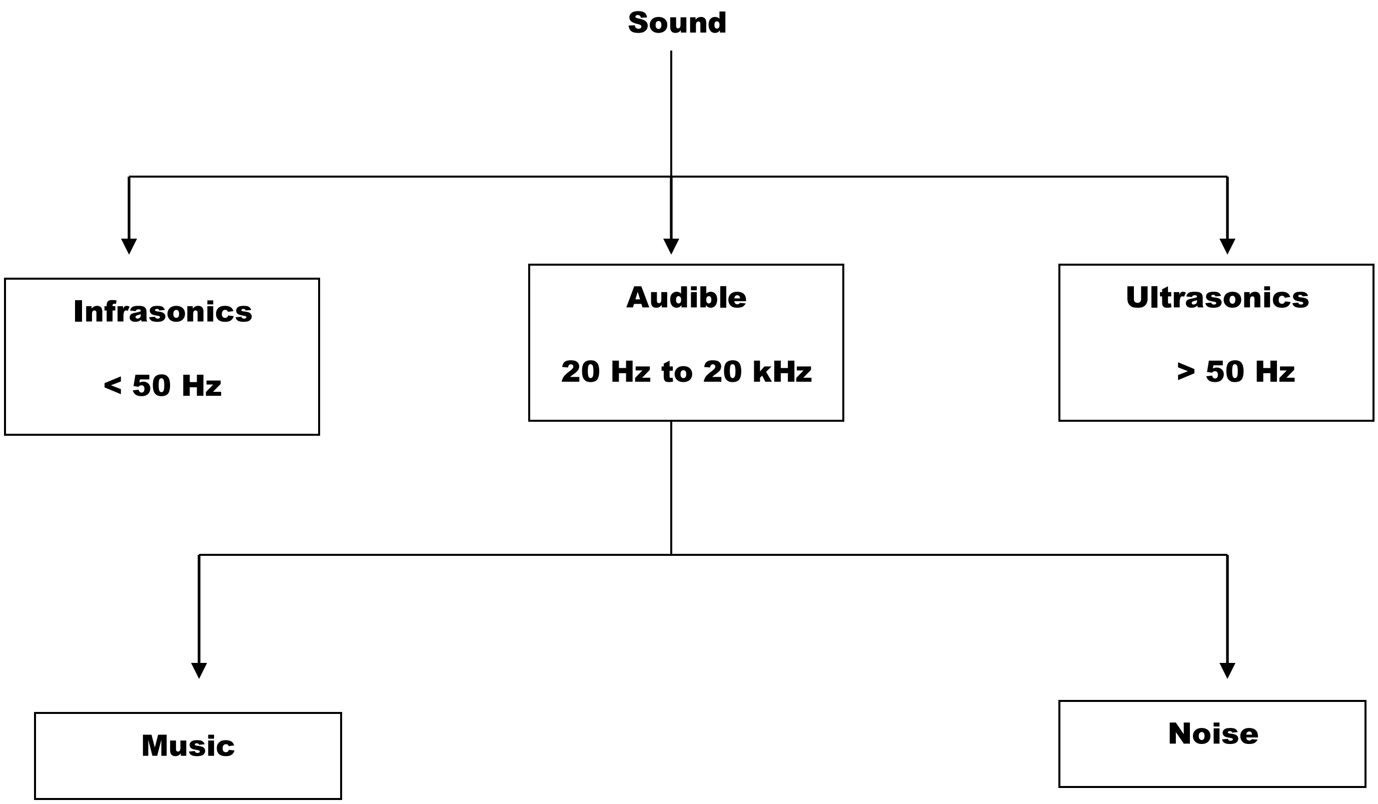
Some sustaining innovations are the incremental year-by-year improvements that all good companies grind out. Other sustaining innovations are breakthrough, leapfrog-beyond-the-competition products. It doesn't matter how technologically difficult the innovation is, however: The established competitors almost always win the battles of sustaining technology.

Because this strategy entails making a better product that they can sell for higher profit margins to their best customers, the established competitors have powerful motivations to fight sustaining battles. And they have the resources to win.

– Clayton Christensen

4 types of Innovation

- **Incremental Innovation** → utilizing your existing technology and increasing value to the customer within your existing market
- **Disruptive Innovation** → applying new technology or processes to your company's current market
- **Architectural Innovation** → taking the lessons, skills and overall technology and applying them within a different market
- **Radical innovation** → giving birth to new industries (or swallowing existing ones) and involving creating revolutionary technology



> Divine sound is the cause of all manifestation. The knower of the mystery of sound knows the mystery of the whole universe.
>
> **— Hazrat Inayat Khan**

Music	**Noise**
It has a pleasing effect on the ears	It has a displeasing effect on the ears
It is produced by regular periodic vibrations of a body	It is produced by irregular vibrations in a material
The amplitude of vibration and its frequency do not change suddenly	The amplitude and frequency of vibration may change suddenly

12 major constellations:

- Aries
- Taurus
- Gemini
- Cancer
- Leo
- Virgo
- Libra
- Scorpio
- Sagittarius
- Capricorn
- Aquarius
- Pisces

Constellations are Star Patterns in the Night Sky

In space there are countless constellations, suns and planets; we see only the suns because they give light; the planets remain invisible, for they are small and dark. There are also numberless earths circling around their suns, no worse and no less than this globe of ours. For no reasonable mind can assume that heavenly bodies that may be far more magnificent than ours would not bear upon them creatures similar or even superior to those upon our human earth.

— Giordano Bruno

The word "universe" means the general assemblage of all nature, and it also means the heaven that is made up of the constellations and the courses of the stars.

— Vitruvius

Type of bond	Difference in Electronegativity
Pure Covalent	< 0.4
Polar Covalent	Between 0.4 and 1.8
Ionic	> 1.8

In the next twenty centuries … humanity may begin to understand its most baffling mystery—where are we going? The earth is, in fact, traveling many thousands of miles per hour in the direction of the constellation Hercules—to some unknown destination in the cosmos. Man must understand his universe in order to understand his destiny. Mystery, however, is a very necessary ingredient in our lives. Mystery creates wonder and wonder is the basis for man's desire to understand. Who knows what mysteries will be solved in our lifetime, and what new riddles will become the challenge of the new generation? Science has not mastered prophesy. We predict too much for the next year yet far too little for the next ten. Responding to challenges is one of democracy's great strengths. Our successes in space can be used in the next decade in the solution of many of our planet's problems.

— Neil Armstrong

Polar Molecule	Non-polar Molecule
Molecule in which one end of the molecule is slightly positive while the other end is slightly negative	Do not possess regions of positive and negative charge
• Water (H_2O)	• Carbon dioxide (CO_2)

Combustion

Rapid Combustion

Combustion is very fast

(Matchstick near stove)

Spontaneous

Combustion is on its own

(Coal dust in Coal Mines)

Explosion

Combustion causes large amount of heat, light and sound

(Firecrackers)

Coal + Oxygen (From air) $\xrightarrow{\text{Combustion}}$ **Carbon dioxide + Heat + Light**

> We see a universe marvelously arranged and obeying certain laws, but only dimly understand these laws. Our limited minds cannot grasp the mysterious force that moves the constellations. I am fascinated by Spinoza's pantheism, but admire even more his contributions to modern thought because he is the first philosopher to deal with the soul and the body as one, not two separate things.
>
> **— Albert Einstein**

Agonists	Antagonists
Drugs that have the ability to produce a desired therapeutic effect when bound to the to the target cell surface receptors.	Drugs that bind well to the receptor but produce no therapeutic effect. They prevent other drugs from binding to the target cell surface receptors, thus they act as blockers.

Phases of Clinical trail

- **Preclinical research:** In this phase, researchers test the investigational product in the laboratory or in animals before it can be tested in humans. Preclinical results frame the basis for applying an investigational new drug (IND) application to the Food and Drug Administration (FDA) to seek permission to use the investigational product in a **Phase I** trial.
- **Phase I:** In this phase, the investigational product is tested in a 20 to 100 of healthy volunteers who are not at risk for disease to determine the safety and a **safe dosage range** (maximum concentration of the investigational product above which the investigational product can produce harmful effects in the body), and identify side effects.
- **Phase II:** In this phase, the investigational product is tested in a 20 to 300 of unhealthy volunteers with the disease to determine the **efficacy** [how well the investigational product works compared to a comparator (marketed product or **placebo**)]. (**Placebo:** a substance that has no **therapeutic effect** but used as a control in testing investigational product).
- **Phase III:** In this phase, the **investigational product** is tested in a 1,000 − 3,000 unhealthy volunteers with the disease (at multiple centers) to confirm the safety, efficacy and side effects of the investigational product. This is the final phase prior to seek marketing approval (or to apply an new drug (ND) application to the Food and Drug Administration (**FDA**) to seek permission to market the product confirming that the investigational product is safe, effective, have **anticipated benefits** that outweigh the foreseeable risks, producible in a consistent quality and purity).
- **Phase IV:** post marketing surveillance to understand the risks, benefits, and optimal use of the marketed product.

Potency	Efficacy
The amount of a drug that is needed to produce a given effect.	The maximum effect that a drug can produce after binding to the receptor.

- **Dose:** The amount of drug prescribed to be taken at one time.
- **Dosage:** The amount of drug to be taken.
- **Dosage form:** means by which the drug reach the target cell to give its actions.

During the **Nuremberg War Crimes Trials**, 23 German doctors were charged with crimes against humanity for "performing medical experiments upon prisoners and other living human subjects, without their consent, in the course of which experiments they committed the murders, brutalities, cruelties, tortures, and other inhuman acts." As part of the verdict, the Court enforced some rules for "**Permissible Medical Experiments**", now known as the "**Nuremberg Code**".

These rules include:

- Voluntary consent.
- Anticipated benefits should outweigh foreseeable risks.
- Ability of the subject to terminate participation.

Epic

Folk Epic

Oral literature about a traditional or historical hero

Literary Epic

Written literature about a traditional or historical hero

Oral Epic Poetry

Poetry that is not written but passed by word of mouth

> Language as a communication tool is the primary element from which literature is created. Even in pre-literate societies, it exists as songs, riddles, or epics that are chanted.
>
> **F. Sionil Jose**

Inquiries

Normative inquiries

Conceptual inquiries

Descriptive inquiries

LAW	**ETHICS**
Refers to a systematic body of rules that governs the whole society and the actions of its individual members.	Branch of moral philosophy that guides people about the basic human conduct.

Teleological Ethics

Ethical Egoism

The view that people ought to pursue their own self-interest and no one has any obligation to promote anyone else's interests

Utilitarianism

Prescribe actions that maximize happiness and well-being for all affected individuals

Eudaimonism

Ethical theory which maintains that happiness is reached through virtue

The main issues that surround Cyber ethics are:

- Copyright / Downloading
- Hacking
- Cyber harassment

Encryption	Decryption
The process of converting normal message (**Plaintext**) into meaningless message (**Ciphertext**)	The process of converting meaningless message (**Ciphertext**) into its original form (**Plaintext**)

Business ethics

- Social responsibility
- Trust
- Connection
- Honesty
- Integrity
- Commitment
- Transparency
- Core values
- Reliability

Replace cyber-bullying with cyber-believing. Let us build each other up instead of bringing others down. BELIEVE & BUILD

— Janna Cachola

3 Harvesting Methods:

- Hand Harvesting
- Harvesting with Hand Tools
- Harvesting with Machinery

Water harvesting

Rainwater harvesting

The collection and storage of rain water, rather than allowing it to run off

Flood water harvesting

The collection and storage of creek flow for irrigation use

- Reduces erosion and flooding around buildings
- **An adequate means for Irrigation purpose**
- Conserves water and reduces demand on Ground Water

Disadvantages

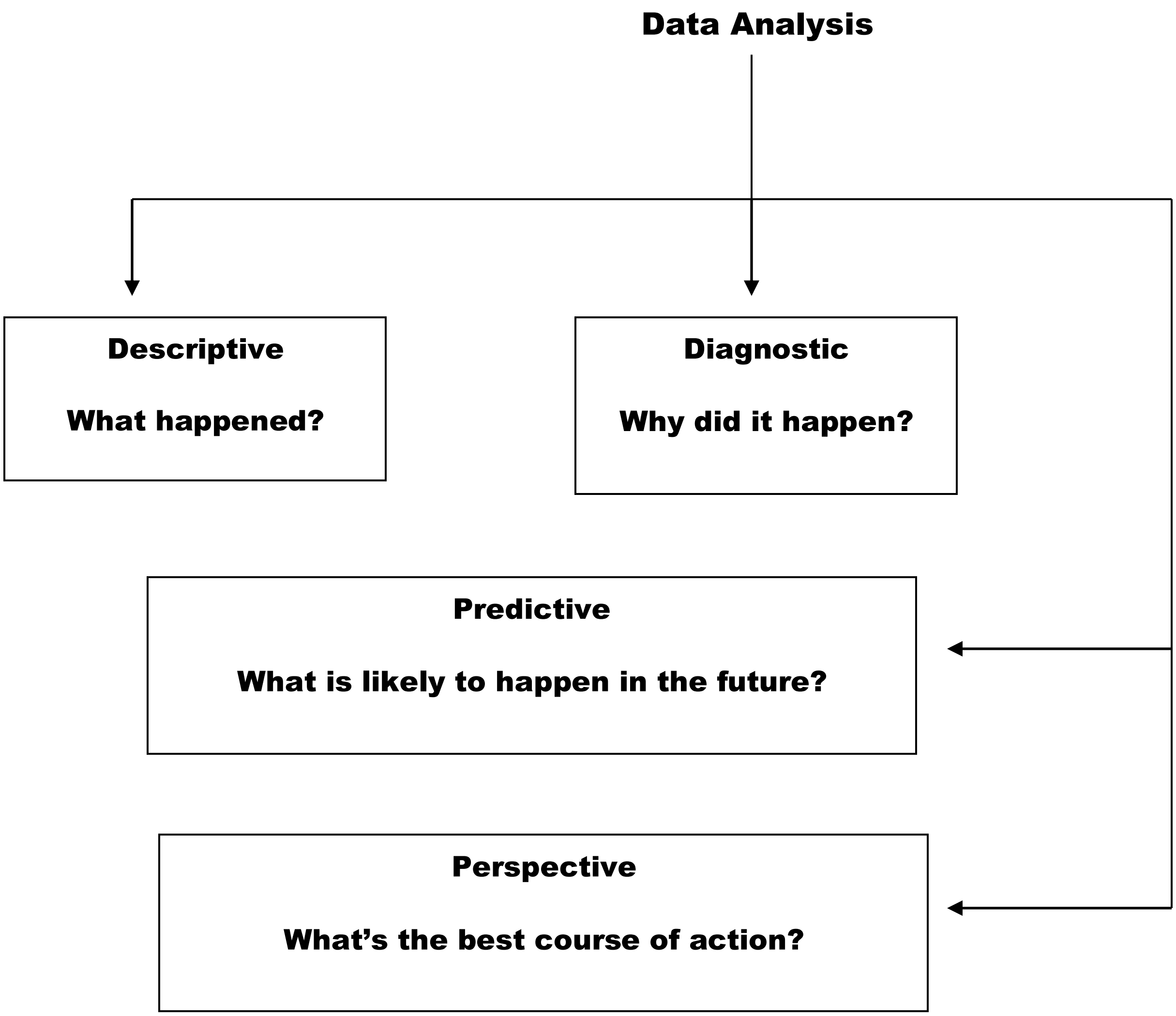
- High Investment
- High Maintenance
- Not Suitable For All Areas

With every drop of water you drink, every breath you take, you're connected to the sea. No matter where on Earth you live. Most of the oxygen in the atmosphere is generated by the sea.

Sylvia Earle

Water Harvesting

- **Water in Air** (Fog and Dew harvesting)
- **Overland Flow** (Rainwater harvesting and Flood water harvesting)
- **Ground water** (Ground water harvesting)



> Machine learning modeling and testing on sample data and going through the business user acceptance test can surprise you!
> And it will definitely make you to rethink on your feature selection and data sampling methods.
>
> **Shitalkumar R. Sukhdeve**

> Facts are stubborn things, but statistics are pliable.
>
> — **Mark Twain**

Statistics

- Provides a better understanding and accurate description of nature's phenomena.
- Assists in the proper and efficient planning of a statistical inquiry in any field of study.
- Assists in collecting appropriate quantitative data.

Descriptive statistics

Inferential statistics

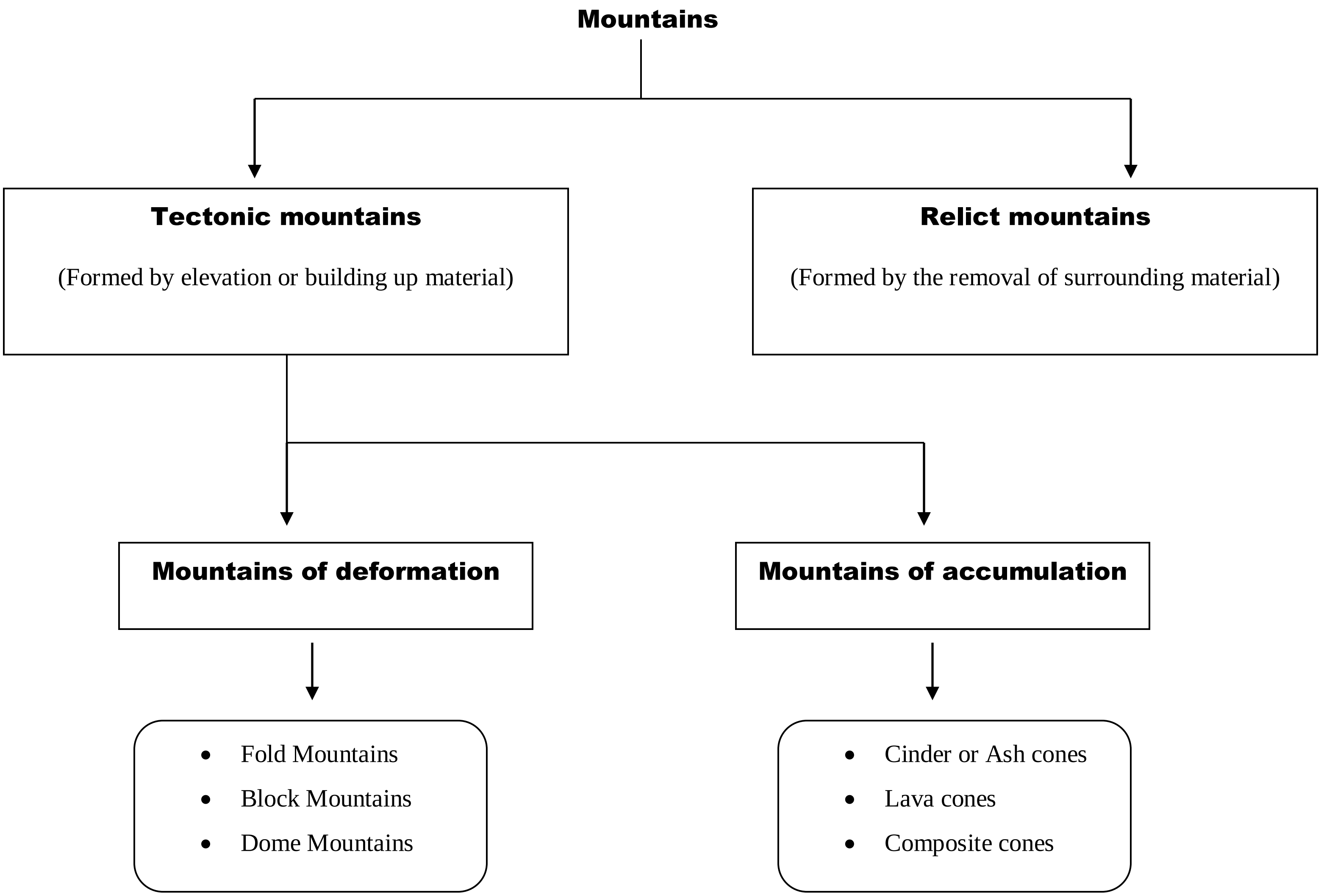
Measure of central tendency

- Mean
- Mode
- Median

Measure of variability

- Range
- Variance
- Dispersion

> Nature has established patterns originating in the return of events, but only for the most part. New illnesses flood the human race, so that no matter how many experiments you have done on corpses, you have not thereby imposed a limit on the nature of events so that in the future they could not vary.
>
> — **Gottfried Leibniz**



> Artificial intelligence is based on the assumption that the mind can be described as some kind of formal system manipulating symbols that stand for things in the world. Thus it doesn't matter what the brain is made of, or what it uses for tokens in the great game of thinking. Using an equivalent set of tokens and rules, we can do thinking with a digital computer, just as we can play chess using cups, salt and pepper shakers, knives, forks, and spoons. Using the right software, one system (the mind) can be mapped onto the other (the computer).
>
> **— George Johnson**

Chemical Indicator

Substances whose solutions change color due to changes in pH

- **Natural indicator**

  (Turmeric, China Rose)

- **Artificial indicator**

  (Litmus)

Physical Change	Chemical Change
There is no formation of new products	There is formation of new products
Temporary change (reversible)	Permanent change (irreversible)
• freezing of water • melting of wax • boiling of water	• burning of coal • rusting

Computers are composed of nothing more than logic gates stretched out to the horizon in a vast numerical irrigation system.

– Stan Augarten

Mass	Weight
The measure of the amount of matter in a body	The measure of the amount of force acting on a mass due to acceleration due to gravity
Mass = volume × density	**Weight = mass × acceleration due to gravity**

Centrifugal Force (Pseudo Force)	**Centripetal Force** (Real Force)
It is the outward push that we experience in a circular motion	It is the pull towards the center in a circular motion
Named by Christiaan Huygens	Named by Sir Isaac Newton

...the scientific cast of mind examines the world critically, as if many alternative worlds might exist, as if other things might be here which are not. Then we are forced to ask why what we see is present and not something else. Why are the Sun and moon and the planets spheres? Why not pyramids, or cubes, or dodecahedra? Why not irregular, jumbly shapes? Why so symmetrical, worlds? If you spend any time spinning hypotheses, checking to see whether they make sense, whether they conform to what else we know. Thinking of tests you can pose to substantiate or deflate hypotheses, you will find yourself doing science.

Carl Sagan

pH	**pOH**
measure of hydrogen ion (H^+) concentration	measure of hydroxide ion (OH^-) concentration
$pH = -\log_{10} [H^+]$	$pOH = -\log_{10} [OH^-]$

Private consumption expenditure

Expenditure for services | **Expenditure for durable goods** | **Expenditure for nondurable goods**

Production

Consumption

Keynesian Law of Consumption:

As income increases consumption also increases – but at a lesser rate than the increase in income.

Consumption

Direct Consumption

Cutting down a tree or branch and burning it for heat

Productive Consumption

Buying a textile to make dresses, shorts, shirts and curtains

Wasteful Consumption

Wasting money by buying things they never use — food, clothes, shoes, CDs, books, exercise bikes, cosmetics, kitchen appliances, and **much more.**

Harmful Consumption

Using prohibited drugs, alcoholic drinks and cigarettes

Mixed Economic System

Market Economy | **Command Economy**

Market Economy	Command Economy
Owned by private sectors	Owned by the government
Freedom to set up business	Government regulation
Supply and demand	Price control
Free market	**Government intervention**

> Agriculture is not crop production as popular belief holds - it's the production of food and fiber from the world's land and waters. Without agriculture it is not possible to have a city, stock market, banks, university, church or army. Agriculture is the foundation of civilization and any stable economy.
>
> **Allan Savory**

Budget

Based on time:

- Long term budget
- Short term budget
- Medium term budget

Based on Function:

- Sales budget and Cash budget
- Manufacturing Overhead budget
- Production budget and R&D budget
- Selling Overhead budget
- Material budget and Labour budget
- Cost of production budget

Based on Flexibility:

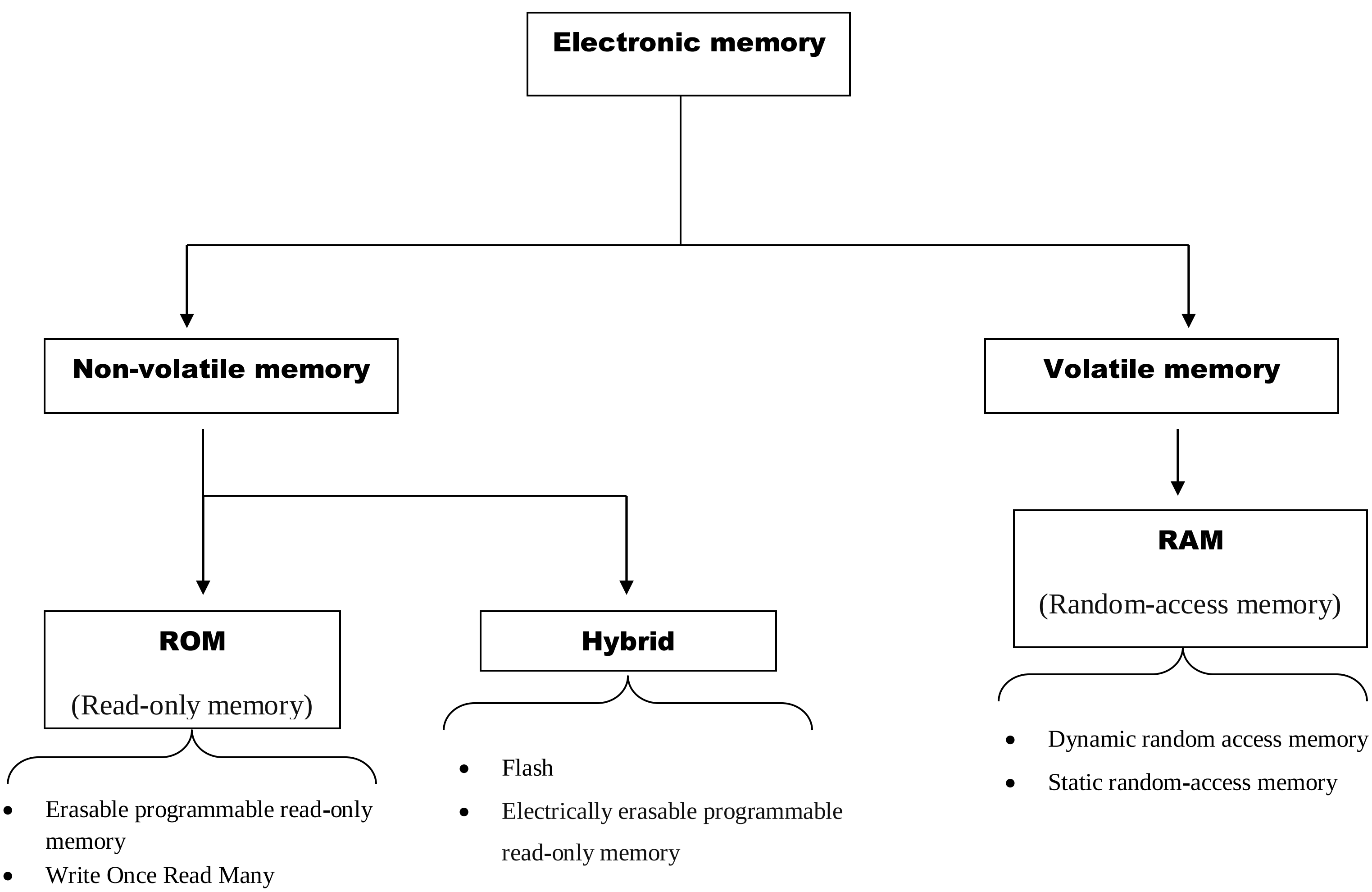
- Fixed budget
- Flexible budget

Logic gates are the basic building blocks of any digital circuit.

There are 3 basic logic gates:

- AND
- NOT
- OR

> Software is a gas; it expands to fill its container.
>
> **— Nathan Myhrvold**



X Chromosomes	Y Chromosomes
Metacentric (X shaped)	**Acrocentric** (Y shaped)
Longer than the Y-chromosome.	Shorter than the X-chromosome.
Contains a large amount of euchromatin.	Contains the small amount of euchromatin.
Contains the small amount of heterochromatin.	Contains a large amount of heterochromatin.
There is a larger amount of DNA or active genes	There is a lesser amount of DNA or active genes
Found in both males and females	Found in only males

Except for the rare cases of plastid inheritance, the inheritance of all known cofactors can be sufficiently accounted for by the presence of genes in the chromosomes. In a word the cytoplasm may be ignored genetically.

— Thomas Hunt Morgan

Biologically speaking, the character of an animal depends on its chromosomal content, not on its size, shape, age, or stage of development. Any organism with the chromosomes and genes proper to a human being can be nothing less than a human being. Human life exists only in human beings, and all human beings are persons.

— Paul Marx

History → Helps us develop a better understanding of the world

- **Political History**
- **Diplomatic History**
- **Cultural History**
- **Social History**
- **Economic History**
- **Intellectual History**

4 Types of Dictionaries:

- General language dictionaries
- Subject dictionaries
- Special dictionaries
- Dictionaries for translation

Voltaire

"History is only the register of crimes and misfortunes."

Napoleon Bonaparte

"What is history but a fable agreed upon?"

Karl Marx

"History repeats itself, first as tragedy, second as farce."

Winston Churchill

"History is written by the victors."

Thomas Jefferson

"I like the dreams of the future better than the history of the past."

John Maynard Keynes

"Ideas shape the course of history."

William Shakespeare

"There is a history in all men's lives."

Mark Twain

"The very ink with which history is written is merely fluid prejudice."

Henry David Thoreau

"It is remarkable how closely the history of the apple tree is connected with that of man."

Alexander Smith

"I go into my library and all history unrolls before me."

Robert Heinlein

"A generation which ignores history has no past and no future."

Marshall McLuhan

"Only the vanquished remember history."

Mohandas Gandhi

"A small body of determined spirits fired by an unquenchable faith in their mission can alter the course of history."

Stephen Covey

"Live out of your imagination, not your history."

Martin Luther King, Jr.

"We are not makers of history. We are made by history."

Dwight D. Eisenhower

"Things have never been more like the way they are today in history."

Encyclopedia

General Encyclopedia

Provides concise overviews on a wide variety of topics

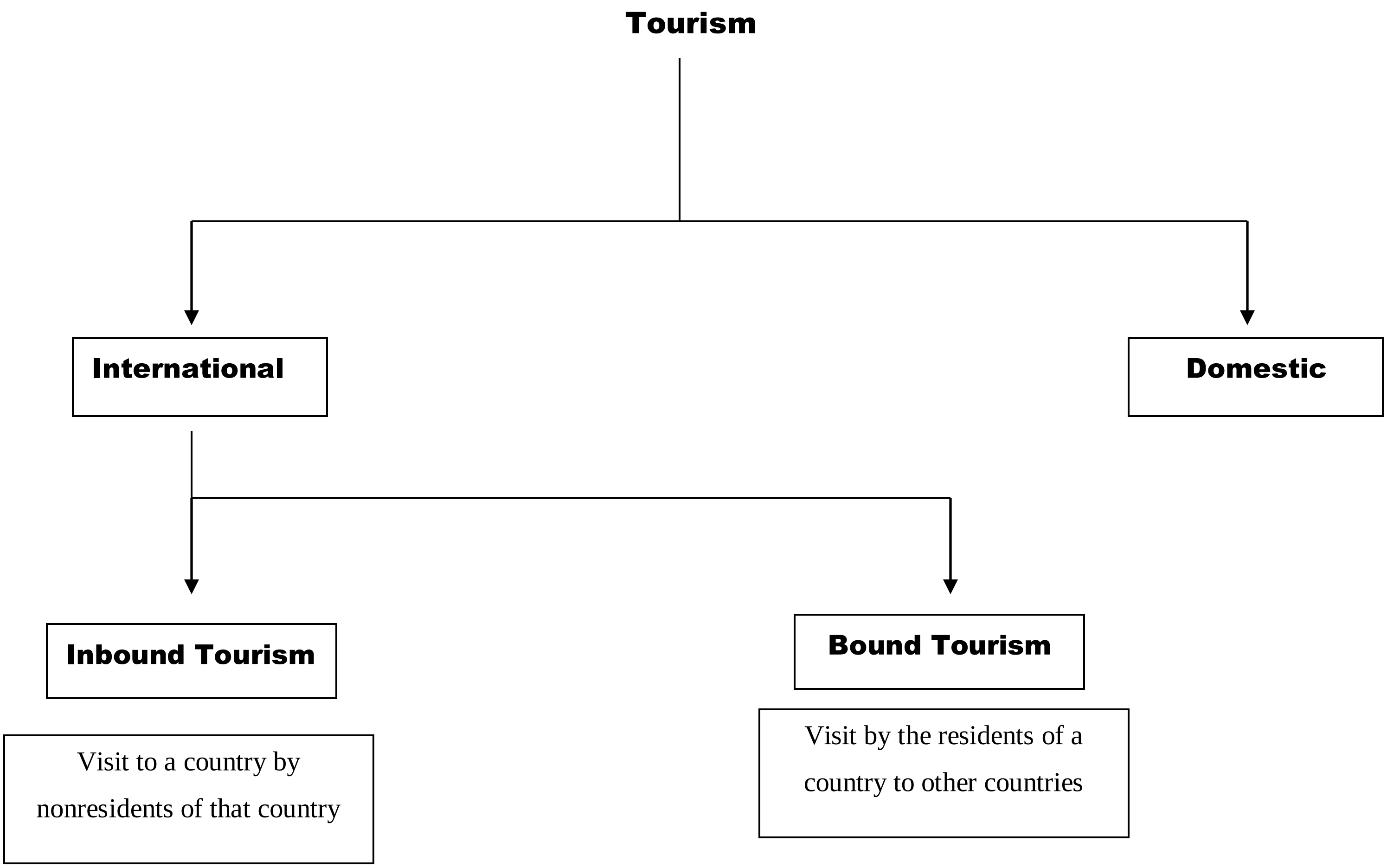
Encyclopedia Britannica

Subject Encyclopedia

Contains in-depth entries focusing on one field of study

The Gale Encyclopedia of Medicine

> Will there ever be an encyclopedia? Possibly. I would say two things about the encyclopedia: firstly, I've always said and I stand by it, whenever I do do a printed encyclopedia I would like all the proceeds to go to charity. Back in 1998 I never dreamt I personally I would be in the position that I could set up a large charitable foundation and personally do things for charity, and I've done other charity books already.
>
> **— J.K. Rowling**



SQL	**NoSQL**
These databases are not suited for hierarchical data storage.	These databases are best suited for hierarchical data storage.
These databases are best suited for complex queries	These databases are not so good for complex queries
ACID (Atomicity, Consistency, Isolation, and Durability) is a model of SQL databases	**Base** (Basically Available, Soft state, Eventually Consistent) is a model of NoSQL databases

Git	Github
It is a software.	It is a service.
It is a command-line tool	It is a graphical user interface
It is installed locally on the system	It is hosted on the web
It is maintained by linux.	It is maintained by Microsoft.
It is focused on version control and code sharing.	It is focused on centralized source code hosting.
It is a version control system to manage source code history.	It is a hosting service for Git repositories.
It was first released in 2005.	It was launched in 2008.
It has no user management feature.	It has built-in user management feature.

Technology like art is a soaring exercise of the human imagination.

– Daniel Bell

In '77 there was no Internet, there was no Twitter or Facebook, and I think that, without being some old git who hates anything new, people's attention spans are too short. Back then you had 'Top of the Pops' and 'Melody Maker,' and you had to make the effort to go to a show so that you absorbed the culture of music.

Steve Jones

	Alligator	**Crocodile**
Color	Blackish/grey	Olive green/brown
Habitat	Southern U.S. and China	Africa, Australia, and America
Snout	Wider U-shaped snout	Longer V-shaped snout
Aggressiveness	Less aggressive	More aggressive
Preferred Water	Freshwater	Brackish or Saltwater
Lingual Salt Glands	Non-functioning	Functioning
Length of adult	4.3 meters	5.8 meters
Nesting	Lay eggs in mounds of vegetation surrounding freshwater	Lay their eggs in mud or sand
Location of dermal pressure receptors	Limited to jaws	Over most of the body
Teeth of the lower jaw	Hidden (cannot be seen when jaw is closed)	Visible (teeth of lower jaw can be seen when jaw is closed)
Lifespan	30 – 50 years	70 – 100 years

You know the trait of a crocodile, don't you? It never hunts outside water. It always goes into the water to catch its prey. It never goes in the villages or in the bush looking for food. It strikes at the appropriate time. So a good guerrilla leader strikes at the appropriate time.

Emmerson Mnangagwa

The main sectors of the economy

Primary Sector

(Extraction and harvesting of natural resources such as agriculture and mining)

Secondary Sector

(Construction, manufacturing and processing)

Tertiary Sector

(Retailers, entertainment and financial companies)

Quaternary Sector

(Knowledge or intellectual pursuits including research and development, business, consulting services and education)

Trade

- **Internal Trade (domestic or home trade):** Buying and selling of goods and services within the boundaries of a nation.
- **Foreign trade (international trade):** Exchange of goods and services of one country with another country.

Gigantism	Dwarfism
Caused due to hypersecretion of the growth hormone in children	Caused due to hyposecretion of the growth hormone in children
Growth of bones and body organs is slowed down	Bones grow very long

Acromegaly is a chronic disease marked by enlargement of the bones of the extremities, face, and jaw that is caused by over-activity of the pituitary gland

I am now convinced that we have recently become possessed of experimental evidence of the discrete or grained nature of matter, which the atomic hypothesis sought in vain for hundreds and thousands of years. The isolation and counting of gaseous ions, on the one hand, which have crowned with success the long and brilliant researches of J.J. Thomson, and, on the other, agreement of the Brownian movement with the requirements of the kinetic hypothesis, established by many investigators and most conclusively by J. Perrin, justify the most cautious scientist in now speaking of the experimental proof of the atomic nature of matter, The atomic hypothesis is thus raised to the position of a scientifically well-founded theory, and can claim a place in a text-book intended for use as an introduction to the present state of our knowledge of General Chemistry.

Wilhelm Ostwald

Wherever there is great property,
there is great inequality.

— **Adam Smith**

Gross Domestic Product

(GDP)

Measures the total value of all goods and services produced within an economy

=

Expenditure method

Consumption
+
Investment
+
Government Spending
+
Net Exports

Income method

Wages
+
Rental rate on Capital
+
Firm profits

Production method

Final value of all goods and services
–
Intermediate costs

Real GDP	**Nominal GDP**
GDP adjusted for inflation	GDP without taking into account inflation

Adam Smith was a Scottish economist, philosopher, moral philosopher, pioneer of political economy and a key figure during the Scottish Enlightenment.

Poverty

Absolute poverty

It is when people cannot meet their basic needs for food, shelter and clothing

Will not change with economic growth

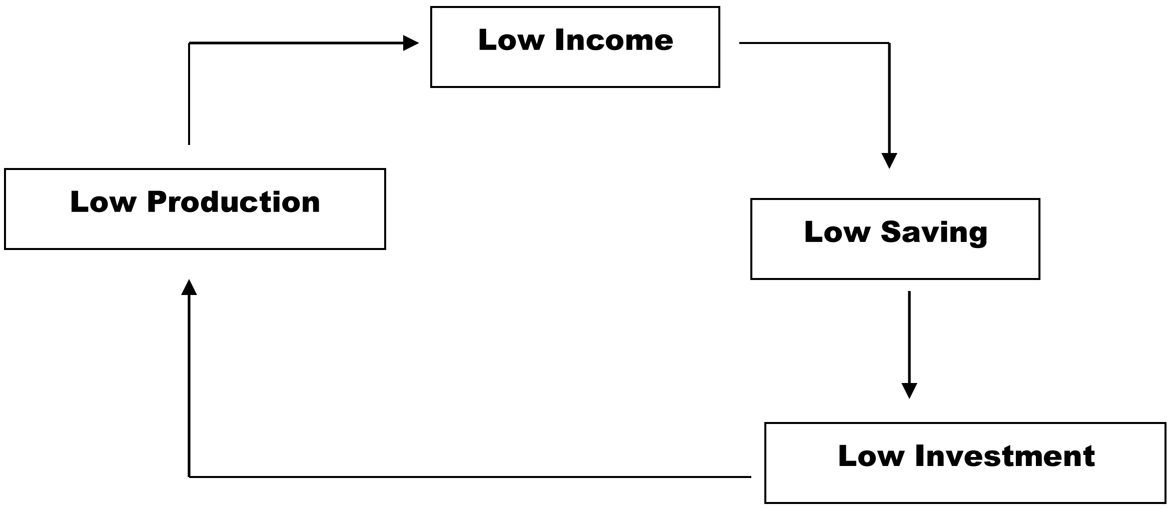
Relative poverty

It is when people have enough to meet their basic needs, but not much more

Will change with economic growth

Even in Europe a change has sensibly taken place in the mind of man. Science has liberated the ideas of those who read and reflect, and the American example has kindled feelings of right in the people. An insurrection has consequently begun of science talents and courage against rank and birth, which have fallen into contempt. It has failed in its first effort, because the mobs of the cities, the instrument used for its accomplishment, debased by ignorance, poverty and vice, could not be restrained to rational action. But the world will soon recover from the panic of this first catastrophe.

Thomas Jefferson



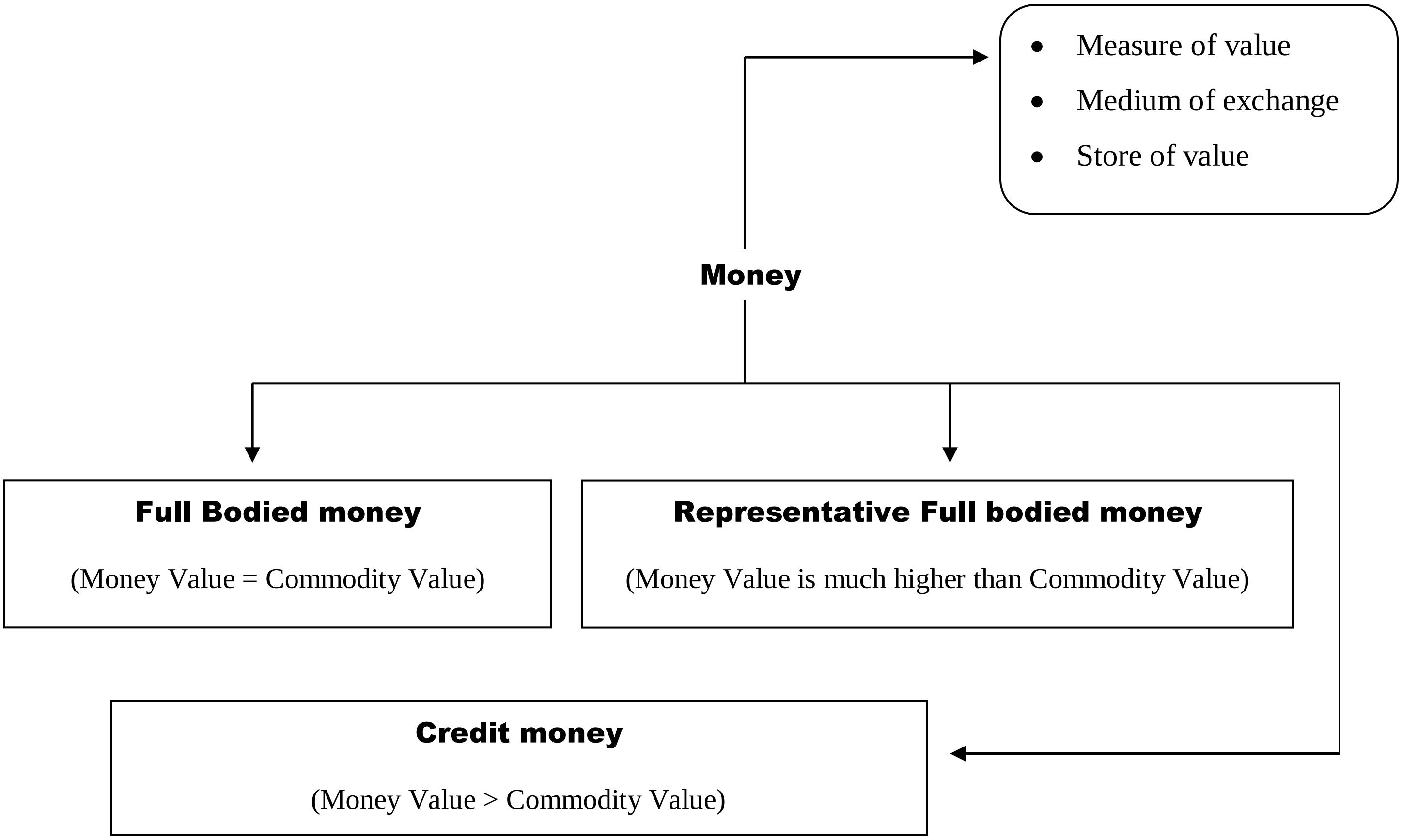
10 Causes of Poverty:

- Unequal Distribution of Wealth
- Less productivity in agriculture
- Environmental Degradation
- Less utilization of resources
- Poor Governance and Unemployment
- A short rate of economic development
- Increase rate of rising population
- Shortage of capital and able entrepreneurship
- Increasing price rise
- Climate change and Poor education

> But poverty, though it does not prevent the generation, is extremely unfavorable to the rearing of children. The tender plant is produced, but in so cold a soil, and so severe a climate, soon withers and dies.
>
> **— Adam Smith**

4 Effects of poverty:

- Homelessness
- Inadequate nutrition and food insecurity
- Inadequate child care
- Lack of access to health care and unsafe neighborhoods



Between the frontiers of the three super-states Eurasia, Oceania, and Eastasia, and not permanently in possession of any of them, there lies a rough quadrilateral with its corners at Tangier, Brazzaville, Darwin, and Hongkong. These territories contain a bottomless reserve of cheap labour. Whichever power controls equatorial Africa, or the Middle East or Southern India or the Indonesian Archipelago, disposes also of the bodies of hundreds of millions of ill-paid and hardworking coolies, expended by their conquerors like so much coal or oil in the race to turn out more armaments, to capture more territory, to control more labour, to turn out more armaments, to capture more territory, to control…

Thus George Orwell — in his only reference to the less-developed world.

I wish I could disagree with him. Orwell may have erred in not anticipating the withering of direct colonial controls within the "quadrilateral" he speaks about; he may not quite have gauged the vehemence of urges to political self-assertion. Nor, dare I hope, was he right in the sombre picture of conscious and heartless exploitation he has painted. But he did not err in predicting persisting poverty and hunger and overcrowding in 1984 among the less privileged nations.

I would like to live to regret my words but twenty years from now, I am positive, the less-developed world will be as hungry, as relatively undeveloped, and as desperately poor, as today.

— Abdus Salam

Harry Govier Seeley was a British paleontologist who determined that dinosaurs fell into two major clades, the **Saurischians** ("Lizard-Hipped" dinosaurs) and the **Ornithischians** ("Bird-Hipped" dinosaurs), based on the nature of their pelvic bones and joints.

Dinosaurs

Saurischians

("Lizard-Hipped" dinosaurs)

- **Theropods** (Beast like reptiles)
- **Sauropods** (lizard footed reptiles)

Ornithischians

("Bird-Hipped" dinosaurs)

Cerapods

- **Ceratopsia** (horned face reptiles)
- **Ornithopoda** (bird footed reptiles)
- **Pachycephalosauria** (thick headed lizards)

Thyreophora

- **Stegosaurs** (plated or roofed reptiles)
- **Ankylosauria** (armour covered reptiles)

A lot of scientific papers do deal with matters of atheoretical fact ... for example, whenever somebody finds a new "world's largest dinosaur," which has only slightly more scientific relevance than shooting the record moose. In short, not everything that gets published in scientific journals bears the distinctive hallmarks of science.

— Matt Cartmill

David Hilbert's 23 Mathematical Problems

- **Problem 1 -** Cantor's problem of the cardinal number of the continuum.
- **Problem 2 -** The compatibility of the arithmetic axioms.
- **Problem 3 -** The equality of two volumes of two tetrahedra of equal bases and equal altitudes.
- **Problem 4 -** Problem of the straight line as the shortest distance between two points.
- **Problem 5 -** Lie's concept of a continuous group of transformations without the assumption of the differentiability of the functions defining the group. (i.e., are continuous groups automatically differential groups?)
- **Problem 6 -** Mathematical treatment of the axioms of physics.
- **Problem 7 -** Irrationality and transcendence of certain numbers.
- **Problem 8 -** Problems (with the distribution) of prime numbers.
- **Problem 9 -** Proof of the most general law of reciprocity in any number field.
- **Problem 10 -** Determination of the solvability of a diophantine equation.
- **Problem 11 -** Quadratic forms with any algebraic numerical coefficients.
- **Problem 12 -** Extension of Kronecker's theorem on abelian fields.
- **Problem 13 -** Impossibility of the solution of the general equation of the 7th degree.
- **Problem 14 -** Proof of the finiteness of certain complete systems of functions.
- **Problem 15 -** Rigorous foundation of Schubert's calculus.
- **Problem 16 -** Problem of the topology of algebraic curves and surfaces.
- **Problem 17 -** Expression of definite forms by squares.
- **Problem 18 -** Building space from congruent polyhedra.
- **Problem 19 -** Are the solutions of regular problems in the calculus of variations always necessarily analytic?
- **Problem 20 -** The general problem of boundary curves.
- **Problem 21 -** Proof of the existence of linear differential equations having a prescribed monodromic group.
- **Problem 22 -** Uniformization of analytic relations by means of automorphic functions.
- **Problem 23 -** Further development of the methods of the calculus of variations.

If one small and odd lineage of fishes had not evolved fins capable of bearing weight on land (though evolved for different reasons in lakes and seas,) terrestrial vertebrates would never have arisen. If a large extraterrestrial object—the ultimate random bolt from the blue — had not triggered the extinction of dinosaurs 65 million years ago, mammals would still be small creatures, confined to the nooks and crannies of a dinosaur's world, and incapable of evolving the larger size that brains big enough for self-consciousness require. If a small and tenuous population of protohumans had not survived a hundred slings and arrows of outrageous fortune (and potential extinction) on the savannas of Africa, then Homo sapiens would never have emerged to spread throughout the globe. We are glorious accidents of an unpredictable process with no drive to complexity, not the expected results of evolutionary principles that yearn to produce a creature capable of understanding the mode of its own necessary construction.

— Stephen Jay Gould

Psychoanalytic theory is the most stupendous intellectual confidence trick of the twentieth century and a terminal product as well—something akin to a dinosaur or zeppelin in the history of ideas, a vast structure of radically unsound design and with no posterity.

— Sir Peter B. Medawar

The biggest animal that has ever lived on our planet: a blue whale. … It’s far bigger than even the biggest dinosaur. Its tongue weighs as much as an elephant. Its heart is the size of a car. And some of its blood vessels are so wide that you could swim down them.

— Sir David Attenborough

5 Most Impactful Inventions That Changed the World:

- **Telephone:** An instrument designed for the simultaneous transmission and reception of the human voice.
- **Electricity:** The presence and flow of electric charge.
- **Airplane:** A vehicle designed for air travel that has wings and one or more engines that enable it to fly through the air.
- **Light bulb:** A device used to convert electricity into light.
- **World Wide Web:** The leading information retrieval service of the Internet.

10 Discoveries That Changed The Archaeological World:

Pompeii

Pompeii, preserved ancient Roman city in Campania, Italy, that was destroyed by the violent eruption of Mount Vesuvius in 79 CE.

Tutankhamun's Tomb

Tutankhamun, commonly referred to as **King Tut**, was an ancient Egyptian pharaoh who was the last of his royal family to rule during the end of the 18th Dynasty during the New Kingdom of Egyptian history.

Rosetta Stone

The Rosetta Stone was found broken and incomplete. It features 14 lines of hieroglyphic script: Detail of the hieroglyphs, including a cartouche featuring the name Ptolemy (written right to left, along with an Egyptian honorific).

Terracotta Army

A collection of terracotta sculptures depicting the armies of Qin Shi Huang, the first Emperor of China.

King Richard III's grave

Richard III was King of England and Lord of Ireland from 1483 until his death in 1485. He was the last king of the House of York and the last of the Plantagenet dynasty.

Olduvai Gorge

The most important fossil sites in the world that holds the earliest evidence of the existence of human ancestors.

Cave of Altamira

The first Palaeolithic cave art featuring charcoal drawings and polychrome paintings of contemporary local fauna and human hands.

Dead Sea Scrolls

A collection of 800 ancient Jewish and Hebrew religious manuscripts found in 11 caves just 2km inland from the Dead Sea and in the vicinity of Khirbet Qumran, an ancient settlement in the West Bank.

Easter Island Moai

1,000 extant monumental statues (Moai) carved by the early Rapa Nui people on Easter Island in eastern Polynesia.

Staffordshire Hoard

The largest collection of Anglo-Saxon gold and silver metalwork found by a metal detectorist buried underneath a farmer's field in Staffordshire, UK, in 2009.

10 Great Biological Discoveries:

- **Antibiotics (1928):** Medicines that fight bacterial infections in people and animals.
- **Gel Electrophoresis (1931):** Technique used to separate DNA fragments according to their size.
- **The Structure of DNA (1952–1953)**
- **DNA Polymerase (1956):** Enzyme that catalyses the synthesis of DNA during replication.
- **Reverse transcriptase (1970):** Enzyme encoded from the genetic material of retroviruses that catalyzes the transcription of retrovirus RNA into DNA.
- **Restriction enzymes (1970):** DNA-cutting enzymes.
- **Polymerase Chain Reaction (1983):** Technique used to make numerous copies of a specific segment of DNA quickly and accurately.
- **Gene Therapy (1990):** Technique that modifies a person's genes to treat or cure disease.

- **RNA interference (1998):** Process of inhibiting gene expression by neutralizing the targeted mRNA molecules.
- **CRISPR-Cas9 (2012):** Genome editing technology.

> Archimedes was not free from the prevailing notion that geometry was degraded by being employed to produce anything useful. It was with difficulty that he was induced to stoop from speculation to practice. He was half ashamed of those inventions which were the wonder of hostile nations, and always spoke of them slightingly as mere amusements, as trifles in which a mathematician might be suffered to relax his mind after intense application to the higher parts of his science.
>
> **— Lord Thomas Macaulay**

Top 12 Engineers Who Shaped World History:

Nikola Tesla	Serbian-American inventor best known for his contributions in the fields of electromagnetism and wireless radio communications
Thomas Edison	American inventor primarily known for inventing the light bulb
Henry Ford	American engineer and industrialist who founded the Ford Motor Company
Archimedes	Greek mathematician who invented the sciences of mechanics and hydrostatics
Nikolaus Otto	German inventor who is credited with the development of the four stroke engine
George Stephenson	British engineer who built the first public intercity railway line in the world
Leonardo da Vinci	Italian polymath who is known for his designs of flying objects

	such as hang gliders
Wright Brothers	American aviation pioneers generally credited with inventing, building, and flying the world's first successful motoroperated airplane
James Watt	Scottish engineer whose steam engine contributed substantially to the Industrial Revolution
Isambard Kingdom Brunel	English civil engineer who is responsible for building bridges and also the first major British railway
Benjamin Franklin	American statesman best known for his invention of the lightning rod
Imhotep	The first civil engineer in the world on record who is known for designing and supervising the step **Pyramid of Djoser**

13 pioneering women in science history:

- **Marie-Anne Paulze Lavoisier** (The Mother of Modern Chemistry): Significant contributor to the understanding of chemistry in the late 1700s.
- **Henrietta Swan Leavitt:** Discovered the relation between the luminosity and the period of Cepheid variable stars.
- **Bertha Parker Pallan Cody:** The first Native-American woman archaeologist.
- **Rosalind Franklin:** British chemist whose X-ray diffraction studies provided crucial clues to the structure of DNA and quantitatively confirmed the Watson-Crick DNA model.
- **Alice Ball:** Black chemist who revolutionized the treatment for leprosy in the early 20^{th} century.
- **Chien-Shiung Wu:** Chinese-American particle and experimental physicist who made significant contributions in the fields of nuclear and particle physics.
- **Barbara McClintock:** Best known for discovering genetic transposition ("jumping genes").

- **Maria Sibylla Merian:** German-born naturalist and nature artist known for her illustrations of insects and plants.
- **Caroline Herschel:** The first woman to discover a comet.
- **Katherine Johnson:** One of the first African-American women to work as a NASA scientist.
- **Marie Curie:** Polish Chemist known for her discovery of radium and polonium, and her huge contribution to finding treatments for cancer.
- **Lise Meitner:** Pioneering physicist who was part of a team that discovered nuclear fission.
- **Marie Tharp:** American geologist who revolutionized our knowledge of the seafloor.

Life-Changing Scientific Discoveries:

- **The Copernican System:** The Sun lay at the centre of the Solar System with the planets orbiting around it.
- **The law of universal gravitation:** $F_G = \frac{GMm}{r^2}$
- **The theory of evolution:** All species are related and gradually change over time.
- **Pasteurization:** The process of heating and cooling food to kill bacteria.
- **The Theory of Relativity:** $E=Mc^2$
- **The Big Bang Theory:** The universe as we know it started with a small singularity, then inflated over the next 13.8 billion years to the gigantic cosmos that we know today.
- **Penicillin:** Antibiotic used to treat a wide range of bacterial infections.
- **DNA:** The molecule that carries genetic instructions in all living things.
- **Periodic Table:** The organized array of all the chemical elements in order of increasing atomic number.
- **X-Rays:** A very energetic form of electromagnetic radiation that can be used to take images of the human body.
- **Quantum Theory:** Description of the physical properties of nature at the scale of atoms and subatomic particles.

- **Atomic Bomb:** An explosive device that derives its destructive force from nuclear reactions.
- **HIV virus:** A virus that attacks the body's immune system.
- **Electricity:** The presence and flow of electric charge.

Top 10 Indian Mathematicians:

- **Aryabhata** was the primary individual to say that the Earth is round and it spins around the sun and expressed the right number of days in a year that is 365.
- **Brahmagupta** was the first to give rules to compute with zero. He also explained how to find the cube and cube-root of an integer and gave rules facilitating the computation of squares and square roots.
- **Srinivasa Ramanujan** was one of India's greatest mathematical geniuses. His chief contribution in mathematics lies mainly in number theory, elliptic functions, continued fractions, partial sums, products of hypergeometric series and infinite series.
- **Prasanta Chandra Mahalanobis** was an Indian scientist and statistician. He is best remembered for the Mahalanobis distance, a statistical measure, and for pioneering studies in the field of anthropometry.
- **C. R. Rao** is a very distinguished scientist and a highly eminent statistician of our time, famous for his "theory of estimation ".
- **D. R. Kaprekar** was an Indian recreational mathematician who described several classes of natural numbers including the Kaprekar, Harshad and self-numbers and discovered the Kaprekar constant, named after him.
- **Harish-Chandra** was an Indian American mathematician and physicist who did fundamental work in representation theory, especially harmonic analysis on semisimple Lie groups.
- **Satyendra Nath Bose** was an Indian mathematician and theoretical physicist. He was a legendary figure of science in the 20th century in India with his revolutionary discovery on the nature of radiation.

- **Bhaskaracharya,** an Indian astronomer, and mathematician helped to disseminate the mathematical work of Aryabhata. He was the one who declared that any number divided by zero is infinity and that the sum of any number and infinity is also infinity.
- **Narendra Karmarkar** is an Indian mathematician who invented one of the first provably polynomial time algorithms for linear programming, which is generally referred to as an interior point method.

Top 10 NASA Inventions You Use Everyday:

- **Water filter**: A device for removing unwanted substances such as bacteria or harmful chemicals from drinking.
- **Cordless tools:** A small electronic device or power tool that doesn't have a cord and a plug for an electrical outlet, but instead is powered by a battery.
- **Safety grooving:** A floor traction control solution − developed specifically to minimize hydroplaning and skidding.
- **Adjustable smoke detector:** A device that senses smoke − typically as an indicator of fire.
- **Long distance telecommunications:** The ability to communicate over a long distance.
- **Shoe insoles:** A loose thin strip placed inside a shoe for warmth or comfort.
- **Ear thermometer:** A thermometer that registers body temperature via the ear canal.
- **Memory foam:** Visco-elastic foam that tends to hold on to the imprint of any pressure exerted for several seconds.
- **Scratch resistant lenses:** Lens that is more resistant to scratching.
- **Invisible braces:** Orthodontic aligners that help straighten human teeth.

Plan

Strategic plan: define the framework of the organization's vision and how the organization intends to make its vision a reality.

Tactical plan: define the tactics that the managers plan to adopt to achieve the objectives set in the strategic plan.

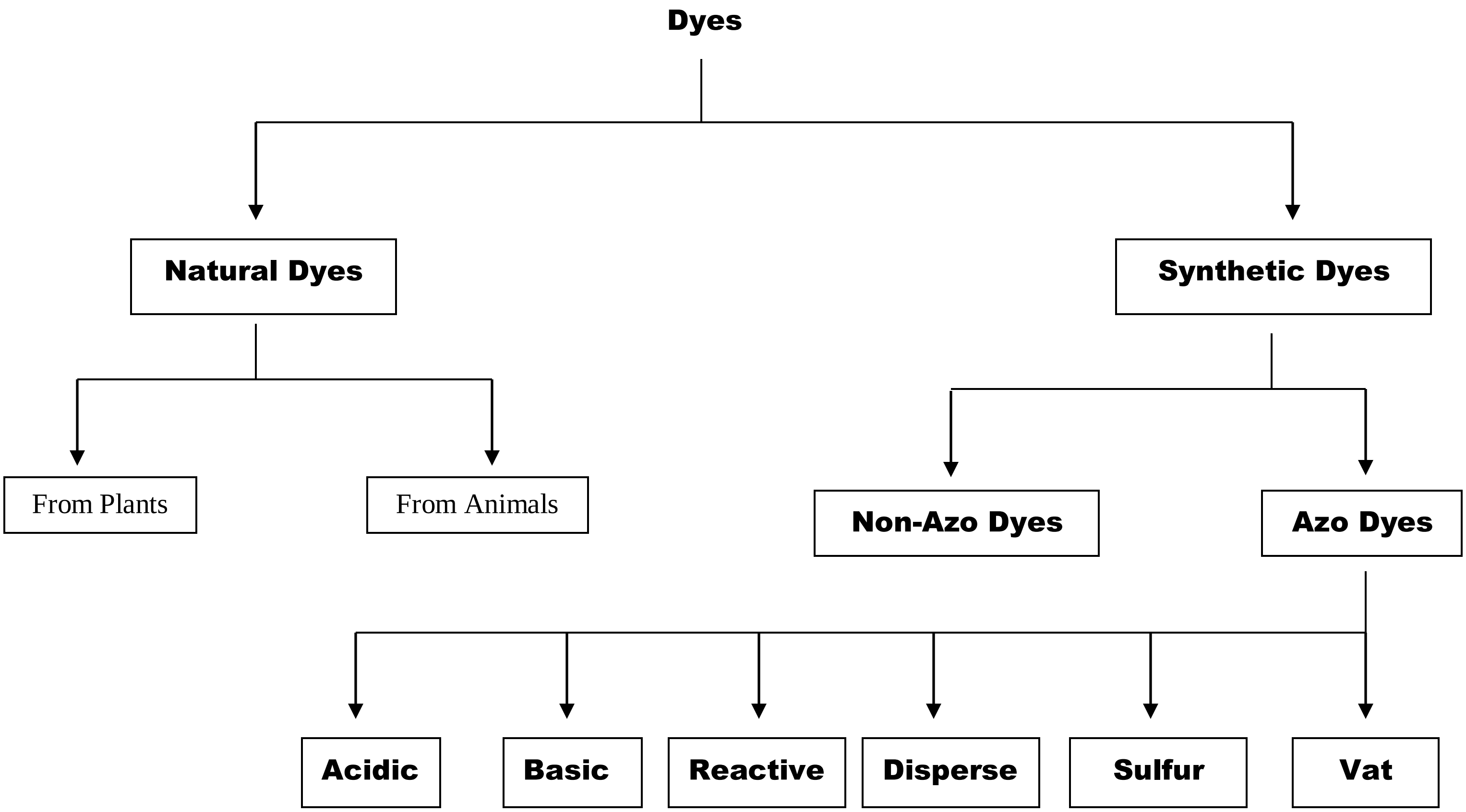
Operational plan: developed to create specific action steps that supports the strategic and tactical plans.

4 Characteristics of entrepreneurship

- Creativity and innovation
- Risk-taking ability
- Profit-making
- Economic activity

Stock market bubbles don't grow out of thin air. They have a solid basis in reality, but reality as distorted by a misconception.

George Soros



Oviparous Animals	Viviparous Animals
Lay unfertilized or fertilized eggs	Give live birth and do not lay eggs
Fish, amphibians, insects, birds, reptiles	Humans, dogs, elephants, cats

Inhalation	Exhalation
Intake of air into the lungs	Expelling air out of the lungs

Transgenesis

↓

The process of introducing a gene from one organism into the genome of another organism

Communicable Diseases (Contagious)	**Non-communicable diseases** (Non-contagious)
diseases that can pass from person to person through the air, water, bodily fluids, etc.	diseases that does not spread from one person to another via any kind of mode.
• Ebola • Enterovirus D68 • Flu • Hantavirus • Hepatitis A • Hepatitis B	• cardiovascular diseases (such as heart attacks and stroke) • cancers • chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) • diabetes

The advance of genetic engineering makes it quite conceivable that we will begin to design our own evolutionary progress.

ISAAC ASIMOV

Can genetic engineers restore a rapid worldwide rise in grainland productivity? This prospect is not promising simply because plant breeders using traditional techniques have largely exploited the genetic potential for increasing the share of photosynthate that goes into seed. Once this is pushed close to its limit, the remaining options tend to be relatively small, clustering around efforts to raise the plant's tolerance of various stresses, such as drought or soil salinity. One major option left to scientists is to increase the efficiency of the process of photosynthesis itself--something that has thus far remained beyond their reach.

Lester R. Brown

List of Nonmetals:

Atomic Number	Symbol	Nonmetal Element
1	H	Hydrogen
2	He	Helium
6	C	Carbon
7	N	Nitrogen
8	O	Oxygen
9	F	Fluorine
10	Ne	Neon
15	P	Phosphorus
16	S	Sulfur
17	Cl	Chlorine
18	Ar	Argon
34	Se	Selenium
35	Br	Bromine
36	Kr	Krypton
53	I	Iodine
54	Xe	Xenon
85	At	Astatine
86	Rn	Radon
117	Ts	Tennessine
118	Og	Oganesson

- **Helium** (He)
- **Neon** (Ne)
- **Argon** (Ar)
- **Krypton** (Kr)
- **Xenon** (Xe)
- **Radon** (Rn)

Noble Gases

Group 18 elements

Exhibits extremely inert chemical behavior

Uses of Noble Gases:

- Helium is used for cryogenics.
- Argon is used to create inert atmosphere.
- Neon is used in lasers and wave meter tubes.
- Krypton is used in tubes of fluorescent lights.
- Xenon is used in photographic flashes and NMR Spectroscopy.
- Radon is used for treatment of Tumors.

- Silicon
- Boron
- Germanium
- Arsenic
- Antimony
- Tellurium

Metalloids

Elements which possess intermediate (physical and chemical) properties to that of metals as well as non metals

Metals are the great agents by which we can examine the recesses of nature; and their uses are so multiplied, that they have become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient to the progress of the human mind towards perfection. They differ so much from each other, that nature seems to have had in view all the necessities of man, in order that she might suit every possible purpose his ingenuity can invent or his wants require.

John Shepard

Metals	Non-metals
Metals are solids at room temperature except mercury	Non-metals exist in all three states
Metals are very hard except sodium	Non-metals are soft except diamond
Metals are malleable and ductile	Non-metals are brittle and can break down into pieces
Metals are shiny	Non-metals are non-lustrous except iodine
Electropositive in nature	Electronegative in nature
Have high densities	Have low densities

Corrosion of iron → rusting

Prevented by

- Painting
- Galvanization
- Tin-plating and chromium-plating
- Alloying
- Applying grease or oil

Enhanced by

- Presence of air (**oxygen**)
- Presence of water (**moisture**)
- Presence of pollutants (**NO_2 and CO_2**)

Ideal gas	Real gas
No definite volume	Definite volume
Elastic collision of particles	Non-elastic collisions between particles
No intermolecular attraction force	Intermolecular attraction force
Does not really exists in the environment	Really exists in the environment

For the evolution of science by societies the main requisite is the perfect freedom of communication between each member and anyone of the others who may act as a reagent.

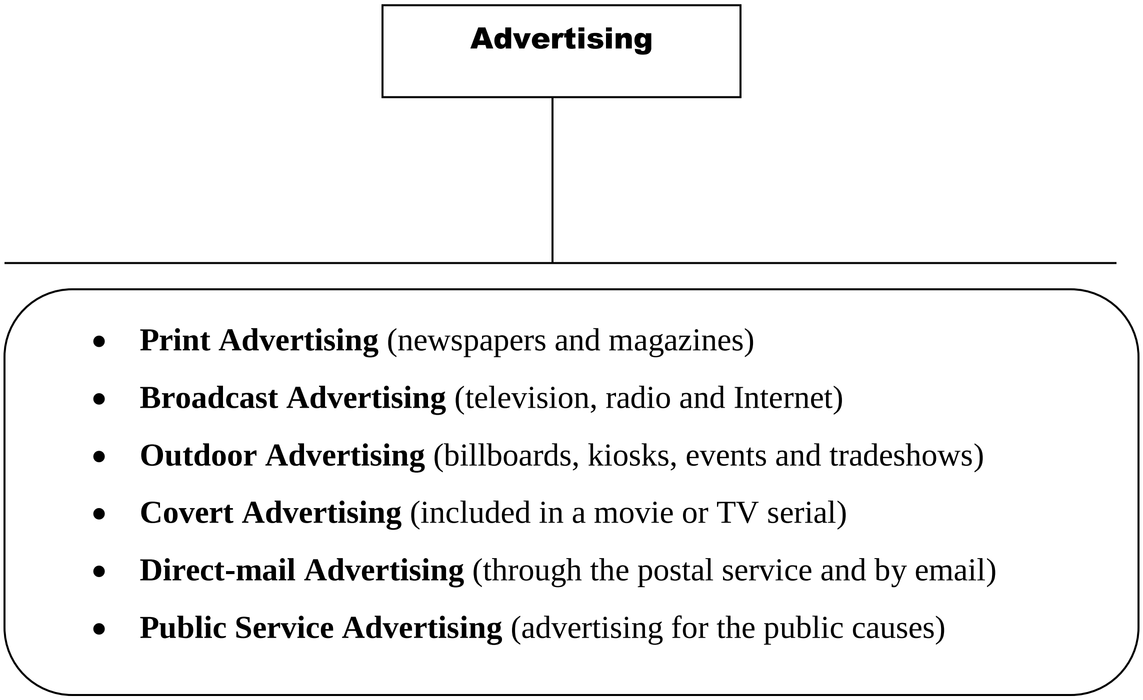
The gaseous condition is exemplified in the soiree, where the members rush about confusedly, and the only communication is during a collision, which in some instances may be prolonged by button-holing.

The opposite condition, the crystalline, is shown in the lecture, where the members sit in rows, while science flows in an uninterrupted stream from a source which we take as the origin. This is radiation of science. Conduction takes place along the series of members seated round a dinner table, and fixed there for several hours, with flowers in the middle to prevent any cross currents.

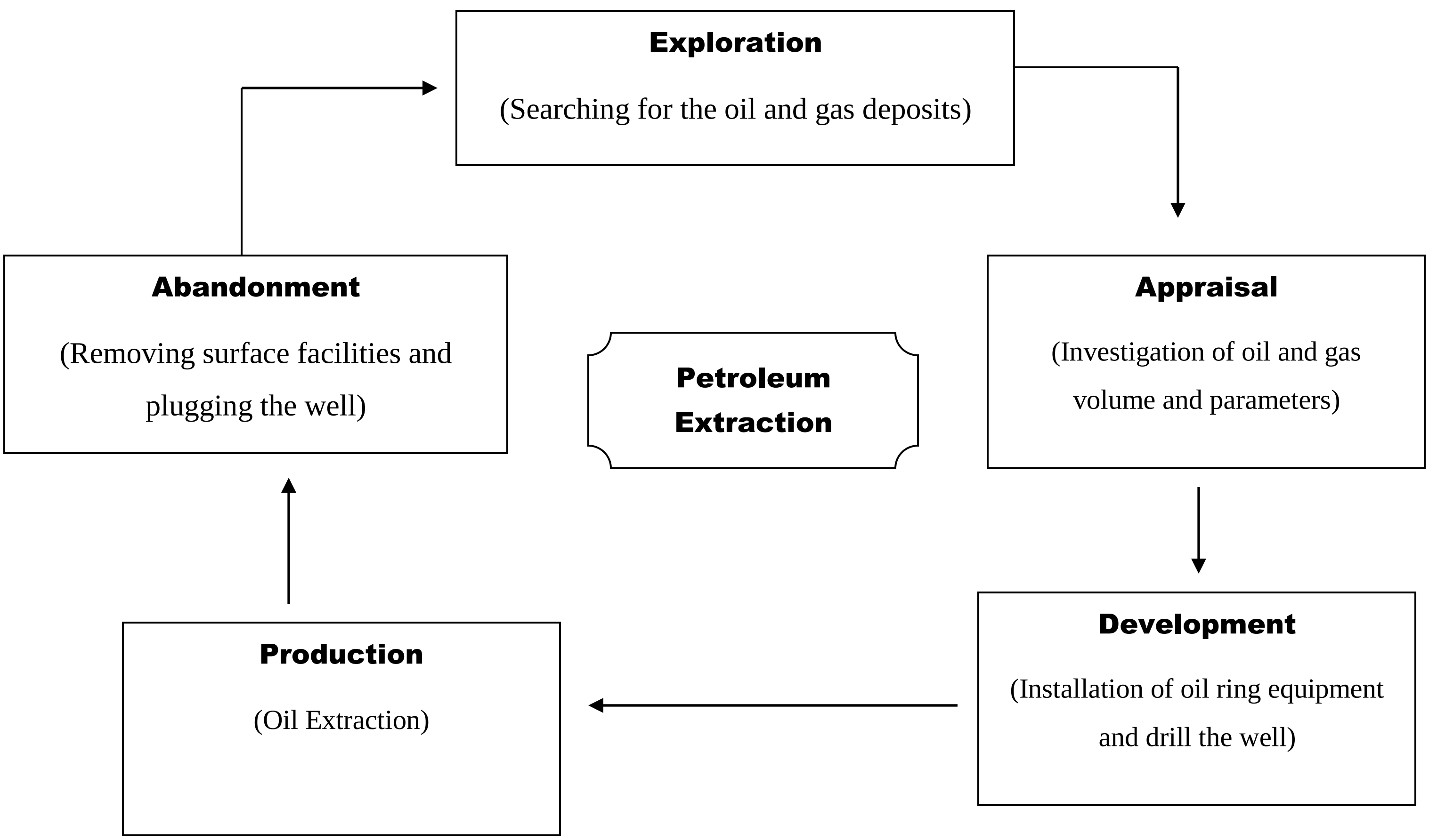
The condition most favorable to life is an intermediate plastic or colloidal condition, where the order of business is (1) Greetings and confused talk; (2) A short communication from one who has something to say and to show; (3) Remarks on the communication addressed to the Chair, introducing matters irrelevant to the communication but interesting to the members; (4) This lets each member see who is interested in his special hobby, and who is likely to help him; and leads to (5) Confused conversation and examination of objects on the table.

I have not indicated how this programme is to be combined with eating.

— James Clerk Maxwell



Advertising
Print Advertising (newspapers and magazines)
Broadcast Advertising (television, radio and Internet)
Outdoor Advertising (billboards, kiosks, events and tradeshows)
Covert Advertising (included in a movie or TV serial)
Direct-mail Advertising (through the postal service and by email)
Public Service Advertising (advertising for the public causes)



Exploration
(Searching for the oil and gas deposits)
Appraisal
(Investigation of oil and gas volume and parameters)
Development
(Installation of oil ring equipment and drill the well)
Production
(Oil Extraction)
Abandonment
(Removing surface facilities and plugging the well)
Petroleum Extraction

"0" or "1" **State** Classical Computers (digital bits)	"0" and "1" **State** Quantum Computers (quantum bits)

Everything, however complicated - breaking waves, migrating birds, and tropical forests - is made of atoms and obeys the equations of quantum physics. But even if those equations could be solved, they wouldn't offer the enlightenment that scientists seek. Each science has its own autonomous concepts and laws.

Martin Rees

Quantum Computers	Classical Computers
Calculates with qubits, which can represent 0 and 1 at the same time	Calculates with transistors, which can represent either 0 or 1
Have high error rates and need to be kept ultracold	Have low error rates and can operate at room temperature
Well suited for tasks like optimization problems, data analysis and simulations	Most everyday processing is best handled by classical computers

7 primary odors:

- **Musky** – perfumes
- **Putrid** – rotten eggs
- **Pungent** – vinegar
- **Camphoraceous** – mothballs
- **Ethereal** – dry cleaning fluid
- **Floral** – roses (floral scent)
- **Pepperminty** – mint gum

- The more water soluble a pesticide is, the greater the potential for runoff and leaching.
- The more volatile a pesticide is, the greater the potential for **pesticide drift** (unintentional diffusion of pesticides).

Pesticide

Herbicide

(Used to kill weeds)

Insecticide

(Used to kill insects)

Rodenticide

(Used to kill rodents)

Nematicide

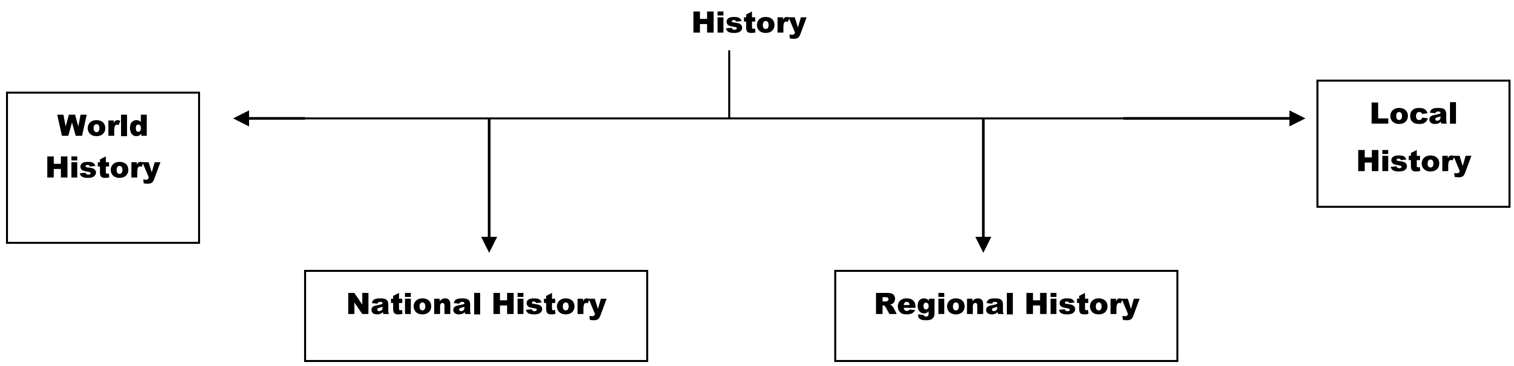
(Used to kill nematodes)

Molluscicide

(Used to kill molluscs)

Training of farmers in integrated pest management is exceedingly important to protect them during the use of pesticides.

M. S. Swaminathan



- Mercury and Venus are the only two planets in our solar system that orbit closest to the Sun and have no moons
- The hottest planet in our solar system is Venus and is named after the Roman goddess of love and beauty.

> Almost always the men who achieve these fundamental inventions of a new paradigm have been either very young or very new to the field whose paradigm they change.
>
> **— Thomas S. Kuhn**

- A light-year is the unit of length used to express astronomical distances and is the distance covered by light in a single year and is equal to 9.46×10^{12} km.
- The Sun accounts for 99.86% of the mass in the solar system and weighs about 330,000 times more than Earth.
- Our solar system is 4.568 billion years old formed from the gravitational collapse of a giant interstellar molecular cloud.
- The highest mountain discovered is the Olympus Mons, which is an enormous shield volcano on the planet Mars.
- Because of lower gravity, a person who weighs 100kg on Earth would only weigh 38 kg on the surface of Mars.

- The Sun has a north and south pole, just as the Earth does, and makes a full rotation once every 25 – 35 days.
- Earth is the third planet from the Sun and the only planet not named after a God.
- The surface of Venus is dominated by volcanic features and has more volcanoes than any other planet in the Solar System.
- Uranus ' blue glow is due to the cold methane gas in its atmosphere.
- In our solar system that are 4 planets which don't have hard surfaces and instead have swirling gases above a solid core − known as gas giants: Jupiter, Saturn, Uranus and Neptune.
- Uranus is an Ice Giant planet and nearly four times larger than Earth and has 27 moons that have been discovered so far.
- A photon of energy $h\upsilon = mc^2$ generated at the center of the star makes its way to the surface. It may take up to several million years to get to the surface.
- Because of its unique tilt, each season on Uranus lasts 21 earthly years and makes a huge difference between winter-summer and autumn-spring.
- Triton is the largest of Neptune's 13 moons and orbits the planet backwards.
- There are more stars in space than there are grains of sand in the world and there exist roughly 10,000 stars for each grain of sand on Earth.
- As photon travel near the event horizon of a black hole they can still escape being pulled in by gravity of a black hole by traveling at a vertical direction known as exit cone. A photon on the boundary of this cone will not completely escape the gravity of the black hole. Instead it orbits the black hole.
- Neptune is 17 times the mass of Earth and takes nearly 165 Earth years to make one orbit of the Sun.
- Pluto's largest moon, **Charon** − also known as Pluto I, is half the size of the dwarf planet Pluto.
- A day on Pluto is 6.4 Earth days or 153.3 hours long.
- Saturn is the second largest planet in our solar system and a gas giant with an average radius of about nine times that of Earth.

- The inner planets or rocky and terrestrial planets − Mercury, Venus, Earth and Mars are the four planets that orbit closest to the Sun.
- Only 5% of the universe is visible from Earth.
- It takes sunlight an average of 8 minutes and 20 seconds to travel from the Sun to the Earth.
- There are three main types of galaxies: elliptical, spiral and irregular.
- There are about 100 thousand million stars in the Milky Way alone.
- The Andromeda Galaxy is a barred spiral galaxy approximately 2.5 million light-years from Earth and the nearest major galaxy to the Milky Way.
- The warp and twist of space-time near the earth. The Moon follows this warp of spacetime as it orbits Earth.

> To make the moral achievement implicit in science a source of strength to civilization, the scientist will have to have the cooperation also of the philosopher and the religious teacher.
>
> **Arthur Compton**

- The astronomical unit is a unit of length, roughly the distance from Earth to the Sun and equal to about 150 million kilometers (93 million miles) or ~8 light minutes.
- Astronauts can grow approximately two inches (5 cm) in height when in space.
- Kuiper belt is a region of the Solar System extending from the orbit of Neptune (at 30 AU) to approximately 50 AU from the Sun (consists mainly of small bodies or remnants from the Solar System's formation).
- **Exoplanets** or extrasolar planets are planets that orbit around other stars.
- The Enormous dust cloud at the center of the Milky Way smells like rum and tastes like raspberries.
- Our only proper natural satellite moon is being pushed away from Earth by 1.6 inches (4 centimeters) per year.
- Saturn is the only planet that is lighter than water.

- Asteroids are the rocky planetoids revolving around the sun and the byproducts of formations in the solar system − more than 4 billion years ago.
- The Earth weighs about 81 times more than the Moon. The moon's density is 3.34 grams per cubic centimeter. That is about 60 percent of Earth's density.
- Mercury is the hottest planet in our solar system and has no atmosphere − which means there is no wind or weather.
- There are 88 recognized star constellations in our night sky.
- Due to the Sun and Moon's gravitational pull, we have tides.
- The five best known dwarf planets in our Solar System are: Ceres, Pluto, Makemake, Haumea and Eris.
- Mars is the second-smallest planet in the Solar System and the most likely planet (which carries the name of the Roman god of war) in our solar system to be hospitable to life.
- Pluto is smaller than Earth's moon and is only half as wide as the United States.
- Astronaut's footprint can last a million years on the surface of the moon as there is no wind.
- There are 79 known moons orbiting Jupiter.
- Most part of the atom is empty.

Quantum mechanics (the theory of subatomic physics and one of the most successful theories of all time) is based on three principles:

- Energy is found in discrete packets called **quanta**.
- Matter is based on point particles but the probability of finding them is given by a wave, which obeys the **Schrödinger wave equation**.
- A measurement is necessary to collapse the wave and determine the final state of an object.

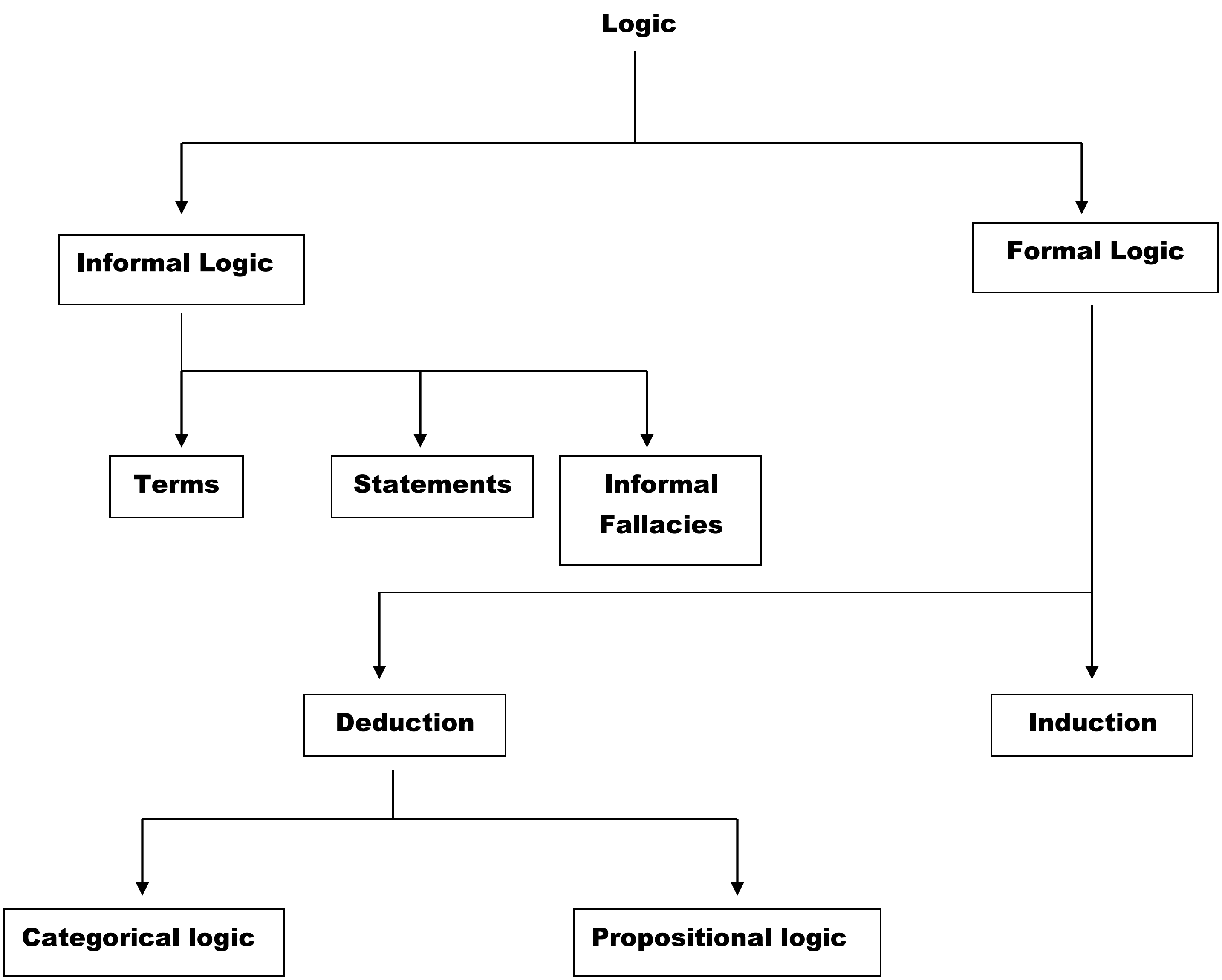
- Linking the two chains in the DNA, are pairs of nucleic acids (purines + pyrimidines). There are four types of nucleic acid, adenine "A", cytosine "C", guanine "G", and thiamine "T." An adenine (purine) on one chain always matches with a thiamine (pyrimidine) on the other chain, and a guanine (purine) with a cytosine (pyrimidine). Thus DNA exhibits all the properties of genetic material, such as replication, mutation and recombination. Hence, it is the **molecule of life**.

An iron rod being placed on the outside of a building from the highest part continued down into the moist earth, in any direction strait or crooked, following the form of the roof or other parts of the building, will receive the lightning at its upper end, attracting it so as to prevent it's striking any other part; and, affording it a good conveyance into the earth, will prevent its damaging any part of the building.

— Benjamin Franklin

About ten months ago [1609] a report reached my ears that a certain Fleming [**Hans Lippershey**] had constructed a spyglass, by means of which visible objects, though very distant from the eye of the observer, were distinctly seen as if nearby... Of this truly remarkable effect several experiences were related, to which some persons gave credence while others denied them. A few days later the report was confirmed to me in a letter from a noble Frenchman at Paris, **Jacques Badovere**, which caused me to apply myself wholeheartedly to enquire into the means by which I might arrive at the invention of a similar instrument. This I did shortly afterwards, my basis being the theory of refraction. First I prepared a tube of lead, at the ends of which I fitted two glass lenses, both plane on one side while on the other side one was spherically convex and the other concave.

— Galileo Galilei



Logic is the beginning of wisdom, not the end.

Leonard Nimoy

Nature is the source of all true knowledge. She has her own logic, her own laws, she has no effect without cause nor invention without necessity.

Leonardo da Vinci

Relativity:

- Moving clocks run slow.
- Moving objects appear shorter.
- Moving object's mass increases.

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

The Patent Office had never seen a year like 1897. An average of 60 patents was being granted Everyday.

If electron is "orbiting", it's accelerating

Accelerating charges emit electromagnetic radiation (energy)

Loss of energy would cause prompt decay of Electron's orbit

- masses ~ 1kg; velocities ~1 m/s $\rightarrow p = mv \approx 1$ kg·m/s
- $\lambda \approx 10^{-34}$ meters (too small!!)

The idea of **duality** is rooted in a debate over the nature of light and matter dating back to the 1600s, when competing theories of light were proposed by Huygens and Newton.

Photoelectric Effect (1887−1905)

$\boxed{KE = h\upsilon - W}$

Discovered by Hertz in 1887 and explained in 1905 by Albert Einstein.

Chemistry is nothing but an application of
Schrödinger Equation (**Dirac**).

J.J. Thomson won the Nobel Prize for Physics in 1906 for demonstrating that the electron is a particle.

With extra dimensions, gravity becomes stronger, **micro black holes** can be created in particle collisions!

"The only way of discovering the limits of the possible is to venture a little way past them into the impossible."

Arthur C. Clarke (1917−2008)

Physical constants → **Small change makes life impossible!**

3 Great Ages of prehistoric time:

- **Stone Age**
- **Bronze Age**
- **Iron Age**

Divided into 3 periods

- **Paleolithic period** (**Lower Stone Age**): First stone tools and weapons were invented, discovered fire from stones for cooking, warmth and protection from animals.
- **Mesolithic period** (**Middle Stone Age**): Bow and arrows were invented to hunt animals, pottery was introduced, domestication of goats and sheep.
- **Neolithic period** (**Upper Stone Age**): Cereal cultivation and experimentation with metals was introduced, mastered weaving, domestication of pigs, chickens, cows and many other animals.

Bronze (**an alloy of tin and copper**) tools and weapons replaced stone versions

Tools and weapons were mainly made of iron or steel

The concept evidence in the **forensic science**

Evidence

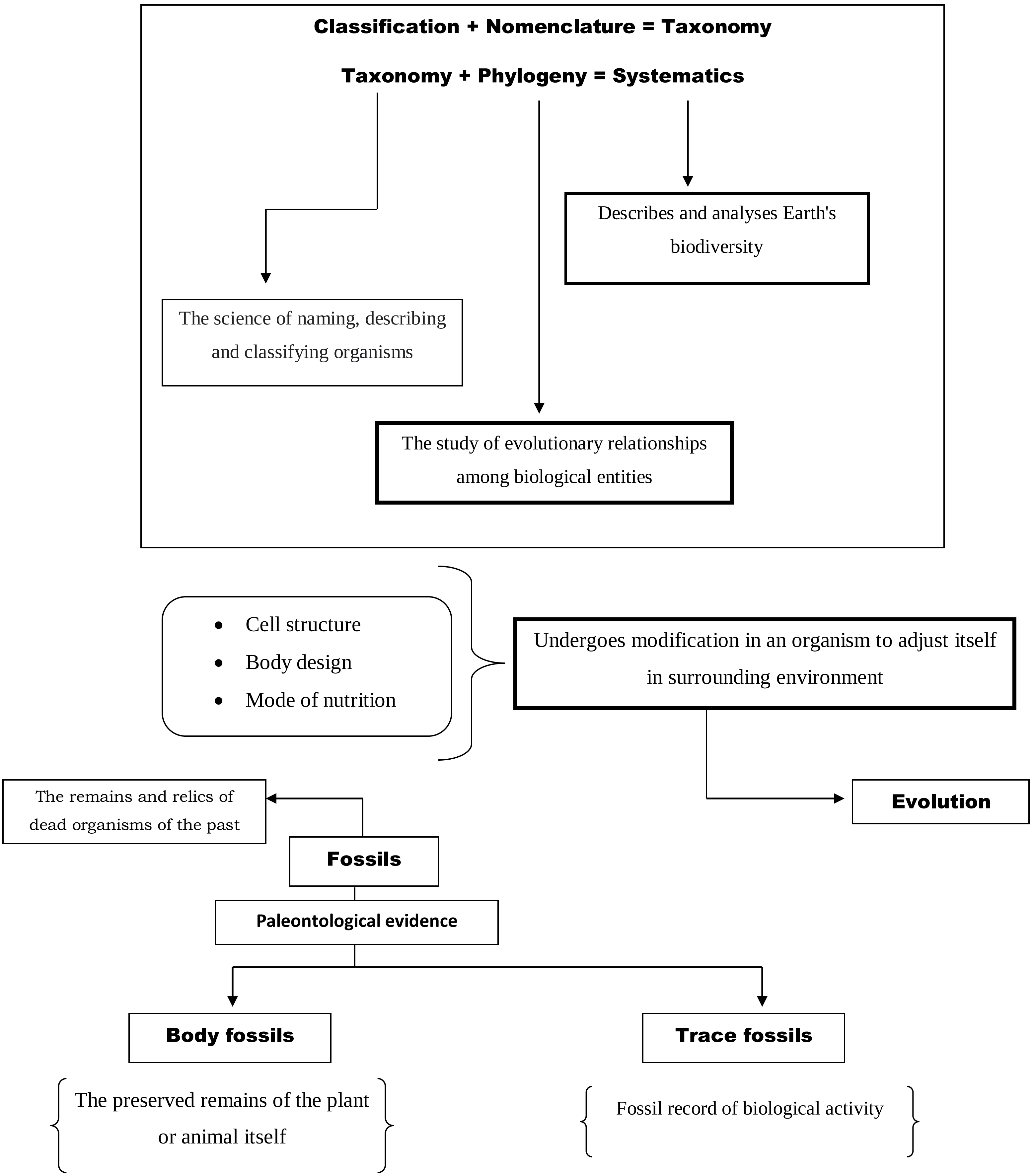
Trace evidence

Blood

Fiber

- Inorganic fiber
- Manufactured polymeric fiber
- Dye fiber

DNA


Classification + Nomenclature = Taxonomy
Taxonomy + Phylogeny = Systematics
Describes and analyses Earth's biodiversity
The science of naming, describing and classifying organisms
The study of evolutionary relationships among biological entities
Cell structure
Body design
Mode of nutrition
Undergoes modification in an organism to adjust itself in surrounding environment
Evolution
The remains and relics of dead organisms of the past
Fossils
Paleontological evidence
Body fossils
Trace fossils
The preserved remains of the plant or animal itself
Fossil record of biological activity

Chemical Bonds

Primary

(Strong bonds)

- Ionic Bonds
- Covalent Bonds
- Metallic Bonds

Bond energy > 42 kJ/mol

Secondary

(Weak bonds)

- Hydrogen Bonds
- Van der Waals Bonds

Bond energy < 42 kJ/mol

Systemic pathology

The study of disease pertaining to the specific organ and body systems

Plasma

Low temperature plasma

(Partially ionized gas)

Thermal plasma

Non-thermal plasma

High temperature plasma

(Fully ionized gas)

Dyson's eternal intelligence

A means by which an immortal society of intelligent beings in an open universe may escape the prospect of the **heat death of the universe** by extending subjective time to infinity even though expending only a finite amount of energy.

Partial impact theory

The partial collision of two stars and the temporary creation of a bright third star as a consequence

Helium planet

A planet with a helium-dominated atmosphere

Electroweak star

A compact stellar-mass object whose gravitational collapse is prevented by radiation pressure resulting from **electroweak burning** i.e., the energy released by conversion of quarks to leptons through the electroweak force

Preons

Hypothetical particles that have been proposed as the building blocks of quarks

Q-Star

A **hypothetical** type of a compact, heavy neutron star with an **exotic state of matter**

As stars continually fuse light elements into heavier ones − eventually there will be an extraordinary amount of iron isotopes. **Exotic quantum tunneling** will break through the iron at a subatomic level. This process, eventually, will give rise to **iron stars** — a hypothetical type of **compact stars** − their mass yet made almost entirely out of iron − that could occur in the universe in the extremely far future, after perhaps **10^{1500} years**.

Frozen star

The rate of hydrogen fusion in the core of such a star is believed to be so low that the star can have a surface temperature of around zero degrees Celsius – cold enough for ice clouds to form in the star's atmosphere.

Tidal disruption event

An **astronomical phenomenon** that occurs when a star passes too close to a compact object such as a supermassive black hole and is pulled apart by the black hole's tidal force – experiencing **Spaghettification**.

Thorne-Żytkow object

A theoretical type of hybrid star created when a dense neutron star is swallowed by a puffy red supergiant star

Interacting Galaxies	2 or more galaxies that are drawn toward each other by gravity
S-Type stars	Giant stars which have a roughly equal amount of Carbon and Oxygen in their atmosphere
Carbon Stars	Red giants which have more carbon in their atmosphere than oxygen
Flare stars	Stars that varies in brightness – sometimes by more than one magnitude– within a few minutes
Quasi-Star	A massive star that is thought to have existed soon after when the Universe was first created
Starburst galaxy	A galaxy undergoing an exceptionally high rate of star formation
Vampire Star	A star that sucks hydrogen and energy from a close and nearby star
Wolf-Rayet star	A hot massive star with a high rate of mass loss that no longer fuses hydrogen but fuses helium or more heavier elements such as nitrogen or carbon

A white dwarf is a stellar core remnant composed mostly of electron-degenerate matter that has burned through its nuclear fuel. Under certain conditions, a white dwarf's burnt-out core re-ignites; the core's subsequent explosion is known as a supernova. Some stars are thought to survive these explosions to become so-called **zombie stars**

Exocomets

Comets outside the Solar System

Exomoon

$\downarrow$

A moon that orbits a planet not in our solar system

Trans-Neptunian object

$\downarrow$

Any solar system minor planet that orbits the sun at a greater average distance than Neptune

Planet	Meaning	Type
Mercury	Messenger of the Gods	Rocky
Venus	Goddess of Love	Rocky
Earth	Unknown	Rocky
Mars	God of War	Rocky
Jupiter	King of Gods	Gas
Saturn	God of Time	Gas
Uranus	Father of Saturn	Gas
Neptune	God of the Sea	Gas
Pluto	God of Death	Dwarf

The Pressure of a Solar Wind:

- **Dynamic Pressure (P_D) =** ρv^2
- **Thermal Pressure (P_T) =** nk_BT
- **Magnetic Pressure (P_B) =** $\dfrac{B^2}{2\mu_0}$

where:

- $\rho \rightarrow$ mass density of solar wind
- $v \rightarrow$ velocity of solar wind
- $n \rightarrow$ number density of solar wind
- $T \rightarrow$ Temperature of solar wind
- $k_B \rightarrow$ Boltzmann constant
- $\mu_0 \rightarrow$ magnetic permeability constant
- $B \rightarrow$ solar wind's magnetic field strength

The Kinetic energy of a solar wind: $KE = \dfrac{3Nk_BT}{2}$

The solar wind's electric field strength: $E = B \times v$

Tachyonic antitelephone

A hypothetical device in theoretical physics that could be used to send signals into one's own past.

The rotational kinetic energy of a neutron star is given by:

$$K = \frac{I\omega^2}{2}$$

$$I = \frac{2MR^2}{5}$$

$$K \propto MR^2\omega^2$$

References:

- Gravitational Frequency Shifts for Photons and Particles by Jing-Gang Xie.
- Fundamentals of Physics by David Halliday.
- Concepts of Physics by H. C. Verma.
- Physics I For Dummies Paperback- June 17, 2011 by Steven Holzner.
- Physics II For Dummies Paperback- July 13, 2010 by Steven Holzner.
- Basic Physics by Nair.
- http://en.wikipedia.org/wiki/ Gravitational wave.
- Hand Book of Space Astronomy and Astrophysics by Martin V. Zombeck.
- Astrophysical concepts by Martin Harwit.
- What is the Strength of Gravity? Victor Stenger (Excerpted from The Fallacy of Fine Tuning, 2011).
- Stephen W. Hawking, A Brief History of Time: From the Big Bang to Black Holes (New York: Bantam, 1988).
- Sharma, A Physics Essays Volume 26, 2013.
- Newton, Isaac Mathematical Principles of Natural Philosophy, London, 1727, translated by Andrew Motte from the Latin.
- A.L.Erickcek, M Kamionkowski and Sean Carroll, Phys. Rev D 78 123520 2008.
- Sharma, A. Concepts of Physics (2006).
- Fadner, W. L. Am. J. Phys. Vol. 56 No. 2, February 1988.
- Einstein, A. Annalen der Physik (1904 & 1907).
- Arthur Beiser, Concepts of Modern Physics, 4th edition (McGraw-Hill International Edition, New York, 1987).
- BEYOND EINSTEIN: from the Big Bang to Black Holes (prepared by The Structure and Evolution of the Universe Roadmap Team).
- Alternatives to the Big Bang Theory Explained (Infographic) By Karl Tate.
- The Origin of the Universe by S.W. Hawking.
- The Beginning of Time by S.W. Hawking.
- A Universe from Nothing by Lawrence M. Krauss.
- The Origin and Creation of the Universe: A Reply to Adolf Grunbaum by WILLIAM LANE CRAIG.

- Weisskopf, Victor [1989]: 'The Origin of the Universe' New York Review of Books.
- The Grand Design by Stephen Hawking and Leonard Mlodinow.
- M. Planck, The Theory of Radiation, Dover (1959) (translated from 1906).
- Black Holes and Baby Universes and Other Essays by S.W. Hawking.
- David Griffiths, Introduction to elementary particles, Wiley, 1987. ISBN 0471-60386-4.
- Feynman, Leighton, and Sands, The Feynman Lectures on Physics, Addison-Wesley, Massachusetts, 1964. ISBN 0-201-02117-X.
- D.A. Edwards, M.J. Syphers, An introduction to the physics of high energy accelerators, Wiley, 1993. ISBN 0-471-55163-5.
- The Universe: the ultimate free lunch by Victor J Stenger (1989).
- BLACK HOLE MATH by National Aeronautics and Space Administration (NASA).
- Matter, Energy, Space and Time: Particle Physics in the 21st Century by Jonathan Bagger (2003).
- Quarks, Leptons and the Big Bang by Jonathan Allday.
- Cosmos by Carl Sagan.
- The Theory of Everything by S.W. Hawking.
- A Briefer History of Time by Stephen Hawking and Leonard Mlodinow.
- The Grand Design by Stephen Hawking and Leonard Mlodinow.
- Hawking SW 1993 Black Holes and Baby Universes (New York: Bantam).
- Relativity: The Special and General Theory by Albert Einstein (1916).
- Neutrinos: Ghosts of the Universe by Don Lincoln.
- The Feynman Lectures on Physics (Volume I, II and III) by Richard Feynman.
- The Evolution of the Universe edited by David L. Alles.
- The Universe: Size, Shape, and Fate by Tom Murphy (2006).
- Paul J. Steinhardt & Neil Turok (2007). Endless Universe: Beyond the Big Bang. New York: Doubleday.
- Carroll, Sean (2010). From Eternity to Here. New York: Dutton.
- Astronomy for beginners by Jeff Becan.
- PARALLEL WORLDS: A JOURNEY THROUGH CREATION, HIGHER DIMENSIONS, AND THE FUTURE OF THE COSMOS by Michio Kaku.
- Steven Weinberg, The First Three Minutes, 2nd ed., Basic Books, 1988.
- Hugh Ross, Creation and the Cosmos, NavPress, 1998.
- A Short History of Nearly Everything by Bill Bryson (2003).
- The Universe in a Nutshell by Stephen W. Hawking (2001).

- On the Radius of the Neutron, Proton, Electron and the Atomic Nucleus by Sha YinYue.
- What Energy Drives the Universe? − Andrei Linde.
- Endless Universe by Paul J. Steinhardt and Neil Turok.
- Greene, Brian. Elegant Universe. New York: Vintage, 2000.
- Davies, Paul. The Last Three Minutes. New York: Basic Books, 1994.
- Lederman, Leon M., and David N. Schramm. From Quarks to the Cosmos. New York: W. H. Freeman, 1989.
- Singh, Simon. Big Bang. New York: HarperCollins, 2004.
- Greene, Brian. Fabric of the Cosmos. New York: Vintage, 2005.
- FUNDAMENTAL UNSOLVED PROBLEMS IN PHYSICS AND ASTROPHYSICS by Paul S. Wesson.
- Griffiths, D. 1987. Introduction to Elementary Particles. Harper and Row, New York.
- What is the Strength of Gravity? Victor Stenger Excerpted from The Fallacy of Fine Tuning (2011).
- PHYSICS OF THE IMPOSSIBLE by Michio Kaku.
- EINSTEIN ' S COSMOS by Michio Kaku.
- Steven Weinberg, The Quantum Theory of Fields, Volume II: Modern Applications (Cambridge, UK: Cambridge University Press, 1996), ISBN 0521550025, LCCN 95002782, bibcode: 1996qtf..book W.
- Davies P (ed) 1989 The New Physics (Cambridge: Cambridge University Press).
- The Gravitational Universe by Prof. Dr. Karsten Danzmann; Horgan, John. The End of Science. Reading, Mass.: Addison-Wesley, 1996.
- The Origin of the Universe and the Arrow of Time by Sean Carroll; Weinberg, Steve. Dreams of a Final Theory: The Search for Fundamental Laws of Nature. New York: Pantheon Books, 1992.
- Robert M. Wald, Quantum Field Theory in Curved Space-time and Black Hole Thermodynamics (Chicago, Ill.: University of Chicago Press, 1994), ISBN 0226870251, LCCN 94011065.
- Gribbin J 1986 In Search of the Big Bang (London: Heinemann).
- Guth A H and Steinhardt P 1984 The inflationary universe Scientific American.
- The Little Book of String theory by Steven S. Gubser (2010).
- Nobel Lecture: From the Big Bang to the Nobel Prize and beyond by John C. Mather.
- It Must Be Beautiful: Great Equations of Modern Science by Graham Farmelo.
- Notes on Weinberg: The First Three Minutes by John R. Boccio.
- Krauss L M 1989 The Fifth Essence: The Search for Dark Matter in the Universe (New York:

Basic).

- Rindler W 1996 Introduction to Special Relativity (Oxford: Oxford University Press).
- HYPERSPACE: A Scientific Odyssey Through Parallel Universes, Time Warps, and the Tenth Dimension by Kaku.
- Change in Energy of Non-Spinning Black Holes w.r.t. the Change in Mass by Dipo Mahto, Rama
- Nand Mehta, Neeraj Pant, and Raj Kumar Sah.
- **Gravitational waves** from orbiting binaries without general relativity: a tutorial by **Robert C. Hilborn**

Source of information:

- https://www.wikipedia.org/

Every atom in your body came from a star that exploded. And, the atoms in your left hand probably came from a different star than your right hand. It really is the most poetic thing I know about physics: You are all stardust. You couldn't be here if stars hadn't exploded, because the elements - the carbon, nitrogen, oxygen, iron, all the things that matter for evolution and for life - weren't created at the beginning of time. They were created in the nuclear furnaces of stars, and the only way for them to get into your body is if those stars were kind enough to explode. So, forget Jesus. The stars died so that you could be here today.

– Lawrence Krauss