# *Evolutionary Pathways in an Unfolding Universe*

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The document contains many statements that are derived from material on the web or elsewhere, brought together from similar or differing accounts. Although giving credit to numerous references has not been practical, all significant sources have been cited in the footnotes.

Finally, I wish to acknowledge that this work has been inspired by the universal concepts presented in the Baha'i Writings. Where relevant, however, they naturally reflect only my personal understanding and interpretation.[2]

[1] Areas of interest

[2] See Appendix A4 for a brief outline of the Bahá'í history and teachings.

# Foreword

By the dawn of the 21st century, humankind has made remarkable strides in unraveling both the secrets of the minute constituents of matter and the mysteries of colossal galaxies in the vast expanse of the universe. Rapid advances in the biological sciences, in particular in the fields of molecular biology and genetics, have brought insights into the working of living organisms and disclosed many secrets of life itself. The mutual interplay of science and technology has revolutionized our way of living and reduced our planet to a 'global village'.

Still, as the billions of people across the world are brought ever closer together in a very short span of time by sweeping changes out of their control, the world has become a stage for ethnic, racial, political, economic, and ideological conflict, and subject to an ever-deepening anguish and despair.

If we are ever to be free from our present predicament and achieve a peaceful and just global civilization, we need both a common understanding of our past and a united vision for the future. Such understanding and vision demand a philosophical basis or worldview that is in agreement with our scientific knowledge and in accordance with the facts of history and the aspirations and deeper shared experiences of mankind as a whole.

This book is not intended to provide solutions to the ever-compounding problems of today's world. It aims, rather, to present a conceptual view of the world that can reconcile science with our intuitive perceptions, and with the many inner convictions of the diverse peoples of the world. It is hoped that this conceptual worldview may help to narrow some of the ideological differences that have polarized our world today and kept us from achieving a peaceful global society.

Rejecting the notion of a static world and acknowledging evolutionary change as a fundamental reality, both of objective existence and subjective experience, is the first step on this path. Just as an understanding of the processes of growth and the stages of maturity in a child enable educators to assist the child in achieving his or her inherent potential, an appreciation of the inherent potential for development and transformation in our world and of the processes of evolutionary change, may allow us to align our actions with the dynamics of such changes and to even influence their course.

The evolutionary nature of our world can best be understood by studying the history of events that have transformed the simple original primordial matter at the presumed inception of the universe into present-day complex structures manifesting consciousness and life. The stages of this transformation include the emergence of elementary particles and atomic structures, the formation and evolution of galaxies and stellar systems, the creation and geological evolution of our planet, the biochemical and biological evolution of living species, the emergence of consciousness and intelligence in man, and the development and progress of science, philosophy and religion.

Although seemingly different, all these processes or 'evolutionary pathways' have many shared characteristics and can be viewed as subsystems of a colossal, integrated and 'unfolding' structure that is the 'universe' itself - a theme that this book aims to explore.

Rafie Mavaddat (Initial version 2009 – Present version 2024)

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# Part I: An Unfolding Universe

# 1. Introduction

Recent strides in the fields of physical, biological, and social sciences have led to the emergence of new paradigms for describing our universe. These paradigms supersede simplistic mechanical models that view the universe as the perpetual, aimless, deterministic motion of matter in space and time, and the appearance of living organisms as incidental anomaly. Instead, the universe can now be viewed as more akin to a complex, information-rich, organic structure that is in continuous dynamic change and goal-driven transformation.

Evolutionary changes have caused the conversion of an undifferentiated primordial matter originating in the very early universe into numerous and diversified complex systems of inanimate structures and living organisms.[1] Each of these systems whether galactic, stellar, planetary, biochemical, biological or social, has gone through dynamic changes and followed its own evolutionary path of development. These pathways and processes of evolutionary change, though diverse and seemingly disparate, have shared characteristics and an inherent coherence between them.[2] The universe can indeed be viewed as a hierarchy of interrelated and interconnected complex evolving systems. As such, it may be even proposed that the many stages of physical, biological, and social evolution, are different phases of a colossal, intricate, and integrated evolutionary process, which is the universe itself.

### *The edifice of science*

In its search for a simple, elegant, and unified explanation of the diverse and complex systems and processes in the universe, humankind has constructed the edifice of science. The first premise of science is that our observations of nature are manifestations of underlying universal laws. These universal laws of nature, it is generally assumed, are invariant over both space and time - they are as equally applicable to distant galaxies formed billions of years ago, as to our planet today.

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[1] The use of the term 'evolution' here signifies changes in a broadly discernible direction and not the specific usage of the word in biological evolution of living forms, as proposed by Darwinian evolutionary theory.
[2] See Appendix A9 for the shared characteristics of the evolutionary systems.

As science progresses, it attempts to cast the laws of nature into more comprehensive and concise schemes, unifying past theories and propositions. Maxwell's integration of the laws of electricity and magnetism into an elegant mathematical formulation of the 'electromagnetic theory' is a notable example of such unification.[1] There have also been attempts to construct similar unifying theories in relation to the known four forces of nature, namely the electromagnetic, weak and strong nuclear forces, and gravitation.[2] A unified theory gives a comprehensive explanation and formulation to the seemingly disjointed and incoherent observations of nature.

Another premise of science is that nature can be understood through a 'reductionist' approach or `attempt to explain a complex set of facts, entities, phenomena, or structures by another simpler set'.[3] Reductionism is of two types, either a description of an object or entity by its constituent parts or alternatively by lower 'levels' of description. A car can be described by separate components - its engine, chassis, wheels, and electrical circuitry, and then again by the components of each part. Similarly, to understand the human body, scientists have studied and described separately the brain, heart, lung, and other bodily organs, and in turn, examined each organ's cellular structure, the chemical composition of each cell, the molecular structure of the constituent chemical compounds, atomic configuration of each molecule, all the way to the elementary particles within each atom.[4] Indeed man has been successful in shredding the stuff of matter into numerous pieces: electron, muon, tau, quark, lambda, sigma, xi, pion, kaon and a host of other particles.

Alternatively, the reduction of a complex entity by 'lower levels' of description would be to say, for example, that a human bad behavior can be described in terms of the study of contributing societal factors, or by an individual's abnormal psychology. Or further, it can be attributed to altered neural activity of the brain as seen by Electroencephalogram (EEG) of the brain. Or still at a 'lower level', as a change in brain neurochemicals.

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[1] The electromagnetic theory in physics describes the interaction of electricity and magnetism, and electromagnetic wave generation and propagation – see Appendix 5.

[2] See Appendix 5 for a description of the four forces of nature. For further discussion, see also: [**Brian Greene**, p.129, **The Elegant Universe**, W.W. Norton & Company, 1999]

[3] Definition of reductionism according to **The Free** Dictionary **by Farlex.**

[4] See: [**The limits of reductionism in biology**, Novartis Foundation Symposium 213, John Wiley & Sons, 1998]

Though important in understanding the detailed functioning of our world, the complex processes at work in our universe cannot be adequately explained through reductionism. The inadequacy of reductionism as an approach to fully describing nature can again be demonstrated by simple analogy. The color, fragrance, and inherent beauty of a flower cannot be described by its constituent parts, regardless of the number of smaller pieces into which it is dissected. Similarly, a grand symphony is the harmonious integration of many musical instruments, far different from playing each instrument separately. Indeed, the combination and arrangement of the elementary parts of a complex system 'create' or 'reveal' a new reality, distinctly different from its component parts.

Thus, detailed knowledge of the constituents of a complex phenomenon or entity or its description by 'lower levels' of representation, though important, are inadequate in describing it fully, nor can they predict its functionality, or current or ultimate purpose.

### *The universe as a colossal complex system*

To understand a complex system, we must consider its substance, form and function, as well as its evolution to its present state and its potential future developmental pathway. The universe itself can be considered as a colossal complex system. Understanding the stages of its evolution helps us not only to gain a better perspective of its current condition, but also an appreciation of our own place within the scheme of existence.

Consider the odyssey of a single minute particle, a constituent of the primeval fireball at the beginning of the universe which has travelled for over 13 billion years to become a part of the neuron of a human brain. We may try to envisage some of its journey - separated by colossal distances and eons of time - through the initial plasma of electrons and ions in the early universe and the expanse of hydrogen gas clouds. We may see it travelling on as part of a massive 'pro-galactic' formation; a spiral galaxy; a new star formation; a broiling star; post-supernova inter-stellar space; the sun's nebula; a molten planet in formation; the crust of the Earth; a forming inorganic molecule; organic matter; molecules in a pre-biotic state as precursors of the origin of life; a living cell; tissues inside the organisms; human zygote; and the mass of a developing embryo's brain. These are but some of the many pathways that this minute primordial matter may have taken on its journey to becoming a part of the human brain. Now at last upon combining with billions of other particles similarly on their travels through space and time, it is engaged in intellectual activity and in the complex process of manifesting self-awareness, perception and cognition, thus unfolding the potentialities inherent within it from the moment of its inception from the presumed beginning of time. Indeed, viewing the universe from such a perspective allows us to see it as a magnificent unfolding evolutionary process and ourselves, including our human intellectual, social, and spiritual development, as its integral part.

# 2. A review of evolutionary processes

It is an immense credit to the human intellect that it has uncovered the many well-guarded secrets of nature and exposed, even though in the form of a rudimentary sketch, chronological events in the evolution of the universe stretching back billions of years in the past. The enormity of events that have transpired since the 'birth' of the universe, and which have resulted in the transformation of an amorphous primordial matter to its present day state of complex and diversified systems, both inanimate and living, is indeed astounding.

The question of whether our physical universe had a distinct beginning and was significantly different from its present state remained controversial for many centuries. Indeed, two opposing 'steady state' and 'evolutionary' views of the universe, were in contention well into the twentieth century.[1] In a 'steady-state' universe, the 'cosmological principle', of the 'large-scale uniformity' of space that it is homogeneous over large distances and the same in every observed direction, is said to extend to the domain of time as the 'Perfect Cosmological Principle'.[2] The latter proposes that over time, the basic configuration of the universe has remained unchanged.[3] However in 1929, Edwin Hubble observed the 'redshift' of distant galaxies, and suggested that the cosmic expansion of space and the divergence of galaxies may be producing a shift in their radiation spectra.[4] A direct outcome of this theory was the notion that the universe had begun from a highly dense state and had expanded to the present mostly void cosmos. The expansion of the universe, according to the basic laws of physics, would also necessitate its gradual cooling, predicting an initial state of very high temperatures. As the concept of a vastly different physical condition in the early, as compared to the present-day universe became increasingly favored by cosmologists, the notion of a static or 'steady state' universe was discarded in favor of an 'evolutionary cosmological view'.

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[1] For the birth and expansion of the universe see Appendix A1.

[2] See: [**Alan H. Guth**, p38 and p57, **The inflationary universe**, Jonathan Cape, 1997]

[3] In 1917, in order to maintain the idea of the universe as being in a 'steady state', Albert Einstein introduced the 'cosmological constant' in his 'field equation' derived from the 'General Theory of Relativity'.

[4] See Appendix A5 for a more detailed explanation of the 'redshift'.

### *Cosmic evolution and the formation of galaxies and stars*

In an 'evolutionary cosmological view', following the initial inflationary expansion of the universe, elementary constituents of matter condensed from an amorphous, undifferentiated state.[1] Accordingly, in the first few minutes of the birth of our physical universe, hydrogen and helium ions were synthesized, while non-ionized neutral atoms formed over a period of several hundred thousand years. During this 'de-coupling period', the universe expanded and cooled and scattered clouds of hydrogen and helium gradually formed. The universe, initially dominated by nearly uniform radiation and opaque, became transparent. The fragmented scattered clouds composed of mostly hydrogen, eventually became the seeds of future galaxies, stars and planets.

### *The formation of the Earth and other planetary systems*

It is believed that planets in our solar system originated as a part of a solar nebula, a massive collection of gas clouds that were the origin of the sun itself. The Planet Earth was formed by the collision and accretion of gas and dust particles within the nebula that constitute the solar system. Initially the Planet reached a molten state, but then cooled to form the inner and outer cores, mantle, and crust of the Earth. The sea and land masses of the Earth's crust reshaped and transformed, eventually producing the present oceans and continents of the world.

Elsewhere outside the solar system, numerous other planets were formed as a part of their own stellar systems. Planets contain the chemical elements successively synthesized inside stars by complex nuclear reactions and which are scattered throughout space in the form of 'supernova' explosions.[2]

### *The evolution of life on Earth*

The proposed processes underlying the geological formation of the Earth are now generally agreed. The origins of life on Earth are, however, less well understood and largely hypothetical.[3] The transition of non-living matter to

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[1] See Appendix A1 for the relevant theory related to the birth of the universe and formation of galaxies.
[2] See Appendix A1 for supernova explosion of stars.
[3] See Appendix A2 for more information on the geological and biological evolution on the Planet Earth.

living organisms capable of metabolism, growth and reproduction is a subject of intense scientific investigation and debate. Differentiation between what consists of 'non-living' and 'living' is a matter of definition, with considerable ambiguity in the demarcation between the two. It is believed that 'pre-biotic' complex chains of organic molecules that replicate and make copies of themselves may have emerged via a process of self-organization from simpler molecules.[1]

Replicating complex chains of organic molecules may have been the precursors of early 'single-celled' organisms. Symbiosis, or the mutually advantageous association of undifferentiated cells, could have brought into being cells that had parts, or 'organelles' specializing in particular cell functions. Unicellular organisms then led to multi-cellular organisms finally leading to organisms with differentiated organs. As described by the theory of biological evolution, such living forms then multiplied and diversified.

Biological evolution is defined as a process of variation and diversification of living forms. As a scientific theory, Charles Darwin's postulate of evolution as chance variations in progeny or offspring, with the natural selection of the fittest in adapting to the environment, has much confirming evidence.[2] However, the mechanisms by which variations in progeny occur were only understood after Gregor Mendel's account of his principles of inheritance, and the progress of the science of genetics. Current 'Neo-Darwinian' theory, a synthesis of Mendelian genetics and random genetic mutation with subsequent natural selection, claims to present a general explanation for the gradual adaptation and evolution of all living organisms on the Planet.[3]

Whether the present theory of evolution as it stands can alone adequately explain the development of life forms on Earth, without other contributing factors, is a matter of debate. There indeed remains a lack of sufficient paleontological evidence linking the transition from one major species to another. Thus 'macro-evolution', as

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[1] For self-organization and emergence of order in 'open dynamical systems', see Appendix A9.

[2] Besides natural selection there are at least two other alternative mechanisms for proposed evolutionary change, known as neutral drift and molecular drive. See: [**Marcello Barbieri**, **The organic codes: An introduction to semantic biology**, Cambridge University Press, 2003]

[3] See Appendix A8 for a further description of 'Darwinian' and 'Neo-Darwinian' evolution.

opposed to incremental transitions or 'microevolution' for which there is abundant observational confirmation, has remained to some degree controversial. Nevertheless, many biologists today believe that the theory of evolution applies to both micro - and macroevolution and that all life forms on Earth have stemmed from a single initial living form. As with all aspects of science, however, there is never a last word and future refinements or even major changes to the theory of evolution are not improbable.[1]

Evolutionary processes operating over eons of time have brought about great biodiversity on the Planet with the development of numerous species including bacteria, algae, fungi, plants, and animals such as amphibians, fish, birds and mammals, each with their own unique form and pattern of behavior, some living in solitude and others frequently in colonies of various sizes.[2] The latter have often patterned themselves in complex but harmonious orders with great organization and efficiency. Living organisms and their environments have formed a slowly evolving hierarchy of highly complex and refined ecosystems.[3]

### *The evolution of the human species - cognitive and social evolution*

The general scheme of biological evolution is also applicable to the evolution of human beings. The actual sequence of evolution of the human species is, however, still ambiguous. 'Cro-Magnon man', the most recent Hominin is direct ancestor or very close relative to humans, lived between 40 to 10 thousand years ago in Europe and was biologically identical to Homo Sapiens Sapiens, the present-day human species. Neanderthals lived prior to that between 100 to 35 thousand years ago, and were considered a different species from modern humans, although there is some indication that there may have been some inter-breeding between the two. Hominin fossil records extend back several million years, indicating the development of bipedalism and an increase in brain size in the course of the evolution of man.[4]

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[1] 'The debate will continue as long as we are curious about our origins and our relationship to the rest of living world.' See: [**Neil A Campbell**, page 497, **Biology** (third edition), The Benjamin/ Cummings Publishing Company, 1993]

[2] For taxonomy (classification) of living organisms on Earth see Appendix A2.

[3] See Appendix A8 for further discussion regarding ecosystems.

[4] See Appendix A2 for a further discussion on the evolution of the human species.

Human evolution has, however, in addition to physical changes over the years, taken a unique path to that of other animate beings, with the development of cognitive processes and conscious self-awareness in man. These additional changes appear to have been largely independent of many biological evolutionary forces. Attributes that appear unique to humans, such as higher levels of consciousness, cognition, self-awareness, knowledge, and ability to understand the external world, do not necessarily evolve by random mutation and selection associated with biological evolution. In higher forms of life, biological changes most often occur in time scales of hundreds of thousands and even millions of years. In contrast, cognitive and social evolutionary change in the human species has taken place at an astonishingly rapid pace, over a millennium or centuries, sometimes even a generation. Human social evolution is brought about by the extension of human experience, knowledge, and technology in one generation and transmission of these acquired characteristics to the next by education and by the cultural milieu.

Humanity has come a long way from its prehistoric hunter-gatherer mode of life. Current urban living is dominated by high-tech gadgetry, instant communication, and access to an almost infinite flow of information. Successive integration of human communities has led to the progress of human society from tribes to villages, to cities and nation states, even to major civilizations spreading across vast regions of the Planet and is now on the verge of becoming an integrated global entity.[1]

### *Evolution of scientific thought*

Parallel with human cognitive and social development scientific, ideological, and philosophical thought of the human species has evolved over the centuries.[2][3] Scientific theories have been modified, and in some cases discarded and replaced by new theories and scientific perspectives.

The earliest scientific enquiries dealt with the dynamic states of material substances and introduced the concepts of speed, mass, and force. Newton's laws of mechanics, formulated towards the end of the seventeenth century

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[1] See Appendix A3 for social development and the rise of human civilizations

[2] See Appendix A5 for a more detailed description of the evolution of scientific thought.

[3] See Appendix A4 for development of philosophical and religious thought.

described the relationship between these parameters. While Newton's laws apply to all objects whether terrestrial or extraterrestrial, exceptions to these laws were found in masses travelling with velocities comparable to that of the speed of light. The inadequacy of Newton's laws of mechanics at velocities comparable to the speed of light, led to the introduction of the 'Special Theory of Relativity' by Albert Einstein in 1905.[1] Similarly, Newton's laws of motion did not adequately describe the movement of particles at atomic scale. The development of 'quantum mechanics' in the early twentieth century overcame many of the anomalies in the description of the motion of elementary particles made by classical mechanics.[2]

A further milestone in the progress of science was the discovery of electricity and magnetism. Static electricity and magnetism were known to ancient civilizations. In the first half of the nineteenth century, it was established that moving or time-varying charges produce magnetism and similarly that moving magnets produce electrical currents in closed wires. This led James Clerk Maxwell to the concept of the electromagnetic field and his formulation of the well-known 'electromagnetic field equations'. Maxwell's electromagnetic field theory showed the possibility of the generation and subsequent propagation of electromagnetic waves by electric and magnetic fields changing with time. The generated electromagnetic wave was noted to travel at the speed of light and hence the nature of light as electromagnetic wave propagation was established. Later after the advent of quantum mechanics, it was recognized that light in fact has the dual nature of particle (known as a photon of light) and wave.

The nature of matter itself has been a subject of speculation for thousands of years. An atomic basis for matter was in fact first proposed in ancient times. In the early twentieth century, Niels Bohr introduced the model of an atom with a central nucleus and several orbiting electrons. It was later realized that the nucleus itself consists of 'protons' with a positive charge and 'neutrons' that are charge neutral. Both protons and neutrons themselves are composed of 'quarks' held together by nuclear forces. Subsequently the orbits of electrons around the nucleus were found to conform to the quantum mechanical 'states' of the electrons within the atom. Numerous other elementary particles have also been discovered in 'particle accelerators', where particles are accelerated to extremely high

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[1] See Appendix A5 for a description of the 'Special Theory of Relativity'.

[2] See Appendix A5 for further discussion of 'Quantum Mechanics'.

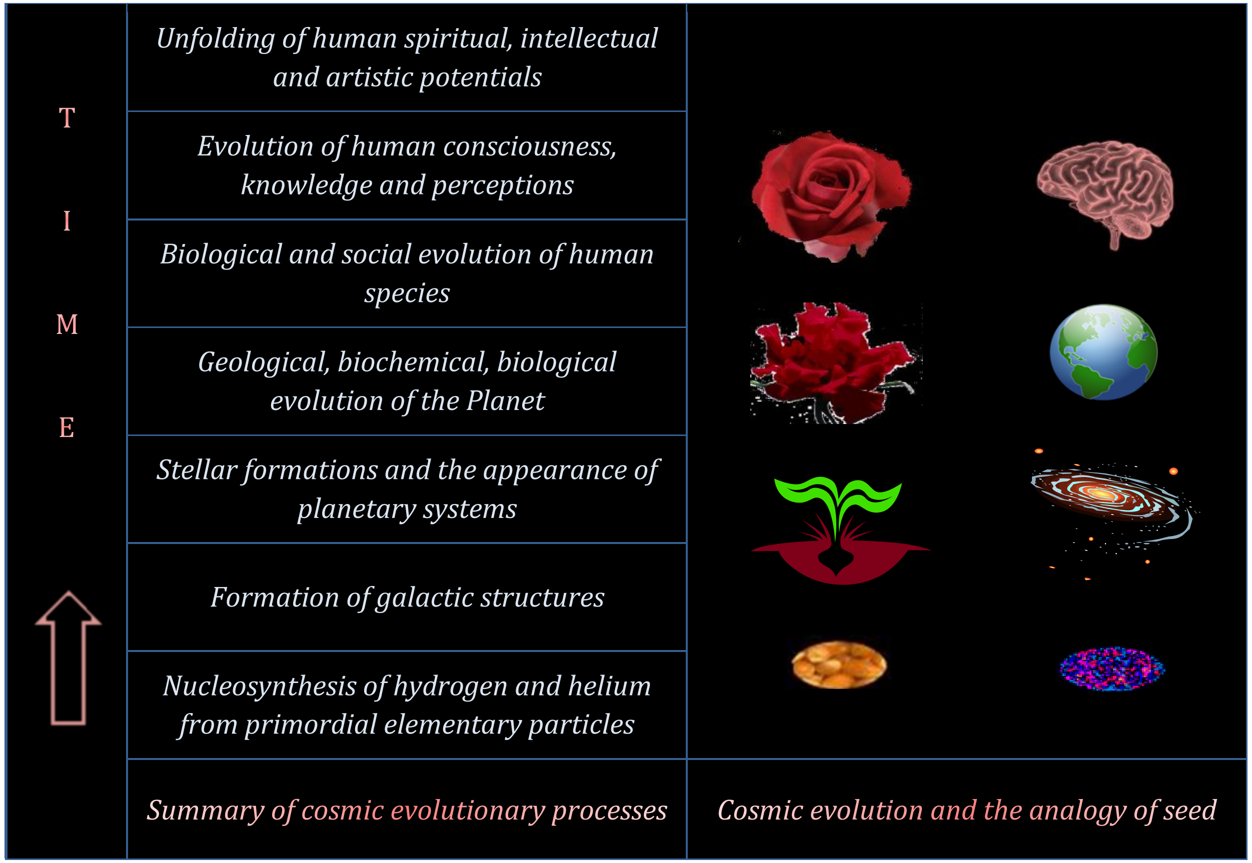
speeds and forced to collide. Many of these particles degenerate into other elementary particles in small fractions of a second.

In parallel with the advancement of physical sciences, the last few decades have seen an explosion in knowledge about living systems and biological processes such as developments in the areas of molecular biology, biophysics, and mathematical modeling of biological systems. Recent scientific enquiries have led to the discovery of multitudes of novel genes and the appreciation of their intimate structures, as well as knowledge of proteins and protein-protein interactions and biochemical pathways. Great strides have also been made in describing the architecture of the human genome including the structure, content, and organization of human genes. Findings of the 'Human Genome Project' have great potential to benefit mankind, including in treating a range of genetic conditions through gene therapies.

### *The development of ideological, philosophical, and religious thought*

Other evolutionary processes at work in human society include the evolution of philosophical and religious thought, as well as human social organization and culture. Philosophical thoughts, ideologies and general perceptions of reality have changed from century to century. The inward experience of aesthetics and its outward expression in literature, music and arts have similarly gone through many historical changes. Evolution is also seen in the 'spiritual' state of humanity. Spirituality may be defined as an inward state as faith, assurance, detachment, contentment, and inner tranquility and in its outward expression as kindness, selflessness and philanthropic and altruistic deeds, commonly defined, promoted and nurtured through the major world religions. Although 'spiritual' principles promoted by the diverse religions could be said to be in essence both similar and eternal, their emphasis and applications have undergone change and transformation during the course of history.

The social, intellectual, and spiritual state of humankind has indeed undergone many evolutionary changes that are in no way less significant than those that have occurred in the processes of physical and biological evolution, just as the intellectual and social maturity of an individual are no less important than his or her physical maturity. Physical evolution can be viewed as a preliminary stage for the subsequent evolution of humanity in intellectual, social, and spiritual dimensions. The emergence of consciousness and intelligence, which are the outcome of a hierarchy of evolutionary changes, can be viewed as integral parts of the universal evolutionary process. As part of this evolving process, our perception of the universe is itself subject to change and evolutionary transformation. Such change in our understanding is driven by the interplay of our objective inquiry, as per the scientific quest, and our subjective experience as reflected in the development of the arts, literature, and culture. Thus, the paradigm of an evolutionary universe encompasses both the universe 'within' and the universe 'without'.




*Summary of cosmic evolutionary processes* — *Cosmic evolution and the analogy of seed*

# 3. Advancement in science and our conceptual worldview

Science has undeniably had an immense influence on our understanding of the world and on our philosophy of life. The knowledge that the Earth is one planet amongst countless other planetary systems in an evolving universe with a time of birth and a potential thermodynamic death, compared to the previously accepted geocentric model of the Planet in a universe that remains forever in the same configuration, leads us to a significantly different philosophical perception of our world. Similarly, the scientific evidence suggesting the gradual evolution of living species over millions of years, as compared with the belief that all creatures have come into being in their present form, gives us a different perspective of life in general, and of our own existence in particular. To form a modern 'worldview', it is therefore important to examine the philosophical implications of contemporary scientific theories.

### *Modern physics*

Our understanding of the world has changed dramatically through significant advances made in the field of modern physics. Our commonly perceived view of nature has been that material objects exist at certain points in space and time, implying that these are separate immutable entities. In this view, any change in the form or position of an object is the result of an external force exerted on the object in its immediate proximity. However, the observation that force can act from a distance on a material object, such as the Earth's gravity acting on terrestrial bodies, has introduced the concept of 'action at a distance' or that of the 'field'. In this paradigm, specific 'fields' such as the 'gravitational field' permeate the space in their vicinity and influence the motion of physical objects by their presence.

In addition suggestions made in modern physics such as of time being a fourth dimension in a spacetime continuum, and propositions of 'space contraction' and 'time dilation' as predicted by 'special relativity' and warping of spacetime in the presence of matter as proposed by 'general relativity', all undermine the notion of space and time as distinct realities independent of both matter and the observer.[1] At the same time, 'quantum theory' has redefined the concept of an elementary particle from a concrete and localized entity to an elusive reality that can only be described by a mathematical 'wave function' from which the probabilities of the presence of a particle in a small region of space and interval of time can be derived.[2,] Hence the simplistic, 'commonsense' view of the physical world as a collection of innumerable rigid isolated particles of matter filling regions of otherwise empty space and moving with the flow of time in their own particular domain, upheld for many centuries, has now been discarded.

### *Modern biology*

The study of living cells, especially at the molecular level and the discovery of DNA - double helix deoxyribonucleic acid - and the deciphering its genetic code, have opened a window to a vista of incredible complexity and magnificence in living organisms. The division of science into physical and biological sciences is a human construct and does not correspond to the reality of nature. Nonetheless, in many instances it is convenient to maintain such a separation, distinguishing living organisms from non-living in their incredible complexity and in the information content of their genetic code.

Animate biological systems ingeniously use the simple basic laws of physics and chemistry but with much detail and sophistication to carry out functions that appear to have a sense of direction and over-riding 'purpose'. For example, multitudes of 'mindless' molecules co-operate to form and sustain a living cell, and 'mindless' cells' work together, with 'ingenuity', to create an organism.

Modern biology has enabled us to increasingly see a living organism as a dynamic system. Even at the level of cells and 'organelles'[3] there is movement, from 'Brownian motion', the random motion of particles in a fluid, to the directional movement mediated by specialized 'cytoskeletal motors'.[4] Cells roll to their destination, are swept away by mechanical flow or summoned by alluring chemicals or adhesion molecules. They meet and greet one another.

[1] For an explanation of space contraction and time dilation, and the warping of space-time in the presence of matter, see Appendix A5.
[2] For the discussion of wave function and different interpretations of quantum mechanics see Appendix A5.
[3] Subunits of a cell specialized in specific functions within a cell.
[4] Cytoskeleton in a cell is a structure responsible for mobility of the cell and its organelles.

Molecules in cells recognize their partners through structural complementarity, and their encounters create overwhelming cascades, bringing together other molecules, with dramatic biochemical consequences.

A remarkable biological phenomenon is the development of the one-celled embryo into the large multi-cellular, multi-system organism of the fetus. A single cell divides and differentiates into various tissues and organs of the organism, predominantly due to the control of gene expression in 'daughter' cells created by an initial cell division. A concentration gradient of chemicals produced in one cell has differential effects on surrounding cells, switching on and off various genes and leading to the production of different proteins in differing cells, thus delineating new types of cells. Positive feedback loops enable gene regulatory proteins to perpetuate their own synthesis, so that the cell type is sustained. Negative feedback loops with programmed delays create a 'cell clock', which controls the timing of events. As the embryo grows, cell death occurs in just the right areas and at the right time for example to form fingers out of an amorphous mass of tissue and so make up a hand. The successive events involved in embryogenesis are finely timed, precise, and directional, with a high degree of complexity and perfection.

Hence contemporary biology has revealed the complexity and intimate interaction and coordination of numerous biological processes and pathways within a living organism and within its environment.

### *Unifying scientific theories*

Scientists have throughout history sought to develop unifying theories for systems that describe natural phenomena. Chemical, mechanical, electromagnetic, heat and many other forms of energy can be converted from one form to another. Hence, the concept of energy unifies many aspects of physics. Likewise, electricity and magnetism have found a unified description in electromagnetic theory, and with light as electro-magnetic wave propagation. Descriptions of space and time in the single framework of spacetime, and of the equivalence of mass and energy, have come about through further understanding from the 'special theory of relativity'. Quantum mechanics provide a common description for many diverse phenomena such as the quantum basis of chemical reactions at the atomic level, orbits of electrons around the nucleus and so-called 'blackbody' radiation, electromagnetic radiation from a body in thermodynamic equilibrium.[1]

Presently, physicists are attempting to find common descriptions for the well-known four forces of nature, with string theories claiming some success., String theories envisage elementary particles as open or closed 'strings' rather than as singular points. Similarly, the theory of evolution in biology has given us a unified view of the development of the countless numbers of living forms. So-called 'modern syntheses' also unify genetics, paleontology, and systematics.[2]

In time, a greater understanding of the chains of replicating molecules in 'pre-biotic' states, the early deoxy ribonucleic acid (DNA), riboxy nucleic acid (RNA)[3], and the appearance of the first simple living cells, could solve the mystery of the transition from 'non-living' to 'living' and further unify the fields of physics and biology. The concept of an unfolding universe is in itself a unifying proposition since it brings together our understanding of inanimate physical processes in the universe and the biological processes seen in living organisms, into a single universal scheme of evolving systems.

Some claim that man will one day formulate a `theory of everything', explaining all observed physical and potentially all biological phenomena. Any attempt, however, to express the underlying order of nature as a unified theorem requires a partial recasting of past scientific notions and a departure from subjective experience. A change of color from red to blue, perceived by our senses, is explained by science as a reduction in the wavelength of electromagnetic waves – a concept alien to sense perception. Proposed string theories are set in abstract dimensions beyond the realm of our immediate experience. It is a fact that any scientific description of external reality is ultimately related to human experience. For instance, with no sense perception of light or sound, there would be no science of optics or acoustics. But as man delves deeper into these realities, the correspondence between the description of external reality and human experience becomes increasingly more obscure and indirect. Ultimately,

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[1] For definition of blackbody radiation see Appendix A5.

[2] Systematics is a branch of biological science that studies the how each species is related to other species through time.

[3] Ribonucleic acid (RNA) is a large organic molecule that carries genetic information for protein synthesis.

it may require an abstraction beyond the perception of the human mind to describe the totality of the universe in one unified theorem.

Any claim that science could, now or in centuries to come, explain in full all observed phenomena, including that of human perception and behavior, should indeed be viewed with great skepticism. The human mind is an outcome, a part, or a subset of nature. It is difficult to conceive that a part will ever be able to comprehend the whole. Nature cannot be defined or confined to what is sensed or perceived by our physical senses or mental perceptions. Science is a voyager in a limitless space that encounters new horizons as it navigates and explores its frontiers and pushes the boundaries of understanding. The frontier of the human mind itself is a vast unknown territory, which science has only just begun to explore.[1]

### *A new vision of reality*

We can therefore conclude that the workings of the universe are far more profound and complex and abstracted from our 'commonsense' view, than we may have ever imagined. The perplexing worlds of special and general relativity and of quantum mechanics of modern physics have bewildered even the most intelligent minds and are testimonies to the profound structure of our universe. Modern biology has in turn shown the incredible complexity of all life forms. The physics and biology of today have indeed revealed two extremes of simplicity and complexity respectively in our world. While the theories of physics have shown that the workings of nature are based on intrinsically simple natural laws, current biology has revealed the extent of its complexity for instance in the human brain. The contemplation of the intricacy required for some fundamental simple laws to manifest, in stages, a universe as expansive and complex as we observe today, should indeed bewilder every philosophical and thinking

[1] 'In the last decades tremendous progress has been gained in neuroscience in terms of the understanding of the function of the brain in integrating different sensory inputs such as the shape and color of an object, to form a coherent whole. At a different level, however, the question of how these physical neural activities is raised to the level of consciousness, remains as obscure as ever'. For a discussion on this, see: [**Robert Lanza** with **Bob Berman,** p173, **Biocentrism,** BenBella Books, 2009]

mind. The contemporary findings of science have therefore given us a new vision of reality, a glimpse into the workings of an elegant universe never previously imagined.[1]

[1] To feel the grandeur and the elegance of the universe, see: [**Brian Greene**, **The Elegant Universe**, W. W. Norton, 1999]

# 4. Systems and processes in an unfolding universe

Examination of the evolutionary processes that have taken place in the past, together with the study of modern physics and biology, leads us to a view of our world as a hierarchy of coherent, integrated, evolving systems and processes, the study of which can operate at one of two levels of scientific inquiry. At a more fundamental level, scientific inquiry seeks to understand the basic laws of nature, for example the laws of mechanics, electricity or magnetism. However, at the level of systems and processes, without invoking any new laws of nature, science examines the actions of a collection of particles or components. For example, thermodynamics and fluid mechanics are two important branches of science that consider the collective effect of large numbers of molecules in producing respectively thermal effects and fluid motion.

A set of components that collectively produce one or a number of specific outcomes is called a system. Many branches of science including computer science, robotics, biology, economics, and many others deal with the study of systems. A system can be an artificial one produced for a particular application such as in communication or robotics. There are also abundant natural systems such as galactic, stellar, planetary, and terrestrial systems. In addition to these inanimate systems, numerous living organisms operate as animate systems.

Natural systems are interconnected and interact in a congruent and cohesive mode. Each system itself is a subsystem of a yet larger system that fulfills a specific function or goal and at the same time contributes to the functionality and integrity of the system as a whole.

In complex systems, there are many levels of organization. For example, an ecosystem contains a number of colonies of different species, each containing hundreds of individual organisms. Each complex living organism has several organs, each with numerous cells. Each cell has several organelles containing a host of complex molecules, each containing large chains of atomic elements. From an opposite perspective, we can view the organizational hierarchy that starts with sub-atomic particles, atoms, and molecules, as widening to sub-cellular organelles to cell units, to specialized organs and individual organisms, ultimately to include the whole cosmos.

### *Common features of systems and processes*

Numerous examples demonstrate the difference between the 'emergent' attributes of a system and the characteristics of its subsystems. A piece of music differs from the musical instrument that has produced it, the meaning of a word from its composition of letters, and the end product of a factory from its machinery.

Another shared aspect of many complex systems is their ability to adjust to varying conditions while maintaining their operational integrity. Several kinds of feedback mechanisms often maintain equilibrium and stability in a system, whether they be artificial and natural inanimate or living systems.[1] In a star, radiation pressure and the counter effects of gravitation produce a negative feedback mechanism, maintaining the star in a stable condition for billions of years.

In living organisms, body temperature, heartbeat and sleep cycle and practically every aspect of biological life, is controlled by a feedback mechanism. Similar feedback can be seen in social and economic systems, such as the automatic adjustment of commodity prices by changes in supply and demand. However, in spite of elaborate 'negative feedback' mechanisms, change and instability frequently can come about in a system with time, either from internal or external influences. If these changes are significant, the system will cease to exist in its original configuration. For example, there is the collapse of stellar systems, the death of living organisms and the extinction of species. Incremental changes or perturbations, on the other hand, can make the system leap from one 'quasi-stable' condition to another, as in the case of biological evolution.

In a system, the relation between input and output parameters can be either 'linear' or 'non-linear'. In contrast to a 'linear' system, a system is 'non-linear' if the changes in system output are not proportional to the changes in the system input. If you work twice as hard, you may not double your income. System 'non-linearity' is a reason for the emergence of many complex natural systems and processes. For instance, the laminar flow of water has a simple form, but 'non-linearity' in the dynamics of the fluid may lead to turbulence, thus creating infinite configurations of vortex flow.[2]

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[1] See Appendix A6 for general complex inanimate systems and A7 for man-made systems.

[2] See Appendix A9

‘Chaos’ refers to the dynamic outcome of complex systems which, due to extreme sensitivity to small parameter changes, become highly unpredictable or ‘chaotic’.[1] System ‘non-linearity’ creates the potential for numerous outcomes, in which any of a large set of possible initial conditions may bring about one of many outcomes within certain confined limits. In ‘non-linear’ systems, extreme sensitivity to small system parameter changes such as a butterfly flapping its wings, may lead to the initiation of a potential storm known as the ‘butterfly effect’.

‘Non-linearity’ that is the cause of chaotic behavior and unpredictability can also become a source of order. Many aesthetically pleasing shapes and colored patterns seen in nature may have their origins partially in non-linear interactions that eventually reached an ordered state from a chaotic phase. In fact, the processes of biological evolution and natural selection have taken place in a ‘non-linear’ physical environment, which has significantly shaped their outcome.

### *Conservation laws of nature – constancy and change*

Universal processes are an interplay of the forces of constancy and change. While change, transformation and renewal are the norms of existence, continuity and permanence play an equally important role. The laws of the conservation of nature are responsible for the stability and integrity of all physical processes. Conservation laws include the conservation of mass, energy, momentum, and electric charge among others. In the absence of the conservation of some physical parameters in nature, the future would be disconnected from the past, and every event an independent random occurrence.

It is hard to imagine a world in which some parameters may change spontaneously at any moment with no influence from the past. Take the example of a simple pendulum. As the mass of the pendulum swings upwards, its kinetic energy decreases, while its potential energy increases. The reverse occurs when the pendulum, after coming to a momentary rest, swings downwards. In both cases, total energy is conserved, with the oscillation of the pendulum sustained through the simple law of the conservation of energy. If energy was not conserved and the ‘memory’ of the ‘conserved energy’ not retained, the motion of the pendulum would be utterly erratic.

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[1] For more about chaos theories see Appendix A9.

Consider also the processes of chemical interactions. If such interactions produced infinitely stable molecules, no further chemical interactions would take place, and the universe would remain a static lifeless mass. On the other hand, if every new molecular formation were short lived, all substances would revert to their original atomic elements and the universe would be void of any substance apart from the atomic elements of the periodic table. Hence conservative forces are necessary for maintaining the continuity of physical systems. This is also true for the integrity and evolution of biological, and even economic and social systems.

All aspects of nature are indeed a delicate balance of constancy and change. An important example in biology is the basic conservation of segments of genetic information transmitted by genes from generation to generation, ensuring the perpetuation of the species, without which no living species would exist today. At the same time, fractional mutation in the transfer of genetic code from generation to generation ensures the incremental changes required for a species to adapt to its environment. It is such balanced, incremental, and cohesive changes in nature that bring about the gradual evolution and unfolding of the physical world.

### *The unfolding universe and the notion of a goal-directed process*

From a historical perspective, we can see the gradual unfolding of our universe as a goal-directed process, beginning with simple primordial matter all the way to its current complex structure. An analogy may be made between the unfolding of this primordial matter through many intermediate steps to our present universe, and the transformation of a seed to a root, stem, bud, and flower – albeit on a vastly different time scale. When dissecting a seed, it is not possible to see signs of the flower within the seed, although it has within it the intrinsic potential to develop into one. Similarly, the properties and structure of the early universe would have contained within it the potential to evolve into the present natural world with all its diversity and myriads of living forms. Both transformations, that of a seed to a flower and that of primordial matter to our present universe, are equally natural and at the same time equally miraculous.

Having witnessed the unfolding of a seed to a flower, it would be difficult to imagine that the complex genetic structure of a seed exists for any purpose other than for its subsequent unfolding into a flower. Similarly, it is most improbable that the singular state of the originating primordial matter was set and finely-tuned for any course other than its subsequent transformation into complex molecular structures, to living forms, and ultimately to the appearance of mind and consciousness.

Presently, the notion of a purposeful or 'goal-directed' process is an acceptable norm in the field of biological sciences. It is considered legitimate, for example, to ask 'what is the purpose of the beating of the heart in the human body?' We are not surprised to learn that there is a reason for this phenomenon, namely, to supply blood to different bodily organs. There are numerous examples of goal-directed processes in biological systems. One most poignant example is that of the systematic development and growth of an embryo's organs, the purpose of which is only apparent when the child is born. Research in the field of biology presumes and seeks out a function or reason for every process that it studies, even at a molecular level. Indeed, all biological processes can be considered as goal-driven, the final goal being predefined by the genetic code.

However, to make a similar enquiry as to, 'why nucleosynthesis occurs inside stars?', and to suggest that the reason is to synthesize the necessary chemical elements that lead to the formation of inorganic and organic molecules, to the appearance of pre-biotic states, and to the evolution of living cells and organisms, has not been generally admitted by physicists. To a physicist, nucleosynthesis occurs merely because hydrogen gas within the star reaches exceedingly high temperatures due to gravitational compression.

Such a stark difference in outlook between the different disciplines of science may be due to their varied historical developments and differing approaches to the study of physics and biology. However, it is legitimate to question why physics cannot ask the same questions of 'why' or 'what for' as does biology. In the light of our present knowledge of cosmic evolution and of subsequent biological evolutionary processes, the acceptance of direction and purpose in both physical and biological sub-systems of nature, is indeed legitimate. [1]

Over a short interval of time, any set of events may be viewed as accidental or a sequence of cause and effect with no direct aim. Over a longer interval of time, the same set of events can be considered as a part of a dynamic system

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[1] 'It is suggested that as biology is integrated and contributes more insight to the physical sciences, science as a whole may witness a rebirth of teleological perspective. We may begin to ask, not only the causes of cosmic events, put also perhaps their utility and their ultimate aim.' See: [**James N. Garner,** p79, **Biocosm,** Inner Ocean 2003]

revealing a specific purpose and direction. The mechanical forces exerted by an unwinding spring on the cogwheel of a clock may cause the motion of the clock's hands. This local description does not reveal the function and purpose of the clock as an instrument for measuring time. Globally, a clock is an instrument that measures time, and in this description even its detailed mechanism of action is mostly irrelevant. The two possible descriptions of the clock as an unwinding spring and as a gauge for the passage of time, however, are not mutually exclusive.

Similarly, the scientific description of the cosmic evolution of our universe as a sequence of certain physical events does not preclude it from having directionality and purpose. The growth of an embryo is the consequence of mere biological processes that conform with the natural laws of physics and chemistry. Yet the realization that every stage in this growth is directed to an end, the birth of a child, in no way contradicts the causal description. At the same time, such a conceptual perspective enriches our understanding of the growth process.

Some may argue that biological evolution based on chance mutation is random and accidental and hence does not follow any direction or goal. Although there are elements of chance in the evolution of species, biological evolution as a whole is clearly not a purely random process. Genetic mutations may be inherently random,[1] but the necessity for survival of the mutant, in conformity with its own internal complex constituents and external environmental conditions, places important constraints upon the evolutionary pathways of living organisms, and undermines the purely random proposition of biological evolution. This is not dissimilar to the example of the motion of electrons inside a material substance. Here, while they may exhibit intrinsically random motion, the electrons will occupy discrete energy levels defined by the atomic structure of the substance as a whole.

Accepting these premises, it is highly probable that if the same initial and subsequent cosmic ecological conditions were present, evolution if started over again elsewhere in the universe, would result in evolved species, that would in time assume many similar though not identical traits to the species living on Earth today.[2] Even here on Earth,

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[1] 'Mutation has many sources and randomness may apply less than what is initially thought.' See: [**Cameron M. Smith**, p240, **The fact of evolution**, Prometheus Books, 2011]

[2] **'**If the tape of life and evolution were rerun - either on Earth or on another planet - the same impulse toward order and self-organization would emerge and the fundamental pattern of ever greater biological complexity would eventually reveal itself.**'** [**James N Gardner,** p54, **Biocosm,** Inner Ocean, 2003]

many physical traits such as wings or vision in animals may have appeared virtually independently several times in the course of biological evolution, a phenomenon known as 'evolutionary convergence'. Indeed, the appearance of highly intelligent life forms would have also been likely.

It seems highly improbable that complexity, life, and consciousness have come about from mere random processes. A blueprint for the universal patterns of physical and biological processes appears inherent within the profound laws of nature and the genetic information of biological forms. Whether or not such a blueprint is 'designed' by an all-pervading omnipresent 'intelligence' does not alter the inherent existence of such a blueprint. How we view the origin of this 'blueprint' depends on whether our context is scientific or philosophical. Science is the modelling of the relationship between observed events as cause and effect and all scientific explanations are given within these confines. However, our intellectual enquiry needs not have the constraints of scientific methods. Philosophy can consider metaphysical questions of the 'first cause' and the ultimate meaning and purpose of existence and life.

### *Determinism and chance – Evolution and progress*

The proposition of an unfolding or evolving universe, does not necessarily infer strict determinism. There are abundant intrinsic random variables in nature that would make the detailed course of events indeterminate. While one may expect a seed to grow into a tree, this is still dependent on the accidental conditions of sufficient water, sunlight, and an adequate soil with nutrients. The same differing environmental conditions also contribute to the fact that no two trees are identical. Hence, in nature we have both elements of determinism and chance. The former defines the general course of events, and the latter is the source of its diversity, richness, and beauty.

The concepts of directionality and 'progress' have become a question of discussion since Darwin proposed his theory of evolution. There are many possible definitions of progress.[1] None of these, however, has proved adequate or universally applicable. There is no objective way to decide whether a flower, a butterfly, a goldfish, or a child,

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[1] For further discussion of the concept of 'progress' see for example: [Section I – Is Evolution Going Anywhere, **Evolution Extended** - Biological Debates on the Meaning of Life, edited by **Connie Barlow**, Massachusetts Institute of Technology, 1994]

seen at the site of a garden pond, can be ordered in a line of ‘progress’ in any meaningful way, as each has reached a degree of ‘perfection’ in its own realm. Nevertheless, a sense of evolutionary direction in terms of increase in complexity, diversity and fulfilment of latent potentialities is easily discernible. It is perhaps not such a great leap to see such increase in complexity as the ’goal’ of evolution. No one can claim that the status of life in the world today, with its millions of species each adapted to their own environment or niche in a balanced and integrated biosphere, is the same as when the first pre-biotic molecular forms came into being three to four billion years ago. Thus, the notion of ‘progress’ may be better replaced by that of an ‘unfoldment’ from less to more complex, such as with a seed that grows to a tree with multiple branches and flowers.

### *The anthropic principle*

It is well known that in addition to the laws of nature, there are certain invariable physical constants that greatly influence the structure and evolution of our universe. A few examples of these are Newton’s constant of gravitation, the Planck constant, the Coulomb constant, and the constant speed of light in a vacuum. It is of interest to note that no cosmic interactions and evolutionary processes could have ever taken place if these physical parameters or constants of nature were fractionally different. Were it not for these seemingly coincidental good fortunes, atomic structures would not have been realized, galaxies, stars and planetary systems would not have been formed, chemical constituents of living organisms could not have been synthesized, and we would not be here to discuss any of these possibilities.[1] The existence of such finely-tuned parameters and the fact that we exist, leads us to the ‘anthropic principle’ that indeed the universe must have properties that allow life to develop within it.

Generally, there are two ways in which we could view the anthropic principle. The first is that the universe has inherent within it the ability and the properties to support life and is in fact designed to be compatible with the evolution of living organisms. If the constants of nature are not arbitrary, but fixed by the laws of physics, nature's physical laws must lead inevitably to the appearance of life and consciousness.

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[1] For discussion on the fine tuning of these universal constants, see: [**Paul C W Davies,** p60, **The accidental universe,** Cambridge University Press, 1987]

The second is that the very fact that life exists in our universe has constrained the values that these physical parameters could have assumed. This suggests that other parallel inhabitable universes in a 'multiverse' may exist that have differing physical constants, but without living organisms that would necessitate a set of favorable physical parameters. However, no matter how many other universes may exist with physical parameters not conducive to life and consciousness, their existence cannot explain the unique universe that does have such favorable parameters. The debate over the parameters conducive to the existence of life is therefore simply raised from the level of discussion of a 'universe' to that of a 'multiverse'. Our 'universe' as a subset of the 'multiverse' cannot assume properties that are absent in the set as a whole. Hence again it can be said that the physical laws and physical constants of the 'multiverse' must be such that they inevitably lead to the appearance of life and consciousness.

Yet another possibility is to envisage our universe as part of a greater structure that has set the favorable initial conditions of our present universe. We have considered our universe as a hierarchy of interacting and evolving systems and processes. Though our present universe may have a finite life span from its inception to its thermodynamic death, it need not be a unique or isolated phenomenon, but may indeed be a part of a greater hierarchy of evolving systems.

Whatever the explanation, the 'anthropic principle' that the universe must have properties that allow life to develop within it, remains true. Indeed life, consciousness and intelligence are integral parts of the cosmos.

### *The universe as an intricate and integrated evolutionary process*

In conclusion, the notion of an accidental or static universe with heavenly bodies in perpetual epicyclical motion is no longer an adequate description of our universe; the universe is dynamic and evolving, with its configuration changing at every instant. As a seed that unfolds through multiple complex processes into a flower, the universe has unfolded through a set of complex dynamical states and processes, each having a specific function and contributing to the integrity of the whole.

# 5. Unfolding social order and emergence of a world civilization

Viewed in its totality, the emergence of life, consciousness and intelligence in the universe, the result of a hierarchy of multiple processes over billions of years, may be seen not as an incidental or divergent anomaly, but as an integral part of the universal evolutionary process. Equally, as part of this evolving process, our understanding of the universe, our empirical knowledge and our intuitive awareness of reality, have themselves been subject to change and transformation. Such transformation has come about through the interplay of objective inquiry as a result of humanity's never-ending scientific quest and by the accumulation of subjective experience as reflected in the evolution of the arts, literature, philosophical, religious and spiritual thought throughout the centuries.

Seeing our world as a universally evolving reality gives new significance to every facet of our existence. In particular, the life of the individual and of social order in human society assume a new meaning and importance. Indeed, individual intellectual and spiritual development, as well as the advancement of human society in its entirety, may be seen as an integral part of a grand evolutionary scheme. However, here, human beings as individuals as well as humanity as a whole has the unique ability to influence to a large extent, the possible outcome of its own evolution.

### *A world in chaos*

In spite of our advanced scientific knowledge and technological achievements, the world today is beset by countless problems and is in a state of ever-increasing chaos and disharmony. It is not hard to see that this confusion stems from a multitude of false human perceptions, ideologies, and convictions.

Materialistic doctrines have led to materialism; the excessive attachment to material gains, greed and competition, pursuit of short-lived pleasures, and to many other of the social ills that prevail in society today. At the same time, religious fundamentalism with its associated rigid mind-set, codes of laws and claims of absolute truth, is ever expanding its hold in the world. Conflicts that stem from racial, national, and ethnic sensitivities and religious and ideological differences are widespread. The world is a stage for war between irreligion and religious fanaticism.

The global issues of climate change, air pollution, land degradation, water contamination, de-forestation, and the depletion of natural resources, which have brought about the extinction of numerous species and resulted in dangers to the biodiversity of our planet and ultimately to human life itself, are rightly drawing the attention of peoples and governments. Global concerns, however, are not confined to issues of the physical environment alone. Violence, acts of terror, political disputes and wars, and large inequalities in the distribution of wealth leading to poverty and disease that constitute our current day social environment, are equally as important to our survival and wellbeing as our natural environment.

### *Purpose and meaning in human life*

Since the advent of empirical science, there has been a perceived dichotomy between science and religion. In essence, religious conviction is the affirmation of meaning and purpose in human existence. Many scientists, however, consider nature to be either a captive of blind forces or a victim of probabilistic incidents. This approach to science has led to a materialistic worldview that excludes any notion of purpose in the universe, and as a corollary, any purpose to that of human existence.

A paradigm that views the world as a coherent system of purposeful processes need neither oppose the findings of science, nor the inner convictions of countless peoples of the world who hold the intuitive belief that the universe with its profound beauty and diversity cannot be a mere aimless and mindless collision of 'particles' or an agitation of 'strings'. In contrast, the acceptance of direction and purpose in the unfolding of the universe allows humanity to find meaning in the scheme of existence. This is particularly significant for us as human beings, who in the absence of a wider purpose may struggle to find a meaningful direction and purpose in our own lives. Finding an answer to the question of the 'ultimate' purpose of existence and life is a never-ending quest. Accepting a direction and purpose to the natural processes in our universe is just a first step in this direction.

Equally, an evolutionary paradigm of renewal and change applied to human philosophical, spiritual, and religious convictions, frees man from narrow-minded orthodoxy, assumptions of superiority and ownership of the absolute truth. All mental constructions of our external world, in whatever form, are subject to transformation and change. Spiritual, philosophical, and religious ideas are no exception to this. All religious teachings have made significant contributions to the advancement of both human consciousness and the world's social order. Each has emphasized the same core spiritual teachings of love, compassion, and detachment from excessive materialism, but with varying social teachings in accordance with the needs of the time. Nevertheless, as all philosophies and religious beliefs are constrained by human perception and the limitations of human language, no religious philosophy can represent the final or absolute truth. In fact, at no time can humankind claim full knowledge or even the capacity to comprehend every facet of reality.

Denial of the multifaceted and dynamic nature of religion, that religious and spiritual understanding as well as practices are subject to change over time, has led not only to conflict, but has also caused religion to contradict itself, becoming its own 'antithesis'. Accepting the progressive and complementary nature of faith and that it should be in accord with science and reason, would reclaim the eminence of religion as a vital force capable of restoring balance between the material and spiritual aspects of human life.

A conviction that our individual and collective existence on the Planet is part of a greater evolutionary process in the universe and has meaning and purpose, makes us to re-examine many aspects of our moral and ethical life and may lead to the cultivation of those qualities that enable individuals to engage constructively in building an advancing human civilization. Viewing each individual as an integrated part of an organic whole should also undermine those tendencies that lead to a sense of racial superiority or excessive national and ethnic pride, tendencies that ultimately lead to conflict and war. At the same time, it can cultivate a sense of solidarity and sharing that could lead to the elimination amongst other ills of the disparity between rich and poor prevalent today across the globe.

Each individual is an outcome of billions of years of evolution and transformation! The constituents of the human body are the same matter that is synthesized and recycled countless times throughout the vast regions of physical space. Indeed, within the human reality are ingeniously enshrined all the laws of nature and their intricate relationships. The ability of the human mind to comprehend the profound laws of nature, even to a limited extent, is a tribute to human ingenuity and merit. Acknowledging the intricate and complex steps occurring over billions of years that have led to the appearance of life, should bring about a greater appreciation of the value of every human being and for that matter, of every living creature on the Planet.

### *Altruism - From aggression to compassion*

Biological evolution is sometimes viewed as a struggle for survival where different species or members of species are competing for limited resources.[1] Within this competitive environment, it is usually the strongest or the 'fittest' that will survive. It is also true that living species are all part of the food chain of predator and prey, with each living organism attempting to maintain its own provisions for life. Similarly, the quality of self-preservation and protection of offspring are natural both to animals and humans. Many have attempted to extend the concept of the survival of the fittest to justify acts of violence and aggression carried out in our society and suggested that humans are by nature aggressive and competitive. It is true that human beings are a part of the animal kingdom and share many physical attributes with other animals. However, the degree of man's cognitive capacity, which enables him to contemplate and comprehend abstruse scientific concepts and bring about astonishing technological advances, sets the human species apart from the rest of the animal world. Many acts that can be justified in animals based on their

[1] Nature has its own reality, its order and scheme, independent of how it is perceived or described by man. To make sense of the workings of nature, however, we need models, analogies, and metaphors. Protons, neutrons, electrons, and other elementary particles and their physical attributes of mass, charge, wavelength, energy are only human models and metaphors for the descriptions of the unknown realities, the ultimate nature of which cannot be apprehended. The models and metaphors we use are provisional, and historically and culturally conditioned.

Presently, at the level of genes, individuals and perhaps species, struggle for survival, selfishness, aggression, arms race and similar descriptions appears to be acceptable metaphors for depicting some aspects of the biological world and biological evolution – although nature itself surely does not embody any such conceptualizations!

On the other hand, at the global level of ecosystems or the biosphere itself as a whole, where countless organisms live in symbiotic relation, with their lives intimately dependent on each other and precisely balanced, the metaphors of coexistence, cooperation, co-adaptation, mutual interaction and interdependence, as well as systemic notions of feedback, stability and emergent order, are much more appropriate.

instincts cannot be justified in humans who have developed the faculties of knowledge and reason. Man is capable of rising above his lower animal nature to conduct himself in ways that overcome the aggressive aspects of his biological evolutionary past. Indeed, within each human being is contained mines of potential capacities, which with proper nurture and education can reveal their gems of nobility and virtue.

Contrary to what has been claimed, it is not against the nature of man to live in harmony and cooperation. Some animals indeed live in groups or colonies based on harmonious cooperation and mutual assistance, with this collaborative mode of living advantageous to each individual member of the species. In emphasizing the competitive mode of biological evolution, one may overlook the fact that the existence of the whole structure of the universe itself is based on the forces of mutual attraction.[1,2] Consider the crucial role of the inter-quark strong force in the formation of the atomic nucleus; electron-proton attraction in the configuration of atoms; the force of gravitation in the realization of galactic structures; fusion in the synthesis of heavy elements; symbiosis in the formation of cell organelles; the cooperative action of constituent parts on the life of a cell; the harmonious functioning of the organs in a living organism; and the integrated action of an ecosystem on the life of each species. Indeed, without attraction, cohesion and intimate collaboration, the universe as we know it would not exist. Survival has throughout history also required man to act in collaborative and altruistic ways, for example in the forming of tribes, villages, city states and nations. Indeed, many altruistic human attributes that may have developed through the past operation of evolutionary forces have now become an integral part of human nature.

Like all evolutionary processes, human society has passed through many changes and stages of development. Some of these have been wrought with upheavals and conflicts. Nevertheless, they may be considered as inevitable stages in the processes of growth and maturation, just as when a child goes through adolescence to reach maturity.

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[1] ‘If competition is evolution’s motive force, then the cooperation is its legacy. And legacies are important, for they can endure long after the force that created them ceases to be.’ See: [**Tim Flannery**, P31, **Here on Earth,** Published by Text Publishing Australia, 2010]

[2] For further discussion see: [Section II – Tools and Metaphors of Evolution, **Evolution Extended** - Biological Debates on the Meaning of Life, edited by **Connie Barlow**, Massachusetts Institute of Technology, 1994]

The notion that human society must necessarily remain in a perpetual state of conflict and war is questionable. Evidence points to the fact that in the face of the many conflicts in the world, there is nevertheless a simultaneous increase in the breakdown of the barriers between races, nations and ideologies as the people and governments of the world find themselves in ever increasing contact, interaction, and integration. With the increasingly global nature of political and economic interactions, it is indeed highly probable that out of the present chaos, a new order or global society may emerge, one that is based on reciprocity and cooperation. Indeed, with the increasingly violent disturbances in our world, humanity may have little choice but to learn how to coexist.

### *A global civilization as a facet of universal evolutionary processes*

While maintaining the diversity of its people's and cultures, a united global civilization living in peace would have unbounded potential for material, intellectual and spiritual development and for unprecedented achievement. The creation of such a civilization is certainly within the reach of the human race and is a fruit of the evolutionary process. A worldview that confirms a direction and purpose not only to the physical evolution of our universe and planets but to all facets of existence, gives a meaning and purpose both to individual and to the collective life of society, and empowers humanity to take part collectively in the enterprise of building a better world. A set of basic principles and common convictions amongst humanity would aid in accelerating such a change towards a peaceful society. A view that the members of the human race are mutually interdependent; that irrespective of racial, national, religious or ideological background all can, and must, contribute to the integrity of the whole; and that humanity is in need of both material and spiritual advancement in order to reach its full potential, will go a long way to ensuring the success of any endeavor to bring about such a global civilization.

When humanity works together, the outcomes can be unimaginable. Already the interconnected and integrated systems of computers around the world have created a new phenomenon in information and data transfer, a 'superhuman mind' connecting the minds of millions of people around the globe. Prehistoric man could not have ever imagined our present-day global society and the vast amount of knowledge and information available to the masses of the Planet with a click of a computer mouse. Similarly, humanity today is unaware of the potentialities to which it can, individually and collectively, aspire and rise, should it choose to live together peacefully. Indeed, if the material and human resources now spent on conflict and war were to be used on education and the development of human capacities, the results would be inconceivable. The intellectual and cultural interaction of billions of people would potentially create astounding sciences, arts, music, and literature on our planet.

Baha'u'llah, the founder of the Baha'i Faith envisaged such a global society more than a century ago as stated by **Shoghi Effendi** in **The World Order of Baha'u'llah** [1937]:

> The long ages of infancy and childhood, through which the human race had to pass, have receded into the background. Humanity is now experiencing the commotions invariably associated with the most turbulent stage of its evolution, the stage of adolescence, when the impetuosity of youth and its vehemence reach their climax, and must gradually be superseded by the calmness, the wisdom, and the maturity that characterize the stage of manhood. Then will the human race reach that stature of ripeness which will enable it to acquire all the powers and capacities upon which its ultimate development must depend. Unification of the whole of mankind is the hallmark of the stage which human society is now approaching. Unity of family, of tribe, of city-state, and nation have been successively attempted and fully established. World unity is the goal towards which a harassed humanity is striving. … The unity of the human race, as envisaged by Baha'u'llah, implies the establishment of a world commonwealth in which all nations, races, creeds and classes are closely and permanently united, and in which the autonomy of its state members and the personal freedom and initiative of the individuals that compose them are definitely and completely safeguarded. … A mechanism of world inter-communication will be devised, embracing the whole planet, freed from national hindrances and restrictions, and functioning with marvelous swiftness and perfect regularity. A world metropolis will act as the nerve centre of a world civilization, the focus towards which the unifying forces of life will converge and from which its energizing influences will radiate. A world language will either be invented or chosen from among the existing languages and will be taught in the schools of all the federated nations as an auxiliary to their mother tongue. … In such a world society, science and religion, the two most potent forces in human life, will be reconciled, will cooperate, and will harmoniously develop. … The economic resources of the world will be organized, its sources of raw

> materials will be tapped and fully utilized, its markets will be coordinated and developed, and the distribution of its products will be equitably regulated. National rivalries, hatreds, and intrigues will cease, and racial animosity and prejudice will be replaced by racial amity, understanding and cooperation. The causes of religious strife will be permanently removed, economic barriers and restrictions will be completely abolished, and the inordinate distinction between classes will be obliterated. Destitution on the one hand, and gross accumulation of ownership on the other, will disappear. The enormous energy dissipated and wasted on war, whether economic or political, will be consecrated to such ends as will extend the range of human inventions and technical development, to the increase of the productivity of mankind, to the extermination of disease, to the extension of scientific research, to the raising of the standard of physical health, to the sharpening and refinement of the human brain, to the exploitation of the unused and unsuspected resources of the planet, to the prolongation of human life, and to the furtherance of any other agency that can stimulate the intellectual, the moral, and spiritual life of the entire human race. …

Our planet is being propelled forward towards a global civilization by forces beyond our control. Presently, however, we are encompassed by enormous challenges that if not promptly addressed may lead to immense human misery and hardship throughout the world. Nothing short of a universal collective effort can divert this impending suffering and set it on the right path to its destined glorious future. It is up to each individual to decide whether through his or her thoughts, words, and actions, wishes to impede or accelerate this stupendous evolutionary process.

# Epilogue

Those of us who live in larger cities are deprived of the beauty and tranquility of the countryside. The glare and noise of a busy metropolis prevents us from hearing the sounds of nature. Far from the confines of the city, however, the rolling hills and green pastures, the flowing rivers and the roaring of the ocean waves can fill our souls with joy and wonder. The gleaming orb of the sun setting over the azure sea leaves us in a reflective mood, and as the darkness of night envelops us, the profusion of stars inspires awe in our hearts.

That every point of light in the night sky is a planet, a star, a stellar cluster or even perhaps a galaxy of billion stars, with its own creatures - teeming with motion, commotion, and life - gives us a sense of the magnificence of our world and its profound organization.

At the same time, the enormity of space can be overwhelming. Are we a mere speck in a dust storm, an insignificant drop in a vast ocean?

Insignificant as we may feel in this immensity and vastness of the heavens, in our absence, all things would fade into a shadowy existence, an elusive reality. The plains and the hills, the vast oceans and multitudes of scintillating stars would be reduced to wave-particle plays of the quantum world or the waltzing of multi-dimensional 'strings' - as described by the current theories in science. In fact, the physical universe bears no resemblance to what our senses perceive, or our minds apprehend.

Perhaps it is the human mind that interprets, or even in some sense, creates the world and its spatial dimensions, the flow of time, spectrum of colors, songs and melodies, the senses of smell and touch, and beyond that, joy and sadness, love and resentment and a vast multitude of feelings. We create a history of the past and anticipate the future, delve into the workings of nature through science and search for meaning through philosophical debate.

While recognizing the enormity of space, we do not need to feel insignificant. In our possession is the most precious gift, our human brain. Held as a collection of neurons in a box of minuscular size - it receives, it stores, and it retrieves a staggering amount of information at every moment. It assigns color to an incoming electromagnetic wave, sound to vibrations of air, taste to chemical substances, smell to a vapor and sense to a touch - an interface between external reality and the realm of our consciousness.

We may ponder the journey that each molecule in each neuron has taken to reach the complexity necessary to fulfill its function: the evolution in eons of time through the galactic, stellar, geological, and biological processes that have taken place to enable it to reach its present state. Indeed, the human brain in some sense captures the history of billions of years of cosmic evolution through many physical and biological pathways, in a universe that is ever unfolding.

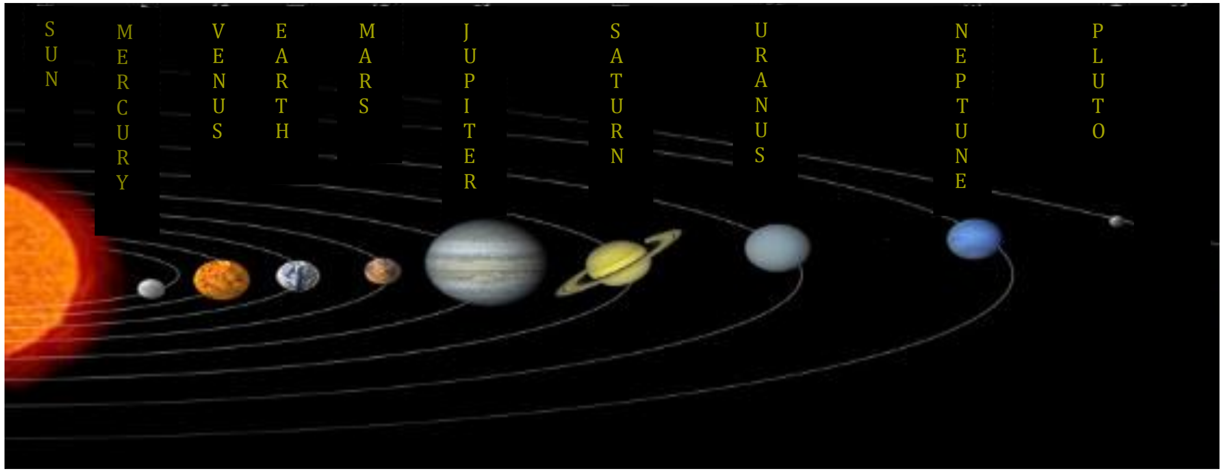
Humanity is astounded by the magnificence of the cosmic structures, and the elegance of the physical laws of nature, by the biological complexity and diversity of life, and the wonders of technological miracles, and yet may have lost an appreciation of its own merit. We wonder endlessly about what is outside of us, but less about our inner reality and potentialities. Is it plausible that the miraculously evolved capacity of our brain to perceive and to construct a coherent mental representation of external reality is but a reflection of deeper laws of nature—and that the emergence of the intelligent observer is a necessary outcome of cosmic evolution, and perhaps the whole of the cosmos a vehicle for the appearance of such a life form?

Aspiration for excellence, a desire to know and search for meaning, a capacity for musical and artistic appreciation, an inclination for altruistic acts, compassion and mercy, tolerance and benevolence, and limitless and boundless love, are but some of many potentialities that are enshrined in the reality of a human being. Poets, seers, philosophers, and prophets throughout the ages have sought to make us aware of our true reality. In the words of Baha'u'llah: man is a 'mine rich in gems of inestimable value'. How regretful if these lustrous gems remain concealed by the dust of perpetual human conflict based on racial, national, and religious prejudices - or by the excessive pursuit of worldly concerns promoted by a materialistic worldview.

Yet as with the unfolding of the physical universe, the social evolution of humankind will move forward and unfold. The forces of history will bring us together and a global civilization will dawn, a civilization that seeks to bring to fulfillment the infinite human potentialities within every member of human society.

# Part II: Appendices

# A1. Birth and expansion of the universe




***A1.1 - The Sun and the solar planets***

The Sun is an average sized star, consisting of about 74% Hydrogen, 24% Helium and the remaining 2% of other heavier chemical elements. Inside the Sun, Hydrogen atoms convert to Helium in nuclear reactions, releasing a tremendous amount of energy in the form of radiating heat and light. The planets rotate around the Sun in elliptical orbits that lie nearly on the same plane.

Our planet Earth and its satellite, the Moon, are parts of a system of nine planets revolving around the Sun. Mercury, the planet closest to the Sun, has a surface temperature reaching approximately 420 degrees centigrade. The hot surface of Venus, the second planet away from the Sun, is disguised by thick white clouds of carbon dioxide and droplets of sulfuric acid. The Earth is the third closest planet to the Sun with its terrain and atmosphere conducive to the perpetuation of life. Mars, the fourth planet away from the Sun is the planet closest to the Earth.[1] Wide channels running on the surface of Mars bend through eroded lava plains of past volcanic

[1] Today science is still in search of life on Mars, but not for little green Martians, but for traces of water and organic substances that may indicate the existence of past or present primitive living forms.

eruptions. Jupiter, the largest planet in the solar system and the next planet away from the sun, has a solid central core surrounded by a liquid layer and then by gaseous hydrogen and helium. On its surface there are many-colored bands of 'counter-flowing' clouds and a fluctuating 'Great Red Spot', which is a storm raging through its atmosphere. Like Jupiter, Saturn, next afar from the Sun and the second largest planet, has counter-flowing winds blowing from east to west and from west to east. Its seven major rings are composed of orbiting ice particles. Next planet Uranus has an extended liquid core with an atmosphere composed mostly of hydrogen, helium, methane and traces of ammonia. Uranus is surrounded by a broad diffused inner ring, and several thin and dark narrow outer rings. Neptune, the next planet away from the Sun is a large planet with a central core and an extended atmosphere that contains vast stormy regions that appear and disappear, reflecting its dynamic nature. Pluto, now considered as a 'dwarf planet', is only two-thirds of the size of the moon and is farthest from the Sun. Pluto may have been formed as an asteroid in the 'Kuiper belt' of objects beyond its orbit. The time that it takes for the planets to orbit the Sun ranges from 88 days for Mercury to 247 years for Pluto.

In addition to the planets, numerous heavenly bodies of various sizes and shapes orbit our solar system. Most of these can be found in the 'asteroid belt' between Mars and Jupiter. Meteors or shooting stars are pieces of rock or metal that reach the Earth's atmosphere and burn up due to the friction with air molecules. Occasionally a large meteor can reach the surface of the Earth and is then called a meteorite. Comets are made of ice and dust and travel an elongated elliptical path around the Sun.[1] As they approach the Sun, their ice particles melt and evaporate producing a 'coma' of glowing cloud of dust and gas with a tail of several million kilometers. The light of the Sun, travelling at a speed of 300,000 km/sec, takes about eight minutes to reach our planet. Travelling at the speed of light, it would take several hours to reach the farthest limits of our solar system, but a journey to 'Alpha Centauri' the closest star to us, in fact a triple star system that appears as a single star to the unaided eye, would take four years and four months. With the present speed of rockets in space, the same journey would take hundreds of thousands of years. Sirius, the brightest star seen from Earth, is almost twice as far away as Alpha Centauri and has twice the mass of the Sun.

### *The Milky Way*

Stars of differing size and brightness inhabit the Galaxy. These range from the very large and bright 'Red Giants', to the very dense, small and dim appearing 'White Dwarfs'. 'Neutron stars' are so dense that if a handful of this stardust were present on the surface of

[1] The last observed comet was a non-periodic comet visible in January 2007 in Sothern Hemisphere.

Earth, it could weigh as much as a mountain.[1] Still there may be even denser stars, the mysterious 'black holes', so dense that no material object, not even light, can escape their gravitational hold.[2]

***A1.2 - The Milky Way Galaxy***

The Milky Way is a spiral galaxy. The disc of the galaxy can be observed in the night sky as a faint band of diffuse stars. Our solar system is about halfway along one of the spiral arms of the Galaxy.

There are also 'variable stars' that change their brightness over intervals of as short as a few hours. Variations in their brightness are caused by either regular or irregular flares on their surface or from the transfer of gas between another star in the vicinity or even a periodic eclipse by a companion star in a binary star system.[3] The Cepheid Variables are massive stars that expand and contract in intervals of a few days to a few months. A 'pulsar' is a neutron star that generates a beam of radiation that rotates with the rotation of the star about its axis. The radiation is received on Earth as regular pulses of radiation - hence the name pulsar (pulsating radio star).

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[1] In a Neutron star the inter atomic space is collapsed and the star is composed almost entirely of neutrons.

[2] If the black holes are completely invisible, how will we ever know that they exist? See: [**T Padmanabhan**, p78, **After the first three minutes**, Cambridge University Press, 1998]

[3] A Binary star system is a system of two close stars with coupled rotational orbits.

***A1.3 - The Pleiades*** ***A1.4 - The Trifid nebula***

The Pleiades is a star cluster of hundreds of stars. The cluster is some 440 light years away from our solar system. A nebula is a vast collection of interstellar clouds of gas and dust. Trifid, a nebula in the Sagittarius constellation, reflects the light from a nearby star.

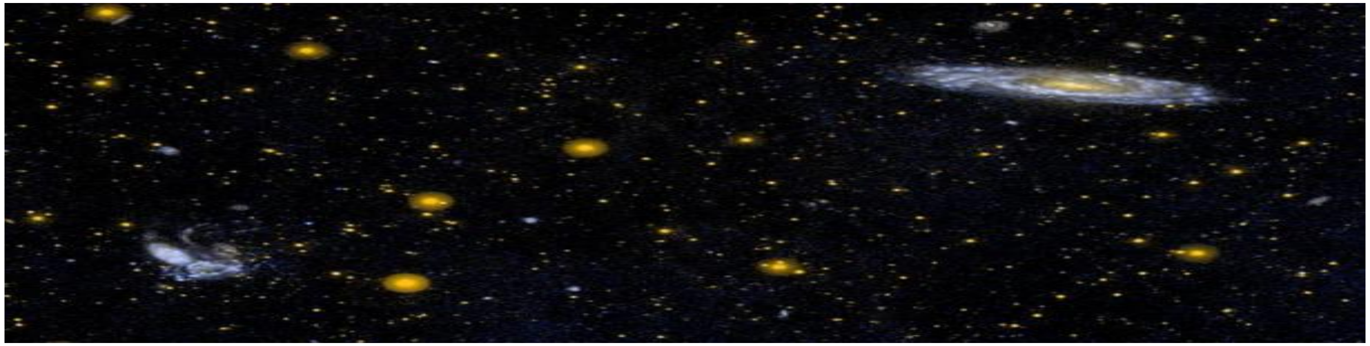
The stars in a galaxy are not uniformly distributed. Some form clusters with loosely associated stars arising from the same 'proto-galactic'[1] structures. These clusters contain thousands or millions of densely concentrated stars. The Messier cluster in the constellation Hercules and the Pleiades of the constellation Taurus are examples of large globular clusters. Interstellar clouds of gas and dust also aggregate to form what is known as a nebula. Reflecting the light of nearby stars, a nebula may have many shades of dim colors. Trifid, a nebula in the constellation Sagittarius, for example, appears red in color.

### *Clusters and super-clusters of galaxies*

The closest galaxy, Andromeda, is 2.5 million light years away from us. The visible universe contains hundreds of billions of galaxies at distances of millions or billions of light years away. Each galaxy contains between tens of millions of stars such as in 'dwarf galaxies', to hundreds of billions of stars as in 'giant galaxies'. The galaxies may either be spiral in the shape of a disk with spiral arms containing bright young stars and gas clouds where new stars are being formed, or ellipsoidal, containing mainly old stars. Andromeda is a spiral galaxy.

[1] Distribution of amalgamated gas clouds before galaxy formation.

Galaxies also come in clusters. The Milky Way and Andromeda, together with eighteen other bright galaxies are part of the 'Local Group', which is at the verge of the Virgo cluster. 'Super-clusters' of galaxies, containing tens or hundreds of galaxy clusters are arranged in long filamentary or flat structures of several millions of light years across. Enormous regions between these 'super-clusters' of galaxies remain almost void of any major collection of visible galaxies.



***A1.5 - Galaxy cluster***

### *Cosmic evolution*

The light from galaxies travels millions and even billions of years to reach our planet. The galaxies farthest away from us are therefore a panorama of the past history of the universe. Looking by the most powerful optical and radio telescopes to these far regions of the universe, we find strange objects such as quasi-stellar radio sources - quasars. Quasars are the brightest objects in the universe.[1] Although relatively small in size, they may be many times brighter than the total brightness of our Galaxy. These may have been the very massive black holes at the centers of the galaxies that appeared when our universe was still very young. Our journey further back in space and time takes us to the very moment of the presumed inception of the universe.

It is now commonly accepted that in the distant past, the universe was substantially smaller in size, and very different from its present configuration. In fact, at a certain time in the past, stars and galaxies did not exist and the universe was dominated by intense radiation. Going further back in time, none of the chemical elements presently known to us existed. The universe was infinitesimally small and

[1] Quasars are probes of the remote past. See: [**Martin Rees**, p49, **Before the beginning**, Simon & Schuster, 1997]

extremely hot and dense.[1,2] When this 'primordial matter', condensed in a foam-like space of minuscule dimensions, inflated, our universe was born.[3] What was there before and what lies beyond our known visible universe and whether it is a part of another encompassing structure, a 'super-universe' - if such questions can legitimately be asked - is impossible to ascertain.[4]

### *Redshift and the expansion of the universe*

Chemical elements within a star emit electromagnetic waves at certain specific frequencies that can be separated by the technique of 'spectroscopy' as different 'spectral lines'. The spectral lines of an element can be in the infrared, visible or ultra-violet regions of the electromagnetic spectrum or beyond. In the visible region of the spectrum, hydrogen has red, argon blue and sodium yellow spectral lines, amongst others.

Stars are in constant motion and at any time our solar system has a relative speed towards or away from a star. Consider two successive crests of light at a specific wavelength reaching our solar system from a star. If the solar system is stationary relative to the source of the radiation, the time difference between the arrivals of the successive crests would be equal to the time period of the radiated wave. However, as the solar system moves towards the star, the successive crests would reach our solar system in a shorter time and, with the speed of light remaining constant, the distance between the two crests, which is the same as the wavelength of the light, appears shorter. As the color blue has a shorter wavelength in the spectrum of visible light, this phenomenon is known as the 'blue shift'. If the star, however, moves away from us, the successive crests separate farther apart, and the light spectrum moves towards a longer wavelength or towards red and this is known as the 'redshift'. The spectral lines of the constituent elements of stars therefore reveal the identity of each element and give us an indication of the direction and speed of the star. The apparent change in the wavelength due to the relative motion of the source with respect to an observer is known as the Doppler Effect, and applies to electromagnetic waves, as well as, to the sound waves.

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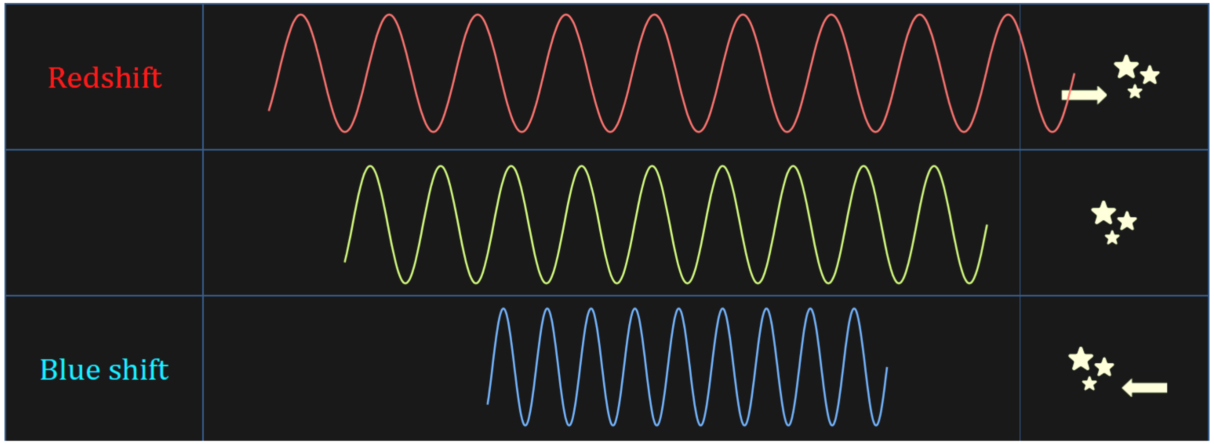
[1] An infinitely small universe that is predicted by the general theory of gravity is only a conceptual mathematical singularity and cannot have a physical reality. Quantum-gravitational treatment of the initial universe could remove this anomaly. See Appendix A5.

[2] See: [Joseph Silk, p112, The Big Bang, W. H. Freeman and Company, 1989]

[3] Due to spacetime quantum fluctuations, the initial minute universe may have not been smooth, but rather foam-like. See Appendix A5.

[4] A proposal by Hawking and Hartley suggests that as we move further in a backward trajectory in time, a point is reached when we inevitably curve back into a forward trajectory. See: [**Bernard Haisch**, p111, **The Purpose-Guided universe**, New Page Books, 2010]




*A1.6- Blueshift and redshift*

As billions of stars and galaxies and cluster of galaxies are in continual motion in every possible direction, it would be expected that on average there will be an equal occurrence of redshift and blue shift. But observation shows that on average the redshift of the far away galaxies far exceeds that of the blue shift. If the occurrence of the redshift is an indication of galaxies moving away from our solar system, the large red shifts of faraway galaxies indicate that on average these galaxies recede from us with tremendous speeds. It has also been observed that the farther away a galaxy is, the greater its speed of recession. The net recession of galaxies proportional to their separation is an indication of the expansion of the universe.

### *The Big Bang and the expansion of the universe*

At the beginning, it is now believed, that in a span of time less than a twinkling of an eye, the minute primordial foam of the universe inflated and became smooth, like the surface of an expanding bubble of soap.[1] High-density radiation filled this 'minute' universe, generating 'particle' and 'antiparticle' pairs that mostly reverted back to radiation by their collision and mutual annihilation.[2]

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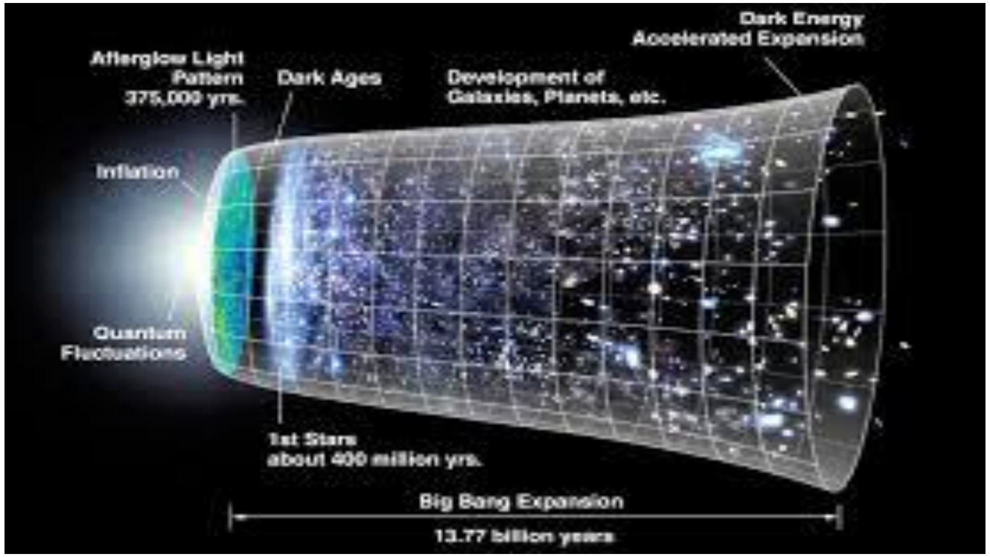
[1] For the theory of inflation or the brief period of extraordinarily rapid expansion of the universe, see: [**Alan H. Guth**, p14, **The inflationary universe**, Jonathan Cape, 1997]

[2] Particles and antiparticles have same mass and opposite charge. In collision they annihilate, converting to other particles or to a burst of electromagnetic radiation.




***A1.7- Schematic representation of Big Bang and the expansion of the universe***

As the universe expanded and cooled, the density of radiation energy decreased and, for reasons as yet not well known, 'particles' became dominant over 'antiparticles'.[1] Eventually a host of elementary particles including 'electrons', 'protons', 'neutrons' and 'neutrinos' appeared in a stable condition. Within a few minutes, hydrogen ions (composed of a single proton), a lesser amount of helium ions (composed of two proton and two neutron), and deuterium ions (with one protons and one neutrons), were formed.

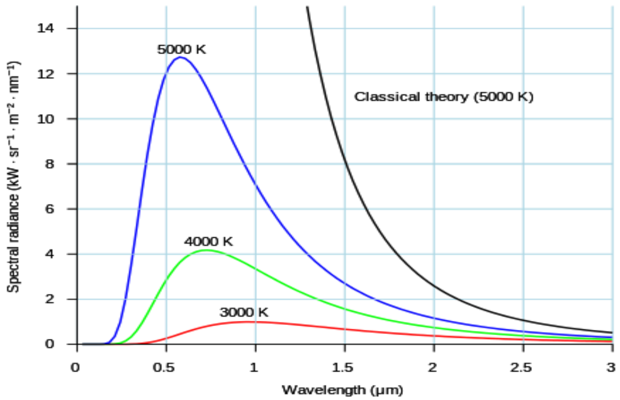
As the universe continued to expand and become less dense, the misty veil of intense radiation gradually lifted and the universe became more and more transparent. Hundreds of thousands of years, however, would have to elapse before the so-called 'de-coupling' of matter and radiation would be complete.

[1] With particles and antiparticles equal, they would annihilate each other with burst of energy. Hence universe would have been filled with radiation only. See chapter 10 for further discussion.

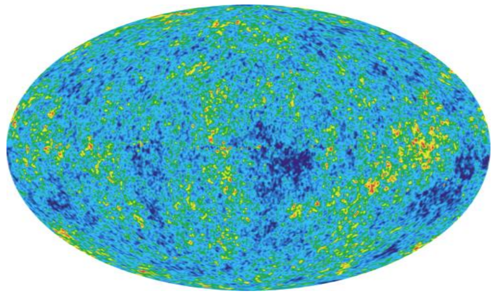
### *Blackbody Radiation and Cosmic Microwave Background Radiation*

It is well known that any substance at high temperatures emits electromagnetic radiation. The electromagnetic spectrum of the radiation is dependent on the temperature of the substance, with the emitted spectrum shifting to lower wavelengths (higher frequencies) as the temperature of the substance increases. If the substance is in the form of a closed container, the spectrum of radiated energy inside the container is independent of the material of the substance and only dependent on the temperature. This is known as blackbody radiation.

In 1964 two radio astronomers (Arno Penzias and Robert Wilson) unexpectedly discovered that their antenna would receive certain background noise, in whichever direction it was aligned. Eliminating all possible sources of electromagnetic artificial noise generation in the vicinity, they concluded that the isotropic noise that had the spectrum of a blackbody radiation was no artefact. As the wavelengths of received radiation were in order of a few millimeters in microwave region of electromagnetic spectrum, the detected noise was termed Cosmic Microwave Background Radiation (CMBR).




**A1.8 - Blackbody radiation**



**A1.9 - Microwave Background Radiation**

CMBR is considered as afterglow radiation subsequent to the Big Bang that filled the space with gamma radiation, with wavelengths many orders of magnitude less than one millimeter. With the expansion of the spatial dimensions of the universe, the wavelengths of the radiation simultaneously stretched to order of one millimeter in the microwave region of electromagnetic radiation spectrum.

Minute fluctuations or deviation from perfect isotropy in CMBR is attributed to small density fluctuation of the primordial gas, leading subsequently to the formation of galaxies.

### *Formation of the galaxies*

The formation of the galaxies may have occurred in one of two possible ways. It has been suggested that relatively smaller 'protostar' nebulae may have been formed first. The collision and mutual gravitational attraction of these nebulae may have then given rise to individual galaxies. Alternatively, vast clouds of matter may have gravitated and assumed a rotational motion, forming the 'protogalactic' nebulae. Stars were then formed from the fragmentation of the 'protogalactic' gas clouds, leading to the formation of the galaxies with numerous stars.[1] Some combination of both scenarios is possible. The galaxy formation is still ongoing, and stars are continuously being formed in younger galaxies.

***A1.10- A Spiral galaxy*** ***A1.11 - An Elliptical galaxy***

The stars in a spiral galaxy lie in a flattened disc with a greater concentration of stars in the so-called spiral arms of the galaxy. Spiral galaxies are usually made of younger stars. In elliptical galaxy stars are distributed within a region that has the form of an ellipsoid. Elliptical galaxies are usually made of older stars. Some galaxies have irregular shapes.

In 'spiral' galaxies, the angular rotation of the protogalactic gas cloud produces a flattened 'galactic disc'. This disc then becomes partially fragmented and regions of the disc with greater concentrations of stars shape the spiral arms of the galaxy. The spiral arms have angular rotation about the axis of the galaxy that is different from the angular rotation of individual stars. In fact, the spiral arms

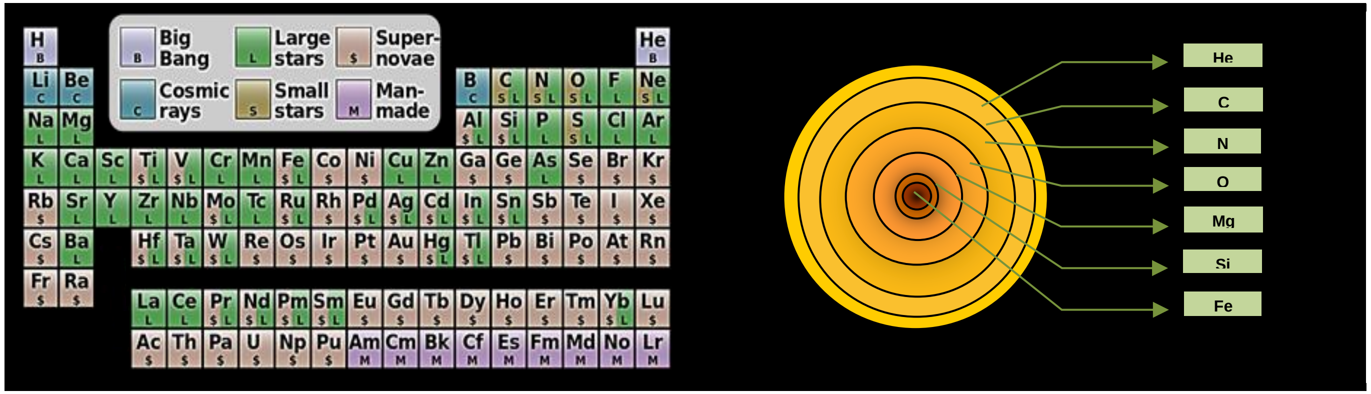
[1] 'Protostar' and 'protogalaxy' refer, respectively, to state of star and galaxy prior to their final formation.

of the galaxy rotate with an ‘angular velocity’ less than that of the individual stars. Hence in vast spans of time each star travels through successive formations of the spiral arms.

Elliptical or irregular galaxies may have been formed by the collision of two or more spiral galaxies destroying their spiral structures, or an initially high rate of star formation may have prevented these galaxies from collapsing into a flat disk.

### *Evolution of stars*

Stars have a life of their own, with a time of birth and a time of death and a span of life, albeit, in billions of years. As greater numbers of particles of ‘protostar’ nebula gravitate together, the size of the protostar cloud increases, and a region of very high pressure is created in the core of the nebula. As a result, the temperature at the core is raised to thousands even millions of degrees, initiating a ‘nuclear reaction’ that fuses lighter elements to heavier elements, mainly hydrogen to helium. Nuclear reactions increase the temperature within the star and produce an outward ‘radiation pressure’[1] that ultimately counterbalances the force of gravity and sets the temperature and size of the star.




***A1.11 - Synthesis of elements in stars***

Apart from Hydrogen and Helium, most other chemical elements are synthesized within a star by nuclear reactions. Heavier elements gravitate to the core of the star. Much heavier elements, however, are produced at the time of supernova explosions.

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[1] Electromagnetic radiations exert pressure on the surface of objects in their path, this is known as radiation pressure.

The steady ‘fusion’[1] of hydrogen in a star may last for billions of years, but as the helium content of the star increases, its core contracts and releases gravitational energy.[2] This in turn, heats up the core and accelerates the process of ‘nucleosynthesis’.[3] This in turn increases the outward pressure, and the size of the star increases substantially until all Hydrogen in the star is converted to helium. At this stage the star is a ‘red giant’. Subsequently, as all the existing hydrogen within a star is converted to helium, nucleosynthesis fuses the helium atoms to heavier elements, and the star increases in density and shrinks in size.

The extent to which a star shrinks to a smaller size depends on the gravitational pressure produced by the mass of the star. A star with the mass of the Sun, for example, may become a ‘white dwarf’. A star with a mass greater than that of the Sun, but less than about three times the mass of the Sun, becomes a ‘neutron star’. A still heavier star collapses without limit to become a ‘black hole’.[4]

In the course of the implosion of the inner core of some massive stars, the outer shell explodes outwards in a spectacular manner, producing a tremendous outburst of radiation sometimes exceeding the amount of radiation in the entire galaxy. This is known as a ‘supernova explosion’.[5] A supernova explosion scatters synthesized elements within the star to vast regions of space.

The first generation of stars formed contained only the elements produced within the first few minutes of the birth of the universe. Heavier elements were subsequently synthesized within these stars and scattered throughout space through supernova explosions. At the time of their formation, later generations of stars such as our Sun contained many of the heavier elements synthesized in earlier stars which were present in the protostar cloud.[6]

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[1] In fusion, two atoms are fused into a single atom, with a mass less than the sum of the original masses of each atom. The mass difference is released in the form of enormous energy.

[2] Gravitational energy is the potential energy of a gravitating body that changes into kinetic energy or to heat if encounters the friction of a material substance.

[3] Nucleosynthesis refers to the reactions involving the atomic nucleus, here mostly the fusion of lighter atoms to form heavier atoms, such as the fusion of Hydrogen atoms to form Helium.

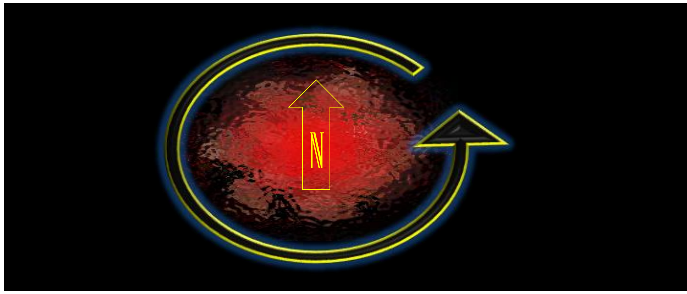
[4] Intense gravity of a black hole prevents any material and even light to escape from its surface.

[5] The brightest supernova seen by an unaided eye since 1604 AD occurred in 1987. An excitement for astronomers, it was first seen in February, reached its peak brightness in May, and then gradually faded away.

[6] For evolution within stars as depicted by Hertzsprung-Russel (HR) diagram, that plots the absolute magnitude of stars against their color, see: [**Timothy Ferris**, p188, **The whole shebang**, Weidenfeld & Nicolson, 1997]

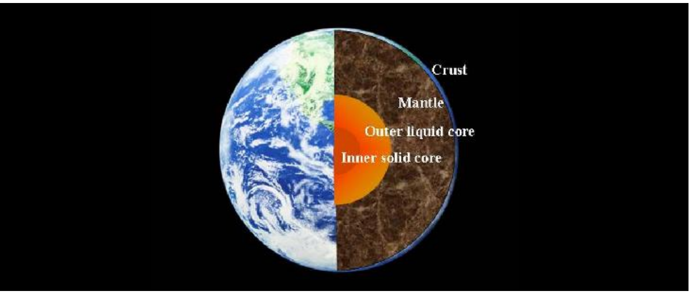
# A2. Geological transformation and the evolution of life

The Planet Earth was formed approximately 4.6 billion years ago by the gradual cohesion and accretion of grains of dust particles, originating from the disk of massive solar nebula, which was also the origin of our Sun. The aggregates of dust initially formed smaller bodies known as ‘planetesimals’, which subsequently collided to form the larger Planet itself.




***A2.1 – Formation of the Earth***

The Planet Earth was formed by accretion of grains of dust and sand. Because of compression and collisions of the particle aggregates, the temperature of the Earth was raised and assumed a molten state. As the particles gravitated to the core, Earth assumed a rotational motion and near spheroidal shape.




***A2.2 – The core, mantle and crust***

The Earth consists of a very hot inner and outer core of iron and nickel alloys, in solid and liquid forms, respectively; the mantle is a solid mixture of magnesium, silicon and iron and the outer crust makes up the landmasses and the oceans of the Earth.

As a result of the energy released from these collisions and the effects of gravitational compression, the temperature of the Earth increased, turning it into a molten globe. Two other factors contributed to the process of Earth’s increase in temperature, namely the impact of asteroids from outside, and the decay of radioactive isotopes inside the Planet. The subsequent formation of the Earth’s atmosphere resulted in asteroids mostly burning up as they entered the Earth’s atmosphere. This as well as the shielding effect of the massive planet Jupiter resulted in a reduction of the number of asteroids reaching the Planet’s surface.

***A2.3 – Impressions of early period of the formation of Earth***

The cooling of the Earth from its molten stage took place over a period of one billion years. Because of frequent volcanic eruptions and the impact of asteroids, the Earth's crust remained in a state of flux. The forbidding conditions of high temperatures and lack of a favorable atmosphere made it unlikely that any life form could have existed on the Earth during this period.

As Earth cooled, the four regions of the 'inner core', the 'outer core', 'mantle' and 'crust' were gradually formed. It is believed that the 'inner core' and the 'outer core' of the Earth consist respectively of solid and liquid metals, such as iron and nickel. These two regions exist at conditions of very high pressure and temperature. The 'mantle' is the next layer and is a solid mixture of magnesium, silicon, and iron. The outer shell or 'crust' makes up the landmasses and the oceans of the Earth.

The cooling of the Earth from its molten stage took place over a period of approximately one billion years. As the Earth cooled, its outer part solidified, with a thin layer of crust gradually forming on its surface. Because of frequent volcanic eruptions and the impact of asteroids, the Earth's crust remained in a state of flux and instability. Forbidding temperatures and lack of a favorable atmosphere made it unlikely that any life form could have existed on Earth during this period.

***A2.4 – Impressions of a later period of the formation of the Earth***

During the next one billion years after the initial formation of the Earth the crust of the Earth began to assume some of its permanent features. Clouds of steam and toxic vapors from volcanic eruptions made up the Planet's initial atmosphere. As the steam clouds cooled, they were converted into rain and filled the depressions on the surface of the Earth as vast oceans. The remaining regions became fragmented landmasses.

During the next billion years, the crust of the Earth began to assume some of its more permanent features. Clouds of steam, carbon dioxide, methane, and nitrogen that came from frequent volcanic eruptions made up the Planet's initial atmosphere. At higher altitudes, the steam clouds cooled and were converted into rain and filled the depressions on the surface of the Earth as vast oceans. The remaining regions of the Earth became fragmented landmasses. During the following two billion years, these landmasses coalesced into vast 'proto continents' with mountains extending through large regions of the land.

Around 600 to 200 million years ago, many of the smaller 'proto continents' of earlier times coalesced into a single 'super-continent' in the South Pole region of the Earth, combining most of the present-day continents in the Southern Hemisphere. What is presently North America, Europe and Asia also moved closer to the equatorial region. From 200 to 65 million years ago, the continents of the world joined into a super-continent called 'Pangaea', which then again separated to form the present-day continents.



***A2.5 - Pangaea*** ***A2.6 - Continents today***

From 200 to 65 million years ago, the continents of the world joined into a super-continent called Pangaea and subsequently separated again to form the present-day continents.

Since that time 'continental drift', or the separation and shift of the continents, has continued and is a major cause of earthquakes. According to the theory of 'plate tectonics' the continents of the world rest on about 12 major and several minor continental plates. The relative motion of the plates initiates seismic disturbances along 'fault lines', where the boundaries of these plates meet.

The crust of the Earth is also altered by volcanic eruptions, by sedimentation and erosion, by changes in sea level and by the activity of the oceans. Atmospheric effects and climate changes also modify the Earth's surface. Another important influence is the effect of plants, animals, and even microscopic organisms. Human activity, especially in the last century, has significantly changed many geological features of our planet.

During the recent evolution of the Planet there have been a number of so-called ice-ages, when the temperature of the Planet dropped substantially, leading to the formation of glaciers covering extended regions of the Earth. The last of these occurred some 100 thousand years ago and lasted until approximately 12 thousand years ago. At this period of time glaciers covered most of Northern Europe and America.

*A2.7 – The crust of the Earth today*

As a result of the constant interaction between the Earth's lands (geosphere), seas (hydrosphere) and air (atmosphere) and living organisms, the Crust of the Earth has assumed a complex, rich and varied terrain of mountains, valleys, plains and forests, as well as, systems of rivers, seas and oceans, sustaining the life of millions of different species.

### *Evolution of life on the Planet*

Because of constant interaction between living organisms and the Earth's lands (geosphere), seas (hydrosphere) and air (atmosphere), the evolution of life on the Planet and its geographical features have been closely linked. Were it not for living organisms, the entire geo-chemical and geo-physical conditions of our planet would have been substantially different.[1] Obvious examples of such interaction are the abundant atmospheric free oxygen and the coral formations in extensive reefs across the globe.

The presence of free oxygen[2] is the direct result of photosynthetic activities of plants that absorb carbon dioxide in presence of sunlight and release oxygen to the atmosphere.  At the same time, the geophysical condition of the Planet has allowed the evolution of

[1] For the complex interaction of the sun and the Earth with its lands, oceans, atmosphere and living organisms, to create an ecological system to sustain life on our planet, see: [**Tim Flannery,** p54, **Here on Earth**, Published  by Text Publishing Australia, 2010]
[2] Oxygen that is not as a part of a molecular compound.

living species. In fact, there has developed in the Earth's 'biosphere' refined and balanced interacting 'ecosystems' involving land, sea and air and living species. These ecosystems have numerous self-maintaining and regulating mechanisms.

How life originated on the Earth and how organic molecules were transformed into living cells approximately three and half billion years ago is still a mystery. The presence of organic material in the tails of comets has led some scientists to suggest that life might have originated outside the Earth's biosphere and brought to Earth by meteorites or other means. The existence of certain primitive cells, or so-called 'super-bugs', in the ocean depths of the Earth's crust, demonstrates the resilience of some primitive forms of life to extremes of environmental conditions and gives credit to the idea that life may have originated in the subterranean regions of the Earth. Hydrothermal vents or hot springs and geysers that are commonly found near active volcanos, or may have been created in the past by impact of meteors, are also suggested as possible locations where life originated. However, the classical hypothesis is that life came about in hot ponds of primordial soup of brewing chemicals in an atmosphere devoid of oxygen but exposed to intense ultraviolet radiation from the Sun.

The building blocks of life are carbon-based organic molecules that also contain oxygen, hydrogen and nitrogen. It has been shown experimentally that these organic compounds can be synthesized from basic inorganic chemicals such as water, ammonia, and methane, in conditions presumably simulating the primitive environment of the Planet.[1]

Under the turbulent conditions of these early times and in the presence of chemical catalysts and intense ultraviolet radiation, long ordered chains of molecules may have arisen by mutual molecular cohesion and self-organization.[2] These molecules could have been the precursors of those involved in the basic structure of living cells. At some stage, these large molecules may have gained the ability to replicate themselves by subdividing into parts with each part subsequently resuming the size and configuration of the original molecule.[3]

These self-replicating molecules may have been the origin of very primitive cells. The evolutionary mechanisms of chance variation and selection may have operated at this stage to select those primitive cells with the ability to withstand adverse environmental conditions. The function of replicating the cell may have then become restricted to specific genetic molecules within the cell. These genetic molecules may have been initially distributed throughout the entire cell, known as 'prokaryotic' cells.

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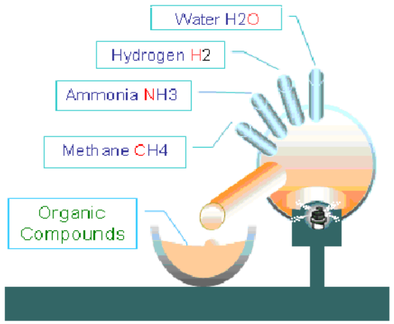
[1] The presumed primitive environment of the Planet assumed in this experiment is only speculative. See: [**Richard E. Dickerson**, **Chemical Evolution of Life**, published in Evolution - **A Scientific American Publication**]

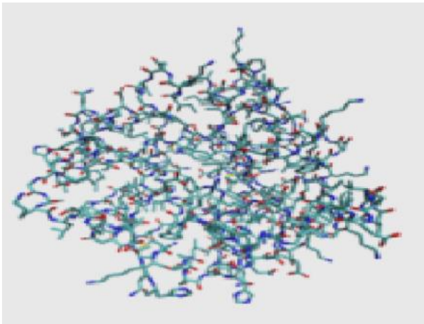
[2] See Appendix 9.

[3] It is also suggested that instead of the process of self-replicating, replication may have been come about by many simpler organic molecules simultaneously acting as catalysts for their mutual replication.




***A2.8 – Miller-Urey experiment***

In this experiment organic molecules were synthesized from inorganic molecules in presence of an electric spark, presumably simulating the condition of the early period of Earth's formation.



***A2.9 – A complex Macromolecule***

The basic constituents of living organisms are proteins. These are large and complex molecules that are synthesized inside the cell by sequencing of the simpler amino acids.

More advanced living cells contain a number of organelles each responsible for a specific function. It is suggested that organelles in the cell may have originated from earlier simpler non-differentiated cells that were brought together by symbiotic association. In symbiosis, two or more living organisms coexist in close beneficial association.

In a possible hypothetical scenario, 'aerobic' bacterium may have lived inside a large prokaryote host cell producing an 'amoeboid'.[1] It is thought that a long spirochete bacterium may have joined the amoeboid producing the ancestors of the animal and fungi kingdoms. Further association with blue-green algae may have resulted in the plant kingdom.

Some procaryotes cells may then have evolved to become 'eukaryote' cells with their genetic material being confined to the nucleus of the cell. 'Asexual' cell division later evolved to 'sexual' cell multiplication involving two parent cells, each cell carrying a different genetic information.[2] This manner of cell reproduction led to a much greater diversification of living organisms.

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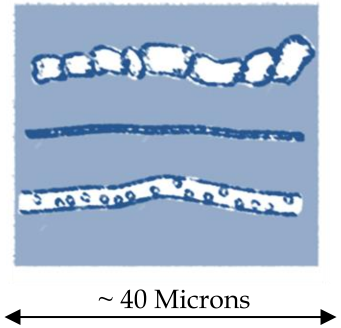
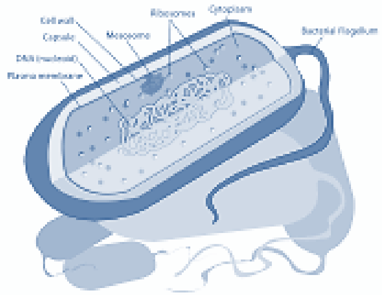
[1] See: [**Lynn Margulis**, **Symbiosis and Evolution**, published in Life Origin and Evolution (A Scientific American publication), 1971]

[2] For asexual or mitosis and sexual or meiosis cell divisions, see Appendix A8.



***A2.10 – Earliest life forms***

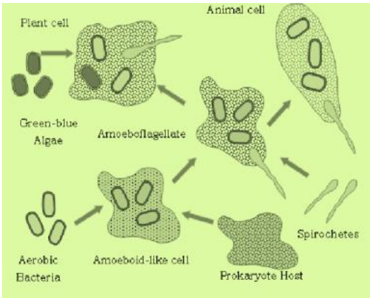
The earliest observed life forms are estimated to be 3.2 billion years old. Some were in the form of rods and others threadlike filaments of organic material in order of few microns long.

***A2.11 – Prokaryote cell***

In Prokaryote cells, the genetic material is distributed throughout the cell cytoplasm. These may have preceded Eukaryote cells with genetic material confined to the nucleus.

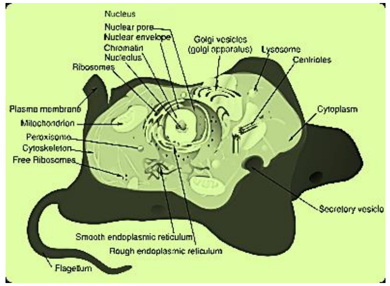
About 700 million years ago, a number of unicellular organisms evolved into multi-cellular organisms each group of cells specializing in specific functions. While it is generally assumed that all life was initially marine, in the course of evolution some marine life evolved into terrestrial forms of life and some species became airborne. Living organisms then increased in number and diversified. An estimated 10-100 million species live today on Earth. While many living species came into being, at the same time many became extinct due to their inability to adapt to changes in the environment such as a reduction of nutrients, climate change or possibly by natural disasters such as the impact of asteroids.

Some biologists classify the living organisms into three domains of ‘Archaea’, ‘Bacteria’, and ‘Eukarya’ and six Kingdoms of: 1. Archaebacteria with single Prokaryote cell in domain of ‘Archaea’, includes organisms such as methanogens, halophiles, and thermophiles. Archaebacteria are anaerobic and live without oxygen; 2. Eubacteria with Prokaryote cell are in domain of ‘Bacteria’, include organism such as bacteria, blue-green algae and actinobacteria; 3. Protists with Eukaryote cell in domain of ‘Eukarya’, include organisms such as amoebae, brown algae, diatoms and slime molds; 4. Fungi with Eukaryote cell is in domain ‘Eukarya’ and include organisms such as mushrooms, yeast, molds; 5. Plants are multicellular with Eukaryote cells in the domain of ‘Eukarya’, include organisms such as mosses, flowering and seed-producing plants, liverworts and ferns. Plants are photosynthetic, they use a pigment called chlorophyll that can convert sunlight to chemical energy; 6. Animals with Eukaryote cells, in domain Eukarya. Some are vertebrates or with backbones, while most are invertebrates with no backbones. They include organisms such as mammals, amphibians, sponges, insects, and worms. Living organisms are further sub-divided to Phylum, Class, Order, Family, Genus, and Species.




***A2.12 – Symbiosis***

In symbiosis, two or more living organisms coexist in beneficial association. An aerobic and a spirochete bacterium living inside a large prokaryote host cell may have formed an early animal cell.

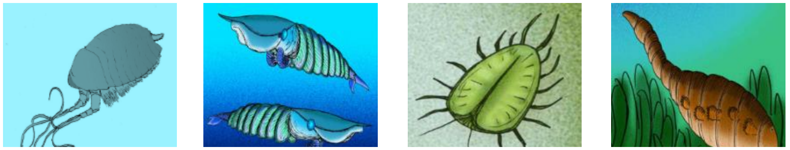



***A2.13 – Eukaryote cell***

A Eukaryote cell has many subdivisions or organelles with each part specialized for a particular function. The genetic material is confined to a region of the cell known as the nucleus.

The biological evolution of the Earth can be divided to six periods - the ‘Azoic’ (devoid of life - 4.5b to 3.8b), ‘Archeozoic’ (ancient life - 3.8b to 2.5b), ‘Proterozoic’ (early life - 2.5b to 540m), ‘Paleozoic’ (older life - 540m to 240m), ‘Mesozoic’ (middle life - 240m to 65m) and ‘Cenozoic’ (recent life - 65m to present) periods.[1] These names are derived from the Greek word ‘zo’ or animal life, although the division of time periods and their designations differ between accounts.

[1] ‘b’ stands for billion and ‘m’ for million years.



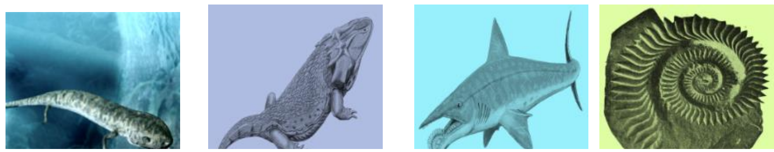
***A2.14 - Paleozoic – Cambrian (570-500 m)***

***A2.15 - Paleozoic – Ordovician (500-430 m)***

***A2.16- Paleozoic - Silurian (435-395 m)***

***A2.17 – Late Paleozoic – Devonian (395-345 m)***

***A2.18 – Late Paleozoic – Carboniferous (345-280) m)***



***A2.19 – Late Paleozoic – Permian (280-230 m)***

***A2.20 - Mesozoic - Triassic (230-195 m)***

***A2.21 - Mesozoic - Jurassic (195-135 m)***

***A12.22 - Mesozoic - Cretaceous (135-65 m)***

***A12.23 - Cenozoic - Paleocene (65-54 m)***

***A2.24- Cenozoic - Eocene (54-38 m)***

***A2.25 - Cenozoic - Oligocene (38-26 m)***

***A2.26 - Cenozoic – Miocene (26-12 m)***

***A2.27 – Cenozoic – Pliocene (12-1.8 m)***

***A2.28 – Cenozoic - Pleistocene (1.8-.01 m)***

***A2.29 – Holocene - insect (present)***

***A2.30 – Holocene - bird (present)***

***A2.31– Holocene - mammal (present)***

Many of the above periods are subdivided into shorter eras, with their names derived mostly from the name of the region or regions where associated fossils were originally discovered.

### *Evolution of the human species*

Despite many paleontology findings of 'hominin'[1] skeletons, the evolutionary history of man is not as yet completely known. Tracing the time of the first appearance of man on Earth and details of his evolution on the Planet has proven a particularly arduous task. Indeed, it has been difficult in some instances to differentiate between the independent, but parallel evolution, of two hominins and their possible evolution from a single ancestry. For example, the two pre-historic species Australopithecus africanus (~3.0-2.0 million years ago) and Homo habilis (~2.5-1.44 million years ago), both lived alongside for a long period of time. It is unclear whether these two species came from a common ancestor, Homo habilis branched from Australopithecus africanus, or if the two evolved independently.

The close correlation between the genome of man and that of the chimpanzee suggests a recent common origin, but this cannot constitute a conclusive proof unless clear fossil evidence of their direct origin is also found. The recently discovered remains of the Toumai in Chad[2] (2001 AD) puts the date of any possible branching of man and ape from a common origin further back in geological time than any previously proposed dates. The Toumai is approximately 7 million years old and shares some features of modern man and could perhaps be classified as a hominin (Although this designation was later disputed by some paleontologists). At the same time a direct link, a truly intermediate species between the ape and man, has not been found so far, and may remain forever missing.[3]

Paleontology excavation and discoveries of new skeletons are ongoing and their designation as hominins, or otherwise, is frequently in scientific dispute. Ignoring this recent finding, 'Australopithecus' was considered to have been the oldest hominin whose fossil remains resembled that of modern man. Australopithecus was short and bipedal (i.e. walked on two legs) and had a small brain. The estimated date of the earliest fossil remains is approximately 4 million years old. Lucy is the well-known partial skeletal remains of the hominin 'Australopithecus afarensis' who lived between 4 to 3 million years ago. Subsequently 'Australopithecus Africanus' lived approximately 3 to 2 million years ago and 'Australopithecus robustus' lived between approximately 2 to 1 million years ago before becoming extinct.

Discovered as recently as 2013 in South Africa, the previously unknown Hominin 'Homo naledi' lived about 2 to 3 million years ago.[4] Many fossils were found collected in a cave, suggesting that it was used as a burial place for their dead. This could be an indication that

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1 Extinct species closely related to human species.

2 2001 AD.

3 Is Nariokotome boy the missing link? 'If that were true, then the boy ought to be a *perfect missing link, half ape, half human*. Instead, he is neither one nor the other but a *novel* combination of characteristics.' See: [**Alan Walker & Pat Shipman**, p236 - 239, **The Wisdom of Bones**, Weidenfeld & Nicolson, 1996]

4 This is an estimate only. No exact dating is still established.

the species performed ritualistic act of burying their death, previously thought to be a unique human practice. With some other conceivable explanations, however, this is not possible to ascertain.

The species 'Homo habilis' is considered to be the direct ancestor of modern man. Homo habilis (also called 'java man', as his fossil was first found in Java) was small and graceful and had a larger brain size than Australopithecus africanus. This species lived about 2 million years ago. Homo habilis has also been nick-named 'the handy man', probably because stone tools were found close to his fossil remains. 'Homo erectus' followed Homo habilis. He was more robust and anatomically closer to modern man. His brain size was intermediate between Homo habilis and later Homo sapiens. Homo erectus, or the 'upright man', lived between 1.6 million and 300 thousand years ago, used stone tools and also made use of fire.

About 300 thousand years ago, Homo erectus evolved into 'Homo sapiens', or 'Man the wise'. One group of Homo sapiens were called the 'Neanderthals' as their first fossil remains were found in the Neander Valley in Germany. Neanderthals had a large skull, a sloping forehead, and a brain somewhat larger than that of modern humans. They lived between 100 to 35 thousand years ago in Europe, the Middle East and North Africa. Neanderthal man showed certain human cultural traits such as burying their dead and appeared capable of performing many functions of modern humans such as tool making.

It is believed that Neanderthals disappeared when the Cro-Magnon man appeared in Europe. 'Cro-Magnon' man was biologically identical to humans today and not considered as a separate species. Cro-Magnon had a culture similar to that of Stone Age humans, even made jewelry out of bone and ivory. Impressive paintings by their artists can be found on the walls.

### *Cognitive evolution of humankind*

One important characteristic of all living organisms is their ability to communicate and exchange information, both internally[1] and with their environment. Without such a mechanism no organism could have survived. At a primitive level this communication was confined to chemical interactions that provided the necessary information for the functioning and survival of the living organism. A single living cell has a complex mechanism to sense the outside conditions and produce the necessary chemicals to interact with its environment, for example as in receiving its nutrients. As living organisms evolved to a greater degree of complexity, communication and exchange of information was specialized by specific organs such as those for auditory and visual perception.

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[1] Such as communication between the brain and other organs.


***A2.32 – Hominins***

Extinct species closely related to human species are known as Hominins. Skeleton remains of Hominins are found going back some millions of years, with many anatomical variations. In spite of many similarities, they are distinctly different from other primates.

***A2.33 – The human family***

The findings of recent genome project have shown that variations in human genetic code of different races and people are minimal as compared to that which is common between all members of the human family.

As humans evolved, they progressively assumed a greater ability to mentally construct the realms of external objects, their physical entity and their conscious selves as three separate realities. Self-awareness and awareness of the external world led humans to greater cognition and perception and even abstraction, together with complex sensations and emotions. At the same time, they developed the enhanced ability of communicating these perceptions, sensations and emotions to others, through spoken and written language. These new dimensions in human consciousness separates man from the rest of the animal world.

# A3. Social development and the rise of human civilizations

Evolution of the human species from the earliest hominins on paleontological records to present modern man has been a long process. The biological evolution of humans has not only been followed by cognitive and behavioral evolution of the individual, but also by the social and cultural evolution of human society. The speed with which these latter evolutionary changes have taken place and the degree to which this has affected the life of the species is not observed in any other life form on Earth.

From existence in the Stone Age, in which people had few tools and limited awareness of their surroundings, humanity has reached the present-day knowledge-based information age within a highly complex global society. The forces directly and indirectly contributing to this evolution have interacted and reinforced each other in subtle and complex ways. The most important civilizing factor influencing such a transformation, in the first instance, was the use of spoken language and later the development of written script. This laid down the basis for communication and the exchange of information. The invention of printing was another milestone in the dissemination of knowledge.[1]

### *The Stone Age*

In the early stages of human social development, at the time known as the 'Stone Age', the use of primitive stone tools became prevalent.[2] In the 'Old Stone Age', between 250,000 and 10,000 BC, people were hunter-gatherers. They would wander in search of food, use primitive stone tools, find shelter in caves, and use fire for the preparation of their food and for keeping themselves warm. In the 'Middle Stone Age', between 10,000 and 5,000 BC, nomadic communities gradually settled in different parts of the world and started domesticating plants and animals. They developed bows for hunting as well as domestic tools. In the 'New Stone Age', between 5,000 and 3,000 BC, people lived in villages. They were engaged in pottery and weaving and specialized in different trades. They cultivated grains and used domesticated animals for food and labor.

The domestication of animals facilitated transportation and brought about interaction initially between neighboring villages and later with communities that were farther away. Such an extended degree of contact between geographically separate regions on the one hand facilitated trade and social and intellectual interaction, and on the other hand, led to conflicts of interest, leading to tribal

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[1] It is not possible to give a date for spoken language as it may have evolved from primitive symbolic sounds over tens of thousands of years. Written language may have started around 4000 BC by use of pictographs of pictures and symbols. Printing may have started in China and Korea in around seventh century AD.

[2] Stone Age, Bronze Age and Iron Age designate the periods that stone, bronze and iron tools were introduced and used.

fighting and even to greater battles and brutal wars. With increased contact, communal allegiance confined to the tribes or villages was extended to larger regional provinces or countries, with first the chieftains and then kings or emperors assuming the role of protecting and ruling their territories.

At the same time, the need to provide means of livelihood led to the invention of rudimentary tools for farming and hunting. Later, basic hand equipment was used to produce clothing and basic domestic utilities. As the techniques for constructing these tools improved, the need for further specialization, division of labor, and the exchange of goods and services arose. This required a greater density of people living closely together and an expansion in the size of communities to larger towns and cities.

Closer individual association and interaction in more populated centers brought about the exchange of ideas, the stimulation of thought and the development of abstract concepts such as distances, angles, and forms in geometry. Ultimately, the foundations for the development of the rudiments of mathematics, physical sciences, philosophy, astronomy, and medicine were laid. These acquired forms of knowledge led to the development of varied skills, innovations and inventions and became the basis for the rise of early civilizations.

### *Ancient civilizations*

Early civilizations arose mainly in the fertile plains of great rivers where there was access to water for irrigation and transportation of crops and other farming produces. The fertile plain between the Tigris and Euphrates rivers in Mesopotamia in present-day Iraq is known as the 'Cradle of civilization'. Civilizations also arose around the Nile River in Egypt, the Yellow River in China and the Indus River in India.

Apart from a few scattered settlements, ancient civilizations existed mainly in the form of city-states such as Sumer and Babylon. These two cities in Mesopotamia date back to around 3000 BC. Sumerians engaged in pottery and made simple metallic objects for utility and artistic expression. They developed their own language and probably invented cuneiform writing with its wedge-shaped characters. Hammurabi (1792–1750 BC) was the first king of Babylonian Empire. He issued his famous code of laws for the orderly administration of his kingdom.[1]

[1] Hammurabi's best-known legacy is his collection of laws engraved on a two-meter-high monument of black diorite. See: [p36, **The Age of God-Kings,** Time Life Books, 1987]

A3.1 - Mesopotamia

The ancient civilization in the fertile plain between the Tigris and Euphrates is known as the cradle of civilization. It consisted mainly of city-states. Sumerian city-states such as Kish and Ur date back to 3000 BC. The first king of Babylonian Empire was Hammurabi, who had his capital at Babylon, issued a famous code of laws for the management of the empire.

A3.2 - Sumerian inscription

The ancient Egyptian civilization developed in the plain of the Nile valley from around 3100 BC to 1300 BC. In Egyptian society, the Pharaoh, a 'semi-divine' ruler, held supreme power and administered the rest of the mostly farmer population through a hierarchy of appointed officials and priests.[1] Egyptians strongly believed in the continuation of life after death and had elaborate burial ceremonies. Pyramids were painstakingly built to house the mummy remains of pharaohs.

A3.3 - Egyptian civilization

The ancient Egyptian civilization can be divided into three periods. In the Old Kingdom (3110-2258 BC), Egyptian culture and commerce flourished, and the great pyramids were built. After a period of decline, Egyptian civilization regained its former glory in the Middle Kingdom (2000 -1786 BC) and reached its zenith in the New Kingdom (1570-1342 BC).

A3.4 - A Pyramid

[1] The Egyptian empire reached its greatest extent about 1450 BC, stretching from Nubian Desert in the south to the middle Euphrates in the north. For the condition of Egypt at that time, see: [p32, **Barbarian Tides,** Time Life Books, 1987]

The Indus Valley civilization was based on agriculture and trade and thrived in the period 2500 BC to 1500 BC around the fertile banks of the Indus River in present day Pakistan. Impressive buildings as well as copper and bronze pottery and pictograph scripts of this civilization have been found by archaeological excavations in this area.

A3.5 - Indus Valley civilization

The Indus Valley civilization flourished in the period 2500 BC to 1500 BC along the Indus River in present day Pakistan. Impressive buildings unearthed are evidence of a complex society based on highly organized agriculture and commerce. Examples of pottery and arts in copper and bronze have been uncovered, as well as pictograph scripts.

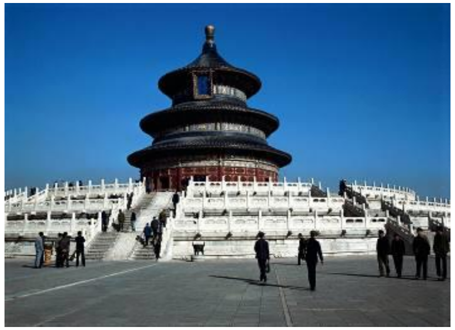
A3.6 - Indus Valley Seals

The ancient Chinese civilization was established along the banks of the Yellow River. This civilization began about 1500 BC and lasted until 1279 AD. During this period, China was ruled by several dynasties. As early as the period of the first known dynasty in China, the Chinese had a system of writing and processed bronze for making domestic goods.[1] In the years 202 BC to 220 AD, during the Han dynasty, China made great advances in producing simple manufactured commodities, while the period between 960 and 1279 AD, when China was ruled by the Sung dynasty, was a time of scholarly and artistic achievements.

[1] For the Chinese achievements in arts, music, literature and specially science and technology, see: [p160-1, **Empires Ascendant**, Time Life Books, 1988]

A3.7 - Chinese civilization

Since 1500 BC successive dynasties ruled China. The Chinese philosopher Confucius lived in the turbulent times of Chou dynasty (1027-256 BC). The construction of the Great Wall of China began during the Ch'in dynasty (221-207 BC). Buddhism and Taoism spread in the glorious age of the T'ang (618–906 AD). The rule of Sung dynasty (960-1279 AD) was a time of scholarly and artistic progress.

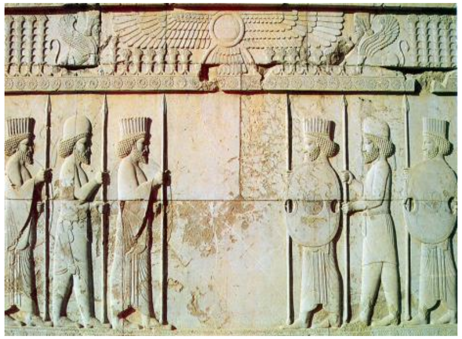


A3.8 - A Chinese Palace

The Persian civilization advanced in the plateaus of Fars in the southern region of present-day Iran. In the middle of the 6th century BC, Cyrus the Great conquered many neighboring regions and created the great Persian Empire.[1] Subsequently, Darius (550-486 BC) organized a highly efficient centralized system of administration extending the Empire from India to the verge of Europe.

A3.9 - The Persian Empire

In the 6th century BC, Cyrus the Great by rapid conquest established the great Persian Empire in the present region of Fars. Subsequently, Darius organized a highly efficient system of administration and extended Persian rule from India to river Danube. The Empire declined after Alexander the Great conquered Persia on 334 BC. Ctesiphon.



A3.10 - Persepolis

[1] As Persian army conquered Babylon, Cyrus was greeted as a liberator and the leaders of Babylonia's former dependencies declared their royalty to him, see: [p17, **A Soaring Spirit,** Time Life Books, 1988]

After Alexander conquered Persia in 334 BC, the Empire declined until the middle of 3rd century BC.[1] A new Persian Empire flourished under the Sassanid dynasty from 226 AD until 637 AD when the invading Arabs took the capital Ctesiphon and established their own rule. Persians were great conquerors and administrators. They encouraged trade, cultural exchange, and dissemination of ideas in their Empire. They also respected the religion, customs, and laws of those whom they conquered.

Greek civilization had a tremendous effect in shaping the cultural and intellectual development of subsequent civilizations, especially in Europe. In the 8th century BC, the ever-warring Greek city-states became united and conquered many surrounding regions from Asia Minor to Spain. In the 5th century BC, the Greeks were able to repel invasions by the Persians and grew in power and influence. This led to the golden age of the Greek civilization and for many centuries Greece became the center of thought and culture. In 338 BC, Phillip, a Macedonian, conquered Greece, and his son Alexander the Great spread the Greek civilization across the then known world. The Empire declined after Alexander the Great conquered Persia in 334 BC.

***A3.11 - Greek civilization***

By 1000 BC settlers in the region that is presently modern Greece, developed many warring city-states. By 8 century BC, Greeks conquered many surrounding regions and later they could repel many invasions of Persians and grew in power and status. For many centuries Greece became the center of thoughts and culture. Greece later declined and fell to Romans.

***A3.12 - The Parthenon***

[1] After capturing Persepolis, the Seat of Persian Empire, Alexander remained there for a few months. During a feast, however, his drunken guests torched the palace and destroyed one of the most monumental ancient architectures. See: [p28-9, **Empires Ascendant,** Time Life Books, 1988]

The Roman Empire has been often cited as an example of a civilization rising to its zenith and subsequently falling by a steady collapse from within.[1] At first Rome was a republic. Around 25 BC the Senate in Rome granted Augustus, a triumphant Roman general, extensive powers, and the title of the first Roman Emperor. Augustus rebuilt the city of Rome and brought relative peace and a cultural revival throughout the Empire. Successive Emperors expanded the territorial domination of the Empire and at its height, it extended from the east of the Mediterranean Sea to the countries of North Africa and most of the European countries to the British Isle. The Romans assimilated the Greek culture and were proficient administrators. They developed an extensive system of roads and commerce throughout their Empire.

***A3.13 - Roman Empire***

Octavian (31 BC–14 AD) was the first Roman Emperor. Successive Emperors ruled the Roman Empire for several centuries extending their dominance as far as Britain. Constantine (306–37 AD) moved the capital from Rome to Byzantium and granted religious toleration to the persecuted Christians. Shortly after the Empire was divided into Eastern and Western sections.

***A3.14 - Coliseum***

The spread of civilization was not confined to Asia and Europe. The aboriginal inhabitants in the regions of central and southern America had their own advanced cultures and civilizations extending back earlier than 2000 BC. Their architecture, agriculture, stonework, and metalwork were advanced to a remarkable degree. Well-known amongst these were the Maya, the Olmec, Toltec, Mixtec, Zapotec and Aztec.[2]

The Mayans developed a 365-day calendar, a written hieroglyphic language and a system of mathematics more advanced than many of their contemporary civilizations.

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[1] In its golden age, imperial Rome was a city of grandeur and poverty, of refined luxury and barbaric savagery, of lofty ideals and low intrigue. For the description of Rome at this time, see: [p45, **Empires Ascendant**, Time Life Books, 1988]

[2] For Aztec beliefs and mythology and their attitude towards war, see: [p155, **Voyages of Discovery,** Time Life Books, 1989]

### *Civilizations based on monotheistic religions*

To varied extents all ancient civilizations were founded on some mythical or religious belief system. Sumerian, Babylonian, Greeks and Romans had their own pantheon of gods and goddesses and magnificent temples dedicated to them. There was also a hierarchy of priests who were not only the custodians of these temples, but also had great influence on temporal affairs of the land. Judaism had much impact on Israelites.[1] The Zoroastrian religion in Persia had great influence in shaping the Persian Empire. Hinduism in the sub-continent of India and Buddhism in East and South-East Asia and China, had tremendous impact on the lives of the people, shaped society and influenced historical developments on those regions.

The Roman Empire split in the year 395 AD into East and West. The Eastern Roman Empire or Byzantine covered Asia Minor and the South Balkan Peninsula. It carried on the civilization of Greece and Roman. Later the Ottoman Turks encircled the Empire and despite a desperate defense, Constantinople fell (1453 AD) to Moslems.

***A3.15 - Byzantine Empire***

***A3.16 - Basilica of San Vitale***

Christian civilization was founded on a great historical episode with later ramifications on the social, political, and cultural life of vast regions of the world from the Middle East to Europe and later to the American Continent (and to a lesser degree on the rest of the world). Christianity in Syria (now Israel) was established in the first half of the first century AD. For several years after it was founded by Jesus, born to a Jewish family, Christianity was an obscure sect confined to the vicinity of its birthplace.

In the first century, the Roman Emperor Nero persecuted early Christians who were spreading Christianity across the Roman Empire, but later in the fourth century AD Constantine granted religious freedom to the Christians. He moved the capital of the Roman Empire from Rome to Byzantium and renamed it as Constantinople. Shortly afterwards, in 395 AD the Roman Empire was divided into the Eastern Roman Empire and the Western Roman Empires. The Western Empire fell in 476 AD and Rome rapidly lost its political

[1] Members of Hebrew tribe from ancient kingdom of Israel.

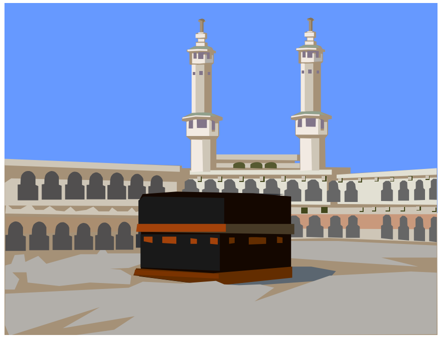
importance. Christianity, however, spread throughout Europe and became the dominating influence in all aspects of life in Europe for many centuries.

The Eastern Roman Empire, or Byzantine Empire, lasted about one millennium, its territory extending to Asia Minor and the South Balkan Peninsula. Its capital was Constantinople. The Empire was based on Orthodox Christianity, but influenced by Eastern traditions and by the Greek, and to a lesser degree, by Roman civilizations. In spite of continuous territorial disputes, wars, violence and internal corruption, it reached great heights of achievement in the arts and architecture, especially in the sixth century AD. Eventually the Ottoman Turks invaded the Empire and in 1453 Constantinople fell to the Moslems. Constantinople remained the seat of the Ottoman Empire with Ottoman Sultan as the Caliph of Islam asserting religious as well as temporal authority over the vast regions extending from the Middle East to the Balkans and to North Africa. In the early 20th century, the Empire collapsed after the Young Turk revolution that led to the eventual formation of the Republic of Turkey.

In the seventh century AD, the Arabian Peninsula had no special prominence in the known world of the time. Its inhospitable terrain was only sparsely populated by warring nomadic tribes whose only claim to fame was their fine poetry. They would read these poems to their fellow travelers reaching oases of crystalline springs amidst the scorching heat of the desert. Here a camel driver of a trading caravan began reciting verses of exquisite prose and claimed that these were revealed to him by Allah or his God. Soon he gathered a small band of followers. As these grew in number, they were harassed by the population and tribal leaders. Several armed encounters took place leading ultimately to the victory of his followers and consequently many tribes of Arabia accepted both his claim and his authority. This was the origin of Islam founded by Mohammad.

***A3.17 - Islamic civilization***

The Prophet Mohammed, the founder of Islam died in the year 632 AD in Arabia. After his death Islam spread as far West as Egypt and East as Persia and then to North Africa and Spain. Soon the Moslem rulers moved their seat from Arabia to Damascus and Baghdad and adapted a more secular path. Astronomy and natural sciences, medicine, arts, and architecture reached new heights.



***A3.18 - Mecca***

Mohammad died in Arabia in 632 AD. His first successors were the four ‘rightly guided’ Caliphs who assumed the role of both spiritual and temporal head of the Moslem Community. After the death of Ali, the fourth Caliph, a cousin of the second Caliph took the rein of power and established the Umayyad Caliphate. Prior to Umayyad, Islam had already reached as far as Persia and Egypt, but under Umayyad a new wave of conquest was launched, extending the rule of Islam to North Africa and Spain. While the spiritual centers of Islam remained in Mecca and Medina, Damascus, the seat of Umayyad (661-750 AD), and later Baghdad, the capital of Abbasids (749-1258 AD), became the centers of secular and commercial enterprise. Natural sciences, astronomy, medicine, the arts, and architecture reached new heights, blending and advancing many past achievements of the Greek and Persian civilizations.

***A3.19 - Western civilization***

In the 18th century, the use of steam power, the advent of railroad and machine production led to what is known as the Industrial Revolution. The Industrial Revolution initiated the social and economic changes that marked the transition from agricultural society to a modern industrial society and led to dominance of the Western civilization.

### *The Renaissance and the rise of Western civilization*

Feudalism, disease and poverty characterized the period in European history between the 5th and the 15th century AD, known as the 'Middle Ages'.[1] During this period ecclesiastical establishments mostly dominated the political and military institutions, as well as the life of individuals. Between the 11th and 13th century AD a series of wars, known as the Crusades, were undertaken by European Christians to conquer back Christian holy places in the 'Holy Land' from the Muslims.[2] These wars brought Europe in contact with the civilization of Islam, and through it, to the rich cultural heritage, which the Islamic civilization had assimilated.[3] This, amongst other factors, led to what is known as the Renaissance (14th to 17th centuries AD), the period which saw the transition from the 'Middle Ages' to modern times.[4]

The Renaissance liberated Europe from excessive domination by religious institutions that to some degrees were impeding the human freedom of expression and though, and was a catalyst for great accomplishments in scholarship, literature, sciences and the arts.

In Europe, Christianity itself did not remain immune from the spirit of an inquiring age. Martin Luther (1483-1546), himself a Christian theologian became disenchanted with the doctrines and practices of the Catholic Church at the time, considering them at variance with the true spirit of Christianity.[5] Luther through his writings and his sermons condemned such practices and initiated what is known as the Reformation, splitting Christianity to Catholic and Protestant denominations.

### *Discovery of America, industrial revolution and the dawn of Western Civilization*

In the pioneering spirit of the age, in 1492, Christopher Columbus sailed from a port in Spain hoping to reach India by a westward journey. Instead, he discovered the vast continent of America. This proved a momentous event and changed the course of history. Not

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[1] The earlier part of the Middle Ages, after the fall of the Rome is known as the Dark Ages. In this period there was a certain decline in literary, artistic, and technological innovations.

[2] Crusades were launched over five centuries by the Popes to combat the enemies of Christendom, whether Muslims or pagans or errant Christians, in the East or in Europe. See: [p63, **The Divine Campaigns,** Time Life Books, 1989]

[3] Arab domination of Spain was also a point of contact between the West and the Islamic heritage at the time.

[4] 'Renaissance was grounded in an unwavering confidence on man's capabilities and his essential goodness. Keenly pursuing his humanistic ideals, scholars set about rediscovering and reinterpreting, sometimes after centuries of obscurity, the achievements of the great civilizations of Rome and Greece.' See: [p13, **The European Emergence,** Time Life Books, 1990]

[5] During the first crucial phase of Reformation, from 1517 to 1525, the issues raised by Luther were most fiercely debated in Saxony and neighboring north German principalities within the borders of Holy Roman Empire. However, by the 1560s, only Italy, Portugal and Spain remained unaffected by Protestant doctrine. See: [p10, **The European Emergence,** Time Life Books, 1990]

long after, white settlers from Spain, England, and Portugal established colonies across the American continent. In 1776 the established colonies of North America rose against England, the main colonial power, in the war of 'American Independence'.[1] In 1861-1865, a civil war broke out between the Confederated States of the South and the Union of the Northern States, which were opposed to the slavery of Africans that was still being practiced in the South. The war ended in the defeat of the Confederate States and the creation of the United States of America with a single Federal government.

In the 18th century the use of steam power and the advent of railroads and large-scale machine production brought about the 'Industrial Revolution' in Europe. The Industrial Revolution initiated the social and economic changes that marked the transition from an agricultural and commercial society to a modern industrial society and led to the European dominance in the contemporary world. In addition, at the end of the century the French Revolution changed the political landscape of Europe and later inspired the revolutionary changes in many parts of the world.[2]

The nineteenth century witnessed the expansion of European influence in all regions of the world leading to the colonization of Africa and most parts of Asia by Britain, France, Germany, Portugal and to a lesser extent by Spain, the Netherlands, Italy and Belgium.[3] This gave Europeans access to vast natural resources and cheap labor available in the colonized countries and at the same time transferred European culture and technical knowledge to many parts of the world.

### *The First World War*

As the nineteenth century drew to a close, there was a sense of stability in the world with potentates and imperial powers in Europe and elsewhere freely exercising their domination over both their own subjects and on the nations that they had already subjugated. It could not be imagined that within only a few years into the twentieth century, Europe could be engulfed in the horrors of a world war,

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[1] The chief drafter of the document for American Declaration of Independence (1976) was a 33-year-old Virginian called Thomas Jefferson. 'A brilliant advocate and scholar, Jefferson filled his declaration with the egalitarian and humanitarian ideals of Enlightenment philosophy.' See: [p110, **Winds of Revolution,** Time Life Books, 1990]

[2] For an account of the French revolution that ended 800 years of French monarchy, see: [p136, **Winds of Revolution,** Time Life Books, 1990]

[3] Compiled list of European colonies by year 1900: BRITAIN: British Honduras; Jamaica; British Guiana; Canada; Gambia; Sierra Leone; Gold Cost; Nigeria; Egypt; Sudan; British East Africa; Nyasaland; Rhodesia; Bechuanaland; South Africa; British Somaliland; Aden; India; Malaya; Sarawak; North Borneo; British New Guinea; Australia; New Zealand. FRANCE: French Guiana; Senegal; Algeria; Tunis; French Guinea; Mauritania; Ivory Coast; Dahomey; French Sudan; French Equatorial Africa; French Congo; French Somaliland; Madagascar; French Indochina. GERMANY: Togoland; Cameroons; German Southwest Africa; German New Guinea. PORTUGAL:Portuguese Guinea; Cabinda; Angola; Mozambique; Portuguese Timor. NETHERLANDS: Dutch Guiana; Dutch East Indies. SPAIN: Rio de Oro; Rio Muni. ITALY: Eritrea; Italian Somaliland. BELGIUM: Leopold's Congo. [Source: **The Colonial Overlords,** Time Life Books, 1990]

the Great War or the 'First World War' of 1914 to 1918. The First World War is said to have started with a minor incident in the Balkans, the assassination of the heir to the Austro-Hungarian throne, giving the 'Central Powers' of Germany, Austria-Hungary and the Ottoman Empire the needed pretext to initiate a war, at first with the alliance of France and Russia, and later with nearly the rest of Europe. The most destructive instruments of war, the deadliest ammunitions, armored tanks, submarines, warplanes, and poison gas were deployed to mutually destroy their perceived enemies. The war resulted in about ten million military and six million civilian deaths.[1]

The First World War ended with the defeat of the Central Powers and especially Germany, which had sought a greater influence and position in Europe. A decisive factor in the defeat of the Central Powers was the participation of Britain and then the United States of America in support of the alliance against the Central Powers.

After the end of the First World War, the signing of the peace 'Treaty of Versailles' in 1919 changed the geopolitics of the European Continent. The treaty included a provision for the creation of the 'League of Nations', which soon came into being and later ratified the treaty in 1920. The League of Nations was proposed by the American President, Woodrow Wilson, as a forum for the resolution of international disputes and prevention of war through collective security.

### *Russian Bolshevik revolution*

While Russia was heavily involved in the war on its western borders, it became engulfed in an internal turmoil that culminated in the Russian Bolshevik revolution in 1917 and the demise of the last Tsar, Nicholas II, ending a thousand year old monarchy of 'the Imperial Russia'. Shortly after, the first communist state, the 'Union of Soviet Socialist Republics', which included the former Russian Empire in Eastern Europe and Asia, was fully established. The spread of the 'Marxist doctrine', predicting the 'dialectic struggle' of the 'proletariat or working 'class' with their 'capitalist' oppressors with the resulting defeat of the capitalists and the ultimate creation of a harmonious classless society, was taken up by many Russian revolutionaries. The disenchantment of peasants and the working class with the upper class privileged elite in the court of the Tsar, as well as the great suffering inflicted by the war, heightened the magnitude of the 1917 insurgency. Later communism spread to countries as different as China and as far as Cuba.

### *The Second World War*

The success of the communist revolution in Russia, the signing of the peace treaty at Versailles and the simultaneous creation of the League of Nations did nothing to alleviate the compounding problems of Europe. Under the rule of Stalin, the communist revolution in

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[1] No weapon was more hated than poison gas. Although intended to disorient and not to kill, thousands died, blinded or their lungs permanently damaged. See**:** [p37, **The World in Arms,** Time Life Books, 1989]

Russia that was intended to create a utopian harmonious classless society became a totalitarian repressive regime.[1] The peace treaty of Versailles embittered the defeated Germans determined to exercise their domination over Europe at the first given opportunity. Inherent imbalance and limitations in the composition and constitution of the League of Nations soon made that body marginal and ineffective.

***A3.20 - World War II***

The 'Second World War' was initiated by Hitler of Nazi Germany by invading Poland in 1939. Soon the world was polarized in two camps of the 'Axis Powers', including Germany and Italy and Japan, and the 'Allies', including France, Great Britain, United States and the Soviet Union. After the initial victory for the 'Axis', the war ended in their defeat in 1945, following the invasion of Europe by Allies and deployment of Atomic Bombs on cities of Hiroshima and Nagasaki in Japan. The human suffering of war was immense with the estimated casualties of 35-60 million people.

The post-war grievances and aftermath of the great depression in the 1930s that began with the collapse of Stock Market shares in United States and resulted in a worldwide economic slump, created a fertile ground for the rise of 'ultra-nationalism' and 'Fascism' in

[1] Almost certainly ordered by Stalin, in December of 1934, the popular and talented Leningrad Communist Party Chief Sergie Kirov was murdered by assailants. This followed by the Great Purge of political rivals by Stalin's agent, and even the purge of agents themselves. See: [p56, **Shadow of the Dictators,** Time Life Books, 1989]

Europe. In Germany, Adolph Hitler, a self-styled fanatical nationalist working through the National Social German Workers or ‘Nazi’ political party, gained prominence assuming the role of President of the German Republic. Through fervent public discourse, Hitler incited his audience with racial and ethnic hatred. He maintained the superiority of the Aryan race that Germans belonged and the need to cleanse the world from the mediocre and racially inferior races that prevented the advancement of the superior races. Included in this racially inferior population were the Jews, blacks and invalids, to whom Hitler freely applied his reprehensible theory of racial cleansing by eliminating in concentration camps and chambers of poison gas.After negotiating a nonaggression treaty with Russia that involved the partition of Poland between the two powers, Hitler invaded Poland. Soon other nations became involved in the conflict, polarizing the world into the two camps of the ‘Axis Powers’ that included Germany and Italy and the ‘Allies’ comprising France, Great Britain, United States and the Soviet Union. Later discord spread across the world to the Middle East, Africa and South-East Asia as well as China and as far as Japan with the latter joining the Axis Powers.[1]

This truly international war, the ‘Second World War’, brought initial victory for the ‘Axis’, but later ended with their utter defeat. First Germany surrendered in May 1945, then Japan in August of the same year after the deployment of atomic bombs on two Japanese cities of Hiroshima and Nagasaki. The human suffering caused during the Second World War was immense, with an estimated 60 million casualties. Atomic bombs dropped on Japan on August 1945 killed over a hundred thousand people in a matter of days and generated spontaneous fires that destroyed a large portion of each city.

### *The birth of the United Nations*

Such a widespread and devastating war again emphasized the need for some international order for the resolution of standing disputes between nations and to evade future major conflicts. An attempt had been made over two decades previously by the creation of League of Nations and failed, but no other alternative was open to humanity. The United Nations was established in October 1945, with its aims and scope of responsibility far exceeding that of the League of Nations. In addition to its primary role of maintaining peace, the United Nations was intended to promote human rights, social justice, economic prosperity, and social progress on the Planet.[2]

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[1] Japan appeared to be firmly set on a course towards parliamentary democracy until in the early 1930s when the world depression brought it to economic ruin. At that time ultra-nationalist groups, led by the armed forces, embarked on a campaign to establish a military dictatorship in Japan. Ultimately this led to Japan joining Germany and Italy in 1940, and eventually, the Axis Powers in World War II. See: [p39, **Shadow of the Dictators,** Time Life Books, 1989]

[2] The United Nations consists of six basic organs: the General Assembly, the Security Council, the Economic and Social Council, the Trusteeship, the International Court of Justice and the Secretariat. The constitution of the United Nations states that while all member states have representation at the General Assembly, the Security Council, which is responsible for matters concerning world security and peace was to have five permanent and

The increase in the United Nations member states from the original 51 in 1945 to the 193 states of today was largely due to the admission to that body of a number of former colonies as sovereign states. In the twentieth century, the struggle of many subjugated people for freedom and independence saw the reversal of the process of the expansion of the colonies by the imperial powers. After many years of struggle and passive resistance, inspired by Mahatma Gandhi, India gained independence from British rule in 1947.[1] The fever of nationalism and independence soon reached the African continent, with over thirty countries gaining independence from their former European colonial powers in the 1960s. However, the burden of racial discrimination in the former colonies was not immediately alleviated. South Africa witnessed forty years of political and sometimes violent struggle against 'Apartheid' until Nelson Mandela became the first black African President of the Republic in 1994.

### *The cold war and the collapse of the Soviet Union*

The formation of the United Nations did not end international conflict on the Planet. Soon a new kind of ideological warfare spread across the globe dividing the world into the two camps of 'Capitalists' and 'Communists'. Communism spread across a significant part of the world, provoking fear of global dominance. Western countries, especially the United States of America perceived in communism a threat to the ideals of freedom and free market enterprise that were the basis of Western democracy. The 'Cold War' between the two camps led to an intensive 'nuclear arms race', which brought the world to the verge of nuclear warfare capable of annihilating the entire human race.

In the earlier years of revolution, the Soviet economy was based on the development of heavy industry and supported by well-trained engineers and scientists. The Soviets sent the first satellite into space in 1957 and the first man into space in 1961. Later, however, as other industrialized nations moved to lighter industries with innovative electronic appliances and other consumer products requiring individual initiative and free enterprise, the centrally planned Soviet economy and industry fell far behind rest of industrial countries in the world. In subsequent years when the short comings of bureaucratic systems were realized, measures such as 'perestroika' economic revitalization and 'glasnost' greater freedom and openness introduced by Russia's President Mikhail Gorbachev, were too little and too late.

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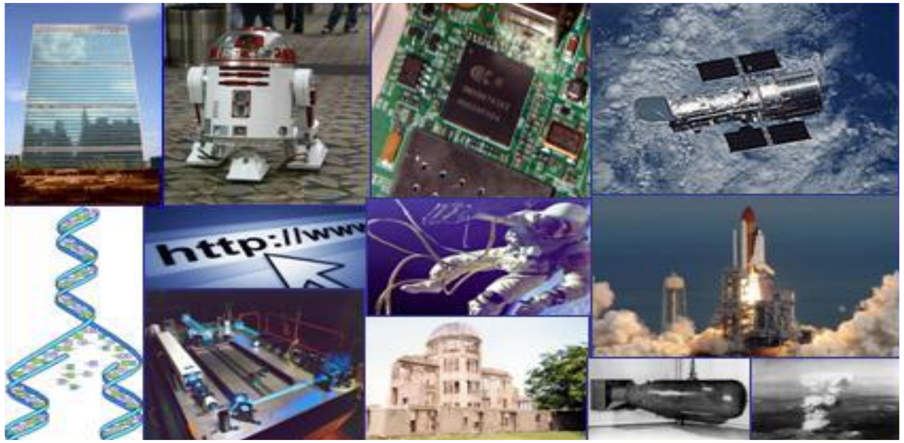
ten short-term members. The decisions of the Security Council are binding on the state members, but every permanent member of Council has the right of veto to annul the majority vote. It is suggested that the UN needs a comprehensive reform to reflect the geopolitical condition of the present century.

[1] Gandhi was revered by millions as a saint. He renounced worldly needs and desires and rejected all violence. See: [p113, **Shadows of the Dictators,** Time Life Books, 1989]




***A3. 21 - The Twentieth Century***

The twentieth century is truly unique in the history of mankind, interlaced shades of light and darkness, hope and despair. It is a century of global awakening, social awareness, profound intellectual achievements and scientific discoveries, miracles of technology and medicine. At the same time, it is stained by two world wars, global conflicts and poverty, disease and misery for millions. The century has also seen the formation of the United Nations and advent of rapid communication, joining every corner of the globe in a maze of internet connections.

The disenchantment of the Soviets with their political ruling party and the uneasiness of the satellite Eastern European Communist States soon compounded, bringing about a rapid disintegration of the Soviet Union and the Communist regime. The end of the 'Cold War' is thus synonymous with the collapse of the Soviet Union and is symbolized with the fall in 1989 of the Wall that for twenty-eight years divided Berlin into East and West. The 'Solidarity' movement in Poland played a key role in the demise of communism in that country. Changes in other Soviet satellite countries such as Hungary, Bulgaria, Romania, and Czech Republic soon followed.

### *The twenty first century*

The twenty-first century did not start with such hopeful signs! On September 11, 2001, three hijacked passenger airlines flew into the World Trade Center in New York City and one into the Pentagon in Arlington, Virginia, destroying the twin towers of WTC and a side of the Pentagon building, a terrorist act that killed some 3,000 people.

In the first decades of this century, we live in a world of contradictions and challenges. On the one hand it is not difficult to see the tremendous achievements of our time in vast areas of human endeavor, whether scientific or technological or in the spheres of human welfare, medicine and health. We can see a better standard of living in many countries of the world, elimination of some scourging diseases and an increase in the life expectancy.

At the same time, millions of air passengers travel across the globe every day, crossing over the boundaries of many countries. Some billion inhabitants of the world are connected via the 'Internet' to the 'World Wide Web', exchanging information and ideas. Intercultural exchange and interracial marriages are on the rise, as is the exchange of scientific knowledge at international scientific forums. Summits of politicians and heads of states take place daily and the number of international social, political, and economic conventions and forums has multiplied. There are some tens of thousands of non-governmental transnational organizations (NGOs) with ever-growing influence on world affairs

Yet in spite of all these advances and unifying forces operating across the globe, the world in the first decades of the twenty-first century remains politically and ideologically divided and is in a state of social and political turmoil. Conflicts and wars range across the globe and thousand peoples are killed, injured, or become homeless. Refugees endanger their lives in merciless seas to settle elsewhere in hope of a better living condition. Spread of global pandemics, the prevalence of disease and famine in many countries in spite of medical miracles; the great disparity between rich and poor; the rise of aggressive fundamentalism; vulnerability of world economic markets; environmental issues of global warming, deforestation and land degradation; alcoholism, the use of illicit drugs and drug trafficking; lawlessness, crime and violence; abuse of women and children and family disintegration; discrimination, injustice and violation of human rights; restriction of political and personal freedom, are but some of the many grievous ills presently afflicting, to varying degrees, the entire human race. [1]

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[1] The present events in the world are strong indication of the depth of political and ideological division in human society today. Recent wars between Russa and Ukraine and the Middle East conflicts are great concerns. Threats of the use of weapons of mass destruction is always present and it is not hard to imagine that they may be used in wars that could engulf many regions of the world.

# A4. Development of philosophical and religious thought

In the same way that the development of intellect in an individual is an integral part of his or her growth process, the development of collective perceptions and insight are integral to the evolution of human society. Any description of human evolution is incomplete without reference to human intellectual endeavors in the realms of religion, philosophy, and science.

***A4.1 - Stonehenge***

Stonehenge was built in phases about 3000 to 1600 BC. It is located near Salisbury in England. It is not very clear if it was used as a religious site or for astronomical observations. Current view is that it was a place where burial ceremonies and rituals were performed.

***A4.2 - Aztec Temple***

The Aztecs, one of the most advanced ancient cultures of Central America, had their own religious rituals. Their temples served many functions including the acts of human sacrifice as an offering to their gods. This was performed by Aztec priests with special ceremonial rites.

Man has throughout the ages and even from his early days on this Planet contemplated the mysteries of existence and life. What thoughts filled the mind of 'Homo erectus' as he looked upon the ancient landscape, and what emotion stirred in the heart of 'Homo habilis' as he gazed on the profusion of stars in the night sky - we shall never know! Perhaps these were not expressed through constructed language, but as facial expressions or bodily gestures. However, as language developed in human society, the reflections and wisdom of one generation could be passed on to the next. This was initially by way of the spoken, and later through the written word. Language laid the basis for the development of philosophical thought and the subject of philosophy itself. Reflection on the mysteries of life and human destiny has also led humankind to infer certain beliefs that have become the basis of religious thought, reinforced throughout the ages by poets, seers, and prophets.

### *Early developments*

The evolution of religious beliefs and practices may have begun with man attributing divine powers to natural objects such as the Sun, the stars, wind and fire. As human imagination expanded, the number, roles and attributes of these gods vastly increased. In Greek mythology, there was an elaborate hierarchy of gods and goddesses sharing human powers and frailties in love, marriage, birth, and death. At the beginning, according to the ancient Greeks, Chaos was a vast space of void and nothingness. Gaea arose from Chaos as the mother of all beings and later her son and husband Uranus, became the first ruler of the world. Later Cronus, son of Gaea and Uranus, dethroned Uranus and took his place as the world's supreme ruler. Soon, however, their power was usurped by Zeus, the son of Rhea, sister of Cronus.

***A4.3 - An Egyptian Temple***

In the long period of its ancient history, many Egyptian temples were built all over Egypt. They were places where gods resided and worshipped. Large number of priests served in each temple and received vast endowments from the Egyptian royalty and other sources.

***A4.4 - Roman Pantheon***

In Roman mythology there were several gods and goddesses such as Cupid god of romance, Diana goddess of hunting, Fortuna goddess of fortune. Pantheon in Rome was dedicated to a collection of these deities. Later Pantheon was converted to a Catholic Church.

In the place of, or in conjunction with the rites of idol worship, there appeared in many parts of the world the practice of Ancestral worship, 'Animism' and 'Spiritism'. Ancestral worship was based on the view that deceased ancestors could influence the course of events in this world. 'Animism' was the belief that there resides a living soul in all things that gives them individual identity and personality. 'Spiritism' was a belief in the possibility of communicating with the spirits of the deceased.

In addition, the doctrine of the Reincarnation of the cycles of birth and death became prevalent and widespread as an explanation for the suffering and injustices that are encountered in the course of a single span of life. 'Polytheism' was followed by ideologies such as 'Dualism'[1], 'Monotheism' and 'Pantheism', respectively, beliefs in the two deities of good and evil, a single supreme deity and the identity of this deity with the entire universe.

***A4.5 - Temple of Artemis***

In Greek mythology, Artemis was a maiden goddess of hunting and wild nature. She was one of the most venerated gods in the Greek culture. Temple of Artemis was built around 550 BC in city of Ephesus in present Turkey, visited by many kings, tourists, merchants, and artisans.

***A4.6 - Anahita Temple***

Anahita is an ancient Persian goddess and a virgin maid guardian of waters and fertility. She was also viewed as a warrior maiden. She supposedly wore an embroidered golden mantle and a diamond crown. Dedicated to her, many temples were built around 400 BC in Persia.

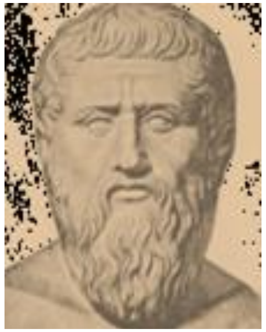
One of the most ancient religions that spread widely and eventually became the official religion of the ancient Persian Empire was Zoroastrianism. It was founded by Zarathustra or Zoroaster who lived around 1600-600 BC. Zoroaster taught that the world is a stage for the continuous battle between the forces of good and evil. Ahura or spirits of good were led by Ahura Mazda, and the forces of evil by Ahriman or the devil. In this struggle, the final triumph of good over evil was assured. Zoroastrians were to be constantly conscious of this battle and assist the victory of good over evil by practicing the three principles of 'good thought', 'good speech' and 'good action',

[1] Dualism is also used in a different sense in philosophy - the view that there are two irreducible substances (usually matter and mind). See later sections in this chapter.

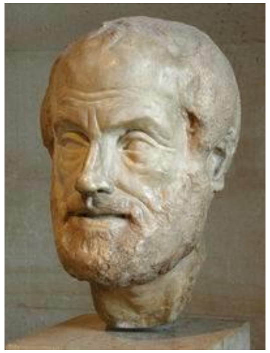
as described in the Zoroastrian Scripture, the Avesta. Zoroastrianism, however, declined after the conquest of Persia by the Arabs in the 7th century AD.

### *Socrates, Plato and Aristotle and developments of Western philosophy**[1]

A study of Western philosophy may begin with the Greek philosophers of the 5th and 4th centuries BC. While there were certainly celebrated thinkers and philosophers before this period both in Greece and elsewhere[2], the three most renowned philosophers of all time Socrates, Plato and Aristotle were born in Greece at this time.  These men together shaped philosophical thought for many centuries to come.



The first of three most renowned philosophers of all time that appeared in Greece was Socrates (469-399 BC). Plato (427-347BC) was a pupil of Socrates. He wrote many volumes of philosophical treatises, referred to as dialogues, the most famous of which is Plato's 'Republic'. The tutor of Alexander the Great, Aristotle (384-322 BC) was a pupil of Plato.



***A4.7 Plato***

***A4.8 Aristotle***

The first of these great Greek philosophers were Socrates (469-399 BC). Socrates held frequent discourse and dialogue with the citizens of Athens, the capital of Greece, on the concept of virtues and morality. Socrates maintained that virtue and morality had an existence independent of those who acquired them. To Socrates these qualities could only be gained through the knowledge of their merit, as one

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[1] This section and other sections related to philosophy are partly based on [**The History of Philosophy** by **Bryan Magee**, Darling Kindersley Books, 1998], [**Ancient Philosophy** by **Anthony Kenny**, Oxford University Press 2004], **[Medieval Philosophy** by **Anthony Kenny**, Oxford University Press 2005] and [**The Rise of Modern Philosophy** by **Anthony Kenny**, Oxford University Press 2006].

[2] Most of the subjects treated by the earliest philosophers would be considered today as scientific. See: [**Richard McKirahan**, chapter 1, **Pre-Socratic Philosophy**, Blackwell Guide to Ancient Philosophy, 2002]

who had true knowledge of good would avoid all acts of evil. Socrates was condemned to death for his views, surrounded by his pupils, as he serenely drank the hemlock that resulted in his death.

Plato (427-347 BC) was a pupil of Socrates, but while Socrates held spoken dialogues, Plato compiled many hypothetical dialogues in volumes of philosophical treatises.[1] In these, he initially expounded the themes discussed by Socrates, but later his own philosophical ideas. Plato extended the concept of abstract realities to being attributes of all objects and events in this ephemeral world, considering the world to be as mere images and reflections of true immutable realities beyond the realm of material existence. As an analogy Plato describes the abstract 'form' of a circle as a perfect and immutable geometrical shape; a circle drawn on a paper has only a semblance of a circle with many imperfections. Plato called these abstract realities 'forms' or 'ideas'. His famous imagery of the cave further illustrates this concept. In this metaphor we are confined to a cave surrounded by people outside it whose shadows we see on the walls of the cave. Unaware of the existence of people outside the cave, we confuse fleeting shadows with reality.[2] Aristotle (384-322 BC) was a pupil of Plato and the tutor of the conqueror Alexander of Macedonia. Aristotle rejected the concept of 'ideas' and 'forms' as abstract realities beyond the existence of material objects. To Aristotle, an object, however, could not be viewed, by merely its material constituents. Its existence could be attributed to four different 'causes' (Greek word *aitia*) or defining aspects. These were the 'material cause' or the material that makes the object; 'formal cause' or the abstract form and pattern of the object; 'efficient cause' or the method by which the object was realized or came to being; and 'final cause' or the final intent of the object.[3] Aristotle wrote treatises on vast fields of knowledge from anatomy to physiology, physics, mathematics, metaphysics[4] and many others. Aristotle's views were considered authoritative for many centuries in Greece and many other parts of the world.[5]

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[1] Socrates never wrote anything himself and his own views are, to an extent, a matter of speculation. On the standard interpretation, the Socrates character in the early Platonic dialogues is thought to be relatively faithful to Socrates' actual views, whereas in the later dialogues he becomes more of a mouthpiece for Plato himself.

[2] In the Republic, his most famous treaty, Plato expounds his political theory. He considers an ideal state consisting of different classes each performing a different function but living harmoniously. These were the guardians, auxiliaries and working classes, which required respectively, the virtues of wisdom, fortitude, and self-restraint. In a just and ideal state every citizen would be given the task that he or she is most suited for.

[3] A dining table is made of wood, it has flat top and four vertical legs, it is made by a carpenter, and it is for dining.

[4] Metaphysics is commonly considered as a branch of philosophy attempting to define and understand the fundamental nature of reality, such as the basic nature of a substance and its attributes, of being and knowing, of time and space and mind and matter.

[5] Academy and Lyceum were two academic institutions founded by Plato and Aristotle, respectively. Not only they were physically located at separate sites in Athens, but they also represented two schools of thoughts. While Academy represented utopian and idealistic, Lyceum promoted utilitarian and realistic philosophies.

### *The four schools of ancient philosophy*

The conquests of Alexander, the great Greek conqueror, spread the influence of Greek culture and philosophy to vast regions of the world. Four schools of philosophy subsequently flourished. These were the 'Cynics', 'Skeptics', 'Epicureans' and the 'Stoics'. The 'Cynics' rejected social convention and even to a degree the pursuit of knowledge itself in order to live a virtuous life. To Cynics, virtuous living, in harmony with nature, would lead to lasting happiness. The most famous Cynic was Diogenes (404-323 BC) who lived in poverty for most of his life.

The 'Skeptics' held the view that truth could not be reached by reasoning and argument, for any argument was always based on other debatable assumptions and could be disputed by a counterargument. Pyrrho (365-270 BC) was the first advocate of this philosophical school.

To 'Epicureans', all things were composed of minute indestructible particles or atoms that would in time decompose. Death was therefore the inevitable end of every existence. They believed that this also applied to the human soul, but as the deceased would not be aware of this state of non-existence, there would be no reason to fear death. Life should be lived in the pursuit of happiness, avoiding those acts that could lead later to regret and remorse. Epicurus (341-270 BC) was the founder of Epicurean philosophy.

To 'Stoics', nature was governed by laws and principles that were intelligible and rational and God, though still material, was the universal reality that pervaded all nature. The moral philosophy of the 'Stoics' was based on the premise that by using the rational faculty and correct reasoning, man could live a life consistent with nature and gain true happiness and freedom. The founder of Stoicism was Zeno (334-262 BC) who lived in Cyprus.

### *Eastern and Far Eastern religions and philosophies*

The initial overlap of philosophy and religion is more apparent in the philosophies of the East than of the West. In classical Chinese philosophy greater emphasis was placed on the nature of man, his attributes, and actions, than on metaphysics or the nature of ultimate reality.

Classical Chinese ethical philosophy was based on the concept of 'Dao' or the 'Way'. 'Dao' had two contrasting yet balancing aspects of 'Yin' and 'Yang', representing the opposing cosmic female and male qualities of tranquility and activity, of weakness and strength. Each philosophical school differed in its definition and interpretation of the 'Dao'. The 'Dao' of Confucius (551-479 BC) was the guiding 'Way' for the kings and rulers and people of virtue. The 'Dao' of Lao-tzu (6th century BC) on the other hand was the 'Way' that was harmonious with nature and life.

A4.9 - Lao-tzu

In classical Chinese philosophy a greater emphasis was on the ethics. Ethical philosophy was based on the concept of Dao or the 'Way'. Dao had two contrasting yet balancing aspects of Yin and Yang, representing the opposing cosmic female and male qualities of tranquility and activity, of weakness and strength. Each philosophical school differed in its definition and interpretation of the Dao.

A4.10 - Confucius

In Hinduism, the collective belief and religious practices of much of the population of the sub-continent of India, the question of human suffering and death was of central importance. It was believed that the sufferings inflicted on man were the result of Karma or individual actions in former and present lives. One could be released from the cycles of rebirth and death and hence from the burden of suffering, by meditation and the practice of yoga. This would lead man to a deeper knowledge and union with reality and liberation from carnal desires and harmful actions. Hinduism is an ancient religion, its origins dating back some 5000 years. The sacred Scriptures of Hinduism are the four Vedas, which contain hymns, rituals, and mystical works. In later Hindu writings, Brahma, Vishnu and Shiva were described as the Creator, the Preserver, and the Destroyer, respectively, of the repeated cycles of the universe.

Buddhism was founded in the 5th Century BC by Siddhartha Gautama, the Buddha or the Enlightened One. Buddha taught a middle way between the excessive indulgence in the affairs of this world and the extreme asceticism practiced by some devout Hindus. Similar to Hinduism, the goal of Buddhism was the elimination of human suffering by reaching a state of total transcendence or Nirvana. The inevitable experience of suffering, its origin in human desire and the 'eightfold noble path' to its elimination, together with the possibility of reaching Nirvana, constitute the 'four noble truths' of Buddha. The 'eightfold path' consists of right views, right resolve, right speech, right action, right livelihood, right effort, right mindfulness, and right concentration. Buddhism originated in India but flourished in Ceylon, Tibet, China, Korea and Japan.

Central to Hinduism, is the theme of human suffering and death. These could be overcome by adherence to Hindu principles and practices.

Buddhism was founded in the 5th century BC by Gautama, the Buddha. He taught a middle way between excessive indulgence and asceticism.

***A4.11 - A Hindu temple***

***A4.12 - A Buddhist temple***

### *Monotheistic religions*

Although the concept of a supreme God predates the Judaic religions, the promotion of Monotheism or the belief in a single God who is the source of all creation is generally associated with Judaism. Many prophets of the tribes of Judah such as Abraham, Isaac, and Jacob promoted worship of and obedience to one God, Jehovah. Moses brought the Israelites out of captivity from Egypt and gave them the Ten Commandments. These included the commandment of not killing, stealing, or committing adultery. A comprehensive set of Jewish laws dealing with individual worship and practices as well as communal and judicial matters subsequently evolved.

Christianity is based on the life and teachings of Jesus, the Christ, or the Anointed one, a carpenter by trade, born in the Israelite tribe of Judea. In spite of his crucifixion and the early persecution of His disciples, Christianity spread to become the official religion of the Roman Empire. In the two millennia since its inception, Christianity has had a tremendous effect on the course of history, especially in the Middle East and Europe.

Jesus, talking mainly in parables, gave a new interpretation of the Jewish Faith, emphasizing the supremacy of love, self-sacrifice, and faith. Closeness to Christ and his 'Heavenly Father' inspired many generations of Christians to intense personal faith and outstanding charitable and philanthropy works.

From its early inception there were certain doctrinal differences amongst followers of the Christian faith, but later divisions occurred that led to considerable discord and even to armed conflicts. Presently, in addition to numerous minor Christian denominations, there are three major branches of Christianity that differ both in their religious perspectives and practices. These are Catholicism, Orthodox Churches, and Protestants.

Another monotheistic religion, founded by the Prophet Mohammad in the seventh century AD amongst the warring tribes of the Arabian Peninsula, was Islam. Mohammad was an illiterate camel driver who served the merchandise caravan of a wealthy woman. In spite of this lack of education, he cited verses of the 'Koran' in exquisite and eloquent Arabic prose, attracting a band of devoted followers. Bitterly opposed and persecuted by his own people in Mecca, he fled to Medina, where he was received with honor and esteem. After armed conflict between the two cities, the followers of Mohammad gained supremacy and Arabia was eventually united under the banner of Islam.

***A4.13 - A Jewish synagogue***

Jewish prophets, Abraham, Isaac, Jacob, and Moses promoted the worship of one God, Jehovah. Moses brought the Jewish tribes out of captivity from Egypt and gave them the ten Commandments that include not killing, stealing, or committing adultery.

***A4.14 - A Christian cathedral***

Christianity is based on the teachings of Jesus, the Christ, or the Anointed one. In spite of the early persecutions, Christians spread their faith to Europe and many parts of the world. Jesus talked in parables and emphasized the supremacy of love, self-sacrifice, and faith.

***A4.15 – A Moslem Mosque***

Moslems are given strict personal and communal laws. They are required to perform five obligational prayers every day, with a ritual of washing hands and feet before each prayer. They are encouraged to perform these at a Mosque in congregation, where the prayer is led by an 'imam'.

Mohammad taught the absolute oneness of God, a God who deals with extreme compassion and mercy with those who believe in Him and live a pious life, but with dreadful justice to unbelievers and people of tyranny and deceit. As in the Jewish Faith, Moslems were given strict personal and communal laws. Muhammad formed the egalitarian community of Moslems who were all to be considered as brothers in Faith.

After his death, however, differences arose between the believers and soon the unity of the Moslem community was shattered. In spite of this, Islam spread as far east as India, and as far west as Spain. With its center first in Damascus and later in Baghdad, the Moslem civilization, at its zenith, surpassed its contemporaries in all human intellectual and literary fields.

***A4.16 - Saint Augustine***

***A4.17 – Avicenna***

Many Christian and Moslem philosophers attempted to create a synthesis of their faith with that of Greek philosophy. Foremost amongst them was Saint Augustine (354-430 AD) who found a basic agreement in the duality in Plato's view of the 'ephemeral' world and the world of 'ideas', to that of the Christian view of the 'physical' and 'spiritual' or 'Earth and 'Heaven'. Avicenna (980-1037 AD) who was of Persian origin and both a physician and a Moslem philosopher, was an authority on the work of Aristotle, but had his own specific interpretation.

### *Christian and Islamic philosophers*

After the advent of Christianity, many Christian scholars attempted to synthesize Christian doctrine and Greek Philosophy. Foremost amongst these was Saint Augustine (354-430 AD)[1] who found that the duality in Plato's 'ephemeral' world and the

[1] Augustine maintained that there were two 'Cities' representing two distinct social orders, one based on the requirements of temporal concerns and other based on divine precepts. A substantive work of Augustine was 'The City of God' where he describes a society based on revelation of God and His love and law. Based on the Bible, nonetheless Augustine attempts to harmonize his views with that of Greek philosophers, notably with that of Plato.

world of 'ideas', paralleled the Christian view of the 'physical' and 'spiritual' or 'Earth' and 'Heaven'. He saw no contradiction between his faith in Christ and his rational philosophical stance.

With the conquest of the Arabs and the spread of Islam, the centers of intellectual pursuit moved from Athens and Rome to Damascus and Baghdad, in the Middle East, and Cordoba in Spain. Here again the great works of the Greek philosophers were translated into Arabic, discussed and compared with Islamic traditions.

Avicenna or Ibn Sina (980-1037 AD), a Persian physician and a philosopher, was an authority on Aristotle, but had his own interpretations of Aristotle's philosophy. He had mastered logic, mathematics, physics, and medicine as a youth and written 200 works on science and philosophy. His treaty on medicine was a reference manuscript for the practice of Medicine in Europe up to the seventeenth century.

Another great philosopher, the Spanish Averroes (1126-1198 AD) upheld the compatibility of reason and faith and believed that religion and philosophy had their own separate but complementary spheres in representing truth.

### *Renaissance and post-renaissance philosophers – Rationalism and Empiricism*

The Renaissance was a period of dramatic transformation of attitudes and ideas. Medieval philosophy in Europe, based primarily on biblical discourse, gave way to more worldly concerns. The works of the Greek philosophers were read anew without reference to theological inference and interpretation. Subsequently old medieval and even Aristotelian philosophies were questioned, and an era of a new scientific and philosophical outlook dawned in Europe.

Two schools in this period were predominant, the 'rationalist' and 'empiricist' schools of thought. For 'rationalists' it was possible to acquire substantial knowledge about the world through reasoning alone, whereas for 'empiricists', significant knowledge about the outside world could only come through experiment and observation. An advocate of rationalism was the French philosopher, Rene Descartes (1596-1650 AD). Descartes made great contributions to mathematics as well as philosophy. Descartes maintained that all human knowledge, similar to mathematical relationships, can be constructed logically from undisputable premises. To Descartes that undeniable premise was his own existence, 'I think, therefore I am'. Based on the affirmation that he existed, he proposed logical arguments that attempted to prove the existence of the outside world as an ephemeral reality, and the existence of God as an immortal reality. For Descartes, the observed world of matter and the inner mind of the observer were separate realities - hence the notion of Descartes 'dualism'.

***A4.18 - Rene Descartes***

***A4.19 - Francis Bacon***

The Renaissance philosophers were basically of two schools. To the 'rationalists', it was possible to construct a consistent philosophy by mere contemplation and rational reasoning, while the 'empiricists' maintained that knowledge can mainly be derived from observation and empirical investigation. An advocate of rationalism, Rene Descartes (1596-1650 AD), maintained that all human knowledge can be constructed logically from undisputable premises. Francis Bacon (1561-1585) promoted the empirical scientific method of confirmation of any hypothesis by an appropriate observation or experiment.

Spinoza (1632-1677 AD) was another rationalist. However, Spinoza rejected the dualism of Descartes and maintained the unity of all that exists. His views were wrongly interpreted by some as being similar to pantheism, which maintains the fundamental unity of all existence and identify of God with the totality of nature. To Spinoza, God was immanent in nature and sustaining Cause of all existence.

By contrast, Francis Bacon (1561-1585 AD), an English lawyer, philosopher, and politician, promoted the 'empirical' scientific method. He believed that any scientific hypothesis could be proved by an appropriate observation or experiment. Believing science to be the basis of all human advancement and prosperity, he encouraged the establishment of scientific societies and colleges for the promotion of science.

Another promoter of 'empiricism' was John Locke (1632-1704 AD). To Locke, knowledge was accessible only through observation and sense perception. The empty mind of an infant is filled from birth with information progressively received through the senses - without this sensory input an individual would have no access to any kind of knowledge.

### *Rise of materialistic philosophies*

The gradual advancement in scientific investigation and the preoccupation of many thinkers and philosophers with the investigation of the physical workings of nature soon gave rise to a materialist worldview. One of the first advocates of such a materialistic philosophy was Thomas Hobbes (1588-1679 AD), a British philosopher. Hobbes rejected an independent existence of the mind and considered all human mental activities as having mechanical origins and consisting of delicate movements of matter inside the brain. His materialistic outlook was reflected in his belief that material needs and fear were the only real motivation for human action. German philosopher Friedrich Nietzsche (1844-1900 AD) said that 'God is dead' and that the religious moral attitudes of humility, selflessness and meekness were 'slave morality' and degradations of the human spirit. Instead, he promoted a life affirming behavioral attitudes based on imagination, courage and boldness leading to self-satisfaction and self-fulfillment of the individual. These, he believed, would also lead to the advancement of human society.

### *Limitations to human knowledge – 'phenomenal' and 'noumenal' worlds*

To philosophers like George Berkeley (1685-1753 AD) and David Hume (1711-1776 AD), one cannot ascertain the existence of any objective reality apart from what is being subjectively experienced.[1] Subjective experience therefore may have no immediate connection to outside reality and is no different from the experience of a dream. Hume argued against the notion of a self that has permanence, as opposed to a 'self' that is in continuous state of flux.

Other philosophers accepted the existence of an objective reality apart from the subjective experience of the observer. Immanuel Kant (1724-1804 AD) however argued that the ability of human beings to perceive outside reality was limited by the capabilities of our senses and mental processes. He maintained that only knowledge of a subset of outside reality is within our grasp. If an instrument can detect sound but not light, this is not proof of the non-existence of light. He used the terms 'phenomenal' and 'noumenal' to differentiate the world of things as they are experienced and the world of 'things as they are in themselves'.

As to the nature of the 'noumenal' world, Arthur Schopenhauer (1788-1860 AD) maintained that the unknown external reality cannot be a world of differentiation, but an undifferentiated single entity. To him, this entity had no attributes of consciousness or mind. By contrast, George Wilhelm Friedrich Hegel (1770-1831 AD) contended that there exists an all-pervading non-material 'spirit-mind' that is at the very core of all existence and is the ultimate cause of all change and transformation in the world.

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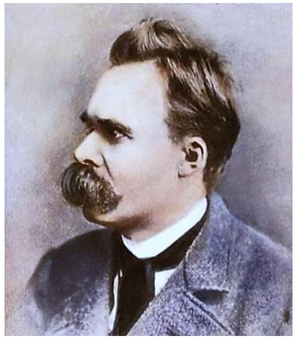
[1] Hume didn't deny the existence of matter or the external world, but he was skeptical of our capacity to know, or even to form rational beliefs about it. For Hume, we are conditioned to form certain beliefs about the external world, and we have no choice in this matter – but these beliefs cannot be rationalized.



A4.20 Friedrich

19th century scientific progress and the concern of many thinkers with the nature of the physical world soon gave rise to a materialist worldview. To Friedrich Nietzsche (1844-1900 AD) 'God is dead' and to Karl Marx (1818-1883 AD) religion was the opium of masses.

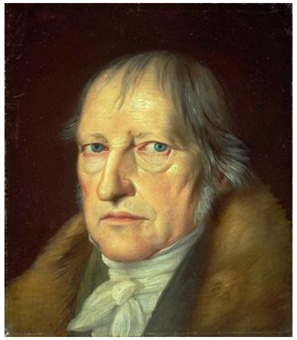
As to the question of the ultimate limits of our knowledge of outside reality, Immanuel Kant (1724-1804 AD) argued that the ability to perceive the outside reality was limited by perception of senses and mental processes.

A4.21 - Immanuel Kant

### *Hegelian dialectic*

To Hegel the world was in a constant state of change. The process of change came about from the interaction of two opposing conditions: a 'thesis' and an 'anti-thesis' leading to a third outcome or syntheses. For example, in the world of ideas, an idea may create an opposing view; the interaction of these then creates a new idea. Synthesis is, however, the next step in a condition of perpetual change. The 'Hegelian dialectic' will continue until the thesis has no antithesis and all things are in perfect harmony.

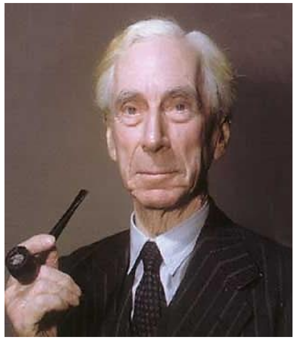
Hegel's dialectic became the basis of the 'dialectic materialism' of Karl Marx (1818-1883 AD). Marx envisaged a rapid mechanization of the means of production (thesis) leading to massive unemployment and eventual revolution of the exploited proletariat classes against the capitalists (antithesis), with the ultimate outcome of such a revolution (synthesis) being a utopian classless society where all historical struggles would cease.



A4.22 - Friedrich Hegel

To Friedrich Hegel (1770-1831 AD) the process of change comes about from a condition or 'thesis' that leads to an opposing condition or an 'antithesis'. The inter-action of the two is the resulting change or the 'synthesis.'

Bertrand Russell (1872-1970 AD) introduced what is known as 'analytical philosophy'. Russell questioned the meaningfulness of certain metaphysical propositions and the basis of 'old-fashioned morality.



A4.23 - Bertrand Russell

### *Analytical Philosophy and Logical Positivism*[1]

'Analytic philosophy' is a broad philosophical tradition that developed in the early twentieth century under the influence of the philosophers Bertrand Russell (1872-1970 AD), George Edward Moore (1873 – 1958 AD) and others. Analytic philosophy is partly characterized by the use of formal methods – particularly symbolic logic – in addressing philosophical questions, and by a shift in emphasis towards questions about language and meaning. Throughout his long career, Russell wrote widely on a range of topics, from logic and the foundations of mathematics to religion, politics, education, peace, nuclear disarmament, marriage, and morality. He is known for challenging many aspects of conventional morality. Many early analytic philosophers were suspicious of the grand metaphysical questions and a priori methods that were characteristic of traditional philosophy. This suspicion took on a particularly extreme form in the philosophical movement known as 'logical positivism' that reached its peak in the 1920's and 30's and was associated with philosophers such as Alfred Jules Ayer (1910–1989 AD) and Rudolf Carnap (1891-1970 AD). According to some 'logical positivists', the only way that a statement could be meaningful is if it was experimentally verifiable or if it is a matter of definition. Anything else was dismissed as meaningless – literally nonsense. The statement that the Earth revolves around the Sun in an elliptical orbit would therefore count as meaningful since it can be verified by astronomical observations. The statement that all vixens are foxes will count as meaningful because it is true purely in virtue of the definitions of the terms involved. But many metaphysical, religious, and ethical statements don't seem to fit into either of these categories and were to be taken as devoid of meaning. While 'logical positivism' had a profound impact on a generation of philosophers and on intellectual culture more broadly,

[1] This section is contributed by **Dr Martin Smith**.

its influence has not been strongly felt in contemporary analytic philosophy, which has returned to many traditional philosophical and metaphysical questions.

### *Existentialism in Europe*

'Existentialism' is a school of thought that rejects the convoluted and abstract philosophical argumentations and speculations pertaining to the nature of truth and the external reality and is concerned to what relates to life and the immediate conscience experience of the individual. To the 'existentialist' neither the world of existence nor human life is directed to any goal or meaning and therefore each has to define their own goals and values and what is conducive to their own happiness. Despite the deterministic nature of many aspects of our physical existence and environment, 'existentialism' suggests that we have the choice over our own inner reality and actions.

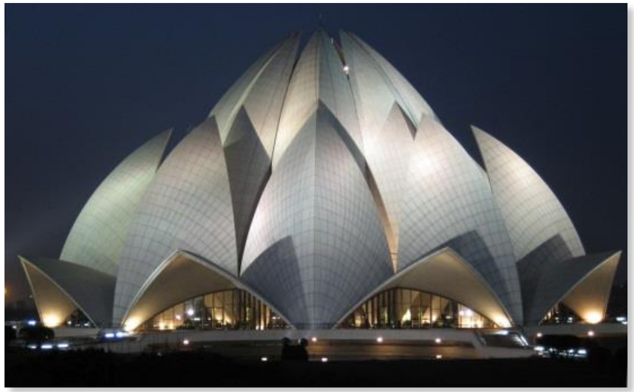
Although aspects of Existentialism existed over centuries, this philosophy became very fashionable in Europe after the World War II, where it moved from the academic circles to become the discourse of intellectuals, poets, journalists, and playwrights. It gave young people a new sense of freedom from the bounds of conventional wisdom to choose their own values and become masters of their own lives. Jean-Paul Sartre (1905-1980), the great novelist and playwright was an outstanding and popular advocate of Existentialism.

### *Philosophy and religion today - The Babi and Baha'i Faiths*

Similar to all scientific endeavor, philosophy in our time has branched into many specialties with discourse on topics such as epistemology, metaphysics, philosophy of science, philosophy of mind, philosophy of language, moral philosophy, social and political philosophy, educational philosophy and many others.

Numerous contemporary religious and pseudo-religious movements have also originated in different regions of the world. These are both from within and outside established religion. There is a basic tendency amongst many people around the world to uphold some spiritual truth and principles without formal adherence to an organized religion. This is the basis of 'new age' movements that have found a vast number of followers.

In contrast to the major world religions that have originated many centuries ago, the Baha'i Faith is an example of a more contemporary religion. The Baha'i Faith, preceded by the Babi Faith, arose in 19th century Iran as an independent religion. The Bab was the founder of the Babi movement who brought new teachings and also foresaw the coming of a great personage after him. The Bab and his numerous followers were persecuted and put to death by the verdicts of clerics and government officials. Baha'u'llah (1817-1892 AD), who Bahai's believe was the one foretold by the Bab, was imprisoned most of his lifetime and died in exile in a remote prison city of Ottoman Empire. Baha'u'llah aimed to spiritually regenerate the human race and based on the principle of the oneness of all humankind, become instrumental for the establishment of a peaceful global civilization.



***A4.24 – A Bahá'í temple***

The Bahá'í Faith that was founded by Baha'u'llah in the 19th century, teaches the basic unity of all major world religions and promotes the concept of the world unity and unity in diversity. A few Baha'i temples around the world are open to members of all religious Faiths.

The Baha'i Faith teaches the unity in diversity and the basic unity of all major religions of the world. Baha'u'llah asserts that although the realm of existence is in perpetual change, it has had no beginning and will have no end. The 'prime mover' and the 'Source' of all existence is an Unknowable Essence, beyond comprehension or description of the profoundest human mind. While all existence reflects to a certain measure the light of this Source, the Founders of the major world religions are as polished mirrors perfectly reflecting this light.

Other teachings of the Baha'i Faith include: equality between men and women, universal education, an auxiliary universal language, harmony between science and religion, and a world economy based on the spiritual principles of sharing and justice. The Baha'i Faith emphasizes freedom from preconceived ideas, superstitions and prejudices and encourages every individual to freely and independently examine and scrutinize all matters for themselves.

# A5. Advancement of scientific knowledge

The notion of evolutionary change and transformation as is manifest in nature is equally pertinent to our conceptual understanding of the physical world. Our scientific views regarding the nature of external reality have changed dramatically throughout the course of history.

In earlier times many of the occurrences that took place on the Planet were attributed to the arbitrary acts of gods or supernatural forces outside the sphere of human inquiry. The premise that certain immutable laws of nature govern our universe has only gained general acceptance over a prolonged period of time. Initially many philosophers assumed that mere rational thinking and logical deduction could ascertain the nature of our world. Only within the last two centuries has the modeling of nature in terms of empirically verifiable physical laws become the standard scientific method of inquiry.

The laws of nature are assumed to be immutable in the sense that they are presumed to be applicable everywhere in the universe and for all time. But such an assumption has the qualification of only being true 'so far as observation has shown'. That an entirely different set of physical laws may govern other hypothetical universes lies beyond the possibility of verification.

It is generally understood that no scientific theory can have the claim of finality, as there is always the possibility that in a particular situation the theory may prove to be inaccurate or inadequate. In this case, the former hypothesis is usually replaced by a more general scientific theory.

### *Two levels of scientific inquiry*

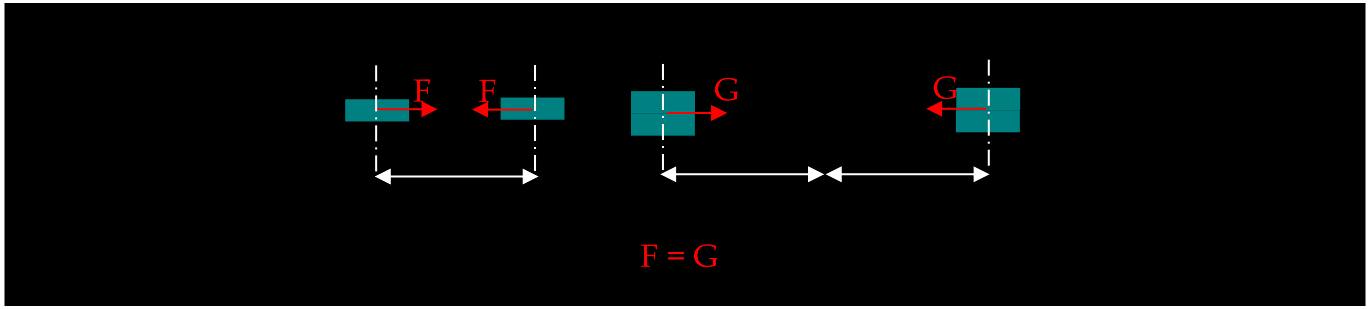
The term 'science' itself may be said to refer to two distinct but closely related levels of knowledge. At one level science explores the basic universal laws of nature such as the law of gravitation or those of electricity and magnetism. At this level science attempts to express the relationships between two or a few entities either in words or through mathematical modeling. Examples of these are Newton's gravitational law relating the forces on two isolated masses, or the laws of electricity and magnetism, describing the force between two isolated charges or current carrying wires, respectively.

At another level, science is concerned with systems of many interacting parts where the knowledge of the action of the entire system is the main point of interest. Thus, scientific quest is more than purely describing the fundamental relationships in idealized conditions constituting the basic laws of nature. Rather all physical and biological systems can be the subject of scientific inquiry at this secondary level. Understanding such systems does not require the introduction of any new basic laws of nature. In many cases it is not easy or even necessary to trace the fate of any individual component, but that of the action of the system as a whole. A simple example of this is that of the temperature or pressure of a gas where very large numbers of molecules of gas are present. Although either parameter of temperature or pressure of the gas can be calculated or measured, the fate of individual molecules is almost impossible to ascertain and is of no real significance.

Historically science has developed in parallel on both these two levels. In earlier years of scientific inquiry, greater emphasis was placed on the formulation of the basic laws of physics. With the advent of computers and complex electronics and control systems, more attention is now drawn to the understanding of the systems with greater complexity, both natural and artificial. In this chapter, we examine the development of science in discovering and formulating the basic physical laws of nature.

### *Study of motion and mechanical forces*

Mechanical concepts of motion and force dominated our early knowledge of the physical world. In the third century BC, Aristotle taught that all things moved towards their natural state. In their natural state, celestial bodies moved in spherical orbits, terrestrial objects fell to the surface of the Earth, and those on the surface of the Earth remained still.




***A5.1 – Newton's law of gravitation***

The Newton's law of universal gravitation states that there is a force of attraction between any two masses of matter. The force on one mass is directed toward the other mass and its magnitude is proportional to the product of the masses of the two bodies and inversely proportional to the square of the separation between the two. If one doubles both the mass and the separation of two bodies, the gravitational force remains constant.

Aristotle's ideas were not largely challenged until the seventeenth century when Descartes gave the correct description of motion. He stated that the natural state of a body was not to reach a state of stillness, but to continue to move with its initial speed, until it comes to rest as the result of frictional forces. Thus, an external force on the object was required to overcome the impeding friction and to change its speed or direction of motion. This was the first law of mechanics out of the three laws that later were described in the same century by Isaac Newton. The second of Newton's laws stated that the acceleration or change in velocity with time of an object was proportional to and in the same direction as that of the applied external force. For a given acceleration, the required force was proportional to the mass of the object. Finally, the third law states that for every action there is an equal and opposite reaction. For example, the gravitational force of a massive object on a table is balanced by an opposite force on the object, keeping the object at rest. This reaction is the result of the collective action of all molecules immediately inside the table.

Together with the law of gravity, which states that the universal gravitational force acting between two material bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them, Newton's laws gave a universal description for all terrestrial, planetary and galactic motion.

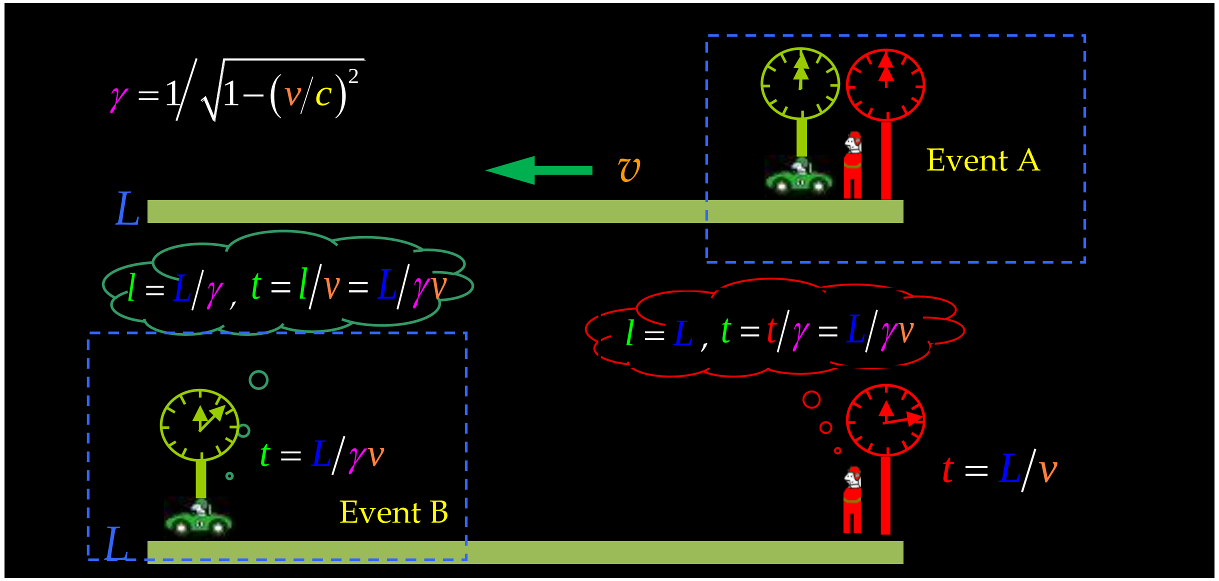
### *Relativistic mechanics*

Early in the 20th century, Albert Einstein introduced the concept of 'relativity' into the formulation of the principles of mechanics. It was generally believed that both space and time could be determined in an absolute sense, or one could find some stationary object in the universe and simply measure the position of every other object with respect to this static frame of reference. A clock would also give the same time whether it measured time on a still or a moving platform. Hence the measurements of position could be repeated at different times and every object would have absolute speed.

However, it was realized that no stationary object could be found anywhere in the universe. The so-called fixed stars had motion relative to the other stars in the galaxy and galaxies moved relative to their associate clusters. In fact, every object had motion relative to every other object. Furthermore, there was no way of determining independently the speed of any moving object without reference to another external material object. A passenger inside a smoothly running train, for example, would neither feel the motion of the train without looking outside, nor would be able to determine its speed by any instrument confined to the interior of the train.

Another consideration was that of the relative speed of light to a moving object or an observer. The relative speed of two trains moving in opposite directions along two parallel rail tracks is well known to be the sum of their individual speeds relative to a nearby stationary platform. If one train moves with speed of light, then it is expected that the relative speed of the two trains would exceed the speed of each individual train and hence the speed of light. This is contrary to the rigorous observations confirming that the speed of light relative to an object remains constant irrespective of the speed of that object.

Hence it was concluded that any reference to time, position and speed for an object had to be made only with reference to another object or an 'observer', as these would be different relative to different observers. A new theory that would embody the idea of relativity in space and time and also ensured that the speed of light remained constant relative to all moving objects was proposed by Einstein and is known as the 'Special Theory of Relativity'. Relativistic mechanics reduces to classical mechanics for the speeds much less than the speed of light.




***A5.2 - Time dilation and space contraction***

A Red man and a Green man synchronize their clocks at 12 pm (event A), as the Green man passes the Red man with a relative velocity $V$. The Red man stays stationary and the Green man drives his car with his clock on a rod of length $L$. At the end of his journey (event B) he signals the Red man that he has reached his destination and gets his clock readings. They expect that Green man's clock would read a time equal to that of the Red man's clock $t = L/v$. The Green's man clock, however, reads an elapsed time of $t = L/\gamma v$. The Green man is convinced that his clock reads correctly, and as he can assume that he is stationary and the rod moves in the opposite direction, he attributes the discrepancy in clock reading as an indication that the length of the road has reduced by a factor $\gamma$. This is called the 'space contraction'. At the same time, the Red man is convinced that the length of the rod has remained constant and attributes the discrepancy to the slow running of the moving clock, again by a factor $\gamma$. This is called the 'time dilation'. These are perplexing predictions of Einstein's theory of relativity! However, for the Red man the interval between the two events is $L^2 - c^2t^2 = L^2 - c^2L^2/v^2 = -(cL/\gamma v)^2$ and for the Green man this interval is $0^2 - c^2t^2 = 0^2 - c^2(L/\gamma v)^2 = -(cL/\gamma v)^2$ and both intervals are equal.

In classical mechanics any point in space can be defined by three distance parameters. For example, the position of two small objects in a box can be represented by two sets of three parameters such as their distance from any three adjacent walls of the box. If we rotate the box, all six parameters would change, but the distance between the two objects calculated from these parameters remains constant. If certain parameters increase by rotation, for the distance between two objects to remain constant, some other parameters need to decrease to compensate.

In relativistic mechanics, it is not the distance that remains a constant but what is known as the interval between two events, with each event defined by four parameters, three parameters of space and one parameter of time. Hence, according to the theory of Relativity, for the interval between the two events to remain invariant, any change in the space parameter in the direction of motion could produce a change in the time parameter and vice versa. For this reason, in Relativity, time is considered as the fourth dimension of a four-dimensional spacetime. The barter between space and time coordinates leads to the famous phenomena of 'space contraction' (a moving rod appears shorter) and 'time dilation' (a moving clock appears to run slower).

Another important aspect of the theory of relativity is the equivalence of mass and energy expressed by the famous relationship that the energy of a particle is equal to its 'rest mass' times the square of the speed of light. The mass of a particle at rest differs from its relativistic mass in motion, which is dependent on its speed.[1]

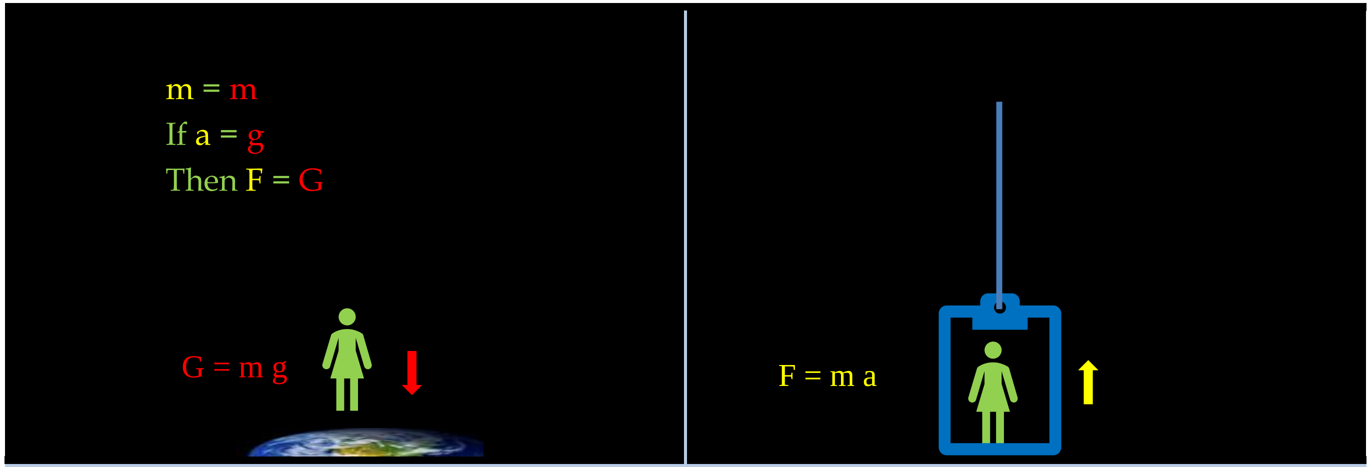
### *The General Theory of Relativity*

Subsequent to his relativistic theory of moving bodies with constant speeds, Einstein proposed his 'General Theory of Relativity' for objects accelerated by gravity, which he based on the 'Principle of Equivalence'. Briefly, the principle states that an observer from the inside of an enclosure cannot distinguish between being accelerated uniformly in a gravitation-free space or pulled by the force of gravity producing an equal acceleration.

With acceleration as a function of distance and time, and time as the fourth dimension in a four-dimensional spacetime, the 'Principle of Equivalence' leads to the geometrical interpretation of the gravitational field, with gravity considered as the distortion of the spacetime continuum. Accordingly, a massive object at any point curves spacetime, with the 'curvature' of spacetime set by the 'mass-energy' density of the object, at that point. At the same time spacetime distortion could move two objects closer, interpreted as gravitational attraction.[2]

[1] For an accessible treatment of relativity see **A Mould, Basic Relativity**, Springer-Verlag, 1994.

[2] 'John A Wheeler has summarized Einstein's theory of general relativity in these terms: Curved spacetime tells mass-energy how to move; Mass-energy tells spacetime how to curve.' See: [**Frank H Shu,** p366, **The Physical universe,** University Science Books, 1981]



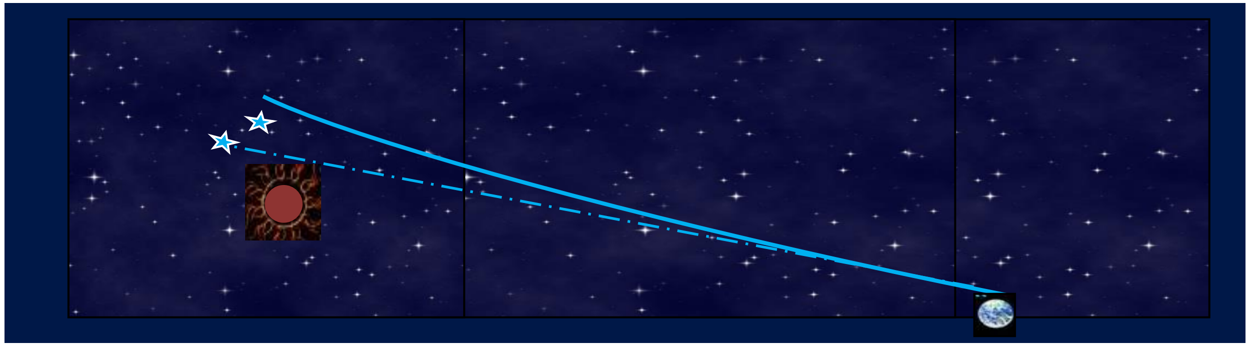

***A5.3 – The Principle of Equivalence***

A person on the ground or in an upward accelerating lift, where there is no gravity, has the same experience of weight. Inertial mass and gravitational mass of a body are equal.

The influence of massive objects on the warping of spacetime has given rise to many interesting speculations. It has been suggested that a 'black hole' distorts the spacetime like a whirlpool on the surface of otherwise still water; a wormhole could connect two such black holes, enabling instantaneous travel between two vastly separate regions of space. The theory of general relativity also predicts the expansion of the universe and the existence of gravitational waves that propagate with the speed of light.

### *General theory of relativity and the expansion of the universe*

After the advent of the general theory of relativity with gravity as its primary concern, it was natural to consider the application of the theory to a large collection of gravitating objects assumed to be uniformly distributed in a vast region of space. With the principle of large-scale uniformity of the universe, this in fact could simulate the configuration of the universe itself. The appropriate equation to be solved was Einstein's so called 'field equation' with certain assumed constraints. A possible solution of the field equation predicted that universe may not be static but expanding. At the time this idea was rejected as being absurd, but later observations by Hubble revealed the spectral redshift of galaxies proportional to their distance from our galaxy, implying a universal recession of all galaxies and possible expansion of the universe itself. Since then, the notion of an expanding universe has gained acceptance by all scientists in the field of cosmology.

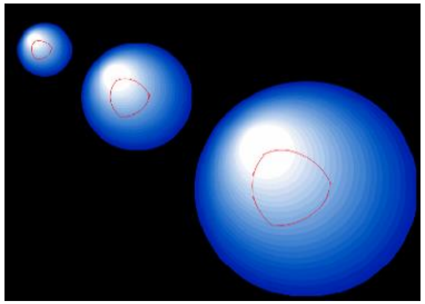


***A5.4 – Gravitational lensing***

A verification of the General Theory of Relativity has come about by observation of the change in the path of light rays as they pass close to massive objects such as the Sun. This phenomenon is known as 'gravitational lensing'.

The recession of galaxies in proportion to their distance from our galaxy, is in apparent contradiction to the Cosmological Principle of large scale uniformity of the universe, and could suggest our unique central position. However, similar to universal separation of all scattered points on the surface of an expanding balloon, the recession of galaxies is universal and every galaxy recedes from every other galaxy.

***A5.5- Expansion of universe and analogy of a balloon***



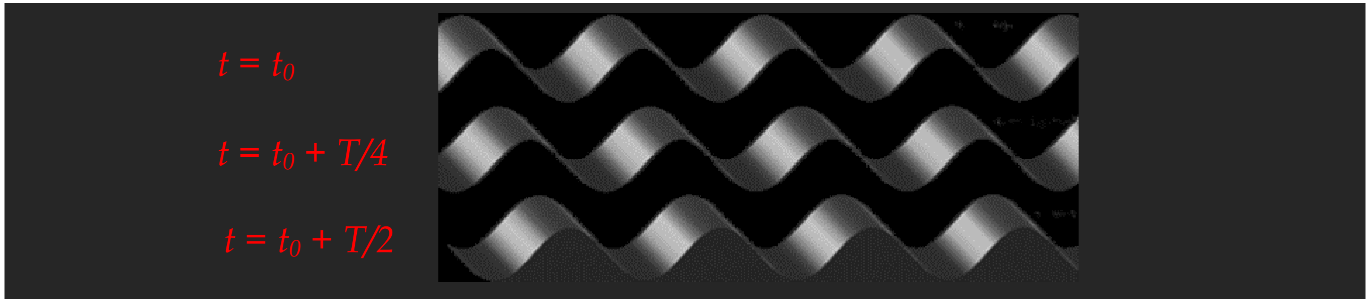
The universal recession of all galaxies implies an expansion of the fabric of space with time analogous to the expansion of the two-dimensional elastic surface of the balloon in a three - dimensional space. By analogy the three- dimensional space of our universe would expand in a fourth spatial dimension. However, the existence of a four-dimensional space is only conjectural. In hypothetical reverse time motion the universe contracts and all galaxies would merge and ultimately reduce to a very dense singular point. It appears that our universe may have started with this kind of near singularity at a time approaching zero and has been expanding ever since. The theory describing such an initial event is known as the Big Bang theory. A singularity, however, is only a mathematical concept and cannot be physically meaningful. But a mathematical singularity can in fact be excluded for the reason that as the universe is reduced in size within a Planck distance ($\sim 10^{-35}$ m) at a time within the Planck time ($\sim 10^{-43}$ sec), quantum mechanical effects would become pertinent and general relativity alone would not be applicable.

### *Development in our conceptual understanding of electromagnetism and light*

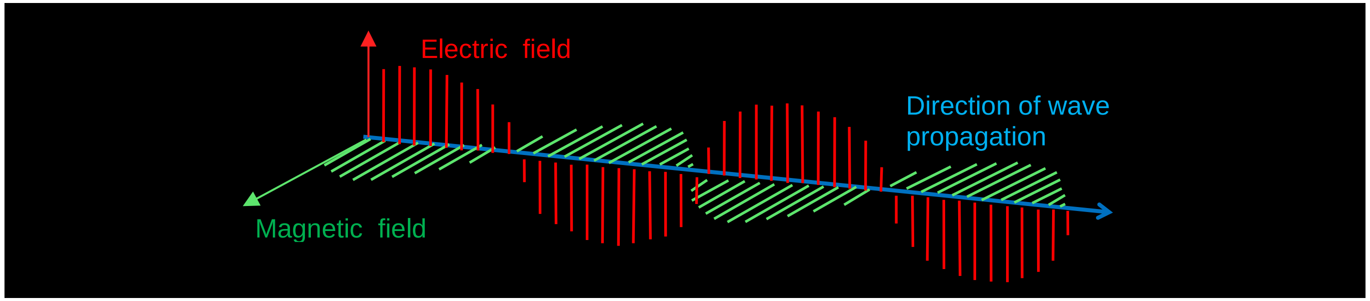
Static electricity was known in ancient civilizations through a substance known as amber which, when rubbed, would attract small particles. Similarly, magnetism was discovered through the substance of lodestones that would attract pieces of iron. The ancient Chinese had even discovered the Earth's magnetism and invented the magnetic compass. However, no detailed formulation of the phenomena was given until the second half of the eighteenth century, when it was demonstrated that the strength of attractive or repulsive electric or magnetic forces both declined in proportion to the square of the distance between the charged or magnetized objects.

Similarly, as far back as the fourth century BC, the Chinese studied the formation of light shadows of objects. In the ninth century AD, Islamic scholars introduced the concept of light rays and in the thirteenth century in Europe, image formation by simple lenses was examined. By the seventeenth century AD, the ray theory of light was well understood and optical instruments such as telescopes and microscopes were invented. It was demonstrated that electric current, or moving electric charges in a wire, produced magnetic effects in their vicinity. Similarly, a changing magnetic field could induce an electric current in a closed circuit. The successive inducement of magnetic fields by time varying 'electric field' and electric fields by 'time varying magnetic field' could lead to the generation and subsequent propagation of electromagnetic waves.

In 1855, Maxwell gave a complete mathematical formulation of electromagnetic fields and electromagnetic wave propagation. It was realized that the speed of electromagnetic wave propagation was equal to the speed of light, establishing the nature of light as a propagating electromagnetic wave.




***A5.6 - Wave propagation***




***A5.7 - Light as electromagnetic wave***

Waves are time varying disturbances of some physical parameter. In a 'standing wave', a particular physical parameter has a periodic time variation at any point in space and a periodic spatial variation at any point in time. Wave propagates when the spatial disturbance moves with a finite velocity along a particular direction, known as the direction of wave propagation. Propagating waves have a period and a wavelength which are the time duration and the space interval that a disturbance repeats itself. Sound waves are the propagation of compression and rarefaction of matter such as air in a medium. Light waves are propagation of coupled electric and magnetic fields in space. Electric and magnetic field directions are perpendicular, and the direction of wave propagation is perpendicular to both.

A particle is associated with something rigid and localized in small region of space and is either stationary or moving with respect to a certain frame of reference, it has momentum and energy. A wave on the other hand is in an extended region of space and is characterized by wavelength and frequency. Looking at a very small region of space, no waves can be found. One particle plus one particle is two particles, but one wave and one wave are a spatial interference pattern where two waves either partially or totally cancel or reinforce each other at each point. When it was realized that light travels at a finite velocity, it was concluded that it would have to have either the nature of a particle or a wave. The particle theory was advocated by Newton and the latter by Christiaan Huygens. In the early twentieth century, it was realized that both aspects of light must be accepted as complementary. The particle theory would explain the 'photoelectric' effect with 'photons' of light having specific energies that could impart to the electrons inside the photoelectric substance and produce the conduction of electricity. The wave nature of light would explain the diffraction and interference phenomena producing interference patterns in light as two merging water ripples in a pond.

### *The nature of matter and the development of quantum mechanics*

The quest for the understanding of the nature of matter goes back to Greek thinkers and even before. In the fifth century BC, the Greek philosopher Empedocles proposed that all things are made of four indestructible substances of fire, water, earth, and air. Around the same time, the atomic state of matter was proposed by Democritus and Leucippus who suggested that all substances were made up of small indivisible particles in perpetual motion. However, it was not until the early nineteenth century that the atomic nature of matter was scientifically confirmed. First it was realized by John Dalton in 1808 that chemical compounds were made of simple ratios of the constituent chemical elements, independent of the total mass of the compound. It was concluded that each chemical element was made up of minute indivisible particles or atoms of equal size and weight and that chemical reactions took place at the atomic level.

Ernest Rutherford further elaborated the structure of the atom in 1911 as consisting of a central positively charged nucleus and orbiting negatively charged electrons. This, however, was not consistent with the fact that an orbiting charged particle radiates energy and that the orbits of electrons cannot remain stable and that in time electrons will have to fall into the center of the atom. This and other anomalies in physics led to the conclusion that like photons, electrons and other elementary particles must exhibit the dual nature of particle and wave.[1]

A theoretical formulation that mathematically describes the above unusual properties of elementary particles is known as quantum mechanics. Quantum mechanics is a powerful but at the same time non-intuitive theory. While there have been many attempts to give a physical interpretation of the quantum theory, there is a consensus that none is a satisfactory intuitive explanation of the quantum

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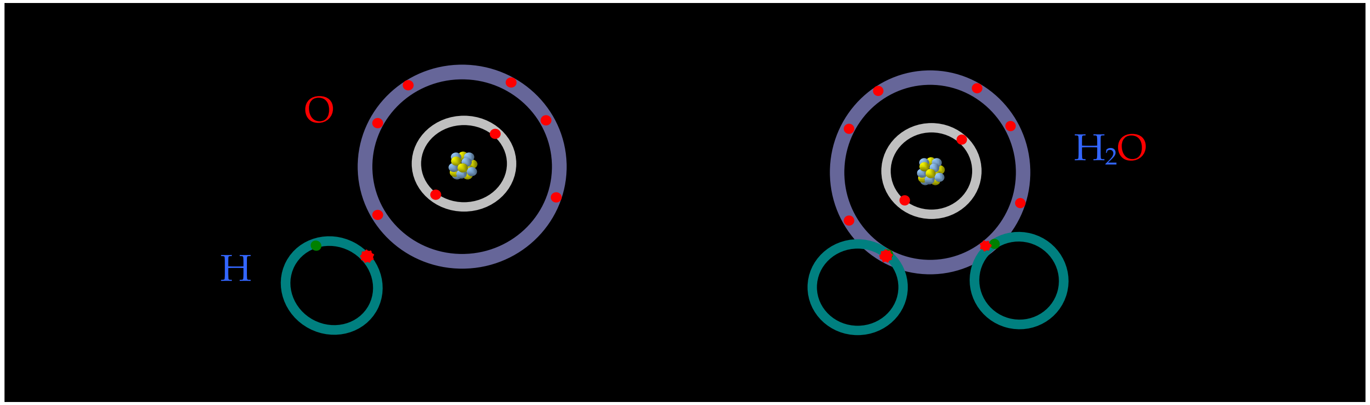
[1] A complete break from classical physics came about by the realization that in addition to photons, all other particles had also a wave nature. See: [**John Gribbin,** p92, **In search of Schrodinger's cat,** Black Swan, 1997]

phenomenon. For example, the concepts of quantum entanglement and non-locality in quantum mechanics, is hard to envisage or comprehend.

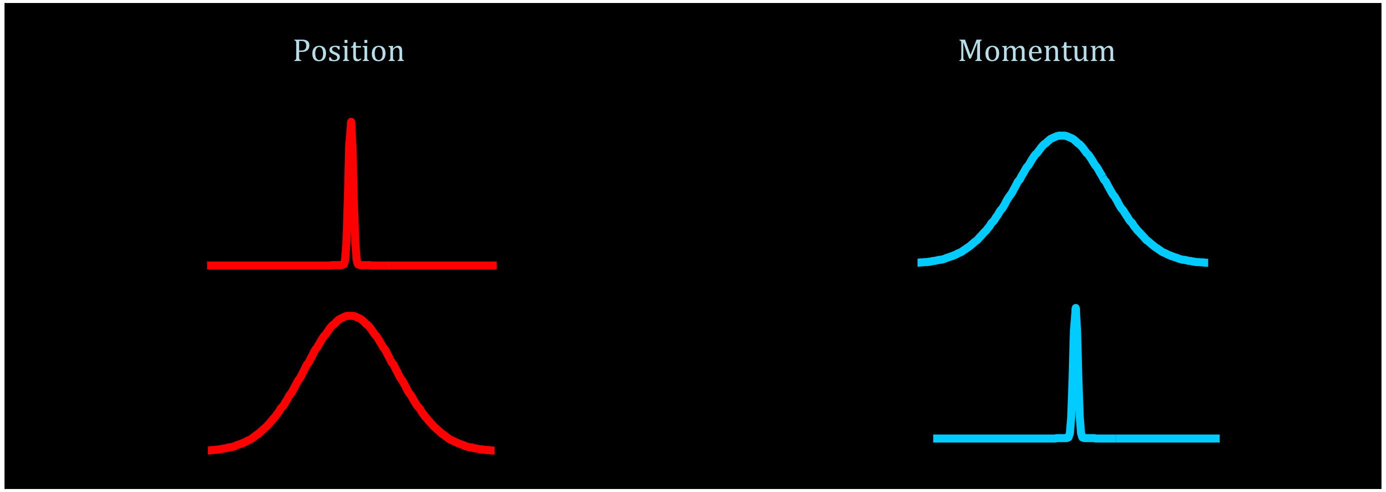



***A5.8 - Hydrogen and oxygen atoms and a water molecule***

Chemical interactions occur at atomic level. Electrons revolve around the nucleus of an atom in different orbits. Each chemical element has a specific arrangement as to the number of orbits and the number of electrons in each orbit. An atom with eight electrons in its outer orbit is inert and cannot react with any other atom. Atoms with a smaller number of electrons tend to bond, thus increasing the number of their outer shell electrons to eight. An oxygen atom with six electrons in its outer shell bonds to two hydrogens of one electron each, thus increasing the number electrons in its outer shell to eight.

Quantum theory explains very accurately many aspects of experimental physics, from so called blackbody radiation to superconductivity[1] and photoelectric[2] effect and many more. The most prominent amongst those who contributed to the development of quantum mechanics were Planck, Einstein, Bohr, Schrödinger, Dirac, de Broglie and Heisenberg.

[1] Condition of near zero electrical resistance assumed by some material at very low temperatures (below 10K).
[2] Generation of electricity by application of light.




***A5.9 – position – momentum relation in quantum mechanics***

Quantum Mechanics maintains that it is not possible to know precisely both the position and momentum of a particle at the same moment in time. If the position of a particle is known with a good accuracy (upper red curve), its momentum is ambiguous and can assume a spread of values (upper blue curve). On the other hand, if the momentum is well defined (lower blue curve), its position can assume a possible range of values (lower red curve). The same principle applies to energy and time.

Quantum mechanics completed the picture of the atomic structure by demonstrating that stable electron orbits are indeed possible, but that these orbits are not necessarily the actual but the most probable position that an electron can occupy. Moreover an electron in a particular orbit has a discrete energy and additional energy has to be supplied for the electron to move to an orbit of higher energy.[1] Alternatively, if an electron returns to an orbit of lower energy, the energy difference is usually radiates as photons of electromagnetic radiation.

[1] Atomic electrons have discrete modes of vibration around the nucleus and hence discrete frequencies and discrete energies. See: [**Paul C W Davies,** p43, **The forces of nature,** Cambridge University Press, 1988]

### *Different interpretations of quantum mechanics*

In Copenhagen interpretation of quantum mechanics, probabilistic knowledge of the outside world is a mere consequence of the randomness of nature itself. In this description, the wave function represents the true reality of sub-atomic particles. However, by the very act of measurement, from all possibilities only one is selected. This is known as wave function collapse.

Alternatively, it could be assumed that nature is deterministic and some 'hidden variables', yet to be discovered, influence the physical parameters, while the ignorance of these hidden variables limits our knowledge to probabilistic estimates. Unaware of all the exact forces that influence the outcome of the throw of a dice for a head or a tail, we assume an equal chance for either outcome.

Another interpretation of quantum mechanics assumes that at every event, all possible states of quantum mechanics are realized, but each in one universe of many parallel universes. This is the many-worlds interpretation of quantum mechanics. At each instance we continue to be associated only with one of these parallel universes and hence observe the occurrence of one quantum state.

### *Quantum entanglement and non-locality*[1]

'Quantum-entanglement' is one of the most inscrutable of quantum phenomena. The effect, confirmed by a significant number of experiments with photons, is manifested when, say, two quantum objects A and B share the same quantum state anywhere in the universe, whether near or far.[2,3] When this occurs, the quantum objects are said to be 'quantum entangled.'

Before the attributes of either quantum-entangled object are observed, the objects appear to be quite independent of each other. It is remarkable that observing the quantum state of the quantum-entangled object A seems to 'fix' the quantum state of object B instantaneously and independent of the distance between them.

Some quantum theorists believe that quantum-entanglement phenomena exist at all levels of reality, including human everyday experience. Indeed, if the phenomenon is real, then the entire universe, whether observable or not, may be quantum entangled.

According to Einstein's special theory of relativity, influences cannot be shared by physically real objects that require information transfer between the objects at a speed faster than the 'speed-of-light' (the 'SOL' postulate). Such phenomena that obey the SOL postulate are said to be 'local.' On the other hand, if 'faster-than-light' ('FTL') information is transferred, such phenomena are said to be 'non-local.' From what has been said, quantum-entanglement phenomena imply faster-than-light transfer of information and are therefore 'non-local' phenomena.

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[1] **Robert Riggs**, private communication – see also www.paraphysicstoday.org

[2] See Nick Herbert, Quantum Reality, Anchor Books, 1985

[3] An example of a quantum state is the spin (polarization) of a photon.

Quantum-entanglement is one among many curious effects that become visible to the human psyche when quantum phenomena become observable in the world of everyday human experience. It is only hoped that quantum-entanglement might someday be used to transmit human communications at FTL speed. Indeed, Einstein (E) and his colleagues, Podolsky (P) and Rosen (R), first pointed out this possibility in 1935. Einstein et al argued that quantum-entanglement violates the locality postulate and is therefore unreal. This has become known as the 'EPR paradox'. Their argument may be considered logically flawed, since it assumes *a priori* that local phenomena constitute all that is real.[1,2]

### *Inside the nucleus*

As electrons surround the nucleus in fuzzy orbits, the size of an atom is not well defined. Dividing the thickness of a paper by ten for six successive times gives an estimate of the diameter of an atom. Dividing it by ten another five times is the estimate of the diameter of the nucleus.

The nucleus itself is made of protons and neutrons. The number of protons in the nucleus of an atom is equal to that of the number of electrons, but the mass of a proton is 1836 times that of an electron. While Protons have a positive charge, Neutrons are slightly more massive than protons, but are charge neutral. Hydrogen, the simplest atom has a single proton and a single electron. Some substances have equal protons and different neutron numbers. These are called isotopes. Uranium-235 has 92 protons and 143 neutrons while uranium-238 has the same number of protons but 146 neutrons. An isotope of a substance can decay to another isotope, emitting so called alpha[3] and/or beta[4] particles and losing mass – this process is called radioactivity.

The nucleon (neutrons and protons) of an atom is made of subatomic particles called quarks, which are never been found in isolation. Six kinds of quarks have been identified – 'Up', 'Down', 'Top', 'Bottom', 'Charmed' and 'Strange'. An 'Up' quark has a positive charge equal to two-thirds of the charge of an electron and a 'Down' quark a negative charge equal to one-third of the charge of an electron. A proton is made of two 'Up' quarks and one 'Down' quark and hence has a total charge of an electron but with the opposite sign. Hence there is an attraction between the electron and the proton. A neutron has two 'Down' quarks and one 'Up' quark, and hence no electric charge. 'Top' and 'Bottom' and 'Charmed' and 'Strange' quarks take part in the formation of other short-lived particles.

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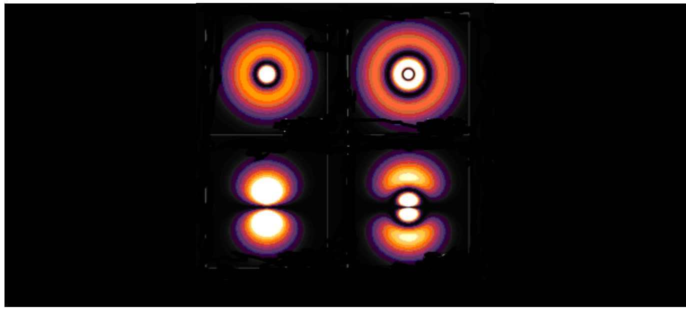
1 See en.wikipedia.org/wiki/EPR paradox

2 See Roger Penrose, The Road to Reality, Chapter 23, Vintage Books, 2007

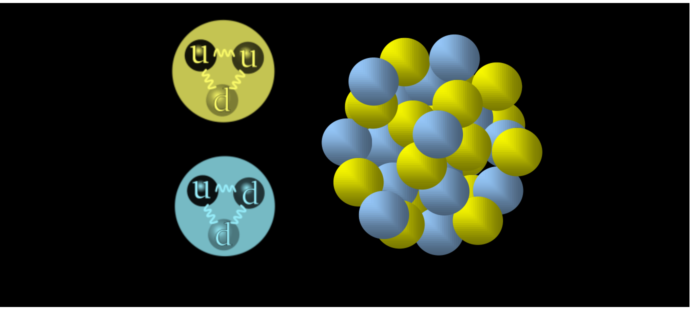
3 Alpha particles consist of two protons and two neutrons and have the same configuration as doubly ionized helium atoms.

4 For the explanation of beta radioactivity, see: [**Paul C W Davies,** p64, **The forces of nature**, Cambridge University Press, 1988]



### *A5.10– Fuzzy orbits of electrons*

An atom consists of a nucleus and a number of orbiting electrons. The orbits of electrons are not well defined, and it is not possible to precisely define the position of an electron at any time. The most probable orbits can be found by the application of Quantum Mechanics.




### *A5.11 – Protons and neutrons*

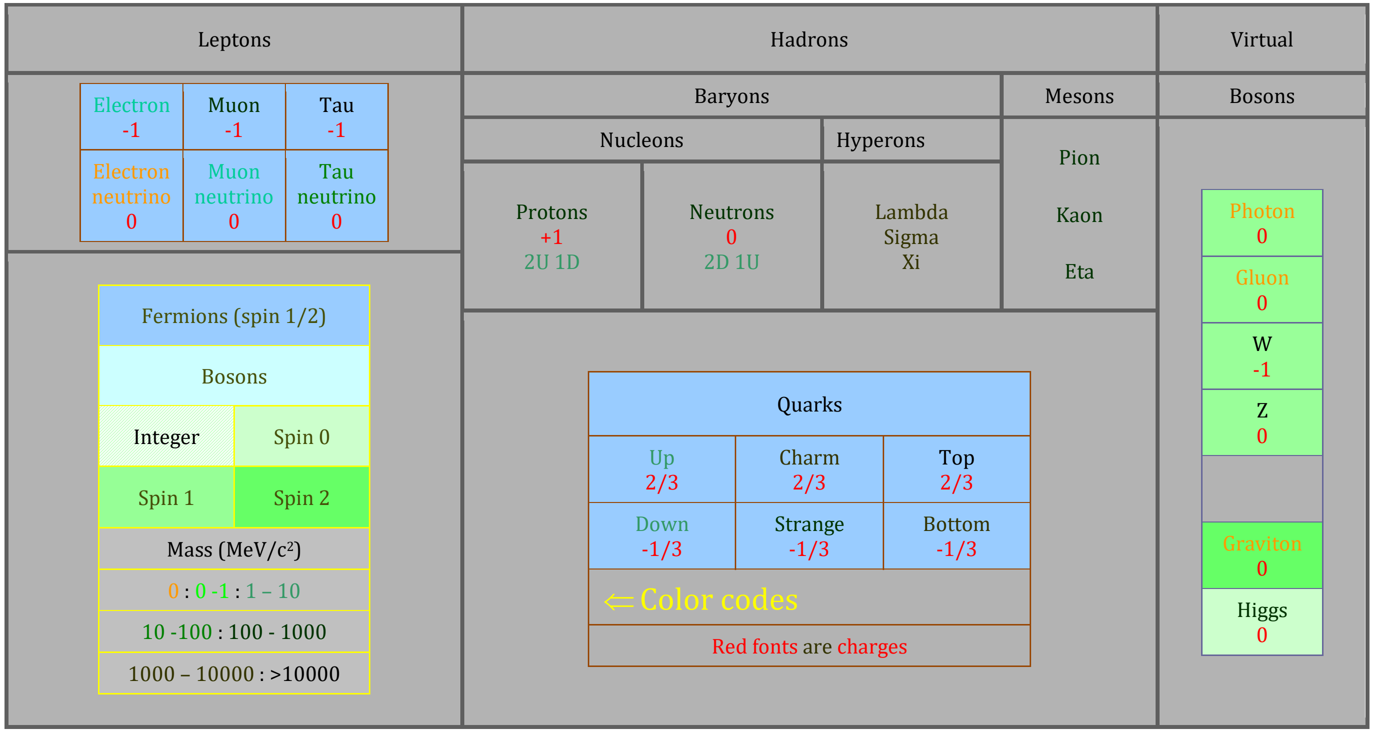
The nucleus of an atom is made of protons (yellow) and neutrons (blue). Protons are made of two up quarks and one down quark and have a positive charge of magnitude equal to the charge of an electron. Neutrons are made of one up quark and two down quarks and are charge-neutral.

## *Exotic particles*

In particle accelerators, where particles are accelerated to very high energies and made to collide with other particles, a host of exotic elementary particles can emerge.[1] Many of these elementary particles are very unstable and decay to other particles within a fraction of a second. Classified in terms of some common properties, the fundamental particles that are the building blocks of matter are designated as ‘Leptons’, ‘Hadrons’ and ‘Virtual Particles’.[2]

[1] The world’s largest particle accelerator is a circular accelerator with a circumference of 27 km at CERN (The European Centre for Nuclear Research), just outside Geneva, Switzerland.

[2] Leptons do not interact with the strong nuclear force. They consist of six particles, electrons, muon, tau and their three neutrinos. Neutrinos are neutral, and their masses are very small but not as yet ascertained. Leptons are ‘fermions’ with half-integer spin and no two leptons can occupy a single energy level (Pauli exclusion principle). Hadrons interact with the strong force and are divided into two groups of ‘mesons’ and ‘baryons’. Mesons include Pion, kaon and eta and are composed of quarks and anti-quarks. Mesons have integer spin number and are ‘bosons’. Baryons are fermions and are ‘nucleons’ and ‘hyperons’. The former group consists of protons and neutrons and the latter include lambda, sigma and xi particles.




***A5.12 - Partial list of elementary particles***

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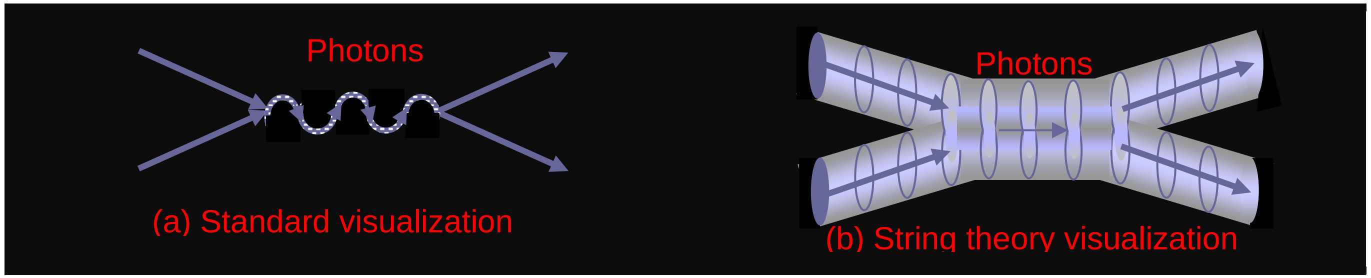
Apart from protons and neutrons all other Hadrons have a very short life. All particles interact with gravitational fields and all charged particles, by definition, interact with electromagnetic fields. Virtual Particles are the particle interpretation of the attractive or repelling forces of nature. The attraction between a positive proton and a negative electron can be interpreted as the exchange of a 'virtual photon'. Nucleons are held together by the short-ranged Strong Nuclear force, which can be thought of as the exchange of 'Gluons'. Weak Nuclear forces taking part in radioactivity are considered as the exchange of so called 'W' and 'Z' particles. The corresponding virtual particle for gravitational interaction may be called the 'Graviton'. All virtual particles are bosons with integer spin number.

All particles have their own 'antiparticles'. The 'antiparticle' of an electron is the 'positron' with equal mass and equal but positive charge. Electrons and positrons in proximity annihilate each other with a burst of photons. The photon is supposed to be its own antiparticle.

The visible matter in the universe by itself cannot correctly account for the observed large-scale configuration of the universe and the galactic structures. It is believed that only a small fraction of the matter in the universe, perhaps around 4%, consists of visible matter. The rest is either dark matter or dark energy. There are many candidates for the esoteric role of the dark matter, including the dark remnants of certain stars, black holes, massive neutrinos, brown dwarfs, magnetic monopoles and a host of others. The term dark energy is used for a substance that is believed to permeate the whole universe and accelerate its large-scale expansion.

### *Grand Unifying Theory – String Theory*

There is always an attempt in science to seek a unifying theory for all observations in nature. A proposition that unifies the electromagnetic and the weak nuclear forces is known as the Electro-weak theory. Such unification can occur at energies approaching $10^2$ GeV, but to include the strong force in a Grand Unifying Theory (GUT), energy has to reach $10^{15}$ GeV and again to extend it to gravitational force, the energy should exceed $10^{19}$ GeV. Although there has been appreciable success in developing the GUT, the inclusion of gravitation force in this unifying scheme has proved to be much more difficult. The string description of particles may lead the way to this ultimate unification, but the theory is not yet complete.




***A5.13 - Particle and anti-particle collision***

A particle and its antiparticle in collision can annihilate each other and produce a photon that can subsequently decay to another particle and antiparticle. (a) Standard representation (particles as infinitesimal points), (b) String theory representation (particles as strings).

If elementary particles are aspects of the same reality, the simplest way to consider them is as vibration modes of some entity, like different musical notes. If we regard elementary particles as being points or singularities in space, it is hard to imagine that they can be different aspects of a common entity. However, if we envisage them as open or closed strings, they could vibrate in many modes as that of a violin string. In fact, it is suggested that elementary particles are strings of dimensions many orders of magnitude smaller than the dimensions of the nucleus of an atom. The string theory formulation of hypothetical strings conforms to quantum mechanics and to both the special and general theory of relativity and thus intends to unify quantum mechanics with gravity. However, to take into account all the different aspects of the known particles and their interactions and also their related constants, such as their mass and charge, we need to invoke the string vibrations in many more spatial dimensions, than the usual three spatial dimensions of every day experience.[1] It is suggested that the 'strings' are not infinitely thin, rather like tubes with a very small cross-section curled in extra space dimensions.

[1] 'Extradimensional geometry determines fundamental physical attributes like particle masses and charges that we observe in the usual three large space dimensions of common experience.' See: [**Brian Greene,** p206, **The elegant universe,** W. W. Norton & Company, 1999]

# A6. Many particle and complex inanimate systems

Scientific inquiry, apart from attempting to uncover the basic laws of nature, also encompasses the understanding and analysis of complex natural and artificial systems. Examples of these are numerous, from simple machines to the neural connections of the human brain. In general, such systems have many parts and are composed of several components, each component contributing to the functioning of the system as a whole.

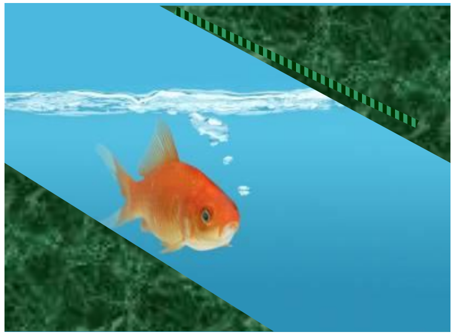
Recent advancements in cosmology have led us to the understanding of the evolutionary nature of the universe passing through stages of initial inflation and the subsequent expansion and formation of protogalactic gas clouds, galactic structures, stars and planetary systems. These evolutionary events can be considered as quasi-independent, self-regulating complex systems and processes. A system description adds a new insight to the workings of nature. In addition, a system paradigm gives a unified perspective of nature that can include both inanimate systems and animate organisms. In this chapter we consider many particles and complex inanimate systems. Man-made and animate systems are discussed in Appendix 7 and Appendix 8, respectively.

### *System of many particles*

The motion of a pair of interacting objects is very amenable to mathematical analysis. The problem is far more complex if another object is added and almost intractable with the addition of a few more. It is an impossible task to calculate the position and momentum of millions of particles in a gas container interacting with each other and colliding with the walls of the chamber. In practice, however, it is their collective effect, for example, the pressure that they exert on the walls of the chamber, is of primary interest. In these cases, we must resort to statistical distributions and averages. Here we consider two situations where large collections of particles are involved.

### *Fluid mechanics*

Fluid mechanics is an important branch of science that applies the basic laws of mechanics to a very large number of liquid or gas molecules. It is concerned either with fluids at rest or the flow of fluids in pipes or open-channels and has important applications in the construction of dams and other hydraulic systems, as well as the design of cars, steamships, aircrafts, and numerous other machineries. A fluid is at rest when there is no net pressure anywhere inside or any resultant tangential force at the boundary of the fluid. When there is a differential pressure, the fluid moves in the direction of the net applied force. Resistance to motion arises from collision of molecules, from attractive forces between the fluid molecules themselves or between the fluid and the walls of the fluid. For the large number of molecules in a fluid, these microscopic forces have macroscopic effects known as viscosity that impedes the fluid flow.



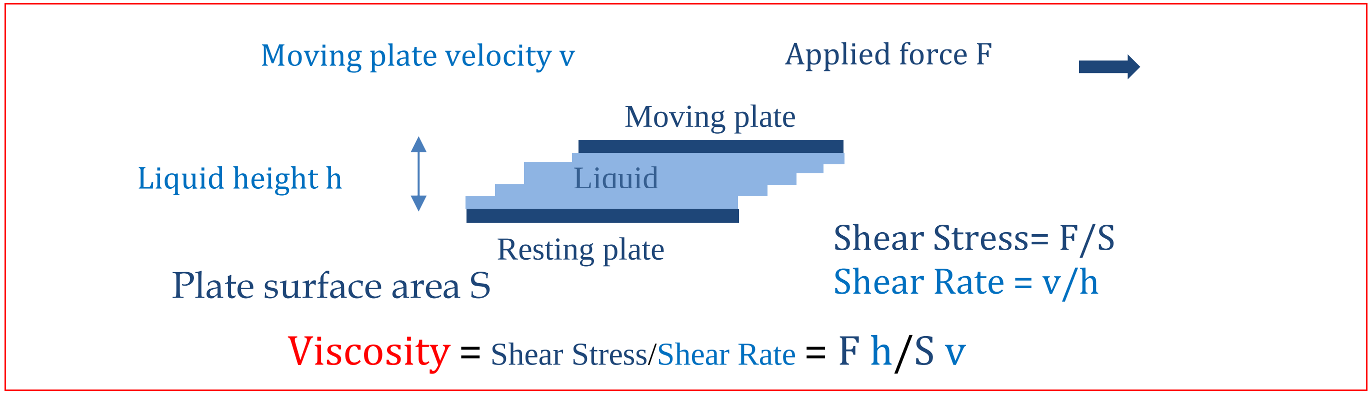
*A6. 1 - Laminar flow*

*A6. 2 - Turbulence*

A fluid is at rest when there is no resultant net pressure anywhere inside the fluid. When there is a differential pressure, the fluid moves in the direction of the net applied force. Resistance to motion arises from the attractive forces between the fluid molecules. For the large number of molecules in the fluid, these microscopic forces have macroscopic effects known as viscosity. For low flow velocities, viscosity is constant and fluid flow is laminar. For high velocities, the relation between differential pressure and the flow velocity becomes nonlinear and fluid motion can become turbulent.

For low flow velocities, viscosity is a constant and the velocity of fluid flow at any fluid position is proportional to the applied differential pressure at that position. At higher velocities the relation between pressure and flow velocity becomes nonlinear and the apparent or effective viscosity increases (or decreases). At these higher velocities, due to the variations of the effective viscosity across the fluid, laminar or orderly flow streams can change to highly unpredictable flow patterns known as turbulence - as in the air turbulence experienced on jet flights.

The unset of turbulence is sudden and is characterized by so called Reynold’s number, which is proportional to velocity and liquid density and inversely proportional to viscosity. Hence for a bullet speeding through a liquid at rest, the greater the viscosity, the higher is the required bullet velocity for the unset of turbulence.




***A6.3 - Newtonian liquids***

Newtonian liquid is an ideal liquid where shear stress and shear rates, as defined above, are proportional. Viscosity is the ratio of the two. Liquids mostly act as Newtonian liquid before the unset of turbulence.

## *Thermodynamics*

***A6.4 - Second Law of thermodynamics***

The second law of thermodynamics is based on the fact that, on its own, no heat can be transferred between two substances held at equal temperatures (Right hand figure). Heat energy will transfer from a hotter to a colder object but will not flow spontaneously from a colder to a hotter substance (Left hand figure). Work can be extracted only from substances that are at different temperatures and once an equilibrium temperature is reached, the system is incapable of doing any further work. This is a state of minimum ordering and maximum disorder or 'entropy', similar to the state of a well-shuffled pack of playing cards that is in a state of maximum disorder.

Another example of a branch of science that is only relevant if enormous numbers of particles are present is thermodynamics. Thermodynamics deals with the dynamics of the transfer of heat energy and its conversion to work. Here we have the motion and vibration of numerous numbers of molecules. In this situation, the exact position or momentum of each particle is impossible to predict and is of no important consequence. The significance lies in the net behavior of the whole system in terms of probability distributions and average values. The understanding of thermodynamics requires no new laws of physics.

The concept of heat transfer between hot and cold substances and the effect of heat on the melting of solids and the boiling of liquids were known even in ancient times. However, a deeper understanding of heat and the subject of thermodynamics was not gained until the seventeenth century when the thermometer, a device for the measurement of temperature based on expansion by heating of substances such as alcohol or mercury, was devised.

The distinction between the temperature and heat content of a substance was made in the next century, when it was realized that different substances required different amounts of heat to reach the same temperature. 'Specific heat' and 'latent heat' were defined, respectively, as the amount of heat required for raising the temperature of a unit mass of a substance by one degree or for changing its state from solid to liquid or liquid to gas.

As to the nature of heat, it was first thought that it consisted of a type of invisible fluid called 'caloric' that would move from a hot to a cold object. Once it was realized that mechanical energy can be transformed to heat, such as in rubbing of a rough surface, the idea of heat as an incompressible fluid was abandoned. The reverse process of converting heat to mechanical work is the basis of steam or other fuel-based engines. The total translational and vibration energy of the molecules inside a substance is the heat content or internal energy of the substance that can be transferred to other substances or to mechanical work.

In the nineteenth century the three laws of thermodynamics dealing with the dynamics of heat transfer and conversion of heat energy to work were formulated. The first law is the statement of the conservation of the total energy of a system. It states that the increase in the internal energy of a system is equal to the heat energy transferred from external sources, minus the mechanical work done by the system.

The second law is based on the fact that, on its own, no heat can be transferred between two substances held at equal temperatures. Heat energy will transfer from a hotter to a colder object but will not flow spontaneously from a colder to a hotter substance. Work can be extracted only from substances that are at different temperatures and once an equilibrium temperature is reached, the system is incapable of doing any further work. This is a state of minimum ordering and maximum disorder or 'entropy'[1], which is similar to a

[1] Entropy is a measure of the disorder of a system at microscopic level.

state of a well-shuffled pack of playing cards. The amount of heat transfer from a hot to a cold object, divided by the absolute temperature reached at equilibrium, defines the increase in entropy. As no heat can be transferred in reverse direction, entropy always increases.

As time passes, it is speculated that the universe would eventually reach a state of thermal equilibrium, with the entire universe assuming a constant temperature. Total entropy is then a maximum and the universe would reach a state of 'thermodynamic death' in which no action of any kind can take place. As a corollary, we can assume that the universe started with very low entropy.

However, the above statement about the irreversible increase in entropy is only true for closed systems. If energy is constantly supplied to a system, the entropy need not increase and the system can assume a more ordered state. A refrigerator supplied by external energy, for example, can extract heat from a cooler plate and supply it to a hotter plate and thus reduce the system's entropy. This is of course true if the refrigerator is considered in isolation. If the surrounding environment is also included, the entropy again increases.

Another pertinent example is of a living organism, supplied by external energy, its complexity and order increase and its entropy decreases. At the same time the dissipated heat from the organism increases the net entropy of the combined organism and its surroundings. As the Sun supplies the Planet with low entropy energy in the form of electromagnetic waves, the complexity and order in living organisms on our planet can increase without the violation of the second law of thermodynamics.

By the third law of thermodynamics, all bodies at absolute zero,[1] where there are no molecular agitations, are at zero entropy.

### *Extension of the Second Law of thermodynamics*[2]

The Second Law of Thermodynamics states that dynamical systems tend to become more chaotic with the flow of time. Except for the Second Law, every law of physics is invariant to the direction of time. We should note, however, that the flow of time or the 'arrow of time' from past through present to future is an arbitrary convention among physicists, while 'intuitive time', as suggested by St. Augustine, seems to flow through us from future through present to past.

The concept of the Second Law (conversion of Order into Chaos), that was originally developed in connection with the physical systems involving heat transfer and conversion of heat to mechanical work, can also be applied to systems theory and information theory. While classical physics and systems theory share the concepts of entropy and negentropy (negative entropy), in information theory these are called, respectively, 'noise' and 'information gain'. The sum of (entropy + negentropy) or of (noise + information gain) is always some constant that, in theory, can be expressed in either 'entropy units' or 'bits'. Thus, a decrease in entropy increases the

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[1] Minus 273.15 degree Celsius.

[2] **Robert Riggs**, private communication – see also www.paraphysicstoday.org

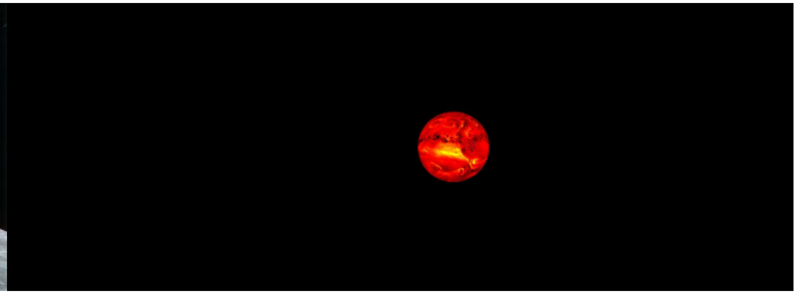
negentropy in a physical system, or a decrease in noise increases the information gain in a communications system. The value of the constant will depend upon the domain under scrutiny.

### *Planet dynamics as an interplay of thermodynamics and fluid mechanics*

The concepts and laws of thermodynamics and fluid mechanics that we have just discussed are the most fundamental in understanding the dynamics of our planet. The Planet receives constant electromagnetic energy from the Sun, mostly as infrared and visible light. A fraction of this energy is reflected back at almost the same electromagnetic spectrum, similar to the reflection of sunlight from the surface of the moon. A larger proportion, however, is converted to heat and is absorbed by land terrains and sea waters and subsequently reflected back in the form of infrared electromagnetic radiation. It is well known that a heated substance radiates energy at a wavelength depending on its temperature. As the absorbed radiation from the Sun raises the temperature of the Earth, the Earth in turn returns back this energy into the surrounding space. Hence the Earth is maintained at a temperature that the total reflected and radiated energy equates to that of the received energy from the Sun.

***A6.5 - Earth seen from the moon***

A fraction of energy received from the Sun is reflected back to the space at almost the same electromagnetic spectrum, similar to the reflection of the sunlight from the surface of the moon.



***A6.6 - Infrared image of the Earth***

As the absorbed radiation from the Sun raises the temperature of the Earth's surface, the Earth in turn returns this energy into the space in the form of infrared electromagnetic radiation.

The molecules in the Earth's atmosphere, in particular water vapor and carbon dioxide absorb the infrared radiation of the Sun and raise the Earth's atmospheric and hence the surface of Earth temperature. This is known as the 'greenhouse effect'. It is believed that human activities on Earth are increasing the absorbing molecules in the atmosphere and hence leading to global warming.

Water is the most consequential element in sustaining the life of our planet. The cycle of the rise of water vapor from the heated oceans and creation of atmospheric clouds and the downfall of rain and subsequent formation of rivers that flow back into oceans is the most fundamental planetary process.

While heat transfer from the Sun and temperature regulation on Earth follow the laws of thermodynamics, the subsequent fluid motion in the oceans, waterfalls, lakes, and rivers are governed by the laws of fluid mechanics. Hence, thermodynamics in conjunction with fluid mechanics are the most fundamental regulating mechanisms of planetary processes. The interplay of thermodynamics and fluid mechanics are also found in Earth's weather system. Here air molecules are the 'fluid' that is set in motion by the heating effect of the Sun's radiation.

### *Gaia hypothesis*

The above description of integrated action of heat transfer and fluid motion creating ecological conditions and thereby sustaining the life of the Planet, leads us to the notion of the Planet as a dynamic self-regulating system. In fact, within this system there are countless subsystems that comprise numerous non-living and living forms and ecosystems of greater and lesser complexity. The degree of self-regulation, interaction and integration of these processes makes the Planet itself akin to a living organism. This is the basis of Gaia hypothesis postulated by James Lovelock.[1] Although the analogy of the physical and biological processes of our planet to that of a living organism cannot be taken too far, it emphasizes the necessity of considering the Planet in the light of a systems paradigm, as a hierarchy of coupled and interacting systems – as in living organisms.[2]

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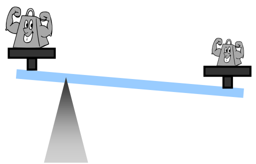
[1] **'**Gaia clearly lacks a command-and-control system, but perhaps something roughly equivalent to pheromones. These are substances, created by life, which can act to maintain conditions on Earth favorable to life'. See: [**Tim Flannery**, p57, **Here on Earth,** Published by Text Publishing Australia, 2010]

[2] 'Interaction between life and the environment has resulted in the evolution of a number of complex and powerful cycles. … These self-regulating cycles interrelate to maintain suitable conditions for the living planet to be true to its name.**'** See: [**Derek Elsom**, p9, **Planet Earth**, Marshall Publishing, 1998]

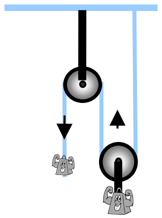
# A7. Man-made complex systems

Based on the earlier gradual accumulation and more recent acceleration in the understanding of the nature of the physical world, humanity has been able to bring about a vast number of complex technological innovations. The extraction and refinement of minerals and other natural resources, mechanization of agriculture, development of manufacturing processes, invention of means of rapid transportation, almost instantaneous communication and data transmission, developments in biomedical engineering, consumer home appliances and entertainment products, are but just a few. In all these applications, science is applied at a level of complex systems.

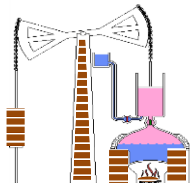
### *Primitive man-made tools*



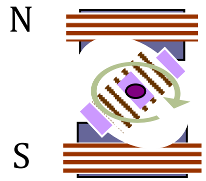
*A7.1 - A lever*



*A7.2 – Rope and pulley*



*A7.3 - Early heat engine*




*A7.4 - An electric motor*

A lever was used to lift heavy loads by attaching the load to the shorter arm of the lever and applying force for a greater distance to its longer arm. A piece of rope and a pulley was used to pull a heavy bucket of water from a well.

Steam engines were invented in the eighteenth century based on the production of steam in a boiler that would in turn move the piston of a rotating turbine. Electric machines and generators were developed by utilizing the rotating permanent or current induced magnets.

The first primitive man-made machines were based on the simple mechanical principle that one could barter between the magnitude of the force in the direction of motion and the distance to which that force is applied – the work done remaining a constant. In the earliest man-made machines, a lever was used to lift heavy loads by attaching the load to the shorter arm of the lever and applying a force for a greater distance to its longer arm. In other examples, a piece of rope and a pulley was used to pull a bucket of water from a well. Turning wheels were also invented to substantially reduce the frictional forces in the transportation of heavy loads. Later a combination of these simple machines was used in more complex systems such as windmills, printing, and mechanical clocks.

### *Steam engine – Electrical machines and generators*

The next generation of man-made systems was based on the concept of the conversion of heat to mechanical energy. Steam engines were invented in the eighteenth century based on the production of steam in a boiler that would in turn move the piston of a rotating turbine. Soon after the invention of the steam engine other kinds of heat engines such as internal combustion engines were invented. The advent of heat engines facilitated the land, sea, and air transport, as well as the mass production of manufacturing goods – freeing man from many laborious manual exertions.

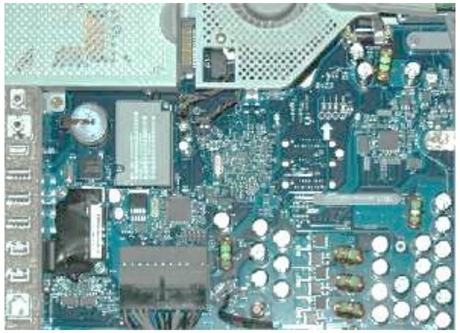
Harnessing electricity was the next step. Electric machines and generators were developed by utilizing the interaction of rotating permanent or current induced magnets. Electrical energy had the added advantage of being readily transportable. This led to the invention of numerous electrical appliances that could be conveniently used at industrial sites or in the home far away from where the electrical power was being generated.

In addition, the transmission of electricity could be controlled or coded at the transmitting end of the cable and readily detected and decoded at the receiving end. A vast complex system of communication networks encircling the globe and connecting every part of our planet is the consequence of the application of this simple coding and decoding principle.

### *Electronics and quantum electronic devices*

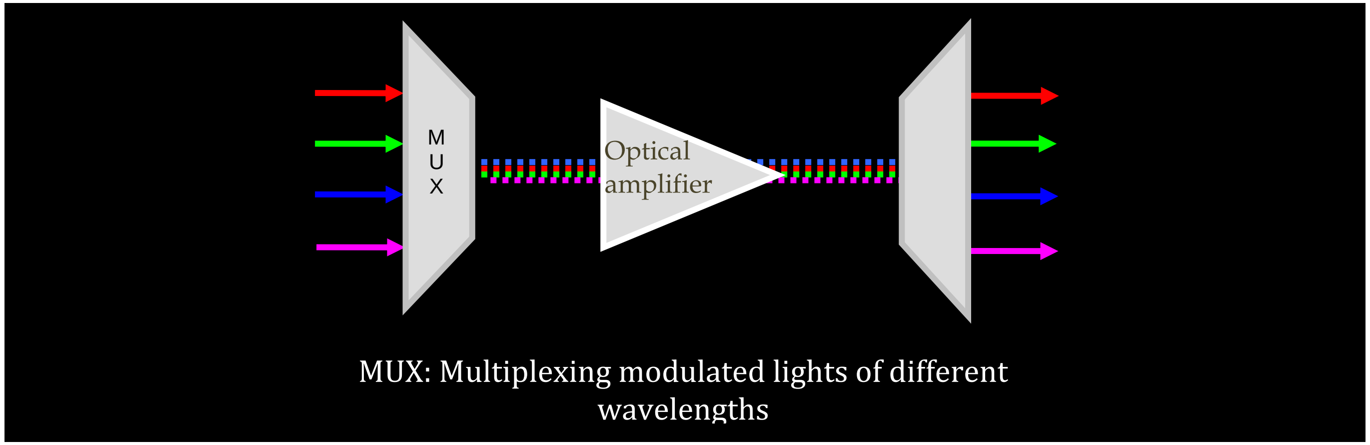
***A7.5 - A vacuum tube circuit***

Electronic devices were based on the control of electron flow in special vacuum tubes. Today's semi-conductor-based electronics has replaced the former vacuum tube technology. While vacuum tubes were bulky, the electronics devices based on semiconductor technology could assume very minute dimensions and be placed on a single semiconductor substrate or electronic chip.



***A7.6 - A VLSI circuit***

To electrical appliances were soon added many devices based on the control of electron flow in special vacuum tubes. Rectifier and amplifier circuitry associated with vacuum tube technology become known as electronics, with applications in communication and control engineering. Today semiconductor-based electronics has almost entirely replaced the former vacuum tube technology. While vacuum tubes were bulky and needed many external circuitry, electronics devices based on semiconductor technology could assume minute dimensions and be placed on a single semiconductor substrate or electronic chip. In fact, tens or hundreds of thousands of electronic devices could be assembled on a single chip with processes known as LSI (large scale integration) or VLSI (very large-scale integration)




***A7.7 - Optical communication system***

Much of the world's communication traffic today passes through a worldwide system of optical communication networks. The transmission medium for such a system is what is known as the optical fiber. Light propagates along the fiber in the same way as a light beam can propagate by reflecting back and forth between two parallel mirrors. Lights of many wavelengths can propagate simultaneously along a single fiber strand. Intended communication messages modulate separately the light at each wavelength and are then collected together (Multiplexing) at the fiber transmitting end. When the light waves reach the receiving end of the fiber, they are separated into individual wavelengths (Demultiplexing) and after demodulation, the original information is retrieved.

The more common cable transmission lines are today being replaced by the much higher capacity optical fiber cables that connect vast regions of the globe passing over the land or lying over deep ocean beds. This has enabled fast transmission of an enormous amount of information across the globe in every second.

Presently there are thousands of communication satellites orbiting the Planet and providing two-way information links between satellites to ground stations. Amongst many other applications, television programs are relayed across the Planet and received by home satellite dishes erected on building sites.

### *Computer systems, Artificial Intelligence and Neural Networks*

The complexity of modern life with the astronomical number of human interactions including transactions across the globe in each instant of time necessitates a great volume of storage, retrieval and processing of information.[1] To respond to this ever-increasing demand for information processing, computers – information processing machines – have developed along with a branch of knowledge known as Information Technology (IT). The speed, memory and processing power of computers are increasing daily with a decrease in their size and cost. Today, one or several personal or laptop computers are to be found in every office or every home. A computer is an excellent example of a complex artificial system.

Artificial Intelligence (AI) refers to a number of computer algorithms that attempt to emulate a subset of human intelligence, namely the recognition of external objects, storage and retrieval of information, learning from repetitive passed experience and with the ability to make appropriate decisions in certain circumstances. Applications of Artificial Intelligence may be found in many areas including computer vision[2]; robotics[3]; medical diagnosis[4] and other expert systems; computer games and many more.

Many of the algorithms of Artificial Intelligence are based on what is known as 'neural networks' (NNet). Similar to neurons with dendrites and synoptic connections to other neurons in a brain, a neural network consists of a large number of interconnected nodes. While a few of these constitute the input and output, the rest are the intermediate or 'hidden' nodes taking part in the computational process. Originally all connections are similar or equal 'weight'. The neural networks then optimized or ‘trained’ for specific inputs by adjusting the weight of connections between the nodes. This is done by the application of large samples of known inputs, while the weights of connections between the different nodes are continuously modified to optimize for the required outputs. After this initial training, the network is ready to recognize an unknown input value that is in one of the same categories in which the neural network has been initially trained.  Thus, a neural network emulates both the learning behavior and the decision-making function of the brain.

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[1] Just consider the ticketing and scheduling of domestic and international flights across the globe and the amount of information that has to be handled every hour of every day.

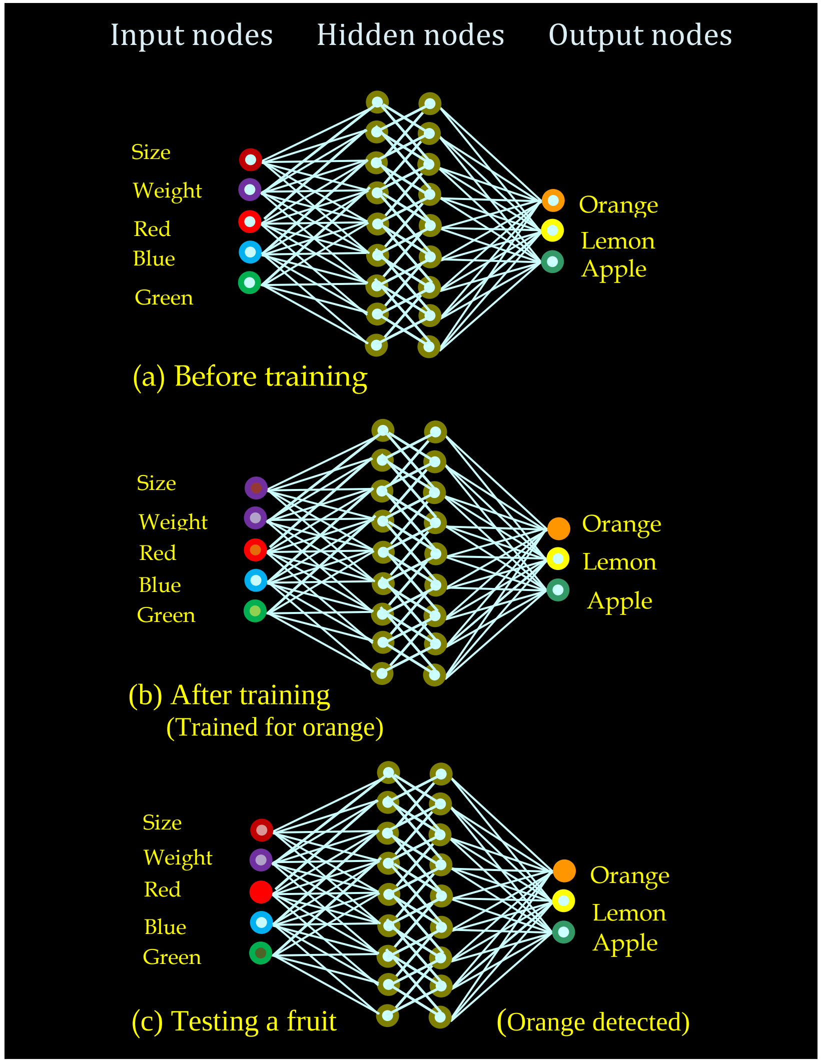
[2] These may include, face, character, pattern recognition.

[3] See the next section.

[4] These may include Computer-aided diagnosis of disease; analysis and diagnosis of medical images; epidemiological data analysis.

### *A7.8- Neural networks*

The general principle of NNets is best illustrated by an example. Consider that we wish to separate oranges, lemons and apples from a mixed batch. We assume that these fruits can be classified by their size, weight and skin color contents (red, blue and green). We can quantify these parameters and represent them as voltages applied to the input nodes of a NNet. The output nodes of the network can consist of three LEDs, each representing a single fruit. Initially (11-a) all the NNet connections are of the same 'weight' and all LED lights are of the same low intensity. The NNet is then presented in turn with large quantities of oranges, lemons and apples of differing shapes, weights and colors. The NNet weights are then continuously readjusted to give maximum LED lights for each particular fruit type (11-b). Once the training is complete, NNet can distinguish and separate the fruits as is presented to it (11-c). The recognized fruit in this case is orange.



There have been suggestions that AI machines that presently emulate a subset of human intelligence, may also made to emulate other attributes of the human mind, such as the vast spectrum of human feelings and perceptions and even human consciousness and self-awareness. We cannot know what the future has in store, but machines based on computational algorithms used by present day computers cannot do this, even in theory. At the same time, similarities between the functioning of AI algorithms with that of human mental processes have prompted some to consider the possibility of attributing actual intelligence to such AI machines. It is argued that if the response of a machine cannot be distinguished from a human response, then there is no reason that we should not consider the machine to be equally intelligent. This is, however, an arguable statement.

Consider a photodetector and a certain optical filter that transmits the light frequencies associated with the color red. A device made of the above detector, filter and simple electronics may recognize a red object and distinguish it from a blue object. We may argue that the detector 'sees' the red color and for this particular function we may have no way to distinguish it from human vision, which can also distinguish red from a blue color. However, to suggest that such a device can perceive the color red is clearly absurd.

AI machines are certainly far more complicated than a device made of a photodetector, an optical filter and some electronics and it may be acceptable to attribute intelligence to an AI device by some restricted definition - as long as there is no confusion between such limited defined intelligence and human conscious intelligent[1].

### *Control engineering and Robotics*

In the industrial world today, a vast number of machines have replaced and supplemented the manual work of man. The precision and efficiency of these are vastly increased by the advancement of what is known as ‘control engineering’ and robotics.

Control engineering is a branch of engineering that aims to precisely control the physical parameters of mechanical and chemical systems such as the position, speed, temperature, pressure, viscosity, and chemical concentration and many more, and works mainly based on feedback mechanism. Briefly if any property of a system differs from the intended value, an action is taken by the system to counteract and readjust that parameter. The performance of the system is then optimum and precise. To this end, most mechanical or chemical systems today work in conjunction with certain computer processors to meet the control requirements of the system’s complexity.

Robotics is a marriage of Artificial Intelligence and control Engineering. The control system that adjusts and guides the actions of a robot are not necessarily preprogrammed in advance but can be modified and adapted by the robot itself. This is based on the learning

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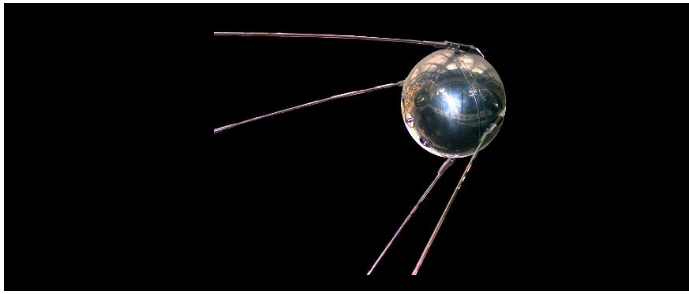
[1] For a discussion on whether our thinking is basically the same as the action of some very complicated computer and the rejection of this notion, see:[**Roger Penrose,** p578-80, **The Emperor’s New Mind,** Vintage, 1990]

algorithms discussed in the last section. Thus, a robot may be trained to respond in a particular manner to each particular encounter. Subsequent to the initial training, the robot itself controls its own actions accordingly.

### *Aviation and space age*



***A7.9 Sputnik 1***

The first artificial satellite, Sputnik 1, was put to outer space by the Soviet Union in 1957. Presently hundreds of man-made satellites orbit the Earth for communication, meteorology, scientific research, navigation, and military surveillance.

***A7.10 First man on the moon***

In 1969, Spacecraft Appolo11 landed on the moon with Neil Armstrong and Edwin Aldrin as the first astronauts to set foot on the surface of the moon. Several Apollo missions followed between years 1969 to 1972. Today many space programs are undertaken worldwide.

A discussion of man-made artificial systems is incomplete without a brief mention of air transportation and space exploration. Human endeavor to make a flying machine and become airborne goes back many centuries. The first flight in the modern sense is attributed to the Wrights brothers who flew a flying machine for a short distance in 1903. Today, there is perhaps an aircraft taking off or landing every second across the globe.

Outer space exploration started first by sending unmanned satellites to revolve around the Planet. The first such satellite was Sputnik 1 that was put into orbit in 1957. The manned mission then soon followed with Russian Yuri Gagarin being the first man in space in 1961. Space missions reached their climax with the Apollo mission and landing of two astronauts on the surface of the moon in 1969. Since then, many programs of space exploration are being advanced around the world. Space explorations have increased our knowledge of the vast celestial structures in outer space.

# A8. Animate systems

Although they share certain characteristics, there are two major differences that separate animate from inanimate systems. The first difference is in the degree of complexity. Among numerous other functions, a living cell produces a number of organic chemicals such as complex proteins. In this respect alone, a cell of a living organism of microscopic dimensions has an intricacy greater than that of many chemical factories combined. The second is the evolutionary dimension of animate systems. It is true that inanimate and artificial systems do change over time. However, the transformation and evolution of animate systems is based on a unique set of genetic codes that are not found in any non-living system.

### *Biology and the study of the cell*

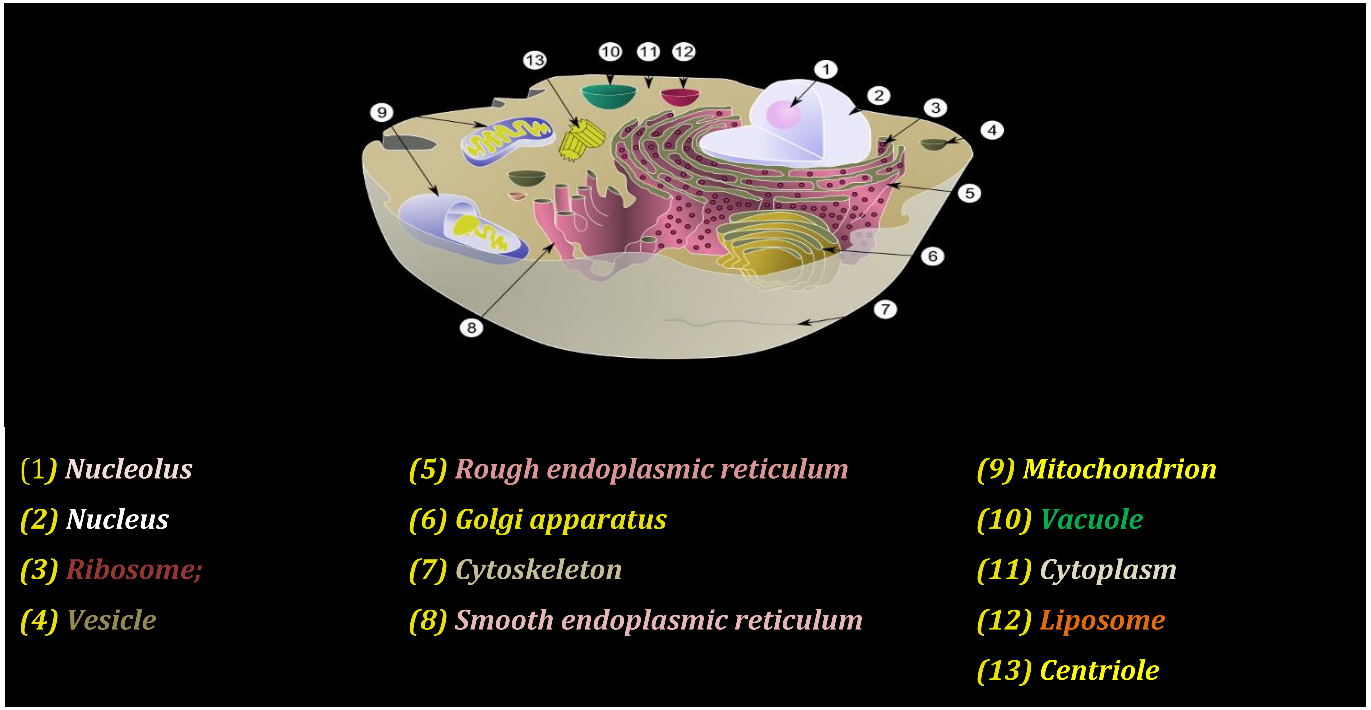
The study of biology started early in the course of history with the simple observation and rudimentary classification of plants and animals. Evidence of this can be found in ancient drawings and stone carvings[1] and later in written manuscripts.[2] This basic knowledge of plants and animals was used in many areas of agriculture, horticulture, and medicine.

A better understanding of living organisms came about in the seventeenth century with the advent of the compound microscope and the dissection of tissues of living organisms. Later, with the improvement in the magnification power of microscopes in the nineteenth century, a new world of microorganisms was revealed, leading to the identification of numerous bacteria and the development of vaccines for the prevention of infectious diseases.

In the last two centuries knowledge of the cell as the fundamental unit of life in both plants and animals has vastly increased. Cells are complex self-contained structures capable of metabolism and reproduction. Although they differ in different living organisms and are specialized for different functions, all cells have basically three distinct parts - the cell wall, an inner part or cytoplasm, and a core that is known as the nucleus. The wall of a cell is not completely impermeable but maintains the integrity of the cell as a self-contained unit. Inside the cytoplasm there are sub-units, or organelles, specialized for different functions. These sustain both the life of the cell and contribute to the functioning of the organism as a whole.  For example, mitochondria are involved in producing energy, ribosome in synthesizing proteins, and lysosome in decomposing unwanted cellular material.

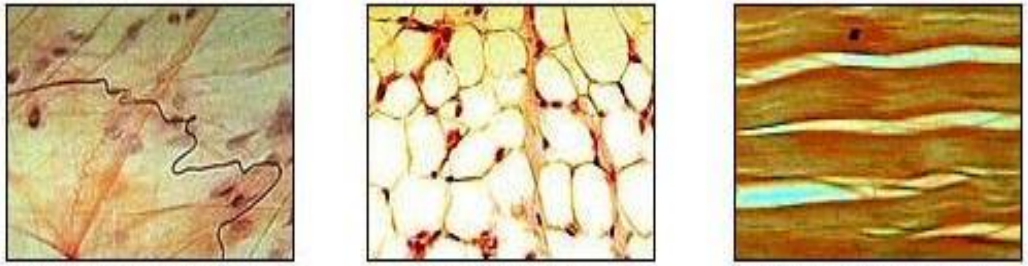
[1] The instances of stone carvings depicting animal anatomy go back to 30,000 BC.

[2] The Greek Philosopher Aristotle (384-322 BC) made a comprehensive classification of all living plants and animals known at the time.




***A8.1 - Inside a cell***

Cells are complex structures capable of metabolism and reproduction and have three distinct parts - the cell wall, an inner part or cytoplasm, and a core that is known as the nucleus. The wall of a cell, although not completely impermeable, maintains the integrity of the cell as a self-contained unit. Inside the cytoplasm there are sub-units, or organelles, specialized for different functions, which sustain both the life of the cell and contribute to the functioning of the organism. Inside the cell nucleus the chromosomes store the genetic information for cell reproduction and subsequent protein synthesis.



***A8.2 - Some living tissues***

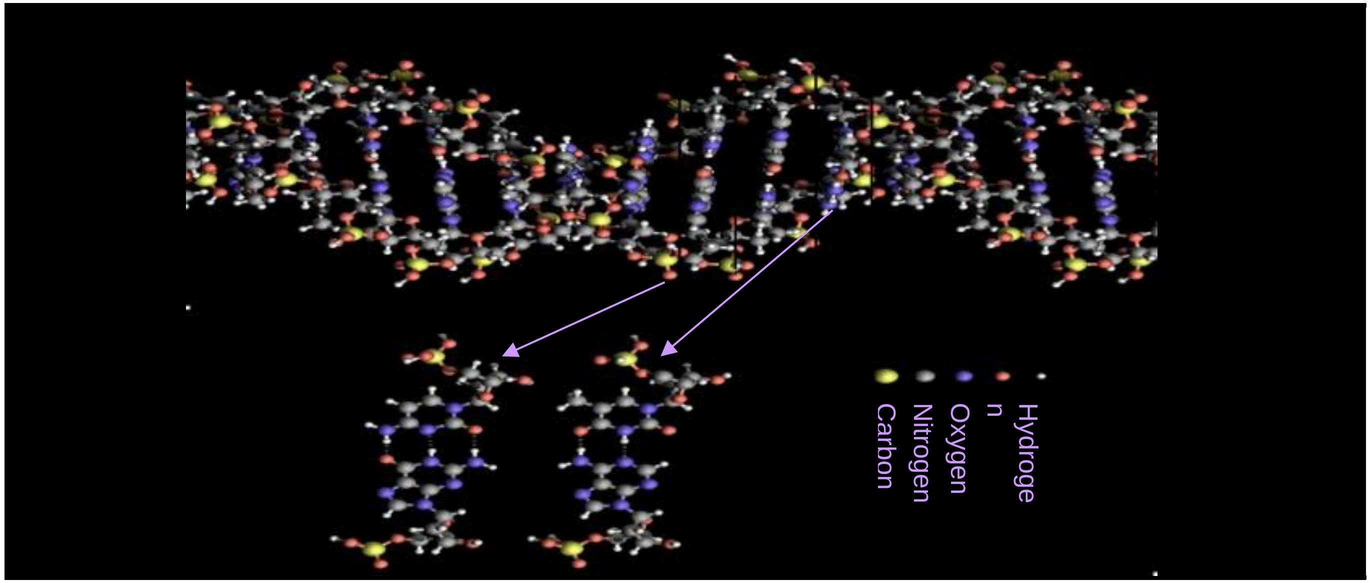
Different organs in a living organism are made of different forms of cell tissues. The shapes and arrangements of the cells in different tissues are very different. There are a large number of tissues in each organism. Left: Areolar connective tissue (binds different tissues together). Centre: Adipose tissue (stores energy in the form of fat). Right: Fibrous connective tissue (forms ligaments and tendons).

### *Genes and protein synthesis*

Inside the nucleus of the cell, chromosomes store the genetic information that directs protein synthesis. Proteins are both the building blocks and tools for the maintenance and growth of the organism and are the largest and most complex molecules known. Proteins are composed of twenty organic molecules known as amino acids.[1] The genetic code defines the steps in sequencing of the amino acids for protein synthesis through complex processes inside ribosome. The genetic information in chromosomes is in the form of different sequences of the four nucleotide bases[2] along each strand of long, double-helical deoxyribonucleic acid (DNA) molecules.

At the time of cell division, genetic information is transferred to the next generation. During 'mitosis' or mitotic cell division, both strands of the DNA molecule are replicated and, together with the old strands, form the DNA of the two new cells. In 'meiosis', another form of cell division, which occurs during sexual reproduction, the new cell receives one set of the duplicated DNA strand from each parent cell.

[1] Alanine; Arginine; Asparagine; Aspartic acid; Cysteine; Glutamic acid; Glutamine; Glycine; Histidine; Isoleucine; Leucine; Lysine; Methionine; Phenylalanine; Proline; Serine; Threonine; Tryptophan; Tyrosine; Valine.
[2] Adenine; Cytosine; Guanine; Thymine.




***A8.3 – DNA***

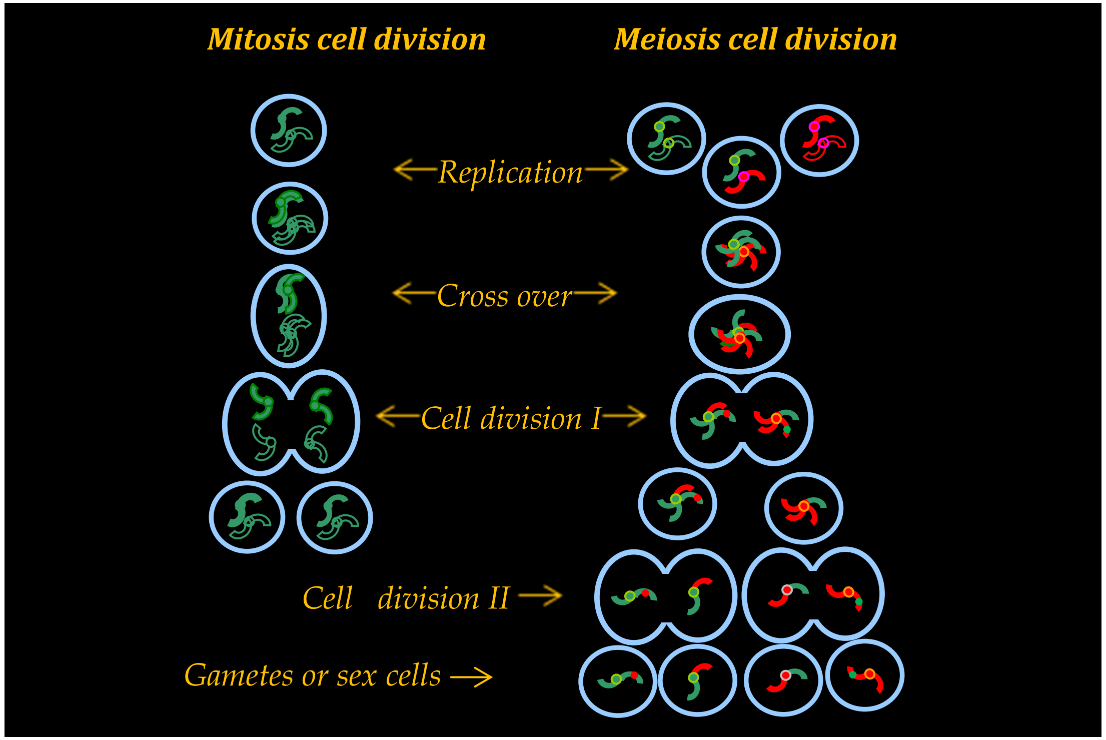
Inside the cell nucleus the chromosomes store the genetic information that directs protein synthesis. Proteins are the building blocks of a living organism and are made up of 20 organic molecules known as amino acids. The genetic code defines the steps in sequencing of the amino acids for protein synthesis through complex processes inside ribosome. The genetic information in chromosomes is in the form of different sequences of four nucleotide bases, adenine, cytosine, guanine and thymine, along each strand of long double helix deoxyribonucleic acid (DNA) molecules.

Replication of DNA is a highly accurate process with 'expert' enzymes and DNA repair mechanisms ensuring high fidelity of replication. In order to make protein, DNA is first 'transcribed' into ribonucleic acid or RNA – a chemical code similar to DNA and then 'translated' into the corresponding protein code.[1]

[1] The steps from genes to organisms includes primary *transcription* from DNA to RNA; removing some RNA strings (*introns*) and joining together (*splicing*) the remaining strings (*exons*), to form messenger RNA or mRNA; *Translation* or the synthesis of a linear chain of amino acids

***A8.4 – Schematic representation of Mitosis and Meiosis cell divisions***

At the time of cell division, genetic information is transferred to the next generation. In 'mitosis' cell division, both strands of double helix DNA are replicated and together with the old strands, form the DNA of the new cells. In 'meiosis', the kind of cell division occurring in sexual reproduction, the new cell receives one set of the duplicated DNA strand from each parent cell.




Numerous feedback and regulatory mechanisms exist to control processes occurring within the cell. Regulatory proteins bind short sequences of DNA or DNA 'motifs' and regulate the transcription of DNA; alternative ways of 'splicing' RNA create various configurations of the protein, with different structures and functions; myriad metabolic reactions within the cell, mediated by catalytic proteins known as enzymes, are regulated in complex positive and negative feedback loops; signals from outside the cell are met by cell-surface receptors that are themselves up or down regulated as the need arises. In a way akin to a key finding the lock and opening

(*polypeptides*) under the direction of mRNA; folding of the linear chain to form a three dimensional protein structure; assembling in turn, different proteins to form different organelles; organelles to form different cells; cells to form the tissues; tissues to form the organ and organs to form the organism.

the door, enormously complex specialized molecules are able to interact and send signals back and forth. Such signals are sometimes transduced far into the depths of the cell nucleus via intricate molecular pathways involving ‘messenger molecules’. Chemical fluxes as simple as that of calcium can mediate the final outcome of the signal, acting as a simple switch wherein may lie the fate of the cell.

### *Epigenetics*

Genes are often thought of as the blueprint for the synthesis of proteins and formation of living cells and hence the development of various tissues and organs in a living organism. While this is largely true, it does not represent the whole picture. A living embryo initially has a single cell, but as the cell multiplies, the new cells are differentiated, leading ultimately to the body organs. In a human body there are four main types of tissues, namely, epithelial or protective, connective, muscular and nervous tissues, but each with many variations, comprising a total sum of some 200 different cell variants. While all the cells have the same identical DNA sequence, they vary greatly in their protein constituent and function. Hence this differentiation of cells has, what we may call, an 'epi-genetic' source, independent of the DNA base sequence of the cell.

Within each cell there are proteins that act as a kind of regulatory control for the switching off and on of genes. The result of gene switching is known as gene expression. If the switch is on, a particular gene is activated and is transcribed to messenger RNA (mRNA) for the formation of the intended protein. Alternatively, if the gene is off, it becomes ineffective in the creation of the new cell. Hence the cells are differentiated by involvement of different genes by an epigenetic mechanism. This epigenetic process occurs at the time of the development of the embryo, as well as in the lifetime of a living organism. While the DNA sequence, apart from certain possible mutations, remains substantially unchanged, the epigenetic process continually modifies the anatomical structure, as well as the physiological functioning of the organism. Epigenetic processes are modified by lifetime environmental conditions, both physical and emotional. Weight loss and gain, hormonal changes mood and mental states are examples among many that can be attributed to epigenetic changes.

### *Multi-cellular organisms*

There are several levels of organization in living organisms. Proteins and amino acids are large, organized molecules with long and highly elaborate chains of chemical constituents. Organelles subunits inside cells are complex chemical factories with their own profound feedback and control mechanisms. The cells themselves are also elaborate systems that perform a number of specific but highly complex functions.

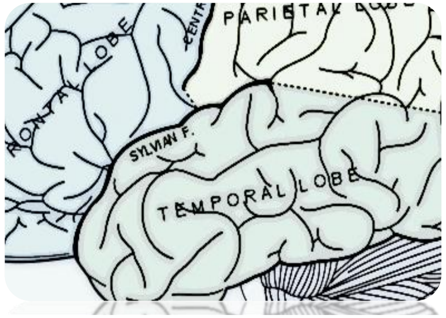
In multi-cellular organisms, there is yet another level of organization with specialized cells forming specific organs. Different kinds of cells make up tissues and organs that are capable of performing unique tasks, assisting in the proper functioning of an organism. Examples of these in plants are vascular systems and in animals the respiratory, digestive and circulatory systems. Sensory systems receive and process visual, auditory, taste and smell and touch perceptions. At the level of the organism, chemical signals such as hormones and neuronal signals integrate the functions of the various cells and organs.

The immune system is one example of a highly evolved and intelligently coordinated system that comprises the main defense mechanism of the organism. It functions by detecting potentially harmful ‘others’ and combating them. An army of various cell types work together. Some are specialized to engulf, maim, or kill the organism. Some are ‘educated’ in their early life to distinguish between one’s own harmless ‘self’ and ‘non-self’- not a trivial task. These cells can also help the less ‘knowledgeable’ cells in their mission. There is ‘memory’ for the harmful intruders so that the second attack will be quicker and more focused. There are means for clearing the battleground such that no remnant of the attack will remain. This complexity and fine-tuning of the immune system has arisen from years of co-existence and co-evolution with the microscopic world of bacteria and viruses, and at times macroscopic world of parasites.

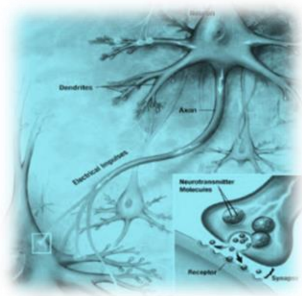
### *The function of the brain*

In higher forms of life, the overall regulation of various quasi-independent systems in the body of an organism occurs through the central coordinating function of the brain. The brain is a complex interconnection of specialized nerve cells known as neurons. In more primitive life forms, the number of neurons is in the order of a few hundred. With the increasing complexity of the organism this number escalates by many orders of magnitude. In humans, the number of neurons in the brain is in the order of hundreds of billions, with each neuron having thousands of synaptic connections to other neurons, making a total order of hundreds of trillions of different neural connections in each adult brain. With each synaptic connection as an information channel between any two neurons, the human brain processes a staggering amount of information at every instant. It is said that the human brain is the most complex structure known in the entire universe. Anatomically, a mammal’s brain has a number of distinct differentiated parts. In humans, the cerebral cortex of the brain, the outer layer of gray matter of the cerebral hemispheres, largely responsible for higher brain functions is much larger than that of other animals and contains many folded convolutions on its surface, which increase the surface area for information processing.

The brain is split into two hemispheres, each with slightly differing functions, with the left hemisphere particularly specialized for language and verbal skills and the right hemisphere more specialized in visual and spatial processing.




***A8.5 – Areas of the Brain***



***A8.6 - Neurons***

### *The human brain*

In higher forms of life, the overall regulation of various quasi-independent systems in the body of an organism occurs through the central coordinating function of the brain. The brain is a complex interconnection of specialized nerve cells known as neurons. In humans, the number of neurons in the brain is in the order of hundreds of billions with each neuron making a very large number of connections to other adjacent neurons. Thus, at every instant the brain cells process a staggering amount of information.

Many functions and processes in the brain occur predominantly in certain localized regions. Motor control in the posterior of frontal lobe, visual in the occipital and auditory in the temporal areas of the cerebral cortex are some examples of the localized functions. The neurons in the 'association cortex', in large parts of the parietal cortex, bring together information from several areas and act as a coordinator.

At the same time, however, many complex processes are performed at different anatomical levels and require the simultaneous involvement of many parts of the brain. An example of this is in the processing of visual information. When the image of a visual scene falls on the retina, light receptors transform the information into nerve signals, which are taken along the optic nerves to the primary visual area of the cortex in the occipital part of the brain. Here the information is processed for different aspects of the visual input such as motion, color, and depth of the visual scene through separate but parallel pathways. Finally, the different information processed through the separate pathways come together to give us a unified picture of the visual scene.

As well as collecting, integrating, and processing sensory input information and acting as the central command for coordinating the voluntary and involuntary actions of the internal and external organs, the brain performs many other cognitive functions. These include storing and retrieving information, attention and concentration, abstract visualization, decision-making, deductive reasoning and experiencing and processing the vast spectrum of human emotions. These collective actions of the brain bring about a state of awareness of the self and the outside world at a conscious level.

The above manifestations of the state of consciousness define, or are attributed to the human 'mind'.[1] We may never be able to fully comprehend the nature of the human 'mind', as human comprehension and reasoning are themselves only subsets of the mind itself and a part is incapable of comprehending the whole. Nonetheless, the concept of the mind as an emergent property of the brain may help in understanding the relation between the two. An emergent reality of a complex system is qualitatively different from the system itself, but it is brought about by the complex associations and interrelationships within the system.[2] By emergence here it is not meant that human 'mind' arises from or is a product of human brain. The ideas in this book in some sense emerge from the pages of the book, but obviously they are not the product of these pages.[3]

### *Human psychology* [4]

In physical sciences it is assumed that there is a cause for every observed physical phenomenon in nature, with the relation between the two embodied in the laws of physics. Similarly, it is anticipated that human behavior could be explained in terms of genetic or environmental conditions. While the laws of physics are precise and amenable to mathematical modeling, the complexity of human conditions makes such an exact treatment of human behavior impossible. The question of the degree to which human behavior is influenced by individual 'freewill' is an added complexity to possible predictability of human behavior. Nonetheless human psychology, or the study of human behavior under varying conditions, has now become an important branch of science. Psychology not only gives insights into the ways we think or act, but also has helped many to modify their behavior for the betterment of both their physical and

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[1] At one level we can examine the actions of neurons and neurotransmitters as a 'micro-view' of the functioning of our brains. At a level higher we can consider the integration of their actions in the brain as a whole. Still this level of integration can be raised to encompass all those who we associate. They not only influence our mental state, but also as a consequence, the very physical configuration of our brain cells. See: [**Daniel J Siegel**, p40, **The mindful brain**, Norton, 2007]

[2] It is suggested that mind and brain correlate their functions, but they are two dimensions of reality that ultimately cannot be reduced to each other. See: [**Daniel J Siegel**, p24, **The mindful brain**, Norton, 2007]

[3] There is a fundamental problem with the idea that mentality arises out of physicality. Although there is an arrow joining the physical world and the mental world, it does not imply that any of these worlds simply emerges out of the other. Although there may be a sense in which they are emerging, the arrows are meant only to represent the fact that there is a relationship between the different worlds. See: [**Roger Penrose,** p94-7, **The Large, the Small and the Human Mind,** Cambridge University Press 1997]

[4] This section is contributed mainly by **Robert Riggs** [paraphysicstoday.org]

mental conditions. Famous psychologist Carl Jung (1875 – 1961) suggests that the human psyche has four basic sub-functions, usually listed as ‘sensing’, ‘thinking/reasoning’, ‘feeling’ and ‘intuition’.[1,2,3]

While sensing, thinking and feeling are commonly accepted aspects of the human psyche, the definition and reality of intuition as a distinct aspect of the mind is still controversial. By a simple experiment with a deck of common playing cards, Parapsychologists such as Robert Riggs have attempted to demonstrate, to a level of proof commonly accepted by experimental physicists, that intuition is a real and independent sub-function and not a spinoff from other aspects of the human psyche.[4]

### *Animal colonies*

***A8.7 – An animal colony of bees***

Many plants and animals form highly structured colonies. In a honeybee colony, there are thousands of bees that maintain their colony within a hive with perfect efficiency. The colony consists of a single queen that has the role of laying eggs. There are a few hundred male drone bees that fertilize the eggs. The majority of bees are known as the workers that carry out multiple tasks.

[1] [en-wikipedia.org/wiki/Jungian_cognitive_functions]
[2] [**C. G. Jung**, Man and his Symbols, Doubleday, 1964]
[3] [**A. Storr, Jung, Routledge**, 1991]
[4] [**Robert Riggs**, ‘Parapsychology? or is it Paraphysics?’- paraphysicstoday.org]

The collaborative association and functional coordination in hierarchies of complex organizations does not end with individual members of a species. Many plants and animals form large colonies of highly structured orders with their members specialized in different tasks. Well-known examples of these are self-organized colonies of ants and bees. In a honeybee colony, there are thousands of bees that maintain their colony within a hive with perfect efficiency. The colony consists of a single queen whose role as the head of the hive is none other than to lay eggs and reproduce the next generation of honeybees, while hundreds of male drone bees fertilize the eggs.

***A8.8 - Ecosystems - Habitat***

A living organism cannot stay alive in isolation but needs a habitat that can provide its sustenance and the other provisions of life. An ecosystem is a physical environment where a number of plants and animals can live through mutual interaction and through interaction with their physical surroundings. It is an elaborate system with self-maintaining and regulating mechanisms whereby many chemical substances are recycled through the complex chains of predator and prey or in conjunction with land, water, or air.

The majority of bees are known as workers that carry out multiple tasks such as building and cleaning the hive, feeding premature bees in their larval state and collecting pollen and water from outside the hive. All the cooperative work within a bee colony is performed by bees exchanging their tasks and coordinating their work, while constantly communicating through their special wing and body movements.

### *The ecosystem*

A living organism cannot survive in isolation but needs a habitat that can provide its sustenance and the other provisions of life. An ecosystem is defined as a physical environment where a number of plants and animals can live through mutual interaction and interaction with their physical surroundings. It is an elaborate system with self-maintaining and regulating mechanisms whereby many organic and inorganic matters are recycled through the complex chains of predator and prey or in conjunction with land, water, or air. The self-regulating mechanism in an ecosystem brings the system back to equilibrium following any small perturbations. However, any major disturbance in the delicate balance of an ecosystem can have detrimental effects on the life of plants or animal species within the system.

The boundary of an ecosystem is not well defined as it can always be extended to a larger region including a greater number of living organisms or other subsystems. At different levels, a garden, a plantation, a wood, or a forest can all be regarded as ecosystems, depending on particular situation. To include the environmental effect of migrating birds, the ecosystem could extend to several continents.

### *Definition and emergence of life*

So far, no definition of 'life' has been completely satisfactory in the sense that it includes all that we intuitively consider as living and excludes all that we intuitively consider as non-living[1]. Ability to metabolize, procreate, adapt, autopoiesis[2] have all been suggested as partial definition for life. However, the historical process of transition between pre-biotic organic molecules to living cells leaves ambiguous the time or the stage when the complex structure could have been said to be 'alive'.

One possible way to avoid the difficulties in defining life is to abandon the attempt at a generic definition of life and rather to define it within its context. For example, we could define life in the mineral kingdom as the power of cohesion, in plants as sensation and growth, in animals as the sense perception and motion and in humans as that of cognition and abstraction. This contextual definition would also abandon the assumed demarcation between the living and non-living.

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[1] For over 60 different definitions of life given by biologists see the appendix of [Marcello Barbieri's book, The organic codes: An introduction to semantic biology, Cambridge University Press, 2003]

[2] Autopoiesis is a process whereby a system produces and replaces its own parts or increases its own complexity.

The question of where, when, and how the replicating DNA or RNA strands of living cells have appeared is still controversial.[1] It is assumed that the first DNA strands originally evolved from complex replicating molecules, themselves synthesized from large organic molecules or polymers.

The basic problem in search for the origin of DNA, however, relates to the complexity of its structure and its information bearing capacity. The notion that given sufficient time such complex structures would be synthesized spontaneously by chance can be discarded. Even in the period of time from the geological formation of the Earth, the estimated probability of such an event is vanishingly small.

Some have suggested the possibility of natural selection acting in pre-biotic states. This proposition is still based on the assumed existence of some prior coincidental complex molecular synthesis. The concepts of self-organization or order arising from chaos in nonlinear complex systems are also considered; suggesting for example that under certain conditions autocatalytic sets of polymers could spontaneously emerge.[2]

There may be partial truths in all that is proposed, but we have to consider also that we may not presently have all the required scientific tools to enable us to explain the emergence of living cells. Even in recent past, many observations in nature could not be explained by the classical physics and had to wait until the advent of quantum mechanics. The appearance of the original living cells and the subsequent evolution of life forms are ultimately linked to later appearance of consciousness and mind, even though these events are long spans of time apart. Perhaps we have to wait for a better understanding of the latter before we can thoroughly understand the former.[3]

### *Biological evolution*

The classification of plants and animals on the basis of similarities of their form may have been the first step in understanding of the biological evolution and modification of species. Linnaeus, a Swedish botanist and physician, in the 18th century was the founder of

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[1] Each cell consists of two major distinct parts, large protein molecules and long nucleotides polymers, representing metabolism and replication. However, there is little conclusive evidence as to which of these basic blocks of the cell might have evolved first. 'Perhaps the most mystifying aspect of the origin of the living cell is the association of two fundamentally different types of molecular structures in a single living cell.' See: [chapter 5: The origin of life, **Marcello Barbieri**, **The organic codes: An introduction to semantic biology**, Cambridge University Press, 2003]

[2] Kauffman considers networks of simple polymers that have general non-specific catalytic activity that can speed up the rates of chemical reactions, including those involved in making these polymers themselves. The result is that the autocatalytic sets emerge spontaneously. See: [**Brian Goodwin,** p173-174, **How the Leopard Changed its Spots,** Phoenix, 1994]

[3] There is no suggestion that a pre-biotic structure would have any form of consciousness or that there is any association of mind with any pre-biotic state. A seed of a tree, however, cannot be wholly understood without knowledge or reference to the tree itself.

modern taxonomy. He produced a system of naming and classifying organisms. Later in the same century, Compte de Buffon produced several volumes of description and classification of biological forms and suggested the possibility of biological evolution and modification. Subsequently, Jean Lamarck proposed the evolutionary theory of species on the basis of the inheritance of the acquired characteristics of offspring from their parents. In 'On the Origin of Species by means of Natural Selection', Darwin elaborated his famous theory of evolution.

Darwin's theory of evolution differed in its description of the mechanisms for the modification of species from that proposed by Lamarck. In his theory, the inheritance of acquired characteristics in the lifetime of an organism was not the cause of the modification of species, but the chance variations from generation to generation. These variations were either detrimental or conducive to the survival of the species. In the first case, the modified species would become extinct, while in the latter, the species would acquire the traits and characteristics better suited to its physical and biological environment.[1]

In the course of the twentieth century the origins of these chance variations were identified with the discovery of genes as the controlling source of both life processes and of inheritance, with individual traits being inherited by duplicated genes transferred from parents to the offspring. However, changes or 'mutations' may occur by chance during the duplication of the genetic material. These random variations then act as the source of trait variations in the offspring and are subject to subsequent natural selection as explained in the Neo-Darwinian theory of Evolution.

Some biologists differentiate between two forms of evolution: 'microevolution' and 'macroevolution'. Microevolution refers to evolutionary processes that lead to relatively minor variations of closely related species. Examples of these are the evolutions of cats and tigers or dogs and wolves from possible common origins. On the other hand, the evolutionary pathways that connect different major 'classes' of species or different 'phyla', such as the proposed evolution of birds from reptiles, are considered as 'macroevolution'. Although it is claimed that instances of 'intermediates' between different major living forms have been found, some still maintain that no continuous spectra of species with either intermediate general appearances (phenotype) or intermediate hereditary information codes in their DNA sequence (genotype) have been so far unequivocally established.

It is suggested that the lack of many 'intermediate' forms in paleontological findings in macroevolution can be explained by assuming a sudden and abrupt, rather than a gradual change in environmental conditions. The short span of time between the original and evolved species could be the reason for not finding the intermediate forms. This is termed as 'punctuated equilibrium'.

[1] Evolution is suggested to be based on the natural selection or the survival of the 'fittest'. However, there is an ambiguity as at what level this selection takes place, whether the fittest is selected at the level of species, race, groups or individuals. These alternatives have been all suggested at different times. It is also suggested that this selection may take place not at any higher levels, but in fact at the level of genes that constitute the fundamental hereditary unit for inheritance. See:[**Richard Dawkins**, **The selfish gene**, Oxford University Press, 2006]

However, certain biologists maintain that many biological novelties in the course of evolution could not have come about solely by gradual step by step or even by abrupt random mutation, and subsequent selection for environmental fitness. These include the arrangement of petals in flowers, feathers in birds, hair in mammals, compound eyes, mammary gland, and numerous others. Not only these novelties could not be traced back to other former species, but also no intermediate forms could be functional to pass the criterion for the Darwinian selection.[1]

The basic facts of replication, mutation, and selection of the Darwinian theory of evolution, leading to speciation and diversity of life forms, in at least microevolution, is now well established and not in dispute. However, as in all aspects of science, a claim to finality is misplaced. In fact, the increasing knowledge of complex systems, together with information from genome sequencing of DNA in many life forms, is leading to what may be considered as a 'new biology'. This new emerging biology is based on the realization of the intimate co-evolution of all life forms and their environment, in conformity with notions of dynamical complexity.[2] Biological mutation as being a purely random process is also reconsidered with the discovery of some genes that control, regulate, or even repair the detrimental genetic mutations.[3]

In addition to genetic information, epigenetic information regulates the life of an organism. While genetic information remains mostly invariable, the outside environment and inner constituent and feedback mechanisms in an organism constantly modify the epigenetic condition. Whereas genetic information is almost faithfully transferred to the progeny, the epigenetic state is reset at the time of zygote formation and epigenetic information modified during the lifetime of an individual is substantially erased.

It is claimed, however, that this reset of information is not perfect, and to some degree, epigenetic information may be transmitted through several generations by different mechanisms. If this is true, it has an important implication in evolutionary theory and has affinity to Lamarckian idea of inheritance of acquired character. It may suggest that what we eat and drink and how we think and who we associate with or in general how we live, not only affects our own lives, but also to some extent the generations to come. This is not only through nurture or cultural inheritance, but also by the actual modification of the cellular structures within our bodies.

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[1] For detailed discussion of biological innovations and the short comings of the Darwin's incremental adaptive theory of evolution see: [**Michael Denton, Evolution: Still a theory in crisis**, Discovery Institute Press, 2016]

[2] 'There is so much complexity and detail revealed by new knowledge that major issues in the life sciences are being reconsidered, such that many agree that a "new biology" is in view, or we are already in it.' See: [**Cameron M. Smith**, p213, **The fact of evolution**, Prometheus Books, 2011]

[3] 'Most biologists have believed over a century that selection is the sole source of order in biology, that selection alone is the "tinkerer" that crafts the forms. But if the forms selection chooses among were generated by the laws of complexity, then selection has always had a handmaiden.' See: [**Stuart Kauffman,** quoted by **James N Gardner,** p55, **Biocosm,** Inner Ocean, 2003]

Biologists maintain that processes of evolution have resulted in diversified species arising from a smaller class of former species through the process of speciation, which prevents new species from interbreeding with members of parent species. This view of evolution is usually represented as a successive branching out from a single trunk of an evolutionary tree.

The inference of this would be that present-day species have all originated from a single species or organism or even a single cell. However, the appearance of a single or a handful of identical living cells once in the course of billions of years of geological evolution of the Planet is not a plausible scenario and would be short of miraculous. New discoveries in biology, especially the possibility of lateral gene transfer may change this conceptual presentation of evolution to something much more complex. [1,2] Indeed, the evolutionary tree may be more similar to a banyan tree with multiple roots.

A common genetic structure of all living forms does not necessarily mean a common origin. A common genetic structure may only mean that life necessitates a certain biological configuration to arise and perpetuate. A laser needs an active medium, an outside source of energy and two precisely aligned mirrors before it can produce a highly coherent light. A laser beam comes about, whenever these conditions are met, independent of the existence of any other laser. At the same time with the vastness of our cosmos it is not conceivable that life can only exist on Earth. Certainly, extra-terrestrial life in a planet millions of light years away, does not have the same origin as the life on Earth.

### *Life after death*

Every physical or biological process has a limited time span, and no one would suggest any possible continuation of life after death with respect to physical compositions. In terms of the emergent attributes of complex processes, however, the query is not meaningless and the answer neither obvious nor trivial. Shakespeare's plays and Beethoven's symphonies have in some senses survived both the death of the poet and composer and the original scripts and musical notes. Once the words are written, the meaning lingers even if the letters are erased. This survival is clearly different to that of any physical survival.

The dimensions of reality are not confined to the physical reality that we perceive through our senses. The question of human consciousness and its relation to physical reality is still an open question.

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[1] '... we saw that life-forms come from parent generation to the next; this is referred to as vertical gene transfer. While this is true, it turns out that there is another mechanism by which some life-forms "get" their DNA. This is called horizontal gene transfer (HGT); horizontal (or, sometimes, lateral) referring to the fact that DNA can sometimes be picked up during the course of life and incorporated into a life-forms' own DNA and passed on to the offspring.' See: [**Cameron M. Smith**, p216-9, **The fact of evolution**, Prometheus Books, 2011]

[2] 'Speciation, Margulis argues, doesn't normally happen by the reproductive isolation and other factors we've seen …; rather… it is the acquisition of large sets of DNA by one species, from another, that "drives the bus of evolution."' [**Cameron M. Smith**, p238, **The fact of evolution, Prometheus Books**, 2011]

### *Animal cloning - Biology and ethics*

Meiosis cell division is the reproductive mechanism for all higher forms of life. However, the possibility of producing an organism from the DNA of a single parent was shown in 1997 with the reproduction of the famous sheep, Dolly. In the process of reproductive cloning, the genetic material from a cell is transferred to an egg depleted of its own genetic material. Thus, the fertilized egg basically derives its genetic material from a single parent.

The realization of animal cloning opens the possibility of other genetic manipulations and even the application of similar procedures for the cloning of human beings. Any such attempts would raise many ethical issues relating to the extent that man should interfere and artificially manipulate the natural processes and specially in human life.

# A9. Shared features of evolutionary systems and processes

In the previous parts of this presentation, we had a synopsis of the evolutionary pathways transforming primordial matter to present day complex structures. Large scale cosmic evolution, biological evolution, social evolution and developments of philosophical, religious thoughts and scientific knowledge have been different pathways in this universal process. Although diverse, all these pathways represent complex processes with many shared features and attributes. Some common features of all these systems, natural and artificial and are discussed in this chapter.

A chemical production plant is a system of numerous parts that take part in several operations that may produce a few specified chemicals. On the other hand, a two-way communication system may consist of a transmitter and a receiver at each end and a communication link in between with the goal of conveying messages between two human operators. The component parts and end goals of the above two systems are vastly different, but they nevertheless, as we shall see, have many aspects in common.

A salient characteristic of all complex systems, as we have already suggested, is the difference between the emergent attributes of a system as a whole and that of its constituent parts. Numerous examples in nature demonstrate this distinction. A living cell has distinctly different attributes from the organic molecules that are its component parts. Visual perception has no semblance to the electro-chemical activities of neurons in the visual cortex. The human mind is an emergent reality of the brain, but consciousness and human perception have no direct similarity to the individual activity of each brain cell.

### *System interactions – Open and closed systems – initial conditions*

Natural complex systems are not formed in isolation and cannot remain immune from either the direct or indirect influence of other systems and processes. The energy or other parameters that influence the dynamics of a system are usually supplied from the outside, either initially or in the course of the system's evolution. The motion of the stars and galaxies is constantly influenced by the presence of other stars and galactic systems. Living organisms interact with each other and their environment and human societies have trade and cultural exchange. It is seldom that a system is a 'closed system' with no input from outside. Most systems are 'open systems' and receive information from the outside and interact with their environment.

At the outset of each process there are a set of parameters that constitute the system's 'initial condition'. For inanimate systems the initial input is the physical parameters such as chemical constituents, densities, velocities, or temperature set by the environment or intentionally supplied to the system. A planetary system emerges from accretion and collision of existing proto-planetary particles initiating the process of planet formation. In a living system, the initial conditions are mainly set by inherited genes from the parental gene pool.

***A9.1 - A closed system*** ***A9.2 - An open system***

A system can be an open or a closed system. A closed system evolves in time with no input from outside. While the battery lasts, a battery-operated clock is a closed system. An open system is influenced by one or several outside parameters. A barometer is an open system as it is affected by atmospheric pressure. Most systems are open systems.

There is an important sequential relationship between all global systems, with one system providing the initial parameters to a subsequent system. The initial synthesis of hydrogen and helium produced the protogalactic gas clouds leading to the formation of galaxies and stars. The evolutionary process of the formation of the solar system approximately four and half billion years ago set the initial conditions for the evolution of life on Earth.

### *Communication – Storage and retrieval of information*

The initial input to a system can be viewed as a transfer of information from one or several prior systems to the new system. In addition, open systems exchange information and communicate with the external world in the course of their evolution. The exchange of so-called 'messenger' particles, such as 'photons' of light and 'gravitons' of gravitational fields, can provide a direct communication mechanism for simpler physical systems. Sensors or transducers are sometimes required for communication in more advanced systems, as in the case of plants sensing the direction of sunlight. In the animal kingdom, communication is through specialized sensory organs such as sight and hearing. In human beings and societies, language is an added means of communication, aided today by numerous transmitting and receiving devices.

For many systems there are also requirements for the storage of information. A simple timer on a domestic appliance is a memory device that stores a required time interval for the completion of a task. In contrast the memory of a personal computer can store the content of a library of thousands of books. In a living organism, the storage and retrieval of information is predominantly the function of the brain. Storage of information in the sequence of the genetic code within the nucleus of a cell with its subsequent retrieval to direct the synthesis of the proteins, the stuff of living organisms, is another important case of information storage. Apart from this genetic code there may also exist additional types of memory storage and biological codes in a cell.[1]

### *Feedback control and system stability*

Another shared aspect of many systems is the ability of the system to adjust to varying situations, maintaining its operational integrity. It is a common experience that an occasional whistle is produced by a system of a microphone and a loudspeaker. As the noise from the loudspeaker is successively amplified through the microphone amplifier, its volume increases and creates an unpleasant sound. However, as the amplifier, in conjunction with the room acoustics, may have a greater amplification for a specific pitch, a particular tone is more strongly amplified and eventually dominates the system. This is an example of positive feedback.

Alternatively, negative feedback increases system stability and occurs when a portion of the output is made to partially cancel the input to the system. A good driver watching the speedometer of his car pulls his foot off the accelerator as it approaches the speed limit. Conversely, if the speed of the car is reduced below the limit, the driver presses the accelerator. This is conscious negative feedback for control of the speed of a car. Many simple radio sets have what is called a volume control. This is simply an arrangement that decreases the amplifier gain when the received signal is strong and increases it when the signal is weak. This is an example of automatic feedback control where information about the strength of a signal is fed back to the system, which makes an appropriate system adjustment.

Automatic mechanical or electronic feedback controls can ensure the proper functioning and stability of complex machinery, electronic and communication systems and even of a very large manufacturing plant. Numerous forms of feedback mechanisms maintain system equilibrium and stability in natural inanimate and living systems. In a star, the radiation pressure and the counter-effect of gravitation, produce a negative feedback mechanism, maintaining the star in a stable condition for billions of years. In living organisms, numerous feedback systems control body temperature, heartbeat, sleep cycles and practically every aspect of life in order to maintain homeostasis and physiological stability. Similar mechanisms of feedback control can be seen in social and economic systems. An obvious example is the automatic adjustment of price by changes in supply or demand.

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[1] See: [**Marcello Barbieri**, The organic codes: **An introduction to semantic biology**, Cambridge University Press, 2003]

***A9.3 - Negative feedback***

We use the principle of negative feedback to close a venetian blind if the sunlight is too strong and open the blind when there is not sufficient light.

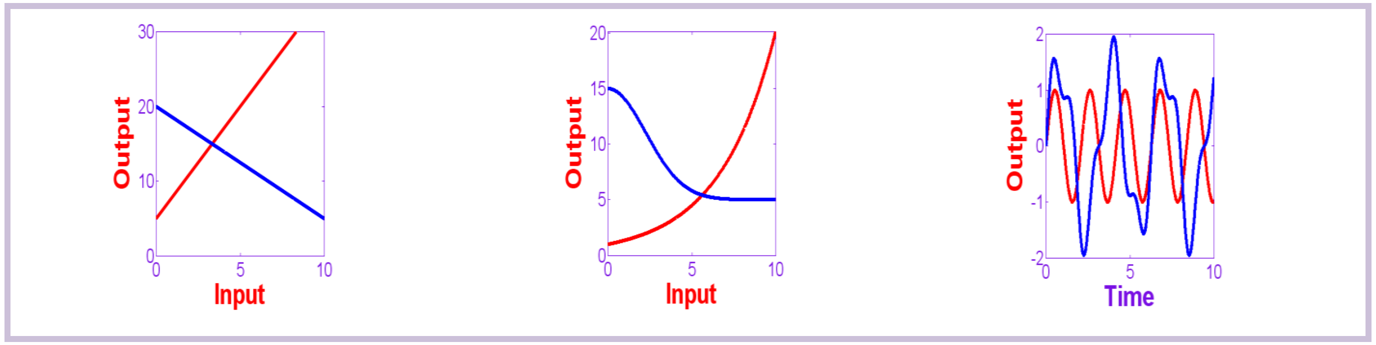
In spite of elaborate negative feedback mechanisms, complex systems do not remain perpetually stable. Eventually instability always sets in, either from inside or from outside influences. If these changes are considerable, the system will cease to exist in its original form. There is the eventual collapse of stellar systems, death of living organisms or extinction of species.[1] Incremental changes or perturbations, however, can make the system leap from one quasi-stable condition to another, as in the case of biological evolution. The length of time that a system remains stable can differ vastly between different systems. Stars can remain stable for billions of years, but the life span of living organisms can be as short as a few hours. The universe in its present phase itself has a limited life span and is doomed to a so-called 'thermodynamic death'. In many complex systems, the simultaneous control of the flow of information from the inside and outside, and the application of numerous feedback controls, necessitates a specialized control unit to maintain the coherent functioning and the integrity of the system as a whole. The brain in living organisms, central processing units in computers and special control sections in manufacturing plants, are examples of these control units.

### *Linear and nonlinear systems*

A system can either be linear or nonlinear. A circuit of interconnections of passive electric elements of resistors, capacitors and inductors is a linear system, independent of the number of components. If you double the voltage across the input terminal of the circuit, the current through all elements will increase by a factor of two. On the other hand, in a nonlinear system the outcome of a change in one parameter may not be proportional to the change in the parameter itself. If you double your income every year you

[1] 'Species have evolved, thrived, dominated, diminished and become extinct throughout the planet's history. The average time span for a species is only about 5 million, although some have lasted considerably longer.' See: [**Derek Elsom**, p14, **Planet Earth**, Marshall Publishing, 1998]

have ‘exponential’ growth of your capital, but if you work twice as many hours every day, your efficiency may decrease, and your yearly income may not double – this is the law of ‘diminishing return’.




***A9.4- Linear, non- linear and oscillatory systems***

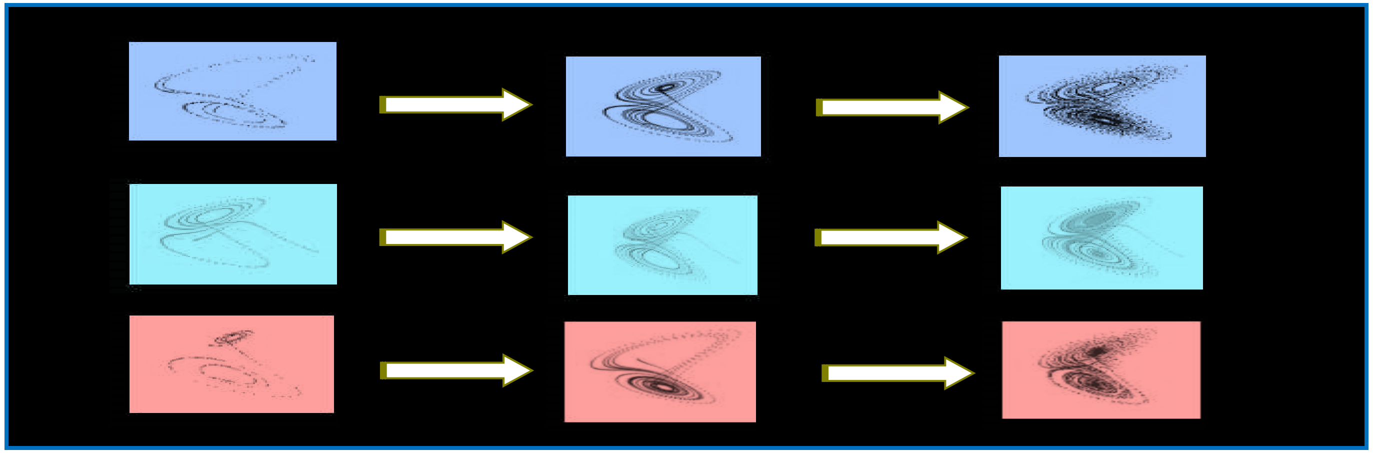
In a system the output can be proportional to the input variable, independent of the input magnitude. This is a linear (left figure) system. Alternatively, the change in the output variable may not be proportional to the change in input variable, this is a nonlinear (middle figure) system. In some systems the system parameters change periodically. This is known as an oscillatory system (right figure).

System nonlinearity is a common feature of all natural evolutionary systems and is in fact essential for the formation of complex processes. Consider the stellar nuclear process that makes the stars like our sun luminous. The process of multiplication of the number of reacting atoms involved in a nuclear reaction is known as a ‘chain reaction’. A chain reaction starts with a few reacting atoms, while the release of additional energy initiates a further nuclear reaction. In stars, the initial exponential growth of the rate of fusion eventually declines and nucleosynthesis reaches a steady state condition, controlled by the star’s other physical parameters.

As previously mentioned, the laminar flow of water has a simple form, but nonlinearity in the dynamics of the fluid may lead to turbulence, creating rich and infinite possibilities of vortex flow patterns. This potential for the emergence of novel configurations and patterns in nonlinear systems has led to the emergence of new forms and diversity in nature.

### *Nonlinearity and Chaos*

Turbulence in the flow of a fluid is an example of the chaotic behavior of a nonlinear system. The relevant theory applicable to nonlinear chaotic systems is known as 'chaos theory' and has attracted appreciable attention in recent times. Chaos refers to the dynamical outcome of complex systems that are highly unpredictable, not because of inherent random parameters, but due to their extreme sensitivity to small changes in any of their system variables.



***A9.5 – Order out of chaos***

Chaos refers to the dynamical outcome of complex systems that are highly unpredictable, not because of inherent random parameters, but due to the extreme sensitivity to small changes in any of the system's variables. The above figures show the evolution of a chaotic system with three slightly different initial parameters. As can be seen, the initial evolution of the system in the three situations are very unpredictable and chaotic (patterns on the left). In some situations, however, as the system evolves it ultimately reaches a well-defined and predictable dynamical state (patterns on the right). This is known as order arising from chaos.

The outcome of tossing a coin can be considered as inherently unpredictable, as there is an equal chance of throwing a head or a tail (at least in theory). However, the motion of a ball-bearing resting on the top of a bent rail that slopes on both sides is highly unpredictable in the sense that a slight push can make it run down on either side. In this system there is a bifurcation - two different paths that can be taken depending on a very small change in any acting parameter. The outcome of a system with one or several bifurcations is difficult to predict and hence the system tends to become chaotic.

Nonlinear systems are extremely sensitive to these initial conditions. The large number of independent variables involved in natural processes also implies a large number of initial input parameters. Nonlinearity creates a potential for numerous outcomes within certain confined limits, while the large set of possible initial conditions selects one of these many possibilities.

Nonlinearity resulting in chaotic behavior and unpredictability can also become a source of order. After a period of time, nonlinear systems that initially evolved differently, could reach a similar end state. The system at first is unpredictable and hence chaotic; the final state, however, can be ordered and predictable – hence order arising from chaos. This so-called principle of 'spontaneous order' or 'self-organization' can be seen in many open complex physical, biological, and even social systems.[1]

However, for the ordered state to persist and not revert to chaotic state and eventually to 'static equilibrium' - where no further action takes place - the system has to be an open system that is continuously supplied by energy and/or matter. Hence a system initially 'far-from-equilibrium', can reach 'dynamical equilibrium', if is maintained by an external source.

A very interesting example of order arising from chaos in 'far-from-equilibrium' conditions can be found in chemical reactions involving organic substances. In a version of the Belousov-Zhabotinsky experiment, the organic substance, malonic acid, is oxidized by bromate ions using a catalyst such as ferrous ions.[2,3] In this experiment, the chemicals are introduced into a reaction container. One would expect that after the completion of many intermediate interactions, the system would eventually settle down to 'static equilibrium' state with a uniform mixture of the end chemical products. Indeed, this would happen if the stream of new chemicals is not being continuously introduced.

With the continuous flow of reacting substances, however, the system is prevented from reaching its 'static equilibrium' state. In this case multiple interactions lead to chaotically changing concentrations of individual substances in the container. Eventually, however, sustained temporal and spatial patterns of concentration of the resulting chemicals are produced, in 'dynamic equilibrium state', manifesting an 'order out of chaos.'

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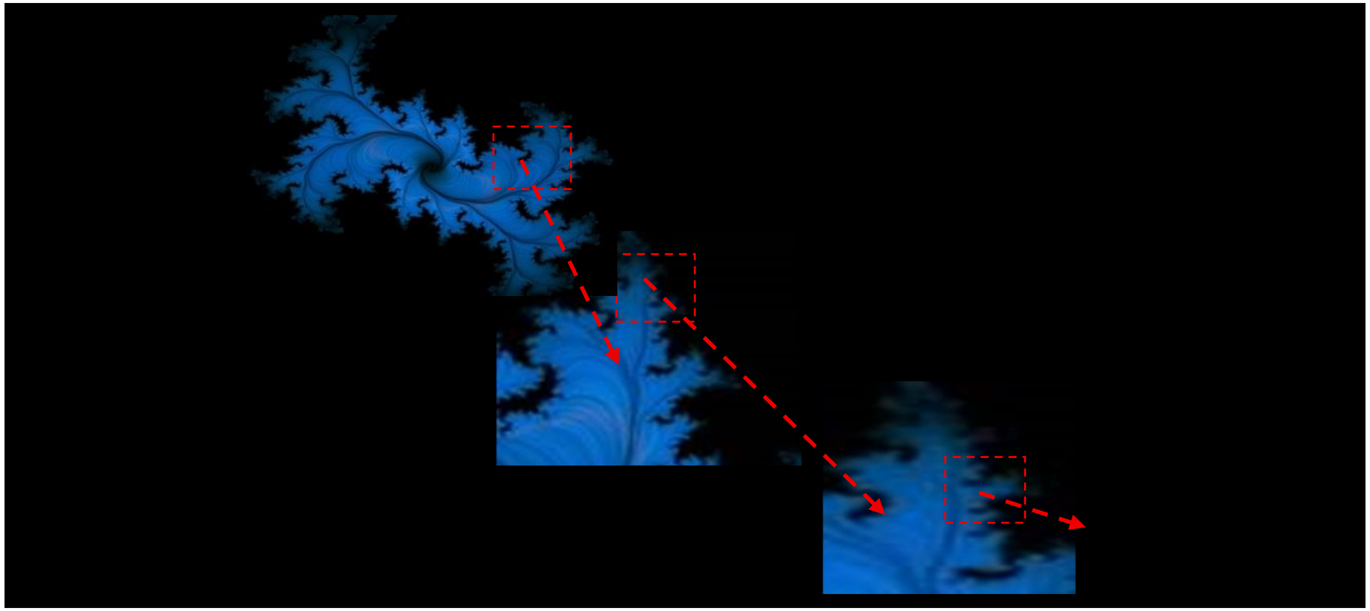
[1] Self-organization, also called spontaneous order, is a process where some form of overall order arises from local interactions between parts of an initially disordered system. The process is spontaneous, not needing control by any external agent. [**Wikipedia**]

[2] The original experiments were devised by B. P. Belousov in 1950s and his work was followed by A. M. Zhabotinsky in 1960s.

[3] For further discussion, see: [**Ilya Prigogine** and **Isabelle Stenger**, p146, p152-3, **Order out of Chaos**, flamingo, 1984]



***A9.6 - A fractal***

Evolution of complex dynamical systems sometimes leads to what is known as fractals. In fractals a particular pattern repeats itself at several levels. The pattern of leaves in a fern or rolling of hills in a mountain range is repeated many times on successively smaller scales. Some computer software can generate impressive fractal patters simulating the fractal patterns in nature.

Many ecstatically pleasing shapes and colored patterns seen in nature may have their origin in highly nonlinear interactions that eventually reach a quasi-ordered state. In animate systems these patterns are the long-term result of interaction between the system dynamics and evolutionary forces. Interesting examples of these are formations that have a hierarchy of repeated patterns in different scales known as fractals. The pattern of leaves in a fern or rolling of hills in a mountain range is repeated many times on successively smaller scales.

***A9.7- Fractal and other pleasing patterns in nature***

Fractal and other patterns arise in nature from what is known as self-organization. Self-organization occurs from dynamics of the system and is mainly associated with system nonlinearity and order arising from chaos. In animate systems these patterns are a result of the long-term interaction between the system dynamics and evolutionary forces.

### *Systems theory – Chaos theory – Science of complexity*

Systems theory is a science that has been developed to identify common aspects and produce mathematical models that may be applicable to all systems. It is a powerful tool for understanding of complex systems, irrespective of the nature of their function and variables. This could include physical to biological, economic and even social systems. The dynamic condition of a system at any time is known as the 'state' of the system.[1]

[1] See: [**Robert L Flood** and **Ewart R. Carson**, Dealing with complexity, Plenum Press, 1988]

A system has an irreducible set of independent variables known as the ‘state space’. The dynamic time evolution of system state is governed by a set of equations relating the incremental variation of the system with an incremental change in time. These equations are generally solved by applying certain initial or boundary conditions. The mathematical solution of these equations gives the intended result of the evolution of the system state with time.

The study of highly complex systems and processes is an important branch of science known as the science of complexity, dealing with the state of complexity in artificial and natural systems.

# Image references and credits

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***A1.6 - Blue shift and redshift - A***
***A1.7- Schematic representation of Big Bang***
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***A3.4 - A Pyramid - M***
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***A1.10 - A Spiral Galaxy***

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***A1.11 – An Elliptical galaxy***

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***A1.12 - Synthesis of elements in a star – A***

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***A2.1 - Formation of the Earth - A***

***A2.2 - The core/mantle/crust – A***

***A2.3 - Impressions of early period of the formation of the Earth - A – M***

***A2.4 - Impressions of a later periods of the formation of the Earth - A – M***

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***A2.5 - Pangaea – A***

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***A2.6 - Continents today - A - M***

***A2.7 - The crust of the Earth today - A - M***

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***A3.6 - Indus Valley Seals***

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***A3.7 - Chinese civilization - A***

***A3.8 - A Chinese Palace – M***

***A3.9 - The Persian Empire - A***

***A3.10 – Persepolis***

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***A3.11 - Greek civilization – A***

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***8.17 - Islamic civilization - A***

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***A2.8 - Miller-Urey experiment – A***

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***A2.9 A complex molecule***

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***URL:****http://en.wikipedia.org/wiki/File:Proteinviews-1tim.png*

***A2.10 - Earliest life forms – A***

***Credit:*** *Adapted from E S Barghoorn, the Oldest Fossils, Scientific American (1971)*

***A2.11 - prokaryote cell***

***Credit:*** *Mariana Ruiz LadyofHats (2006)*
***Status: WP – PD****, Released by the author*
***URL:****http://en.wikipedia.org/wiki/File:Prokaryote_cell_diagram.svg*

***A2.12 – Symbiosis - A***

***Credit:*** *Adapted from L Margulia, Symbiosis and Evolution, Scientific American (1971)*

***A2.13 - Eukaryote cell***

**Status: WP – PD**, Released by the copyright holder

***A2.14 – Cambrian***

**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author: Apokryltaros (2009)
**URL:**http://en.wikipedia.org/wiki/File:Hurdia_victoria_pair.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, releases by the author
**Credit:** Author, Apokryltaros (2008)
**URL:**http://en.wikipedia.org/wiki/File:Yuyuanozoon_magnificissimi.JPG
**Credit:** Original uploader was Apokryltaros at en.wikipedia (2007)
**URL:**http://commons.wikimedia.org/wiki/File:Cameroceras_trentonese.jpg
Status: PD, released by copyright holder
**Credit:** OAR/National Undersea Research Program,

***A3.18 - Mecca – M***

***A3.19 - Western civilization – A***

***A3.20 - World War II***

**Status: WP – PD** UK Government, Crown copyright expired
**Credit:** Source, www.archives.gov
**URL:**http://en.wikipedia.org/wiki/File:Waves_of_paratroops_land_in_Holland.jpg
**Status: WP - PD**, US government resource (1941)
**Credit:** User, Miborovsky
**URL:**http://en.wikipedia.org/wiki/File:Changde_battle.jpg
**Status: WP - PD**, US government resource
**Credit:** Crew of PB4Y-1 107-B-12 of VB-107, original uploader Nick Dowling (1943)
**URL:**http://en.wikipedia.org/wiki/File:Submarine_attack_%28AWM_304949%29.jpg
**Status: WP - PD**, US government resource

***A3.21 – The twentieth century***

**Status: WP – GNUFDL**; **CCASA3UL**, releases by copyright holder
**Credit:** User, Piotrus (2008)
**URL:**http://commons.wikimedia.org/wiki/File:Gen_Con_Indy_2008_-_robots_2.JPG?uselang=en-gb
**Status:**
**Credit:** NASA, James McDivitt (1965)
**URL:**http://en.wikipedia.org/wiki/File:Ed_White_First_American_Spacewalker_-_GPN-2000-001180.jpg
**Status: WP - PD**, NASA resource
**Credit:** (2007),
**URL:**http://en.wikipedia.org/wiki/File:Pelikan_Walvis_Bay.jpg
**Credit:** Author: Feezo (2010),
**Status: WM - CCASA3UL**, published by copyright holder
**URL:**http://commons.wikimedia.org/wiki/File:Wildturkey.jpg

***A4.1 - Stonehenge – M***

***A4.21 - Aztec Temple - M***

***A4.3 - An Egyptian Temple***

**URL:**http://commons.wikimedia.org/wiki/File:Nur01508.jpg
**Status: PD**, released by copyright holder

***A2.15 – Ordovician***

**Credit:** Original uploader was Apokryltaros at en.wikipedia (2007)
**Status: WP – GNUFDL**; **CCASA3UL**
**URL:**http://commons.wikimedia.org/wiki/File:Cameroceras_trentonese.jpg
**Credit:** Author, Kittil hagen (2009)
Status: PD, released by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Discoceras_boreale.JPG
**Credit:** OAR/National Undersea Research Program,
**Status: PD**, U.S. works where the copyright has expired
**URL:**http://commons.wikimedia.org/wiki/File:Nur01508.jpg
**Credit:** Author, Theoricien Quantique
**Status: PD**, released by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Triarthrus_Eatoni.jpg

***A2.16 – Silurian***

**Status: WP – GNUFDL**; **CCASA3UL**
**Credit:** Author, Apokryltaros (2007)
**URL:**http://commons.wikimedia.org/wiki/File:Acutiramus_cummingsi.jpg
**Status: WM – PD**, the author has waived all of his rights
**Credit:** Author, Nobu Tamura
**URL:**http://en.wikipedia.org/wiki/File:Mixopterus_BW.jpg
**Credit:** Stanton F. Fink (2008)
**URL:**http://commons.wikimedia.org/wiki/File:Mesacanthus_Parexus_Ischnacanthus.JPG
**Status: WP – GNUFDL**; **CCASA3UL**, releases by the author
**Credit:** Author: Dwergenpaartje,
**URL:**http://commons.wikimedia.org/wiki/File:Primipilaria_primipilaris_pedunculate_valve.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder

***A2.17 – Devonian***

**Credit:** Stanton F. Fink (2008)
**Status: WP – GNUFDL**; **CCASA3UL**, releases by copyright holder
**URL:**http://commons.wikimedia.org/wiki/File:Mesacanthus_Parexus_Ischnacanthus.JPG
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***A4.4 - A Roman Pantheon***

**Status: WP – PD** i*n the United States, and those countries with a copyright term of life of the author plus **100** years or fewer.*

***A4.5 - Temple of Artemis***

**Status: WP – GNUFDL**; **CCASA3UL**, releases by copyright holder

***A4.6 - Anahita Temple***

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***A4.7 – Plato***

Status: WP – PD

***A4.8 – Aristotle***

**Status: WP -** ***CCASA*** 2.5 Generic license, Attribution: Sting, released by its author as long as due credit is given

***A4.9 - Lao-tzu***

**Status: WP – PD***,* copyright has expired
**Credit:** Author unknown

***A4.10 – Confucius***

**Credit:** Author unknown
**Status: WP – PD**, copyright has expired

***A4.11 - a Hindu Temple***

**Status: WP – PD**, released by copyright holder (2006),

***A4.12 - Buddhist Temple***

**Status: PD CCASA3UL**

***A4.13 - A Jewish Synagogue***

**Status: WP – CCASA3UL**; Released under the **GNUFDL**

***A4.14 - A Christian Cathedral***

**Status: WP -** Released under the **GNUFDL**

***A4.15 - A Moslem Mosque***

**Status: WP -** Released under the **GNUFDL**

***A4.16 - Saint Augustine***

**Status: WP – PD**, This image comes from the Portrait Gallery of the
**URL:**http://ca.wikipedia.org/wiki/Fitxer:Augustinus_1.jpg
**Credit:** Author, Alefbe
**URL:**http://en.wikipedia.org/wiki/File:IbnSina-Dushanbe.jpg
***Credit:*** Artist, after Frans Hals; Source, André Hatala [e.a.] (1997) *De eeuw van Rembrandt*, Bruxelles Crédit communal de Belgique

**Credit:** User, Apokryltaros,
**Status: WP – GNUFDL**; **CCASA3UL**, releases by the author
**URL:**http://es.wikipedia.org/wiki/Archivo:Cephalaspis_tenuicornis.jpg
**Credit:** Author: Dwergenpaartje,
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://commons.wikimedia.org/wiki/File:Primipilaria_primipilaris_pedunculate_valve.jpg
**Credit:** Author, Dunkleosteus_terrelli_7.jpg: Original uploader was Apokryltaros at en.wikipedia, derivative work: Kevmin,
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://commons.wikimedia.org/wiki/File:Rhynchodus_major.jpg

***A2.18 – Carboniferous***

**Status: WM – PD**, released by the author
**Credit:** Author: Charles R. Knight (1897)
**URL:**http://en.wikipedia.org/wiki/File:DimetrodonKnight.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, released by copyright holder
**Credit:** Author: Nobu Tamura (2008)
**URL:**http://en.wikipedia.org/wiki/File:Pulmonoscopius_BW.jpg
**Credit:** Author, Nobu Tamura (2008)
**URL:**http://en.wikipedia.org/wiki/File:Cardiocephalus_BW.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Creator: Dmitry Bogdanov (2008),
**URL:**http://en.wikipedia.org/wiki/File:Helicoprion_bessonovi1DB.jpg
**Status: WM – PD**, copyright expired

***A2.19 – Permian***

**Credit:** Author, Nobu Tamura (2008)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Cardiocephalus_BW.jpg
**Credit:** Creator, Dmitry Bogdanov (2008)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Dasyceps1DB.jpg
**Credit:** Creator: Dmitry Bogdanov (2008),
**Status: WM – GNUFDL**
**URL:**http://en.wikipedia.org/wiki/File:Helicoprion_bessonovi1DB.jpg
**Credit:** Author, J.Walther (1914)
**Status: WM – PD**, copyright expired

**URL:**http://en.wikipedia.org/wiki/File:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg
**Credit:** Author unknown
**URL:**http://commons.wikimedia.org/wiki/File:Francis_Bacon.jpg
**Credit:** Author unknown, contemporary to his life, before 1900
**URL:**http://en.wikipedia.org/wiki/File:Portrait_of_Friedrich_Nietzsche.jpg
**Credit:** 18th century painting, artist not specified
**URL:**http://en.wikipedia.org/wiki/File:Immanuel_Kant_%28painted_portrait%29.jpg
**Credit:** Artist: Jakob Schlesinger, Alte National gallery (1831),
**URL:**http://en.wikipedia.org/wiki/File:Hegel_portrait_by_Schlesinger_1831.jpg
**Credit:** The image is copied from Russell's images in the following site
**URL:** http://www.gap-system.org/~history/PictDisplay/Russell.html

***A4.17 - Avicenna***

**Credit:** Author, Alefbe
**Status: WP – GNUFDL**; **CCASA3UL**, releases by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:IbnSina-Dushanbe.jpg

***A4.18 - Rene Descartes***

***Credit:*** Artist, after Frans Hals; Source, André Hatala [e.a.] (1997) *De eeuw van Rembrandt*, Bruxelles Crédit communal de Belgique
**Status: WP – PD**, copyright expired
**URL:**http://en.wikipedia.org/wiki/File:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg

***A4.19 - Frances Bacon***

**Credit:** Author unknown
**Status: WM – PD**, copyright expired
**URL:**http://commons.wikimedia.org/wiki/File:Francis_Bacon.jpg

***A4.20 - Friedrich Nietzsche***

**Credit:** Author unknown, contemporary to his life, before 1900
**Status: WP – PD**, copyright expired
**URL:**http://en.wikipedia.org/wiki/File:Portrait_of_Friedrich_Nietzsche.jpg

***A4.21 - Immanuel Kant***

**Credit:** 18th century painting, artist not specified
**Status: WP – PD**, copyright expired

**URL:**http://en.wikipedia.org/wiki/File:Helicoprion_Bessonovi2.jpg

***A2.20 – Triassic***

**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Nobu Tamura (2007)
**URL:**http://en.wikipedia.org/wiki/File:Ericiolacerta_BW.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Diucón (2009)
**URL:**http://es.wikipedia.org/wiki/Archivo:Plagiosauridae.jpg
**Credit:** Author, Nobu Tamura (2009)
**URL:**http://en.wikipedia.org/wiki/File:Adeopapposaurus_BW.jpg
**Status: WM – PD**, released by copyright holder
**Credit:** Author, Dmitry Bogdanov (2000-8)
**URL:**http://en.wikipedia.org/wiki/File:Muraenosaurus_l2.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder

***A2.21 – Jurassic***

**Credit:** Author, Nobu Tamura (2009)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Adeopapposaurus_BW.jpg
**Credit:** Author, Vassil (2008),
**Status: WM – PD**, released by copyright holder
**URL:**http://fr.wikipedia.org/wiki/Fichier:Balanocidaris_marginata_180308.jpg
**Credit:** Author, Dmitry Bogdanov (2000-8)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Muraenosaurus_l2.jpg
**Credit:** Author, ArthurWeasley
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Ornitholestes_BW.jpg

***A2.22 – Cretaceous***

**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Nobu Tamura (2007)
**URL:**http://en.wikipedia.org/wiki/File:Comahuesuchus_BW.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Autho, Ferahgo the Assassin (2010)
**URL:**http://en.wikipedia.org/wiki/File:Saurornitholestes_digging_Burrows_wahweap.jpg
**URL:**http://en.wikipedia.org/wiki/File:Immanuel_Kant_%28painted_portrait%29.jpg

***A4.22 - Friedrich Hegel***

**Credit:** Artist: Jakob Schlesinger, Alte National gallery (1831),
**Status: WP – PD**, copyright expired
**URL:**http://en.wikipedia.org/wiki/File:Hegel_portrait_by_Schlesinger_1831.jpg

***A4.23 - Bertrand Russell***

**Credit:** The image is copied from Russell's images in the following site
**Status: PD**, The site owners believes that the image is in public domain
**URL:** http://www.gap-system.org/~history/PictDisplay/Russell.html

***A4.24 - A Bahá'í Temple***

***A5.1 - Newton's law of gravitation - A***
***A5.2 - Time dilation and space contraction - A***
***A5.3 - The Principle of Equivalence - A***
***A5.4 - Gravitational lensing - A***
***A5.5 - Wave propagation - A***
***A5.6 - Light as electromagnetic wave – A***
***A5.7 - Hydrogen and oxygen atoms and a water molecule - A***
***A5.8 - Position – momentum relation in quantum mechanics - A***
***A5.9 - Fuzzy orbits of electrons***

**Credit:** Author, PoorLeno (2008),
**Status: WP – PD**, released by its author
**URL:**http://en.wikipedia.org/wiki/File:Hydrogen_Density_Plots.png

***A5.10 - Proton and neutron – A +***

**Credit:** Arpad Horvath (2006)
**Status: WP – PD**, released by its author
**URL**:http://commons.wikimedia.org/wiki/File:Quark_structure_neutron.svg
**URL**: ttp://commons.wikimedia.org/wiki/File:Quark_structure_proton.svg

***A5.11 - Partial list of elementary particles – A***
***A5.12 - Particle and anti-particle collision - A***

***A6.1 - Laminar flow - M***
***A6.2 - Turbulence – M***

**Credit:** Author, Apokryltaros (2010)
**URL:**http://en.wikipedia.org/wiki/File:Archaeus_species.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Nobu Tamura (2008)
**Credit:** Author, Nobu Tamura (2008)
**URL:**http://en.wikipedia.org/wiki/File:Purgatorius_BW.jpg
**Credit:** Author, Kevmin (2009)
**URL:**http://en.wikipedia.org/wiki/File:Branchioplax_washingtoniana_01_SR_EC_07-01-13.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Heinrich Harder (1920 - probably)
**URL:**http://en.wikipedia.org/wiki/File:Phenacodus.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder

***A2.23 – Paleocene***

**Credit:** Author, Apokryltaros (2010)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Archaeus_species.jpg
**Credit:** Creator, Dmitry Bogdanov (2010)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Barylambda2010.jpg
**Credit:** Author, Nobu Tamura (2008)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder **URL:** http://commons.wikimedia.org/wiki/File:Waimanu_BW.jpg
**Credit:** Author, Nobu Tamura (2008)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Purgatorius_BW.jpg

***A2.24 – Eocene***

**Credit:** Author, Kevmin (2009)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Branchioplax_washingtoniana_01_SR_EC_07-01-13.jpg
**Credit:** Author, Nobu Tamura (2008)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://commons.wikimedia.org/wiki/File:Georgiacetus_BW.jpg
**Credit:** Author, Heinrich Harder (1920 - probably)
**Status: WM – PD**, copyright expired

***A6.3 - Newtonian liquids - A***

***A6.4 - Second law of thermodynamics – A***

***A6.5 - Earth seen from the moon***

**Credit:** Apollo 8 crewmember Bill Anders, NASA (1968)
**Status: WP – PD** NASA material
**URL:**http://en.wikipedia.org/wiki/File:Earth-moon.jpg

***A6.6 – Infrared image of the Earth***

**Credit:** F. Hasler, D. Chesters, et al., GOES Project (2002), NASA/GSFC
**Status: PD**, NASA material (To be confirmed)
**URL:**http://apod.nasa.gov/apod/ap020323.html

***A7.1 - A lever – A - M***

***A7.2 - Rope and Pulley – A - M***

***A7.3 - Early heat engine***

Credit: (2006),
Status: WP – GNUFDL; CCASA3UL
**URL**:http://en.wikipedia.org/wiki/File:Newcomen_atmospheric_engine_animation.gif

***A7.4 - An electric motor - A***

***A7.5 - A vacuum tube circuit***

**Credit:** Author Adrian Pingstone (1958),
**Status: WP – PD**, released by its author
**URL:**http://en.wikipedia.org/wiki/File:Valve.radio.arp.600pix.jpg
**Credit:** Author Eric Barbour (1984),
**Status: WP – PD**, released by its author
**URL:**http://en.wikipedia.org/wiki/File:RCA12ax7.jpg

***A7.6 - A VLSI circuit - A A7.7 - Optical communication system - A***

***A7.7 - A light emitting diode***

**Credit:** Author: PiccoloNamek (2005),
**Status: WP – GNUFDL**; **CCASA3UL**, uploaded by the author
**URL:**http://en.wikipedia.org/wiki/File:RBG-LED.jpg

***A7.8 - A laser***

**Credit:** Author: US Air Force
**Status: WP – PD** US Federal Government resource
**URL:** http://en.wikipedia.org/wiki/File:Military_laser_experiment.jpg

***A7.9 - Optical communication system - A***

**URL:**http://en.wikipedia.org/wiki/File:Phenacodus.jpg
**Credit:** Author, Smokeybjb (2009)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Presbyorni

***A2.25 – Oligocene***

**Status: WM - CCA*3UL***, published by copyright holder
**Credit:** Author, Heinrich Harder (1920?)
**URL:**http://en.wikipedia.org/wiki/File:Arsinoitherium_hharder.png
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Creator, Dmitry Bogdanov (2009)
**URL:**http://en.wikipedia.org/wiki/File:Indricotherium11.jpg
**Credit:** Author, Massimo Olmi & Adalgisa Guglielmino (2011)
**URL:**http://commons.wikimedia.org/wiki/File:Dryinus_grimaldii_ZooKeys-130-505-g002.jpg
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Nobu Tamura (2007)
**URL:**http://en.wikipedia.org/wiki/File:Purussaurus_BW.jpg
**Status: WM – PD***, copyright* expired

***A2.26 – Miocene***

**Credit:** Author, Massimo Olmi & Adalgisa Guglielmino (2011)
**Status: WM – CCASA3UL**
**URL:**http://commons.wikimedia.org/wiki/File:Dryinus_grimaldii_ZooKeys-130-505-g002.jpg
**Credit:** Author: Smokeybjb (2009),
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Procariama.jpg
**Credit:** Author, Nobu Tamura (2007)
**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Purussaurus_BW.jpg
**Credit:** Author, S.V. Wood (1856)
**Status: WM – PD***, copyright* expired
**URL:**http://nl.wikipedia.org/wiki/Bestand:Wood-2_XXXI-26_Eastonia_rugosa.jpg

***A2.27 – Pliocene***

**Status: WP – GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Nobu Tamura (2009)

***A7.10 - A computer system***

A Mainframe Computer:
**Credit:** IBM Mainframe Center of Excellence
**URL**:http://mainframe.bmstu.ru/en/1.php
**Credit:**wpclipart
**Status: PD**
**URL**:http://www.wpclipart.com/computer/hardware/server/mainframe.png.html
A modern Tablet Computer - A

***A7.11 - Neural networks - A***

***A7.12 - Laparoscopic Surgery Robot***

**Credit:** Original uploader was Nimur, (2006),
**Status: WP – GNUFDL**; **CCASA3UL**; assigned by the owner
**URL:**http://en.wikipedia.org/wiki/File:Laproscopic_Surgery_Robot.jpg

***A7.13 – Sputnik I***

**Credit:** Author: NSSDC, NASA (2004)
**Status: WP – PD** NASA material
**URL:**http://en.wikipedia.org/wiki/File:Sputnik_asm.jpg

***A7.14 – First man on the moon***

**Credit:** NASA (1969),
**Status: WP – PD** NASA material
**URL:**http://en.wikipedia.org/wiki/File:Aldrin_Apollo_11.jpg

***A8.1 - Inside a cell***

**Credit:** Author: MesserWoland and Szczepan 1990 (2006),
**Status: WP – GNUFDL**; **CCASA3UL**; assigned by the owner
**URL:**http://en.wikipedia.org/wiki/File:Biological_cell.svg

***A8.2 - Some living tissues***

**Credit:** User Arcadian (2006)
**Status: WP – PD** US Federal Government resource
**URL:**http://en.wikipedia.org/wiki/File:Illu_connective_tissues_1.jpg

***A8.3 – DNA***

**Credit:** Author, Zephyris (2011)
**Status: WP – GNUFDL** published by the owner
**URL:**http://en.wikipedia.org/wiki/File:DNA_Structure%2BKey%2BLabelled.pn_NoBB.png

**URL:**http://it.wikipedia.org/wiki/File:Deinotherium_BW.jpg
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, Nobu Tamura (2008)
**URL:**http://en.wikipedia.org/wiki/File:Zygomaturus_BW.jpg
**Credit:** Author, Alannis (2009)
**URL:**http://commons.wikimedia.org/wiki/File:Deinotherium.jpg
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright holder
**Credit:** Author, ArthurWeasley (2007)
**URL:**http://commons.wikimedia.org/wiki/File:Varanus_priscus_BW.jpg
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright holder

***A2.28 – Pleistocene***

**Credit:** Author, Alannis (2009)
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://commons.wikimedia.org/wiki/File:Deinotherium.jpg
**Credit:** Author, Original uploader was Apokryltaros at en.wikipedia (2007)
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Miracinonyx_inexpectatus.jpg
**Credit:** Author, ArthurWeasley (2007)
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright
**URL:**http://commons.wikimedia.org/wiki/File:Varanus_priscus_BW.jpg
**Credit:** Stanton F. Fink (Apokryltaros at en.wikipedia}
**Status: WM - GNUFDL**; **CCASA3UL**, published by copyright holder
**URL:**http://en.wikipedia.org/wiki/File:Procoptodon_goliah.jpg

***A2.29 – Holocene - insect***

**Status: WM – PD**, US government resource
**Credit:** Photo by Scott Bauer
**URL:**http://pam.newikis.com/File:Aleiodes_indiscretus_wasp_parasitizing_gypsy_moth_caterpillar.jpg.html
**Status: WM - CCASA3UL**, published by copyright holder
**Credit:** Author? (2005)
**URL:**http://en.wikipedia.org/wiki/File:Patanga_japonica.jpg
**Credit:** Author: Tragopan (2007),
**URL:**http://commons.wikimedia.org/wiki/File:Chilenischer_Flamingo_Tiergarten_Bernburg_2007.jpg
**Status: WM - GNUFDL**; **CCASA3UL**, published by the author
**Credit:** Author: Rui Ornelas from Lisboa, Portugal (2006)

***A8.4 - Schematic representation of Mitosis,Meiosis cell division - A***

***A8.5 - Human brain***

**Status: WP PD**

***A8.6 - Neurons***

**Status: WP - PD** US Federal Government resource

***A8.7 - Animal colony***

**Status: WP – GNUFDL**; **CCASA3UL**; assigned by the owner

***A8.8 - Ecosystems – Habitats***

**Status: PD** US government resource
**URL:**http://www.nps.gov/wrst/images/owl_1.jpg
**URL:**http://www.nps.gov/badl/images/Prickly-Pear-Close-up.jpg
**URL:**http://www.nps.gov/seki/images/indexFall.jpg
**URL:**http://www.nps.gov/bibe/images/hp_mexjay.jpg

***A9.1 - A close system - A***

***A9.2- An open system - M***

***A9.3 - Negative feedback - A***

***A9.4- Linear, non-linear and oscillatory systems - A***

**Credit:** Matlab software
**Status:** Program written by the author

***A9.5 - Order out of Chaos - A***

**Credit:** Matlab software
**Status:** Program written by the author

***A9.6 - A fractal***

**Credit:** Jozef Kosoru zyzstar technology,
**Status: PD** assigned by the owner
**URL:**http://zyzstar.kosoru.com/?fractals

***A9.7 - Fractal and other pleasing patterns in nature***

Brockley – M
Fern - M
Cloud patterns – M
Lena river delta – M
Snowflakes – M
Butterfly - M
Spiral galaxy
Peacock feathers – M

**URL:**http://en.wikipedia.org/wiki/File:Pelikan_Walvis_Bay.jpg A pineapple – M
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