A Mathematician's Journey to the Edge of the Universe

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

— Socrates

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<center>What's the Ultimate Question?</center>

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 often get asked:

- What is Dark Matter? ...
- What is Dark Energy? ...
- What Came Before the Big Bang? ...
- What's Inside a Black Hole? ...
- Will the universe continue expanding? Will it just stop or even begin to contract?
- Are We Alone?

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:

  - **Big Bang:** The model describes how the universe expanded from a very high-density and high-temperature state, and offers a comprehensive explanation for a

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broad range of phenomena, including the abundance of light elements, the cosmic microwave background (CMB) radiation whose temperature at any redshift z is:

$T = 2.725 \pm 0.002 (1 + z)$ and, large-scale structure and Hubble's law (the farther away galaxies are, the faster they are moving away from Earth).

- o **Big Bounce:** It 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. 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.
- o **Spontaneous creation:** An interesting idea is that the universe could be spontaneously created from nothing and the problem of singularity can be avoided naturally.

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 by a factor of the order of 10^{26} over a time of the order of 10^{-33} to 10^{-32} seconds– Rapid expansion in which the universe cooled from about 10^{27} down to 10^{22} Kelvin, 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 h 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: $F_G = \dfrac{GMm}{r^{n-1}}$, 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: $F_E = \dfrac{Qq}{4\pi\varepsilon_0 r^{n-1}}$, 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 r^{n-1}. So in a 4 dimensional universe (3 spatial dimensions + one time dimension) forces are proportional to $\dfrac{1}{r^2}$; in the 10 dimensional universe (9 spatial dimensions + one time dimension) they're proportional to $\dfrac{1}{r^8}$. 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 $\dfrac{1}{r^8}$ or proportional to $> \dfrac{1}{r^8}$). 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 $= \dfrac{GMm}{r}$ (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 $\dfrac{1}{4}$ if one doubles the distance. In four dimensions it would drops to $\dfrac{1}{5}$, in five dimensions to $\dfrac{1}{6}$, 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.

$$e^+ + e^- \rightarrow 2\gamma$$

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 $E = mc^2$. 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: $E = 2h\upsilon = 2m_0c^2$ where m_0 is the rest mass of the electron or positron.

$$2h\upsilon = 2m_0c^2$$

Since $\upsilon = c/\lambda$. Therefore:

$$\lambda = \frac{h}{m_0c}$$

But $\frac{h}{m_0c} = \lambda_C$ (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).

$$m_0c^2 = k_BT_P$$

where: T_P imply the threshold temperature below which the electron or positron is effectively removed from the universe.

$$\lambda \times T_P = \frac{hc}{k_B} = c_2 \text{ (second radiation constant)}$$

$$\lambda_C \rightarrow \frac{h}{m_0c}$$

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.

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: $S = k_B$ ln {number of states} which, for N particles of the same type, will be:

$$S = k_B \ln \{(\text{no of one-particle states}) \, N\}$$

$$S = k_B \, N \ln \{\text{a not-too-big number}\}$$

$$S = k_B \, N$$

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 "$g = \dfrac{GM}{R^2}$" 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 and 10^{-20} times the diameter of a proton) = $\sqrt{\dfrac{G\hbar}{c^3}}$ = 1.6×10^{-33} centimeter.

For time: Planck time (represents a rough time scale at which quantum gravitational effects are likely to become important) = $\sqrt{\dfrac{G\hbar}{c^5}}$ = 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, Ω_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, Ω_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: $\dfrac{F_E}{F_G} = \dfrac{e^2}{4\pi\varepsilon_0 G m_p m_e}$, where e is the charge $= 1.602 \times 10^{-19}$ Coulombs, G is the gravitational constant, ε_0 is the absolute permittivity of free space $= 8.8 \times 10^{-12} \dfrac{F}{m}$, m_p is the mass of the proton $= 1.672 \times 10^{-27}$ kg and m_e is the mass of the electron $= 9.1 \times 10^{-31}$ kg. Plugging the values we get: $\dfrac{F_E}{F_G} = 10^{39}$ 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 $\dfrac{F_E}{F_G} = 10^{39}$ 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 $\dfrac{F_E}{F_G}$ 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., $\dfrac{F_E}{F_G} = 1$. Moreover, when the relativistic variation of electron mass with velocity is taken into account then the ratio $\dfrac{F_E}{F_G}$ 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 $\rightarrow$ 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

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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. Electromagnetism fundamentally determines all macroscopic, and many atomic levels, properties of the chemical elements, including all chemical bonding.

In a four kilogram (~1 gallon) jug of water there are 2.1×10^8 C of total electron charge. Thus, if we place two such jugs a meter apart, the electrons in one of the jugs repel those in the other jug with a force of 4.1×10^{26} N. This force is larger than the planet Earth would weigh if weighed on another Earth. The atomic nuclei in one jug also repel those in the other with the same force. However, these repulsive forces are canceled by the attraction of the electrons in jug A with the nuclei in jug B and the attraction of the nuclei in jug A with the electrons in jug B, resulting in no net force. Electromagnetic forces are tremendously stronger than gravity but cancel out so that for large bodies gravity dominates.

- **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

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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 $\alpha = \dfrac{e^2}{4\pi\hbar c\varepsilon_0}$ (where e is the charge $= 1.602 \times 10^{-19}$ Coulombs, ε_0 is the absolute permittivity of free space $= 8.8 \times 10^{-12}\dfrac{F}{m}$, 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 $\hbar$ 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.

Quantum field theory = {Group theory + quantum mechanics}

$\text{Lim}_{N \to \infty}$ Quantum mechanics = 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. Spontaneous births and deaths of roiling frenzy of particles so called virtual particles momentarily occurred everywhere, all the time − violated the Energy-momentum relationship: $E^2 = m_0^2c^4 + p^2c^2$ − is the conclusion that mass and energy are interconvertible; they are two different forms of the same thing. The word virtual particles literally mean that these particles are not observed directly, but their indirect effects are measured to a remarkable degree of accuracy. Their properties and consequences are well established and well understood consequences of quantum mechanics. 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 $T = \dfrac{\hbar c^3}{8\pi G M k_B}$) and they shrink and dissipate faster even before they are observed. Moreover, if a black hole has a mass less than the Planck mass ($2.176435(24) \times 10^{-8}$ kg $= \sqrt{\dfrac{\hbar c}{G}}$), its quantum mechanical size could be outside its event horizon. This wouldn't make sense, Planck mass is the smallest possible black hole.

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:

- $\alpha = 4.0015061$ amu

Total mass of products = $\alpha + \alpha = 2\alpha = 8.0030122$ 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 $E = mc^2$. However, the observed energy is 17.2 MeV.

Expected energy = 18.87 MeV (i.e., 0.02026875 amu $\times c^2$)

Experimentally observed energy = 17.2 MeV

Expected energy is $\neq$ 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. The mass m

in motion at speed v is the mass m$_0$ at rest divided by the factor $\sqrt{1 - \dfrac{v^2}{c^2}}$ implies: the mass of a particle is not constant; it varies 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 reduces to:

$$m = m_0$$

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: $m < 0$) 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.

$E = h\upsilon$ (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 $= 6.625 \times 10$ 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 $= \dfrac{h}{mv} = (6.625 \times 10^{34} \text{ Js})$ / (100kg) (1m/s) $= 6.625 \times 10$ 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 $\leq \dfrac{h}{4\pi}$ (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.,

$$\text{Proton charge was} = (\frac{2}{3}\,e) + (\frac{2}{3}\,e) + (-\frac{1}{3}\,e) = e$$

$$\text{Neutron charge was} = (\frac{2}{3}\,e) + (-\frac{1}{3}\,e) + (-\frac{1}{3}\,e) = 0$$

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

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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). 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.

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 $_2He^4$, 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 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 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. The universe became disorderly as time went on. The total entropy of the universe S_{uni}, was

continually increasing with time and entropic energy of the universe was never less than or greater than TS_{uni} but $= TS_{uni}$. 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

- Below Planck Time: $\sqrt{\dfrac{\hbar G}{c^5}}$

- Below Planck Length: $\sqrt{\dfrac{\hbar G}{c^3}}$

- Above Planck Temperature: $\sqrt{\dfrac{\hbar c^5}{G k_B^2}}$

All the known laws of physics were meaningless. The Planck units were characteristic of the properties of the Universe during its first moments.

At time $\rightarrow \sqrt{\dfrac{\hbar G}{c^5}}$

- The Universe was at the Planck temperature.

- The mean energy of photons was close to the Planck energy $\sqrt{\dfrac{\hbar c^5}{G}}$.

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

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

- $G_{\alpha\beta} \rightarrow$ curvature of space
- $T_{\alpha\beta} \rightarrow$ distribution of mass/ 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?

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.

- $\frac{2}{3}$ 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?

"It Takes Fundamental Constants To Give Us Our Universe, But They Still Don't Give Everything."

PLANCK FORCE

Planck force is the derived unit of force resulting from the definition of the base Planck units for time, length, and mass. It is equal to the natural unit of momentum divided by the natural unit of time.

$$F_P = \frac{m_P c}{t_P} = \frac{c^4}{G}$$

Schwarzschild Black Hole:

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.

$$E = \frac{F_P}{2} \times r_s$$

This means: Half of the Planck force is responsible for confining the energy $E = Mc^2$ of the Black Hole to a distance $r_s = \frac{2GM}{c^2}$.

Note: Any object with a physical radius smaller than its Schwarzschild radius ($r_{object} < \frac{2GM}{c^2}$) will be a Black Hole.

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 ($M_\odot = 2 \times 10^{30}$ 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.

$$E_s = \frac{F_P}{4} \times r_s$$

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).

$$E = \frac{F_P}{3} \times r$$

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: 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.

Planck temperature, denoted by $T_P = \sqrt{\dfrac{\hbar c^5}{G k_B^2}}$, 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.

$$T_P = \sqrt{\frac{\hbar c^5}{G k_B^2}} = \frac{c_2}{2\pi L_P}$$

where: L_P is the Planck length.

This means:

$$T_P \times L_P = \frac{c_2}{2\pi}$$

Elementary Particles:

The rest mass energy of any particle is defined by the Einstein's mass energy equivalence relation: $E_0 = m_0 c^2 = k_B T_0$, 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_0 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: $\upsilon_0 = \dfrac{m_0 c^2}{h} = \dfrac{c}{\lambda_C}$, where: λ_C is the quantum mechanical property of a particle (i.e., the Compton wavelength of the particle).

$$h\upsilon_0 = \frac{hc}{\lambda_C} = k_B T_0$$

$$\lambda_C \times T_0 = c_2$$

where: c_2 is the second radiation constant and is related to the Stefan–Boltzmann constant (also known as Stefan's constant) by: $\sigma = \dfrac{\pi^4 c_1}{15 c_2^4}$. **This means:** The Compton wavelength of the particle is inversely proportional to the threshold temperature below which that particle is effectively removed from the universe.

$$T_P \times L_P = \frac{c_2}{2\pi} = \frac{\lambda_C \times T_0}{2\pi}$$

$$\frac{L_P}{\lambda_C} = \frac{T_0}{T_P}$$

where: λ_C is the reduced Compton wavelength of the particle.

$$r_s \times \lambda_C = 2 \times L_P{}^2 = 2 \times \text{Planck area, where: } L_P = \sqrt{\frac{\hbar G}{c^3}} \text{ is the Planck length and}$$

λ_C 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.

$$E_0{}^2 = m_0 c^2 \times h\upsilon_0$$

$$E_0 = E_P \times \sqrt{\frac{r_s}{2\lambda_C}}$$

where: $E_P = \sqrt{\frac{\hbar c^5}{G}}$ is the Planck energy.

PLANCK MASS:

$m_P = \sqrt{\frac{hc}{G}} = 2.17647 \times 10^{-8}\,\text{kg}$, where: c is the speed of light in a vacuum, G is the gravitational constant, and $\hbar$ is the reduced Planck constant.

$\frac{m_P}{m_0} = N$. This means: 'N' number of particle masses is required to create one Planck mass.

$$\frac{m_P c^2}{m_0 c^2} = \frac{k_B T_P}{k_B T_0} = N$$

$$T_P = N \times T_0$$

$$\lambda_C = \frac{c_2}{T_P} \times N$$

This means: The Compton wavelength of the particle is directly proportional to the number of particle masses that make up one 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,

$$\alpha_G = \frac{Gm_e^2}{\hbar c} = \frac{m_e^2}{m_P^2} \text{ where: } m_e \text{ is the invariant mass of an electron.}$$

$$\lambda_{C,e} = \frac{c_2}{T_P} \times \sqrt{\alpha_G}$$

This means:

$$\frac{c_2}{T_P} \longrightarrow \text{constant}$$

The Compton wavelength of the electron is directly proportional to the square root of gravitational coupling constant.

$$L_P \longrightarrow \text{constant}$$

$$\lambdabar_{C,e} = L_P \times \sqrt{\alpha_G}$$

The Reduced Compton wavelength of the electron is directly proportional to the square root of gravitational coupling constant.

Quantum of circulation: Half the ratio of the Planck constant to the mass of the electron.

$$Q_0 = \frac{h}{2m_e} = \lambda_{C,e} \times \frac{c}{2}$$

$$E_e = m_e c^2 = \frac{hc}{\lambda_{C,e}} = \frac{c_1}{4\pi Q_0}$$

This means: The rest mass energy of the electron is inversely proportional to the Quantum of circulation. The classical electron radius is sometimes known as 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 given as (in SI units):

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} = \alpha \times \lambda_{C,\,e}$$

where: ε_0 is the electric constant or permittivity of free space, $\alpha = \dfrac{e^2}{4\pi\varepsilon_0 \hbar c}$ is the fine structure

constant and $\lambda_{C,\,e}$ is the reduced Compton wavelength of the electron.

$$r_e = \frac{c_2}{2\pi T_P} \times \sqrt{\alpha_G} \times \alpha$$

$$r_e = L_P \times \sqrt{\alpha_G} \times \alpha$$

This means: The classical electron radius is directly proportional to the fine structure constant times the square root of gravitational coupling constant. The Bohr radius (a_0 or r_{Bohr}) is a physical constant, approximately equal to the most probable distance between the nucleus and the electron in a hydrogen atom in its ground state. In SI units the Bohr radius is:

$$a_0 = \frac{\hbar}{m_e c\,\alpha} = \frac{\lambda_{C,e}}{\alpha} = \frac{c_2}{2\pi T_P} \times \sqrt{\frac{\alpha_G}{\alpha}}$$

$$a_0 = L_P \times \sqrt{\frac{\alpha_G}{\alpha}}$$

This means: Bohr radius is directly proportional to the ratio $\sqrt{\dfrac{\alpha_G}{\alpha}}$.

Wien's constant:

$$b = \frac{hc}{4.9651 k_B} = \frac{c_2}{4.9651}$$

$$c_2 = 4.9651\, b$$

This means: The second radiation constant is 4.9651 times the Wien's constant.

Radiation density constant

$$a = \frac{4\sigma}{c} = \frac{4\pi^2 k_B^4}{60\hbar^3 c^3} = \frac{32\pi^5 k_B}{60 c_2^3}$$

$$a = \frac{4\sigma}{c} = \frac{4\pi^4 c_1}{15 c_2^4} \sqrt{\mu_0 \varepsilon_0}$$

where: μ_0 is the absolute permeability of free space and ε_0 is the absolute permittivity of free space.

$$\frac{32\pi^5 k_B}{60 c_2^3} = \frac{4\pi^4 c_1}{15 c_2^4} \sqrt{\mu_0 \varepsilon_0}$$

$$k_B = \frac{c_1}{2\pi c_2} \sqrt{\mu_0 \varepsilon_0}$$

Magnetic flux quantum:

$$\Phi_0 = \frac{h}{2e}$$

Conductance quantum:

$$G_0 = \frac{2e^2}{h}$$

$$\Phi_0 \times G_0 = e$$

where: e is the elementary charge.

von Klitzing constant:

$$R_K = \frac{h}{e^2} = \frac{h}{\Phi_0^2 G_0^2}$$

Second radiation constant, $c_2 = \dfrac{hc}{k_B} = \dfrac{R_K \Phi_0^2 G_0^2 \, 2\pi c_2}{c_1 \varepsilon_0 \, \mu_0}$

$$\Phi_0 \times G_0 = \sqrt{\frac{c_1 \varepsilon_0 \mu_0}{2\pi R_K}}$$

Magnetic flux quantum × Conductance quantum × von Klitzing constant $= \dfrac{h}{e}$

$$\Phi_0 \times G_0 \times R_K = \text{Quantum / Charge Ratio}$$

$$\boxed{\frac{\Phi_0 \times G_0 \times R_K}{2Q_0} = \text{Electron mass-to-charge ratio}}$$

Planck charge:

$$q_P = \sqrt{4\pi\varepsilon_0 \hbar c}$$

$$q_P{}^2 = 4\pi\varepsilon_0 \hbar c$$

$$q_P{}^2 = 4\pi\hbar \sqrt{\frac{\varepsilon_0}{\mu_0}}$$

$$q_P{}^2 = \frac{2h}{Z_0}$$

where: Z_0 is the impedance of free space.

$$q_P{}^2 = \frac{2R_K e^2}{z_0}$$

$$\boxed{q_P = e \sqrt{\frac{2R_K}{z_0}}}$$

Rydberg constant:

$$R = \frac{m_e e^4}{8\varepsilon_0^2 c h^3} = \frac{G_0^2 Z_0^2 c}{64 Q_0}$$

Hartree energy:

$$E_h = 2R\,hc = \frac{2G_0^2 Z_0^2 c}{64 Q_0}\, hc$$

$$\boxed{E_h = \frac{G_0^2 Z_0^2 c_1}{64\pi Q_0}}$$

The **Bohr magneton** is defined in SI units by:

$$\mu_B = \frac{e\hbar}{2m_e}$$

$$2\pi\,\mu_B = e \times Q_0$$

$$2\pi\,\mu_B = \Phi_0 \times G_0 \times Q_0$$

$$\boxed{Q_0 = \frac{2\pi\mu_B}{\Phi_0 G_0}}$$

Black Hole Temperature:

$$T_{BH} = \frac{\hbar c^3}{8\pi k G M}$$

$$\frac{T_{BH}}{T_{Pl}} = \frac{m_P}{8\pi M}$$

Even if $M = m_P$:

$$\boxed{T_{BH} \neq T_{Pl}}$$

Black Hole Density:

$$\rho_{BH} = \frac{3C^6}{32\pi G^3 M^2}$$

$$\frac{\rho_{BH}}{\rho_{Pl}} = \frac{m_P^2}{32\pi M^2}$$

where: $\rho_{Pl} = \frac{c^5}{\hbar G^2}$ is the Planck density.

Even if $M = m_P$:

$$\boxed{\rho_{BH} \neq \rho_{Pl}}$$

The rate of evaporation energy loss of the black hole:

$$P = -\frac{dMc^2}{dt} = \frac{\hbar c^6}{15360\pi G^2 M^2}$$

$$\frac{P}{P_{Pl}} = \frac{m_P^2}{15360\pi M^2}$$

where $P_{Pl} = \dfrac{c^5}{G}$ is the Planck power.

Even if $M = m_P$:

$$\boxed{P \neq P_{Pl}}$$

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

- If the mass of the star < 1.4 solar masses
    i. Electrons prevent further collapse.
    ii. 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
    i. Electrons + protons combine to form neutrons.
    ii. Neutrons prevent further collapse.
    iii. The core will thus continue to collapse and form a neutron star.

- If the mass of the star > 3 solar masses
    i. Gravity wins! Nothing prevents collapse.
    ii. The core will thus continue to collapse and form a black hole.

$$\text{Half-life} = \frac{\ln(2)}{\text{Decay constant}}$$

- 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 ($E = nh\upsilon$).
- Momentum is quantized ($L = n\hbar$).
- Charge is quantized ($Q = ne$).

- The Thermodynamic Laws think big: they dictate energy behavior…
    i. **1 Law:** Energy is conserved; its form can be converted.
    ii. **2 Law:** Energies can flow, equilibrate.
    iii. **3 Law:** "Driving force" for equilibration uniquely defined.
    iv. **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):
    i.   Different vibrations → Different particles.
    ii.   String combinations → Particle interactions.

MATTER UNDER EXTREME CONDITIONS

Nuclei + heat + pressure → quark-gluon plasma

- If $\dfrac{\text{number of neutrons}}{\text{number of protons}} \approx 1$ (atomic number between 1 and 20):

Nucleus has equal number of protons and neutrons to become stable.

- If $\dfrac{\text{number of neutrons}}{\text{number of protons}} > 1$ (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 $\dfrac{\text{number of neutrons}}{\text{number of protons}}$ >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.

- **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.
- At Planck length $\sqrt{\dfrac{\hbar G}{c^3}}$, space-time becomes "foamy," with tiny bubbles and wormholes appearing and disappearing into the vacuum.
- Because dM = $\dfrac{k}{8\pi}$ dA+ ΩdJ + ΦdQ the size and shape of the black hole depends only on its mass, charge and rate of rotation, and not on the nature of the star that had collapsed to form it.
- Just like a dozen is 12 things, a mole is simply Avogadro's number of particles.
- Wavelength of UV radiation < Wavelength of IR radiation < Wavelength of microwave radiation
    i. Molecule dissociates (when it absorbs UV radiation).
    ii. Molecule vibrates (when it absorbs IR radiation).

iii.   Molecule rotates (when it absorbs microwave radiation).

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

- Fibonacci numbers − 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144...
    - i.   Each number is the sum of the previous two.
    - ii.   The ratio between the numbers = 1.618034 (golden ratio).
    - iii.   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.
- 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:

$$V - E + F = 2.$$

- All material particles have properties such as charge and spin. Space itself has properties such as dimensions. These properties are purely mathematical.
- The Gas laws deal with how gases behave with respect to pressure, volume, temperature …
    - i.   Boyle's law: Volume and pressure are inversely proportional.
    - ii.   Charles' law: Volume is proportional to temperature.

iii.   Pressure law: Pressure is proportional to temperature.

iv.   All three combined: $\dfrac{PV}{T} = \text{constant}$

- Grand unification energy $\rightarrow$ The energy above which the electro-magnetic force, weak force, and strong force become indistinguishable from each other.

- The distance — and the path — that a body travels, looks different to different observers.

- Faint light means fewer photons.

- Wormholes provide shortcuts between distant points in space.

- In more than three spatial dimensions, planetary orbits would be unstable and planets would either fall into the sun or escape its attraction altogether.

- Electric and magnetic fields turn into each other in a wavelike motion, creating an electromagnetic field that travels at the speed of light.

- The laws of physics remain unchanged under the combination of operations known as C, P, and T (C $\rightarrow$ changing particles for antiparticles. P $\rightarrow$ taking the mirror image so left and right is swapped for each other. T $\rightarrow$ reversing the direction of motion of all particles — in effect, running the motion backward).

- Speed of light is the limiting velocity in the universe, unaffected by the movement of its source and independent of all observers.

- Fractals make up many aspects of our world, included the leaves of ferns, tree branches, the branching of neurons in our brain, and coastlines.

- Bees build their hive using a tessellation of hexagons.

- **Concentric Circles in Nature:** A common example is in the ripples of a pond when something hits the surface of the water.

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 $\rightarrow$ force that is responsible for binding together the fundamental particles of matter to form larger particles.

i. 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.

ii. 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.

   i. 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.

   ii. 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.

   i. If stronger: Chemical bonding would have been disrupted; elements more massive than boron would have been unstable to fission.

   ii. 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

i.   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.

ii. 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

  i.   If smaller: Galaxy clusters, galaxies, and stars would have not formed.

  ii. If greater: Galaxy clusters and galaxies would have been too dense.

- Ratio of exotic matter to ordinary matter

  i.   If larger: the universe would have collapsed before the formation of solar-type stars.

  ii. 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

  i.   If larger: Stars would have not formed within proto-galaxies.

  ii. If smaller: No proto-galaxies would have formed.

- Polarity of the water molecule

i. If greater: Heat of fusion and vaporization would have been too high for life.

ii. 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?

Energy budget of the universe:

- Billion Years ago (when the Universe was 380,000 years old)
  - i. Dark Matter: 63%
  - ii. Neutrinos: 10%
  - iii. Photons: 15%
  - iv. Ordinary Matter: 12%

- Today
  - i. Dark Matter: 23 %
  - ii. Dark Energy: 73%
  - iii. Ordinary Matter: 4%
  - iv. Out of 4% we only make up 0.03% of the ordinary matter.

"Isn't it sad to place your head into your grave without ever wondering why were you born?"

- We understand the things we see
- We don't understand what we can't

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.

"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. - Why the Big Bang is a fizzle and stars cannot evolve out of gas... "

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=mc²: Einstein's equation that gave birth to the atom bomb and heralded a new world of atomic physics

"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)

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)

- 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.

"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

"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."

<div align="right">— Gordon L. Kane</div>

"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."

<div align="right">— Isaac Asimov</div>

Existence of Worm Holes is still **?**

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?

The faster you move,

<div align="center">the shorter and the heavier you are</div>

And that is the Theory of Relativity.

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

- Motion and gravity makes the clock tick slower.

Because $\Delta t = \dfrac{\Delta t_0}{\sqrt{1-\dfrac{v^2}{c^2}}}$, 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?

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 is still?

Black holes have no hair, says No hair theorem: Wait, What? Explaining the black hole

The answer is Simple:

<div align="center">Mass, Charge and Angular Momentum</div>

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

"Science is a game — but a game with reality, a game with sharpened knives … If a man cuts a picture carefully into 1000 pieces, you solve the puzzle when you reassemble the pieces into a picture; in the success or failure, both your intelligences compete. 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. The experiment is the tempered blade which you wield with success against the spirits of darkness — or which defeats you shamefully. The uncertainty is how many of the rules God himself has permanently ordained, and how many apparently are caused by your own mental inertia, while the solution generally becomes possible only through freedom from its limitations."

— Erwin Schrödinger.

Why the neutrinos only feel the weak force?

"In a scientific sense, earthquakes are unpredictable. But that does not mean that you can't predict things about them."

— PETER SAMMONDS

"$(x, y, z, t) + w, v,…?$ Science fiction?"

− Jonathan Feng

"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."

– STEPHEN HAWKING

"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

"It is cosmology's most fundamental question: How did the universe begin?: Alexander Vilenkin"

"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

Fermi's Paradox:

If there are so many aliens where are they?

"If and when all the laws governing physical phenomena are finally discovered, and all the empirical constants occurring in these laws are finally expressed through the four independent basic constants, we will be able to say that physical science has reached its end, that no excitement is left in further explorations, and that all that remains to a physicist is either tedious work on minor details or the self-educational study and adoration of the magnificence of the completed system. At that stage physical science will enter from the epoch of Columbus and Magellan into the epoch of the National Geographic Magazine!"

— George Gamow

"We are storytelling animals, and cannot bear to acknowledge the ordinariness of our daily lives."

– STEPHEN JAY GOULD

Why the Quarks feel the strong force, leptons do not?

If the leptons would have felt the strong force, then they would have combined to form different particles.

The entire picture of Particle Physics would have been quite different.

- Long-duration gamma ray bursts are associated with the deaths of massive stars in a specific kind of explosion called a supernova.

"Euclid taught me that without assumptions there is no proof. Therefore, in any argument, examine the assumptions" : Eric Temple Bell

Temperature $> \sqrt{\dfrac{\hbar c^5}{G k_B^2}}$ cannot exist only for the reason that the quantum mechanics breaks down at temperature $>$ than 10^{33}K?

- The discovery and confirmation of the cosmic microwave background radiation, or CMBR, in 1965 secured the Big Bang as the best theory of the origin and evolution of the universe…

$$S_{BH} = \frac{k_B A}{4 L_P^2}$$

"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."

The objects of different masses are accelerated towards the earth at the same rate, but with different forces

- $a = \dfrac{F}{m} = \dfrac{98 \text{ N}}{10 \text{kg}} = 9.8 \text{ m/s}^2$

- $a = \dfrac{F}{m} = \dfrac{9.8 \text{ N}}{1 \text{kg}} = 9.8 \text{ m/s}^2$

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

A virtual-particle pair has a wave function that predicts that both particles will have opposite spins. But if one particle falls into the black hole, it is impossible to predict with certainty the spin of the remaining particle.

− S. W. Hawking

- **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.

"If they not be inhabited, what a waste of space."

: Thomas Carlyle, Scottish Essayist (1795-1881)

- **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."

"What we know is a drop, what we don't know is an ocean."

: Isaac Newton

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."

<div align="right">Charles Darwin to Joseph Dalton Hooker, 11 January 1844</div>

- **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

[8] Antoine-Lau rent Lavoisier

Birth: Aug. 26, 1743, Paris, France

Death: May 8, 1794, Paris

Known for: the Revolution in Chemistry

[9] Johannes Kepler

Birth: Dec. 27, 1571, Weil der Stadt, Wurttemberg [Germany]

Death: Nov. 15, 1630, Regensburg

Known for: Motion of the Planets

[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*

[12] James Clerk Maxwell

Birth: June 13, 1831, Edinburgh, Scotland

Death: Nov. 5, 1879, Cambridge, Cambridgeshire, England

"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

- **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."

[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
$$S = \kappa \cdot \log W ?$$
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

[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."

[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."

[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

[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."

<div align="right">

— Heike Kamerlingh Onnes

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[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."

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— Thomas Hunt Morgan

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[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."

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— Hermann von Helmholtz

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[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."

[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."

[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

[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 hailstorm; 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

[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

[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."

[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

- **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.

- **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

- **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)

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 nucleosynethsis of the elements.

- **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,

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"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."
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According to **Hawking**,

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"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."
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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.

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        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
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- 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.

- **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.

- **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).

- **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.

- **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.

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- **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.

- **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 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 $r = \dfrac{3GM}{c^2}$ — 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., $E = \dfrac{hc}{\lambda}$).

- **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.

- **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.

- **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.

- **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.

- **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 $E = mc^2 = \dfrac{m_0 c^2}{\sqrt{1 - \dfrac{v^2}{c^2}}}$. 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.

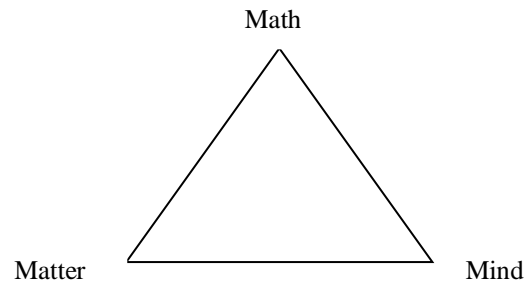$$\Delta x \bullet \Delta p \geq \frac{\hbar}{2}$$

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

- **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.

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:**

```
                    Math
                     /\
                    /  \
                   /    \
                  /      \
                 /        \
                /          \
               /            \
         Matter ──────────── Mind
```

Quarks → Come in three colours

Leptons, other Gauge Bosons − γ, $W^{\pm}$, Z^0 → Don't carry colour

Up quark has charge $+\dfrac{2}{3}$

Down quark has charge $-\dfrac{1}{3}$

Quarks have spin $\dfrac{1}{2}$

Proton = uud

Neutron = udd

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

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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.

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                            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, ...
```

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Gravitational waves → extremely weak

- Stringent verification of General Relativity

- Direct evidence of black holes

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?

What is the universe made of?

What holds the universe together?

Where did we come from?

Particle physics is a modern name for centuries old effort to understand the laws of Nature

- E. Witten (String Theorist)

Historical Landmarks of Particle Physics

- **1897:** Electron discovered by J.J. Thompson

- **1899:** Alpha particle discovered by Ernest Rutherford in uranium radiation

- **1900**: Gamma ray (i.e. photon) discovered by Paul Villard in uranium decay.

- **1911:** Atomic nucleus identified by Ernest Rutherford, based on scattering observed by Hans Geiger and Ernest Marsden.

- **1919**: Proton discovered by Ernest Rutherford

- **1932:** Neutron discovered by James Chadwick

- **1932**: Positron discovered by Carl D. Anderson (proposed by Paul Dirac in 1927)

- **1937:** Muon discovered by Seth Neddermeyer, Carl Anderson, J.C. Street, and E.C. Stevenson, using cloud chamber measurements of cosmic rays. (It was mistaken for the pion until 1946)

- **1947:** Pion discovered by Cecil Powell (predicted by Hideki Yukawa in 1934)

- **1947:** Kaon, the first strange particle, discovered by G.D. Rochester and C.C. Butler

- **1955:** Antiproton discovered by Owen Chamberlain, Emilio Segre, Clyde Wiegand, and Thomas Ypsilantis

- **1956:** Neutrino detected by Frederick Reines and Clyde Cowan (proposed by Wolfgang Pauli in 1931 to explain the apparent violation of energy conservation in beta decay)

- **1962:** Muon neutrino proved distinct from electron neutrino by group headed by Leon Lederman

- **1964:** Higgs boson predicted as a result of a mechanism for electroweak symmetry breaking proposed by Peter Higgs (remains hypothetical as of 2005, but widely expected to be found at the Large Hadron Collider at CERN in the early 2010s)

- **1969:** Partons (internal constituents of hadrons) observed in deep inelastic scattering experiments between protons and electrons at SLAC; this was eventually associated with the quark model (predicted by Murray Gell-Mann and George Zweig in 1963) and thus constitutes the discovery of the up quark, down quark, and strange quark.

- **1974:** J/Ψ particle discovered by groups headed by Burton Richter and Samuel Ting, demonstrating the existence of the charm quark (proposed by Sheldon Glashow, John Iliopoulos, and Luciano Maiani in 1970)

- **1975:** Tau lepton discovered by group headed by Martin Perl

- **1977:** Upsilon particle discovered at Fermilab, demonstrating the existence of the bottom quark (proposed by Kobiyashi and Maskawa in 1973)

- **1979:** Gluon observed in three jet events at DESY.

- **1983:** W and Z bosons discovered by Carlo Rubbia, Simon van der Meer, and the CERN UA-1 collaboration (widely expected, predicted in detail by Sheldon Glashow, Abdus Salam, and Steven Weinberg in the 1960s)
- **1995:** Top quark discovered at Fermilab
- **2000:** Tau neutrino proved distinct from other neutrinos at Fermilab

```
           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!
```

By convention ['*nomos*'] sweet is sweet, bitter is bitter, hot is hot, cold is cold, color is color; but in truth there are only atoms and the void.
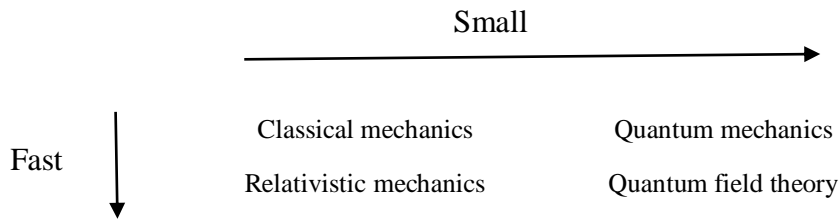
– **Democritus**

Force Carriers

- **EM** → Long range ($\frac{1}{R^2}$)
- **Weak** → Short range (10^{-21} m)
- **Strong** → Short range ($< 10^{-15}$ m)
- **Gravity** → Long range ($\frac{1}{R^2}$)

EM + Weak + Strong + Gravity → make the Sun shine

- **Feynman diagrams:** Powerful tool to write down scattering amplitudes (for higher order perturbations)
- **Feynman rules:** Set of rules to get from a Feynman diagram to the mathematical expression

Small →

Fast ↓

	Small
Classical mechanics	Quantum mechanics
Relativistic mechanics	Quantum field theory

The most basic mechanism of the Standard Model (does not include gravity), that of granting mass to particles remained a mystery for a long time

A major step forward was made in July 2012 with the discovery of what could be the long-sought God particle Higgs boson!!

Five mysteries the Standard Model can't explain

- Why do neutrinos have mass?
- What is dark matter?
- Why is there so much matter in the universe?
- Why is the expansion of the universe accelerating?
- Is there a particle associated with the force of gravity?

$$1 \text{ TeV} = 1 \text{ Tera electron volt} = 10^{12} \text{ electron volt}$$

Physics targets

- Origin of mass
- Nature of Dark Matter
- Understanding space time
- Matter versus antimatter
- Primordial plasma

LHC Facts:

- Colder than the empty Space in the Universe: 1.9K i.e. above absolute zero

- Hotter than in the sun: temperature in the collisions is a billion times the one in the centre of the sun

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

As the momentum of a particle increases, its wavelength decreases, providing details of smaller and smaller structures.

Conservation laws → Fundamental symmetries in nature

In the study of particle interactions, it was found that certain interactions did not occur, even though they conserve energy and charge.

Proton + neutron → Proton + Proton + Antiproton

A new conservation law was proposed: the conservation of **baryon number**.

- There are 118 elements starting with **hydrogen with atomic number 1** to **Unounociam with atomic number 118**
- Of these elements − up to Plutonium (atomic number 94) were formed naturally and the rest were synthesized in laboratory nuclear reactions.

Kinematic description of the Solar System (Kepler)

+

Dynamic description of the Solar System (Newton) → Development of celestial mechanics

1650's to 1700's → improvements in the telescope → more precise measurements of planet positions → more accurate tests to the theory of gravity

I still remember a guy sitting on a couch, thinking very hard, and another guy standing in front of him, saying, "And therefore such-and-such is true".
"Why is that?" the guy on the couch asks.

"It's trivial! It's trivial" the standing guy says, and he rapidly reels off a series of logical steps: "First you assume thus-and-so, then we have Kerchoff's this-and-that, then there's Waffenstoffer's Theorem, and we substitute this and construct that. Now you put the vector which goes around here and then thus-and-so. . . " The guy on the couch is struggling to understand all this stuff, which goes on at a high speed for about fifteen minutes!

Finally the standing guy comes out the other end, and the guy on the couch says, "Yeah, yeah. It's trivial." We physicists were laughing, trying to figure them out. We decided that "trivial" means "prove". So we joked with the mathematicians: "We have a new theorem—that mathematicians can prove only trivial theorems, because every theorem that's proved is trivial."

— Richard P. Feynman

Surely you're joking Mr. Feynman! (1985)

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