VOLUME 4 SCIENCE SERIES.

COSMOS ** II

Evolution -
From Microbe to Man

(Origin of Universe, Life and Man)

A Review/Compendium
of Current Understandings

(For the non-technical reader)

by

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About This Book

This book attempts a synthesis across the many disciplines covering **the greatest saga of them all**, Evolution, the physical origin of the universe, life and man, and where we are heading. It is historical, scientific and philosophical.

The Table of Contents (TOC) indicates the huge sweep of the subject area, providing a useful map for the non-professional.

Each topic is covered in essential detail to provide a self-contained picture, with discussion of the relevant issues. Overall, the volume is a mini compendium, worth keeping by for reference.

This book is written at the level of the non-technical informed reader.

The Bottom Line

Intelligent man was a quantum leap, a turning point.
Evolution continues thereafter through civilisation, with man in charge.
The study questions, inter alia, whether the next quantum leap
will be beyond materiality.

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Scope of the Study

The object of the study has been to understand the latest thinking on the origin and evolution of life, where evolution is heading, and the role of man.

The study looks for a grand design, if there be one. The study does so in the **Part A – The Physical Universe** by reviewing the pre-biotic development of the universe, which may be thought of as the preparatory phase. The study seeks to understand the processes by which the pre-conditions for life came to be distributed and located on planet Earth. In fact, the first question arising is whether this was unique to the Earth.

The study proceeds in the **Part B – The Earth-Life Cosmic Dance** to trace the emergence of life in the single-cell prokaryote, and its progression to multi-cellular eukaryotes, to soft-bodied life, to animals and plants, and to Homo Sapiens, interacting at each stage with and influenced by our maturing physical environment.

The study proceeds in the **Part C – Evolution of Man** to follow the emergence of the human, from early modern man to modern man, and finally to Man as the apex and turning point of evolution, and to identify his role.

The study finally asks Quo Vadis? (what Next?), where is evolution heading, whether its terminal objective is in the temporal domain or may lie beyond materiality, which issue will be further examined in the next Volume 5 - Cosmos*** III - Beyond Materiality.

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Preface

This review has been an Internet-based research exercise. To the extent that the various search engines today incorporate first-line AI, the exercise has benefitted from the latter. I have not otherwise used AI tools.

I am by career fact-centred, with wide experience in assessing technical matters for policy decision. I am comfortable the output is a factual picture of our subject at the informed non-specialist level.

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TO THE READER

The book has ended up to be a substantial compendium covering all aspects of evolution.

The Table of Contents is extensively hyperlinked and paginated to enable the reader to find what he wants.

To SAMPLE its quality, read "The Saga of the Cyanobacteria", hyperlinked here for convenience.

Genealogy of this Book

After my second retirement, and sundry other research work, I decided to do a roundup of the frontiers of science, moving onward on a piece by piece basis, and inevitably focussing on evolution.

This undertaking has emerged to be a multi-part odyssey. Three of my earlier studies have led to this fourth volume. Indications are there needs be another (see Genealogy).

By professional habit, I captured the outputs as I went along, and over the years released them as follows:

Volume	Title	Description
1	Quantum Mechanics, A Non-Technical Brief ISBN 978-981-14-9875-6 2020	Coinciding with the first quantum computers
2	Virus* The Biological Predator ISBN 978-981-18-3046-4 2021	Coinciding with and including a detailed coverage of Covid-19
3	Cosmos* The Physical Universe ISBN: 978-981-18-7401-7 2023	An historical survey of man's discovery of the universe. It summarises what we know today, and looks to the future. Written in preparation for and timed with the launch of the James Webb Space Telescope (25 Dec 2021)
4A	Cosmos* II, (**Precis of**) Evolution – From Microbe to Man ISBN 978-981-94-5191-3 2026 (Feb)	Pre-release of Volume 4
4 This work	**Cosmos** II (The full work) Evolution - From Microbe to Man ISBN 978-981-94-5192-0 2026 Second Quarter (due)**	**Covering the Origin of Life, Role of Man - and the Way Forward**
5	Cosmos*** III (under edit) Evolution - Beyond Materiality? IBSN 978-981-94-5007-7 2026 Mid-Year (due)	Covering evolution beyond materiality

I issued the Precis (Volume 4A) to capture the my overall findings fresh, and serve for easier digestion by others, as the main volumes together are substantial.

I have released all the above as self-publications on the Internet at https://geraldpillay.wordpress.com/, and will do the same for those due. All my publications, including the above, are also available at https://independent.academia.edu/GeraldPillay

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Dedication

To Mabel, my wife,
in whose eyes
I saw my first stars,
in celebration of our
64th wedding anniversary
on 6 Feb 2026.

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Editorial Note:

For convenience,
I use the masculine to include the feminine,
“man” (and its derivatives) to include woman,
and I refer to the Supreme Being in the masculine.
I make no apology.

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* ya = years ago

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COSMOS** II
Evolution of Life

OVERVIEW: MICROBE TO MAN

Definitions

The term “cosmos” in most contexts means the physical “universe,” In context, it does however connote a larger well-ordered whole not necessarily limited to the physical, and I use the term interchangeably.

The term “big bang” refers to the original eruption in Planck time (before our time) that gave birth to our cosmos. It is still an hypothesis. Theoretically, all the energy that has powered the universe since the beginning originated from it. It in turn began as an minute mathematical “singularity”, of one unimaginably hot particle. Some speculate that the imminent cause was small perturbations, ie. disturbance or irregularity, in the fabric of the pre-existing space. Despite precise modelling, many questions remain to be answered. However, as a thesis, the big bang has worked remarkably well integrating our diverse understandings and speculations about the universe – to the extent we know it today. This review goes by it.

I use the term “pre-biotic” to mean before the dawn of life.

Focus

This exercise seeks to discern how life began, and then evolved, taking it from the big bang to the emergence of man. The focus is trying to discern whether it is one sequence of events or a string of occurrences that could have swung anyway and anyhow.

We next need to take Into account that man (human) emerged in due course. And with man, we crossed over from the physical to acquiring a brace of non-physical faculties. Again the question is whether the last was a third stage of an original process or yet another fortuitous and fecund outcome of nature made, possible by the pre-existence of the cosmic and the biological.

Subject to revisions in the light of future discoveries, I find it hard not to think that the big bang was like the birth of a baby, who contained and determined all the fundamentals of the future man. There may be no scientific basis yet, but Ii is not beyond man to think that he is not a chance outcome but the or a fulfilment.

Coverage

The central feature Is biogenesis, how the microbe became, and how the microbe became man. It begins with a recount of the birth of the physical universe. This is to investigate whether it formed any kind of basis for life. The exercise then proceeds to look at the emergence of life, and thereafter.

The evidence seems to suggest that the physical universe formed a concatenative preparation for life. There seems no question but that the evolution life itself has been progressive and cumulative, even persistent, notwithstanding interruptions, dead-ends and extinctions.

I draw a distinction between man and human. The former reflects the attainment of consciousness and those rational skills with which humans function. Human incorporates additional faculties (if indeed they are additional) capable of contemplating the non-physical dimensions of reality (such as metaphysics and philosophy) and indeed matters outside the universe. If such a distinction emerges, the question would be whether it is yet a further step in evolution - and what next.

The second central feature of Cosmos II is that we have discovered life so far only on the planet Earth. This limitation is imposed on us by the scale of the physical universe, the short human life-span, and the limits of our own concepts of space-time So far, we are not able the travel beyond the Solar system. Therefore, our conclusions about life's emergence and evolution are specific to this planet. Man is uniquely an earth creature. There could be other life forms and histories elsewhere This is not an exclusive story.

And thirdly, just as science has not yet been able to explain what caused the big bang, so too there are quantum leaps in Cosmos II which are still being intensively investigated and still to be clarified. One is the emergence of life itself contrary to our own concepts reflected in the laws of thermodynamics and of entropy. The other is the emergence of the human with an intellect and an individual identity, for which there appear to be so far no antecedents in the evolutionary chain.,

There is the further question whether evolution is continuing, and how, and role of Man in it. We shall examine the next volume, hopefully in the light of deeper scientific discoveries and hopefully new knowledge of other extraterritorial life forms as we conquer the universe. This is an open-ended story.

Cosmological Principle

The cosmological principle underpins all investigation of the universe. It assumes that the latter is both isotropic and homogeneous, meaning that the universe has no preferred location (is the same everywhere) and has no preferred direction (isotropy means uniformity in all orientations.) It is of particular interest in our review of the origin of life and emergence of man.

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PART A

The Physical Universe

Chapter One
The Macro Universe

Pre-biotic Preparatory Phase

Definitions

In this part, unless the context otherwise requires:

“cosmos” means the universe and all that exists or may exist beyond it, known, unknown and conjectured, and unknowable.

“universe” means the physical world within our time-space, including all biotic or living things

“pre-biotic” means before the emergence of life.

“metaphysical”, appertaining to all speculative thought relating to existence, being, reality, the origin and causes of things, and the purpose of man; and to knowing about these matters.

“philosophic”, the application of metaphysical (and related understandings) to what constitutes moral behaviour, a good life and the ultimate satisfactions of human existence.

“exoplanet”, planets found beyond our solar system, in orbit around other stars or as free-floating "rogue" planets.

Overview

The study finds that, spectacular and separate as they were, the many concatenated events in the universe, together, may be viewed in the light of the end results as a single preparatory programme of stage-setting, to set up the conditions required to engender life.

It does not appear that the above was incidental, subsidiary or adjunct to some other purpose or objective of the development of the universe, or to have occurred by chance. On the contrary, the preparatory programme appears to be itself the primary purpose of the developing universe.

It would not be wrong to say that the universe was being set up to enable lfe according to the factors assembly therein - at the appropriate place and time.

We may add a qualifier. There are major areas within the universe still not understood. Among these are dark matter, dark energy, gravity, the apparently accelerating universe, and the time barrier. Therefore, as we progress, we shall be reformulating our understandings of the universe. However, as far as we can see, they will not change the facts as they already happened. The pre-biotic preparatory activities did take place, enabling evolution of life. This study proceeds on that basis.

Thanks to quantum science we know that the entire universe is made up of the same matter. Not only that, the same forces and processes operate everywhere. Stars and planets are made in the same way and comprise the same stuff everywhere. The whole universe consists of the same set of elements bound up in the same way chemically and which respond to the same set of fundamental forces, including gravity.

Thanks particularly to the particle accelerators, we have a complete model of the big bang, the universe and its history. The universe exists in a gravitational bubble called space-time, which came into existence 13.87 billion light years ago with the big bang.

We have one of the most advanced forms of engineering in the James Webb Space Telescope, some 150 million km in space circling the Sun and designed to look into cosmic time up to 180 million light-years from the big bang. Through astrometry we can tell the location, distance, speed, path, mass, composition, atmosphere, temperature, and pressure of every star we can see. With the quantum computer, soon we shall in this century have the processing power to catalogue and GPS the universe.

The only problem is that we are extremely limited in our ability to travel, and the universe is so big. We are limited by astrophysics to the speed of light, which will take us 4.2 light-years to reach Proxima Centauri, our nearest star. At our present speeds, we shall take about 75,000 years to get there. There Milky Way, our own galaxy, is 26,000 light-years away and out of reach, We have to rely on distance-technology to fact-find and mathematical modelling to find out the shape and history of things.

The universe itself is immense, and continues to expand (faster than the speed of light).. Scientists have calculated that the diametre of the observable universe (ie. with us at the centre) is at present some 93 billion light-years, from the forward limit of our observable universe (the event horizon) to the rear limit of visibility (the particle horizon). This gives us a radius of some 46,5 billion light-years, which gives us the distance to which the universe has expanded in one direction since the big bang. The total size of the universe is still unknown.1 (Scientists believe it may be at least 250 times larger than the observable universe , or it may be infinite).

We further know that visible or baryonic matter makes up only 5% of the total mass-energy of the universe. The rest is made up of DME, that is Dark Matter (26.8%) and Dark Energy (68.2%), the common characteristic of both being that they do not interact with light (hence are termed “dark”). So far, our science requires light-energy to pick up objects to study. We only know or can hypothesise about DME from their gravitational effects. And we know that it is gravity that holds us all together in space-time.

While DM is thought to be matter, DE is conceived of as the “vacuum energy” of space, quite independent of gravity. The prevailing theory is that It exercises a gravitationally-negative (or repulsive) force, which has since overcome the effects of gravity’s retardation of the universe following the big bang and could be what is propelling the physical universe forward at accelerated speeds. It follows from this modelling that while baryonic matter and DM dilute proportionately as space-time expands, DE remains constant. DE is still debated as an hypothesis to explain expansion. An alternative view suggests DE does not exist, but that space-expansion could be more localised and driven by other causes, ie. density-gravity variations. On. the flimsy facts availabl, I tend to favour the alternative theory. However, as DE (in. this form) does not feature in our story of the emergence of life, I shall look no further into it.

On the other hand, DM emerged into space-time as part of the big bang and may be described as the sub-structure of the cosmos. DM is thought to be denser and comparatively slow moving and therefore the earliest to coalesce. In this way it formed the framework around which baryonic matter condensed into our universe . As far as we know, DM has played no direct part in the origin of life - the emergence of man to be precise.. For our purposes, therefore, we need not consider DM further, except that our world sits as a thin filament on top of DM – and DE if there is such a thing.

Our story is concerned with the happenings in this thin visible baryonic universe, which is itself vast. Only in 2021, scientists have discovered a Giant Arc, some 9.2 billion light years away, stretching 3.3 billion light years across part of the sky. Our observational technology has been so amazing that almost all we know (as reflected in this study) has been discovered from ground level on Earth.

[1] - https://www.britannica.com/topic/observable-universe

The Big Bang

I indulge in some descriptive rewind here to identify connections if any to our story.

Inflation

Our models indicate that the big bang was a stupendous eruption of radiant energy. It was the "mother" of all fireballs. In the first pico-seconds, as it inflated. It hit temperature levels exceeding 1032 Kelvin and energy levels exceeding 1019 GeV.

In such a state, the primordial constituents of matter or "pre-matter" were too super-hot and over-energised to coalesce. The universe was a plasma, a soup of particles known as quarks and gluons. The fundamental forces that bind matter came into existence early, with gravitation first followed by the others, but their effects would come later.

The radiant energy produced pairs of quarks-antiquarks, electron-positrons and other particle-antiparticle pairs. However, as the particles and antiparticles collided in the high energy gas, they annihilated back into electromagnetic energy. This continued until the temperature cooled enough so that pair creation became no longer energetically possible, leaving behind the net differential of a matter universe for us. I could get no precise information when or how DM a took shape and whether it involved an anti-matter stage.

At that time, quarks and gluons condensed into protons and neutrons. We began to have other sub-atomic particles and isotopes of the lightest elements. The universe then still consisted of plasma of nuclei, electrons and photons. Massless and near-massless components such as photons and neutrinos moved around at or close to the speed of light.

At one second, neutrinos were the first to decouple from baryonic matter to form the cosmic neutrino background, which we can detect still today.

The sphere of space that will become the observable universe was approximately 10 light-years in radius at this time.

Nucleosynthesis (atomic nuclei)

From about 2 minutes of time, conditions were suitable for nucleosynthesis, the creation of atomic nuclei. Not surprisingly, these earliest nuclei were those of hydrogen (protium), with one proton and no neutron (Atomic No 1), and helium with two protons, two electrons and two neutrons each (Atomic No 2). There were also traces of lithium (Atomic No 3) with three protons and three electrons each, also deuterium, which is an (unstable) isotope of hydrogen loaded with an electron.

Substantial quantities of more massive nuclei were not made in the big bang because the densities of the particles and energies were not great enough to initiate further nuclear reactions. As it expanded under inflation, the universe cooled down rapidly. Thereafter, temperature controlled the average energy and the formation of matter.

By 20 minutes, the universe was no longer hot enough for nuclear fusion, but still far too hot for neutral atoms to form or exist, or photons to travel far. It was therefore still an opaque plasma. Once the thermal energy dropped below 0.03 MeV, nucleosynthesis effectively came to an end..

Recombination (atoms)

As the universe continued to expand and cool, things began to happen more slowly, drifting into the era of recombination, which began around 18,000 years after the big bang.

Around 370,000 years the temperature of the universe fell to the point where atomic nuclei could combine with electrons to create neutral atoms. For the first time, electrons could to be trapped in orbits around nuclei, forming the first atoms. As might be expected, these were mainly hydrogen and helium atoms.

After the neutral helium atoms formed, helium hydride was the first molecule. Much later, hydrogen and helium hydride reacted to form molecular hydrogen (H2) the fuel needed for the first stars
.
The newly formed atoms—mainly hydrogen and helium with traces of lithium —quickly reach their lowest energy state (ground state) by releasing their electrons (photon de-coupling). These photons were the only source of light) at the time. They made the cosmos transparent (visible) for the first time.

However, these freely propagating photons red-shifted to infrared in time and the universe was again devoid of visible light. They can, however, still be detected today as radio frequencies, constituting the cosmic microwave background (CMB) radiation, the oldest direct observation we currently have of the universe.

Recombination lasted for a relatively short burst of time in cosmological times, about 100,000 years and then petered out. One result was that the decoupling of fresh photons (light) also petered out and the cosmos went into darkness.

The spherical volume of space grew to 42 million light-years in radius at this time. The proportion of hydrogen and helium atoms per m3 was approximately a billion times higher than today.

The macro universe was born an hydrogen-helium world, which went on to nurture a hydrogen-related fife.

Large Scale Structures

Gravitational collapse is a fundamental mechanism for structure formation in the universe. Over time an initial, relatively smooth distribution of matter will collapse to form pockets of higher density, typically creating a hierarchy of condensed structures.

Scientist visualise that, as the earliest matter condensed, namely DM, it gravitated to form the primary Large Scale Structures (LSS) of the universe. These became the framework within space-time around which both DM and the baryonic universe accreted and grew. As the universe expanded, so did the LSS, the Inter Stellar Medium (ISM) and the Voids.

Exactly where DE fitted in I could not establish, but the current theory is that, while DM and baryonic matter diluted with expansion, DE remained constant and drove the latter..

Cosmic Web

The current picture is then that the universe was first formed by the extrusion of DM into space, accompanied by ordinary matter basically occupying the interstices. This process would result in forming long filaments and networks of filaments across the voids.

The hot dense primordial gaseous hydrogen and helium hung about in massive clouds , drawn together by gravity. This process would result in forming long sheets and networks of filaments across the voids. The end-result would be creating cosmic webs, the whole wrapped in screens of primal gasses and molecular cloud.

The cosmic web is the building block of the cosmos, consisting primarily of DM laced with gas, on which the galaxies were built.

Voids

The universe is also composed largely of voids - which account for 80 percent of the observable universe. It seems to be an undisputed assumption that no life will be found in voids. Science has no way of contemplating the existence of spirits. We therefore exclude further consideration of voids in this part of the exercise.

Filaments and Walls

Filaments are the largest known structures in the universe, thread-like structures with a typical length of 150-250 million light-years. Each filament is in turn basically a wall of galaxies, each stretching for hundreds of millions of light-years. They are the next biggest structures in the known universe.

The filaments coalesced within themselves further into strings of clusters and superclusters of galaxies. The latter in turn further condensed within themselves into nebulae of molecular gases and particles, which further condensed into stars within the galaxies.

The filaments may be thought of as the wombs of the universe. The first stars and stellar clusters formed therein, and these subsequently merged with gas and dark matter to form galaxies.

Galaxies.

It is estimated that there are between 200 billion (2×1011) to 2 trillion galaxies in the observable universe, and 6 sextillion (6x1023) stars in them. (I have to say, different estimates vary widely).

Most galaxies are 3,000 to 300,000 light-years in diameter and are separated by distances on the order of millions of light-years.

Galaxies begin as gravitational fields of hydrogen-helium, in which stars are born. They end when the last star burns out its hydrogen-helium, when they may sink into a black hole..

The smallest of galaxies contain a “mere” few hundred million stars while the largest galaxies contain up to one hundred trillion stars. Scientists have been able to group galaxies into 4 main types: spiral, elliptical, peculiar, and irregular.

The strict definition of a galaxy is all that is gravitationally bound together and rotate round its centre. Every star revolves round its galaxy, in addition to itself.

Galaxies can be gravitationally bound in clusters. There is no central point round which all in a cluster orbit, but each galaxy moves within its own path in its common gravitational field. Sometimes galactic concentrations become super-clusters. The latter again do not have a common gravitational attraction, but are made up of assembles of galaxies and clusters.

All galaxies, clusters, super-clusters and the stars in them are at the same time moving away from each other due to the expansion of the universe brought on by the Big Bang.

Scale of the Universe

Our universe is confined within a capsule called space-time. Nothing within it can travel faster than 1.08 billion kms/hr or 300,000 km/sec, the speed of light. Any matter attaining that speed becomes light. Distance is measured by light-years, ie the distance travelled by light in one (Earth) year.

The **observable universe** is a spherical region of the universe consisting of all matter that can be observed from Earth. This means that the electromagnetic radiation from these astronomical objects has had time to reach the Solar System and Earth since the beginning of the cosmological expansion (the big bang) some 13.8 billion light years ago.

The universe has been expanding, on the average, faster than light. I do not pretend to understand the mathematics of it, but it is said that the radius of the observable universe has grown about 46.5 billion light years. This means the diametre of our observable universe is 93 billion light years.

In any case, because space-time is curved, corresponding to the expansion of space, the above distances do not correspond to the true distance at any moment in time. There is the further suggestion that the ouster parts are expanding faster. The lesson is that man will among other things really need to get his distances properly measured and his plotting instruments deadly accurate if he is to travel anywhere in space.

The James Webb Space Telescope (JWST) launched in Dec 2021 is already discovering small and distant galaxies not previously seen.

We are part of the Local Area of the Orion Arm of the nearest galaxy, the Milky Way, sited about 26,000 light years from its centre. There could be as many as 300 million Earth-sized habitable exoplanets within the Milky Way alone. The nearest could be 4.2 light-years away, orbiting the red dwarf Proxima Centauri.

The Elements

The earlier nucleosynthesis phase created only a limited range of nuclei and isotopes, Therefore, only these were available for formation of atoms, and only the lightest elements were made, namely hydrogen, helium, together with only traces of deuterium, lithium, and beryllium. All the other (heavier) elements were made much later by nucleosynthesis during star formation.

Hydrogen and Helium

Today, approximately 73% of the mass of the visible universe is in the form of hydrogen, helium makes up about 25% of the mass, and everything else represents only 2%, see table following.

Table 1
Ten most common elements
in the MILKY Way Galaxy
estimated spectroscopically[2]

Z=atoms	Element	Mass fraction (pp/million)
1	Hydrogen	739,000
2	Helium	240,000
8	Oxygen	10,400
6	Carbon	4,600
10	Neon	1,340
28	Iron	1,080
7	Nitrogen	960
14	Silicon	650
12	Magnesium	560
16	Sulfur	440
	108 others	less
118	Total	999,000

Whether by chance or design, in the first stage, the big bang created a universe of hydrogen and helium. As the lightest elements, these were amenable to gravitational condensation and dispersion, spreading matter for the formation of stars. In the next stage, these would form the fuel for the stars to burn, to provide the energy and the heat for formation of the stellar-planetary systems, including the rest of the elements.

All Other Elements

The low-mass elements, hydrogen and helium, were produced in the hot, dense conditions of the birth of the universe itself. The other “heavier” chemical elements were created in the nuclear reactions during the birth, life, and death of the stars. This stagger has a logic of its own. The heavier elements were not needed until star formation.

2 https://en.wikipedia.org/wiki/Abundance_of_the_chemical_elements

There are a total of 118 elements in the Periodic Table of Chemical Elements, identified as of 2023. A chemical element, simply called an element, is an atom which has a specific number of protons in its atomic nucleus (i.e., a specific atomic number, or Z). Hydrogen has 1, Carbon 6, and Oxygen 8. The element with 118 is Oganesson. The eight which make up most of the Other Elements is also shown in Table 1. Of the atoms, 94 are naturally occurring and 24 are man-made.

As far as modern science can make out, the composition and proportions of the elements in the universe are constant throughout. If they provide the basis for creation of life on Earth, it should be the same on every planet – subject to other factors.

While the proportion of the more massive ("heavy") elements seems quite low, they are important in that most of the atoms in our bodies and Earth are a part of this small portion. Elements in their natural state can be solids, liquids or gases. They are inorganic and are also known as :"chemical elements'".

Everything around us is formed from chemical elements or substances made up of one or more elements. Most of these elements are found combined with other elements as chemical compounds.

Minerals are naturally occurring elements or compounds. Most natural compounds are inorganic and mostly solids. There are also a range of organic compounds ("organic" means "includes carbon") which support life – more of these later

By weight, 99.5 per cent of minerals are formed from only 12 of the natural elements. Clearly, some elements are far more common than others. The same goes for minerals. Of the 5,800 or so known minerals, only 10 make up 95 per cent of the Earth's crust.

Cosmic Dawn

Dark Ages

With the end of recombination and the source of photons, the universe went into a prolonged period known as the "dark ages" which lasted altogether about one billion years (till about 1 Ga.) The most significant features during this epoch were that (1) the universe continued to cool, in fact from about 4,000 Kelvin to about 27 Kelvin, and (2) it continued to expand, at that point at a decelerating rate.

One source stated that as matter-density fell below DE (dark energy) density (vacuum energy), the expansion of the universe began to accelerate; and this timing happened to correspond roughly to the time of the formation of the Solar system and the evolution of life. I have not been able to verify this. Other information suggests that the latter events did not happen until and after 4.5 billions ago (looking back) which means when the universe was 9.8 billions years. Other independent sources say the re-acceleration began about 7.5 billion years from the big bang.

What we do get a sense of is that while the dark age extended over a billion years it was over-lapped and eventually cancelled out by the "cosmic dawn" brought about by the formation and ignition of stars starting from 150 million years atter the big bang.

Cosmic Dawn

A star is born through the gradual gravitational collapse of a cloud of Inter Stellar Matter (ISM). The compression caused by the collapse raises the temperature until thermonuclear fusion occurs at the centre of the star, at which point the collapse gradually comes to a halt as the outward thermal pressure balances the gravitational forces. The star then exists in a state of dynamic equilibrium. At this stage, the star will radiate light, re-igniting the universe. The first star is believed to have been born around 150 millions after the big bang.

Stars remains the longest in the stage when burning[3] hydrogen into helium. In the case of our Sun, this is estimated to be about 4.5 billion years more. For more massive stars, which burn faster, this stage lasts for only a few hundred million years.

[3] "burning" means fusion. Hydrogen "burns" into Helium. When it is exhausted and or temperatures rise, the Helium "buns" into Carbon, ad tandem.

Stars

Taken together, the stars represent the end products of the big bang, working out the life cycle of the latter. When they burn up all their fuel and the last star is extinguished, the universe will end. At this point, we do not know what comes next.

Formation of Stars

Stars begin in irregularities in the post big bang primordial space, when gravitational nodes begin to attract matter, compressing the same into hot dense balls of plasma. When the core reaches superheat-conditions, nucleosynthesis takes place.

The individual stars are like the body-cells of the cosmos, but not akin. New stars are born by gravitational attraction of the original material, but in no sense does this represent growth or reproduction of new life.

Stars are classified into three groups: Population III stars, which were the first to be born, and are now practically undetectable because dead or have drifted beyond the (rear) particle horizon; Population II stars, which are the mature stars of today, and Population I stars which are still in their emergent and early stages. Most galaxies carry all of them, reflecting their long-term role.

Types of Stars by Life Cycle

Stars can be classified by what stage in their life cycle they are.

Protostar
This is the stage where gravity and inertia work to pull in gas and dust from space. When gravity's pull is stronger than the force of inertia, the gas and dust will begin to spin, forming a large spherical ball. The force of gravity causes pressure on the core of the sphere preparing the star for the next stage in its life cycle. It takes a protostar approximately 100,000 years to make it to the next stage.

T Tauri Star
This is the second stage in a star's life cycle. T Tauri stars are named after a young star in the Taurus star-forming region. They cannot yet perform nuclear fusion. It will take an average of 100,000 million years to reach the next stage in its life cycle.

Main-Sequence Star

A star in its third stage of life is called a Main-Sequence star. In this stage, the star begins nucleosynthesis, also known known as thermonuclear fusion or nuclear fusion, and the temperature increases. This is the central function of a star. The balance between the gravitational force and the gas pressure causes it to have very long life cycle in a state of equilibrium.

This stage of life depends on how massive the star is. Stars with more mass tend to burn through their energy much faster. This results in main-sequence stars having an average life span between 20 billion to 100 billion years.

Red Giant Star

A red giant is a star that has exhausted the supply of hydrogen in its core and has begun thermonuclear fusion of hydrogen in a shell surrounding the core.

The star begins to grow much larger. These red giants can be as much as 100 times bigger than they were when they were Main-Sequence stars. This stage will last about one million years because of how quickly red giants burn through their energy resources.

When nuclear fusion of hydrogen stops, a star has reached the fourth stage. The equilibrium between the gravitational pull and gas pressure no longer exists.

White Dwarf Star
The fifth, and last, stage in a star's life cycle is the white dwarf star stage. These stars are no longer able to perform nuclear fusion. These stars will use up any remaining energy they have to create heat and light. Once their reserve is spent, they will begin to cool down and become black dwarfs with no energy to give off heat and light.

Supernova

A supernova is an explosion that occurs when the star runs out of fuel and fusion stops. Without the outward pressure from the fusion in the core there is nothing to counteract the inward pressure of gravity. Red stars about eight times or more massive than the Sun tend to end their lives in this spectacular way.

First, the outside of the star swells into a red supergiant. The core of the star begins shrinking and grows hotter and denser. For a while, a new series of nuclear reactions occur that turn the core to iron. This temporarily stops the collapse of the core. When the core contains mostly iron, it has nothing left to fuse, and fusion in the core ceases.

In the same second, the star begins the final phase of its collapse. The temperature in the core rises to over 100 billion degrees as the iron atoms are crushed together. There are a lot of forces going on at this point - some repulsive, some compressive. Finally, the whole star explodes and produces a shock wave that forces the matter from the star into space.

Neutron Star

All that remains of the original star (after a supernova) is a small, super-dense core composed almost entirely of neutrons. This is a neutron star. Neutrons are subatomic particles with no net electrical charge and with slightly larger mass than protons. Neutron stars have a radius on the order of 10 kilometres (6 mi) and a mass of about 1.4 solar masses. A normal-sized matchbox containing neutron-star material would have a weight of approximately 3 billion tonnes

Black Hole

If the collapsed or remnant star has a mass of around 2 solar masses, the combination of degeneracy pressure and nuclear forces is insufficient to support the neutron star and it continues collapsing to form a black hole.

Spectral Classification

For various purposes including cataloguing them, it is necessary to classify stars. Stars are classified by Luminosity (Absolute Magnitude) as against Temperature (Spectral type), using the Hertzsprung-Russell (HR) Diagram[4].

About 90 percent of the stars in the universe, including the Sun, fall into a band in the HR Diagram called the Main Sequence. Main sequence is when a star is burning hydrogen in its core. For reasons determined by the cosmos, these main sequence stars are bounded by upper and lower mass limits of about 80 solar masses and about 0.08 solar masses, respectively. These stars can range from about a tenth of the mass of the Sun to up to 200 time as massive.

Luminosity-Mass

Luminosity is a rate of the total radiant energy output of a star. It is the intrinsic brightness of a star stretched over the entire electromagnetic spectrum, not just the portion that includes visible light The luminosity (brightness) of a Main Sequence star is based on its mass with a simple equation: L=M3.5

[4] https://www.astro.princeton.edu/~burrows/classes/204/stellar.atmospheres.HR.pdf

where L= luminosity, and M-Mass (valid only for main. sequence stars).The greater the mass, the greater the luminosity.

Temperature-Colour

The surface temperature of a star determines the colour of light it emits. Blue stars are hotter than yellow stars, which are hotter than red stars. The mass and luminosity of a star also relate to its colour. More massive stars are hotter and bluer, while less massive stars are cooler and have a reddish appearance.

Classification System

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The 7 Main Spectral Types of Stars*:
.- O (Blue) (10 Lacerta)
.- B (Blue) (Rigel)
.- A (Blue) (Sirius)
.- F (Blue/White) (Procyon)
.- G (White/Yellow) (Sun)
.- K (Orange/Red) (Arcturus)
.- M (Red) (Betelgeuse)
(* Names of actual stars of the class)

Off the main sequence, a relatively cool star can be quite luminous if it has a large enough radius (red giants) and a relatively hot star can have very low luminosity, if its radius is very small (white dwarfs).

The Sun is set as the reference point 1 on both scales, and works out to have the Classification of G2. Its classification is Yellow dwarf, with another 5 billion years more to go.

Stars have many different properties: mass, luminosity, radius, chemical composition, surface temperature, core temperature, core density.. Astronomers today can measure and calculate these with incredibly comprehensive and precise tools and mathematics. In fact, the entire history of how an isolated star will evolve can be determined by just two properties: mass and chemical composition

It is estimated that there are 6 sextillion (6x1023) stars in the universe. I leave others to calculate how many are in the Main Sequence, AND for that matter how many may have a G2 classification.

One source states that 80% of main sequence stars are red dwarfs. That seems to suggest the cosmos is in an advanced stage of its own life-span.

Stellar Nucleosynthesis

ti is when a star is in the Main Sequence that it carries out stellar nucleosynthesis. The latter represents the second and final stage in the cosmic preparation of the universe to support life. In this stage, all the other elements are formed and come within consumable reach to support life as needed.

Nucleosynthesis is the fusion of atoms, which in nature is the process creating the elements. The principles of fusion are straightforward. Fusion depends on temperature. The higher the temperature, the greater the number of atoms that can be fused, and hence the "heavier" the resulting element. The greater the number of atoms, the greater the "binding" energy required. At a specific temperature, there is more energy available for release (for heat, light, etc) the smaller the number of atoms to be bound, and vice-versa. Interestingly, after iron (Fe, z=26), nucleosynthesis absorbs energy rather than releases energy[5.]

[5] Known as the "iron peak". Iron cannot be fused into anything heavier because of the insane amounts of energy and force required to fuse iron atoms. The atomic structure of iron is very stable, more so than most other elements. The process beyond is neutron capture, The only way to create substances heavier than iron is by a process called neutron capture, where neutrons penetrate an atomic nucleus—for example, an iron atom—which absorbs the neutrons, creating a new, heavier atomic nucleus and thus a new element.

Nucleosynthesis begins with temperatures of around 100 million (109) degrees Kelvin, upwards.

At the big bang, only hydrogen atomic nuclei were formed. At that point, hydrogen was a plasma, not a gas. Given the rapid drop in the temperature gradient, it would appear that fusion only began when the drop slowed down sufficiently to that point allowing nucleosynthesis of the lightest element, hydrogen. More, It was a cardinal happening, the first directional post which set the whole history of the visible cosmos down to man.

In the first pico-seconds of the big bang, temperature levels exceeded 1032 Kelvin, and energy levels 1019 GeV. Cosmic inflation expanded in space of the order of 1026 over a time of the order of 10−36 to 10−32 seconds. On the other hand , the universe supercooled down sharply to 10-22 Kelvins. From about 2 minutes of time, conditions were suitable for nucleosynthesis, the creation of atomic nuclei. By 20 minutes, the universe was no longer hot enough for nuclear fusion,

As the universe continued to expand and cool, things began to happen more slowly, drifting into the era of recombination, which began around 18,000 years after the big bang. Around 370,000 years the temperature of the universe fell to the point where atomic nuclei could combine with electrons to create neutral atoms. For the first time, electrons could to be trapped in orbits around nuclei, forming the first atoms. As might be expected, these were mainly hydrogen and helium atoms.

As a star begins to form, once the core temperature has reached about 10 million Kelvin, fusion of hydrogen occurs, releasing energy The tremendous heat given off causes the gas to glow creating a protostar. This is the first step in the evolution of a star.

In stars, initially gas pressure alone is not sufficient to withstand the gravitational collapse, and the core temperature will rise. A star of one-tenth the Sun's mass will have a core temperature of around 40 million degrees Kelvin and a star with 50 times the Sun's mass will have a core temperature of around 400 million degrees Kelvin.

As temperature rises, heavier elements are nucleocyntheised, with these being the major ones: hydrogen (H, z1), helium (He, z2), carbon (C,z6) nitrogen (N, z7), oxygen (O, z8), phosphorous (P, z15), sulfur (S, z16), chlorine (Cl, z17), sodium (Na, z11), magnesium (Mg, z12), potassium (K, z19), calcium (Ca, z20), and iron (Fe, z26). Hydrogen fuses into Helium and largely disappears, and Helium fuses into Carbon at 200 million Kelvin..

On average, heavier elements are less abundant in the universe, but some of those near iron are comparatively more abundant than would be expected. Heavier elements are also made during a supernova and neutron star collisions.

Nucleosynthesis takes place when a star is in the Main Sequence of its life cycle. When it cools and it typically forms a red giant, nucleosynthesis ceases.

Hydration of the Cosmos

Water is crucial for life as we know it on Earth. The molecule water (H_2O) comprises two hydrogen atoms and one oxygen atom chemically bonded together.

All hydrogen atoms were created about 380,000 years after the big bang. Oxygen, on the other hand, was created much later in the nuclear furnaces of individual stars, towards the end of their life cycles. This would only have begun after the Cosmic Dawn, a billion year later.

Then that oxygen had to disperse and unite with hydrogen in significant amounts. To form water, they must be subjected to an energy charge.

Water was finally formed when dust and debris, also created by stars, passed through oxygen in hydrogen-filled space, delivering the necessary energy, forming icicles. Water was therefore first formed in deep space. The latter was then carried on to planets, etc or accumulated in space.

Since the earliest stars would have taken some time to form, mature, and die, it was presumed that it took further billions of years for oxygen atoms to disperse throughout the universe and attach to hydrogen to produce the first interstellar "water."

Most of the water in the universe is nowadays created by reactions on the surface of interstellar grains of dust. The general impression is that today space is pretty “saturated” with icicle-water.

In the early universe, there would have been much less oxygen as well as dust in the interstellar medium. It would have taken eons of years before the interstellar medium held significant quantities of ice-water to supply the planets.. This would have been the determining factor for the beginning of life.

New theoretical work finds that water vapor could have been just as abundant in pockets of space a billion years after the Big Bang as it is today.(If vapour, why not ice to follow.)

The first generation of stars are believed to have been massive and short-lived. Those stars generated elements starting with the light elements like oxygen, which then spread outward via stellar winds and supernova explosions. This resulted in "islands" of gas enriched in heavier elements, including oxygen. Even these islands, however, were much poorer in oxygen than gas within the Milky Way today.

The new research poises that the universe’s first reservoirs of water may have formed much earlier than previously thought - less than a billion years after the Big Bang, when the universe was only 5 percent of its current age.

Researchers have found that at temperatures around 300 degrees Kelvin (27 degrees Celsius), the formation process became very efficient, and concluded that in the gas phase of the universe abundant water could form despite the relative lack of raw materials.

They now increasingly believe that it is possible to have built up significant quantities of water earlier in the “gas phase “ (pre-stellar) of the universe, without much enrichment in heavy elements. They are checking out the proposition that water could exist in the gas phase within molecular clouds that would form later generations of stars and planets.

The research is also moving to address questions such as to how much water could have existed as interstellar ice, as in our own galaxy, and what fraction of all the water might actually be incorporated into newly-forming planetary systems.

We might make the observation here that water became the reductant that enabled photosynthesis, which supplied both the necessary levels of energy and oxygen for advanced life.

Pre-Biological Evolution of Organic Matter

Organic compounds are compounds containing carbon and hydrogen. All organic compounds are biological. They have each evolved to serve a biological function. There are myriads of organic compounds. Every living thing on Earth is a skinful of organic compounds. They only exist where there is life, and they constitute living matter. So, where there is no life, there should not be any organic compounds. If life only exists on Earth, we should not expect to find organic compounds elsewhere. The corollary however is that if they are found elsewhere they would be a signature of life.

The big mystery has been if there were no organic compounds arounds, how did the first proto-organisms make them and come to life.

Recent researchers in cosmic biology have been investigating the chemical evolution of molecule compositions in the universe, and the mass distribution of interstellar and intergalactic molecules

The latest theory, which is capturing a lot of attention, focuses on the evolution of molecule masses and suggests as a natural principle operating in the cosmos that small molecules grow by random diffusion and large molecules by a preferential attachment, a process leading eventually to life's molecules. The process has taken place following the big bang, like the condensation and dispersal of water. One suggestion is that it may have begun as early as 185 billion years after the big bang. Others speculate that the process may be more realistically associated with dispersion processes of the star lifecycle, in which case it will directly impact their planets.

There is considerable evidence that there has been much organic material brought to Earth by the bombardments of comets, meteorites and asteroids. As these missives originate within the Solar system, including the Ord Belt, the evidence gels with the new theories, even provoking speculation that life exists or has existed within the Solar system before Earth and may have been brought here.

Lastly, many if not most of the organic compounds can today be artificially synthesised with modern science, and many can be synthesised in labs simulating early Earth conditions. The same could be the case in different space conditions. It suggests that the prebiotic environment on Earth was well prepared to facilitate the birth of life.

We leave the matter on the note that it might well be part of the cosmic design to include the provision of pre-biotic organic matter, like water. It would explain evolution’s choice that Earthlings would be a carbon-people. It also expands the likelihood of more life in the universe than we can know

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Chapter Two
The Solar System

Milky Way

A future traveller plotting his way to Earth on his GPS may well start by coding in the galactic quadrant reference of the Pisces–Cetus Supercluster Complex. It is a galaxy-filament estimated to be about one billion light-years long and 150 million light years wide. Then he should find within it and code in the reference for the Virgo Supercluster (Virgo SC). The Virgo SC is one of about 10 million superclusters in the observable universe and has some 100 galaxy groups. Among the latter, he should locate the Virgo Cluster and enter its Local Group. The Local Group in turn consists of three large galaxies – the Andromeda galaxy (biggest), our Milky Way (2nd-biggest) and the Triangulum galaxy (3rd biggest), along with 50 or so much smaller dwarf galaxies . The first two galaxies are linked in a dumbbell shape; the Milky Way and its satellites form one lobe, and the Andromeda Galaxy and its satellites constitute the other. Andromeda, although the galaxy next door, is 2.5 million light-years from the Milky Way. Both are moving toward one another.

Plot the Milky Way on the GPS, and then the Sun, and then steer for home. We should compensate in course corrections for the fact that the Milky Way-Local Group overlaps another huge super-cluster, the Laniakea Supercluster, next to the Virgo Supercluster, in which lies a powerful gravitational node known as the Great Attractor that exerts a significant pull over our Local Group and all within.

The Milky Way is the galaxy that includes the Solar System, It is a medium-sized disk-shaped spiral galaxy, with a diametre or length of 100,000 light-years but only about 1,000 light-years thick at the spiral arms (more at the bulge). Its name describes the galaxy's appearance at night from Earth. Recent evidence suggests that a dark matter area, also containing some visible stars, may extend the diametre to nearly 2 million light-years.

Astronomers believe that our own Milky Way galaxy is approximately 13.6 billion years old. The oldest stars in the Milky Way are nearly as old as the universe itself, probably formed shortly after the Dark Ages.

The Milky Way has several satellite galaxies. It is estimated overall to contain 100 billion stars and at least that number of planets. The Galactic Centre is an intense radio source known as Sagittarius A, which is a massive black hole of 4,100 million solar masses.

The Milky Way still has star formation regions, most famously the nearby Orion Nebula. Nevertheless, astronomers have concluded it is far past its best years, with a rate of star formation that might be classed as “mostly dead” – just one to two stars a year by some estimates, two to five in others. The Milky Way is predicted to end in its collision with Andromeda about 4.5 billion years from now.

The Solar System is a star system in the Milky Way at a radius of about 26,000 light-years from the Galactic Centre. It is located in a Local Bubble suburb on the inner edge of the Orion Arm, one of the inner spiral arms of the galaxy.

It is very difficult to count the number of stars in the Milky Way from our position inside the galaxy. Our best estimates tell us that the Milky Way is made up of approximately 100 billion stars These stars form a large disk whose diameter is about 100,000 light years” (NASA).[6] I find these figures difficult to handle. It means we encounter 2.7 stars every one light year in a straight line, or if we squeeze them in into the thickness of the galaxy of 1,000 light years, we encounter one star every 0.365 light-days.

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6 https://imagine.gsfc.nasa.gov/science/objects/milkyway1.html#:~:text=It%20is%20very%20difficult%20to,is%20about%20100%2C000%20light%20years.

On the other hand, we know it takes 26,000 light years to get to the Galactic Centre, while the nearest star-system, Alpha Centaurus, is 4.24 light-years away.

The Solar System is in and near the centre of the Milky Way. It rotates as part of the galaxy on its own "galactic orbit" once every 212 million years. (The last time it was here – where we are today – we had dinosaurs.)

The life-span of a human being is under 100 years, At our present space speeds, it takes us about 20,000 years to cover the distance of one light year. It will take us 540 million years to reach our own Galactic Centre inside the Milky Way. Our own Sun would be dying by then.

Within the Milky Way

The Orion Arm @ Orion-Cygnus Arm is actually a minor inner spiral arm of the Milky Way, approximately 10,000 light-years long and some 3,500 light-years across.

By comparison, the whole Solar System is very small, with a heliospheric diametre of roughly 200 AU =0.003 light years. It resides in a relative cavity or empty space in the Arm's Inter Stellar Medium (ISM), known as the Local Bubble, about halfway along the arm's length.

The Solar System has been traveling on its galactic orbit through the region currently occupied by the Local Bubble for the last five to ten million years Its current location lies in the Local Interstellar Cloud (LIC), a minor region of denser material within the Bubble.

We get some impression of the size and internal spacing by looking across at our 10 largest neighbouring (stars) suns of the Milky Way many of them familiar objects in Earth's night sky.:

10.Antares	Size: 883 x Sun.	Distance from Earth: 550 light-years
9. Betelgeuse	Size: 887 x Sun,	Distance from Earth: 643 light-years
8. KW Sagittarii	Size: 1,009 x Sun,	Distance from Earth: 7,800 light-years
7. VV Cephei A	Size: 1,050 x Sun,	Distance from Earth: 4,900 light-years
6. Mu Cephei	Size: 1,260 x Sun,	Distance from Earth: 6,000 light-years
5. KY Cygni	Size: 1,420 x Sun,	Distance from Earth: 5,000 light-years
4. V354 Cephei	Size: 1,520 x Sun,	Distance from Earth: 9,000 light-years
3. RW Cephei	Size: 1,535 x Sun,	Distance from Earth: 3,500 light-years
2. VY Canis Majoris	Size: 1,420 x Sun,	Distance from Earth: 3,900 light-years
1. UY Scuti	Size: 1883 x Sun,	Distance from Earth: 5,219 light-years

The closest system is Alpha Centauri, with Proxima as the closest star in that system, at 4.24 light-years. The brightest, most massive and most luminous object in the sky is Sirius A at 8.61 light-years. These would all be within the Local Interstellar Cloud.

Solar Planetary System

The Solar sytem was formed 4.6 billion years ago from the gravitational collapse of part of an interstellar molecular cloud into a star-forming nebula, caused probably by an exploding supernova. This one also consisted mostly of hydrogen, with some helium, and small amounts of heavier elements fused by previous generations of stars.

The part that would become the Solar System condensed under gravity, which also induced its rotation The centre became a dense and hot pro-star, eventually reaching fusion conditions and the birth of a star – our Sun

As the proto-star rotated, it began to flatten into a proto-planetary disk, in which dust and gas coalesced. The planets formed by accretion from this disc. Hundreds of proto-planets may have existed in the early Solar system, but they either merged or were destroyed or ejected, leaving the present planets, dwarf planets, and leftover minor bodies .

In time, there came to be eight planets, in order from the Sun - four terrestrial planets, named Mercury, Venus, Earth and Mars, two gas giants named Jupiter and Saturn, and two ice giants named

Uranus and Neptune. The terrestrial planets have a definite surface and are mostly made of rock and metal. The gas giants are mostly made of hydrogen and helium, while the ice giants are mostly made of volatile substances such as water, ammonia, and methane.

Six planets have satellites or moons orbiting around them. All the giant planets and a few smaller bodies are encircled by planetary rings composed of ice, dust and sometimes debris.

Today, precisely 99.87% of the Solar system's mass is made up by the Sun and most of the remainder by the planet Jupiter. The planetary diametre of the Solar system is roughly 200 AU[7] (30 billion km).

There are an unknown number of smaller dwarf stars and innumerable small bodies orbiting the Sun. These objects are distributed in the asteroid belt between Mars and Jupiter, and beyond Neptune's orbit in the Kuiper Belt, an area known as the Scattered Disk and further out in the Oort Cloud.

The Solar stream is a stream of charged particles which flows outwards from the Sun, and creates a bubble-like region known as the heliosphere. The heliopause is the point at which pressure from the solar wind is equal to the opposing pressure of the ISM and extends out to the edge of the Scattered Disc. Technically, it is the boundary of the Solar System. The Oort Cloud is like a thick bubble of icy debris beyond the Solar system, extending a good way round it, and stretches a distance roughly a thousand times after the heliosphere. Beyond is the end of the Solar system.

The Sun

As the Sun is our origin, source of energy and life, continually impacts us and determines our longevity, we take a closer look at it. By mass, the Sun is mostly hydrogen (92.1%) and helium (7.9%). Various metals make up less than 0.1%, the reminder.

Basically, the Sun is a ball of plasma, held together by its gravity, a huge glowing sphere of hot gas. Most of this gas is again hydrogen (about 70%) and helium (about 28%). Carbon, nitrogen and oxygen make up 1.5% and the other 0.5% is made up of small amounts of many other elements.

The temperature of the sun's surface is about 5,726^{o} Celsius (or 5 999.15^{o} Kelvin). Nothing could live on the Sun, but its energy is vital for most life on Earth.

The Sun’s Core

The temperature in the Sun's core is about 27 million degrees Celsius (or 27,000,273 Kelvin**)** – hot enough to sustain nuclear fusion. This creates outward pressure that supports the star's gigantic mass, keeping it from collapsing.

Fusion occurs when protons of hydrogen atoms violently collide and fuse to create a helium atom. – known as a PP (proton-proton) chain reaction. The Sun fuses about 620 million metric tons of hydrogen every second. It generates an enormous amount of energy in its core.

Every 1.5 millionths of a second, the Sun releases more energy than all humans consume in an entire year. Without it there would be no light, no warmth, and no life. Its heat influences the environments of all the planets, dwarf planets, moons, asteroids, and comets in our solar system

Only a small part of the solar energy reaches the outer layer of the earth's atmosphere.
About 29% is reflected back into space, primarily by clouds, but also by other bright surfaces and the atmosphere. Thus, about 71 percent of the incoming solar energy is absorbed by the Earth system. In fact, it takes the only 0.00000005% of the Sun’s total energy output to keep us alive - while for us we cannot survive without it. It is called complete dependency.
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The Sun is only a medium-sized star. But few people realise how HUGE a reality it is from Earth. It’s diameter is 1.4 million km as against the Earth which is only 12,742 km wide. It would take more than

[7] AU means Astronomical Unit, the distance between the Sun and the Earth. 6,3241.1 AUs =1 light year.

330,000 Earths to match the mass of the Sun, and it would take 1.3 million Earths to fill its volume.. We are less than a dot.

Fortunately, the Sun is some 150 million km away – you can put 107 suns in between – which offers some degree of insulation and allows some 8 minutes to take action in the event of any untoward occurrence on the Sun, which can be frequent.

For most practical purposes, we take its presence in the sky for granted, quite often as bothersome. In fact, it totally determines our existence, and it totally out-scales us in power and impact. The Sun is incredibly volatile and unpredictable. We live next to a ball of fire.

The Sun's energy sustains the whole Solar system, It generates this energy as electromagnetic radiation, across the full frequency spectrum –microwave, radio-waves, light, x-rays and gamma rays. It takes 1,700 years to reach the surface, passing through several layers. The interior regions include the core, the radiative zone, and the convection zone.

The Sun's Atmosphere

Next is the photosphere, the visible surface of the Sun. The Sun does not actually have a solid surface. The photosphere has a thickness of about 600 km with the temperature coming down to 5,500^{o} Celsius. Most of the energy that we receive is the visible or white light that radiates from this thin relatively cool photosphere.

Next follows the chromosphere, the intermediate layer of the Sun's atmosphere. The hydrogen atoms in this layer absorb much of the energy that passes through from the surface. This energy is converted into red light that is emitted into the corona.

Finally, we have the corona, the outermost layer of the Sun's atmosphere. Mysteriously, the corona is much hotter than the Sun's surface, sometimes reaching about 2 million degrees Celsius. Researchers speculate that it is possible that millions of nanoflares at the surface are creating the energy that heats up the corona.

In spite of its high temperature, the corona yields relatively little heat, because of its low density, The corona is also usually hidden by the bright light of the Sun's surface

The Heliosphere

The corona continually varies in size and shape as it is affected by the Sun's magnetic field. Once material leaves the corona at supersonic speeds, it becomes the solar wind, which forms a huge magnetic "bubble" around the Sun, called the heliosphere. The heliosphere extends beyond the orbit of the planets of the Solar System. Thus, Earth exists inside the Sun's atmosphere. Outside the heliosphere is interstellar space

The Sun's Magnetosphere

The Sun generates a magnetic field that extends out into space. This forms the inter-planetary magnetic field which pervades the whole Solar system. The field is carried through by the solar wind. The Sun's magnetic field dominates the heliosphere. Since the Sun rotates, the magnetic field spins out into a large rotating spiral, known as the Parker spiral.
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Approximately every 11 years, the Sun's geographic poles change their magnetic polarity – that is, the north and south magnetic poles swap. During this cycle, the Sun's photosphere, chromosphere, and corona change from quiet and calm to violently active. Sunspots, solar flares, and coronal mass ejections are common during this period.

Solar activity can release huge amounts of energy and particles, some of which impact the Earth, causing geomagnetic storms. .

The Sun rotates on its axis as it revolves around the galaxy. Its spin has a tilt of 7.25 degrees with respect to the plane of the planets' orbits. Since the Sun is not solid, different parts rotate at different rates. At the equator, the Sun spins around once about every 25 Earth days, but at its poles, the Sun rotates once on its axis every 36 Earth days.

The Sun's Age

Our Solar System began 4.6 billion years ago. Geologists have (so far) found that the earliest signature of life on Earth dates back to 13.7 billion years ago. It took slightly under one billion years for the Sun to attain equilibrium and the Solar system to settle down to conditions that supported life on Earth.

Now a yellow white main sequence star, the Sun has already past the peak of its own life cycle and is settling into maturity. It has another 4.5 billion years' supply of hydrogen-helium to go.

The Planets[8]

A planet must be a satellite of a star, ie. orbiting it, and not be large enough to carry out fusion on its own – or it would be a star. And it will have sufficient gravitational integrity to form a sphere, which means attracting smaller objects and repelling the grasp of other bodies.

Size varies. Jupiter is large and Mercury is small Their composition and their physical characteristics vary, depending on their location, their history and their stage of evolution.

Planets nearer their mother-star receive more energy, with higher surface temperatures. If we can use the expression, "mainstream" planets are formed with a hot denser centre due to their original material and gravity, which provides internal heat until exhausted.

Composition of Planets

All matter making up the planets were created by nucleosynthesis in the stars, or derived therefrom. They condensed from the extrusions of the galaxies and material in the surrounding nebula, or were delivered by meteoric and other bombardments.

For our purposes, suffice it to say that all planets are made of the same stuff, and that planetary matter is substantially composed of minerals and rocks.

Minerals may be elements or compounds, ie elements bound together chemically. By mineral we include all forms, whether solid, liquid or gas. They may in practice be mixed, without losing their identity.

Planetary compounds are inorganic compounds. When life emerged on Earth, it created a range of biological compounds which came to be known as organic compounds. We shall be dealing much with this subject later.

Rocks are solid aggregations of minerals compressed together. When molten or plastic beneath the surface they are said to be magma, and when molten on the surface, lava.

They may be igneous (original), metamorphosed (changed by tectonic pressure), or sedimentary (laid alluvially and compressed). Judging from Earth experience, advanced life on land is best supported by soil rich in minerals laid down by the weathering of rocks.

The process of gravitational differentiation results in the heavier elements settling at the core, and the lighter elements forming the mantle, the crust and the atmosphere.

[8] https://spaceplace.nasa.gov/planet-what-is/en/#:~:text=Gravity%20collected%20lots%20of%20material,and%20dust%2C%20eventually%20forming%20planets.

The surface of the crust is dominated in the early stages by meteor bombardments (cratering) and savage gravitational ruptures, and in the later stages by tectonics, volcanism, lava flows and the atmosphere (geomorphology).Where conditions are right, water in liquid form collects in the lower and cooler parts.

Planets have a life expectancy tied to their star. They may survive a supernova and continue as old dead planets or as a rogue planet. If a planet is life-habitable, it will be during the Main Sequence period of their star's life cycle.

Nurseries of Life

The planets are the only places in the universe that could possess the conditions where life as we know it could emerge.

To initiate itself, life requires a happy balance of liquid water, energy and the presence of the right mineral consumables. Water is present almost everywhere in the Inter Stellar Medium, and can subsist as gas (steam), liquid (water) or frozen (ice) depending on the temperature and pressure. It is only on a planet with the optimum combination of the latter and terrain that water can exist as bodies of liquid on the surface. Conditions are most favourable when the latter is in optimal contact with the energy of sunlight, nestled comfortably on a solid surface and lapping mineral rich earth-rock.

To support life, a planet must have the right combination of sunlight and heat, the former to provide the energy for photo-synthesis and or other life support needs. Taking the Earth as the norm, by far the greater source of energy for direct life support is sunlight. Internal heat is considerable but mainly affects conditions on the surface, including tectonics and volcanism. This narrows prospective planetary locations to a limited band not too near or far from the mother-star.

A mother-star's radiation is a primary factor affecting a planet's ability to support life.
By their rotation planets generate a magnetic field of their own. In Earth's case, it filters out UV radiation which Is harmful for life, maintains the ozone layer and keeps the atmosphere from escaping. When Mars lost its magnetic shield, it lost its atmosphere and all prospects of sustaining life.

The violent disturbances of the Sun's corona can disrupt life, and has been associated with past exterminations and near extinction of life. Needless to say, crashes of meteorites and comets have been responsible for the same.

Given the extraordinary size and diversity of the universe, subject to local conditions, planets are the logical location to look for life, and life to look for a home.

By the nature of their formation and their history, not all planets offer the above. Some planets are too cold and others too hot. There is a band in between, with planets of the right characteristics, known as the habitable zone of a star system.

Formation of our Planets

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During the formation of our system, where the outer regions of our disk were colder, tiny fragments of ice hitched a ride with dust. Dirty snowballs amassed into giant planetary cores. These colder regions also allowed gas molecules to slow down enough to be drawn onto a planet. This was how Jupiter, Saturn, Uranus and Neptune are thought to have formed. Jupiter and Saturn are thought to have formed first and quickly, within the first 10 million years of the birth of the Sun

Jupiter took most of the mass left over after the formation of the Sun, ending up with more than twice the combined material of the other bodies in the solar system.

Research suggests that Uranus and Neptune were actually potential gas giant cores that formed in the same region as Jupiter and Saturn but lost the race to reach runaway gas accretion.

After the icy giants formed, there was not a lot of gas left for the terrestrial planets to accrete In the warmer parts of the disk. Rocky planets began to form. Planets that are rocky like Mercury, Venus, Earth and Mars took tens of millions of years to form after the birth of the Sun.

Habitability of our Planets

Not all our planets are suitable for life

Table 2

The Planets of the Solar system

	Name	Mass (1=Eart)	Solar Radius (million km)	Solar Orbit (Earth days)	Mean /Range Surface Temp (Celsius º)	Surface/ Crust	Atmo-sphere
1	Mercury	0.06	37m	87.97	M=67º R=43 to -160º	rocky crust	Only thin exosphere.
2	Venus	0.82	108m	224.7	M=464º R=482 to 438º	Volcanic Highlands and lowlands	Carbon dioxide
3	Earth	1.00	*150m	365.2	M=14º R=58 to -88º	Land and standing. body of the Oceans	78 Nitrogen 21% Oxygen
4	Mars	0.11	220m	689.0	M=-60º R=20 to --15º	Volcanic Highlands and lowlands Plenty of Water under-Ground	Carbon. Dioxide, Methane
	Asteroid Belt		340m to 490m				
5	Jupiter	318.00	780m	4332.6	M--108.95º	No land Surface Swirling gases Liquids/water deeper down on its Moon Europa .	Hydrogen Helium, Methane Ammonia
6	Saturn	95.00	1.429m	10,591 .7	M=-197.2o	No land surface Mostly swirling gases and icy liquids/water below	Hydrogen Helium, Methane Ammonia
7	Uranus	14.54	2,870m	30,679 .3	M=-197.2o	No land surface Mostly Icy swirling. gases and icy liquids/water below	Hydrogen Helium, Methane Ammonia
8	Neptune	17.00	4,500m	60,263 .0	M=-201o	No land surface. Unexplored	Hydrogen Helium, Methane Ammonia

The Earth is the only planet in our Solar System that does support life. Given our limited travel access to the universe, it is the only planet with life that we know of.

The Earth has proceeded to evolve three further stages of life, which have other requirements (eg oxygen).

We may as well dispose of the special question of Mars here. Being the next outer planet (fourth from the Sun) its temperature overlaps on both sides of the norm for habitability. It has large reserves of water underground but the latter can only remain liquid in the lowest places in the summer months for a brief period and not form a standing body – in fact optimally 6,000 m below the surface. And the summer is too short. When the atmosphere disappeared, all the surface water evaporated due to the drop in pressure and raised temperature.

The evidence is that Mars earlier was a wet planet, with surface drainage and standing water and a supportive atmosphere. It is even thought there could have been early microscopic forms of life there. At some stage, the planet lost the protection of its magnetic shield, and all of its atmosphere after that. Mars is today a dry planet with no signs of life. In this decade, man hopes to set foot on Mars and succeed in finding traces of past life.

The global ocean on Jupiter's moon Europa contains about twice the liquid water of all the Earth's oceans combined. New research suggests that there may be plenty of oxygen available in that ocean to support life, a hundred times more oxygen than previously estimated.

Recent studies from September 2019 concluded that Venus may have had surface water and a habitable condition for around 3 billion years ago and may have been in this condition until 700 to 750 million years ago.

The best places to look for life are where the ocean overlies warm rock. This may be the case inside the moons Europa (Jupiter) and Enceladus (Saturn), but chemical reactions with the rock would make the liquid water salty.

Today, Venus has some of the most inhospitable surface conditions in the entire solar system. But going by the standard definition of "habitable zone", Venus sits inside because the current definition of habitable zone only examines the amount of sunlight reaching a planet.

Habitable Exoplanets

An exoplanet is any planet beyond our Solar system. Most orbit other stars, but free-floating exoplanets, called rogue planets, orbit the galactic centre untethered to any star.

It has been gestimated that there are 6 sextillion stars in the universe, with some 100 billion in the Milky Way alone. Even if we assume that there might be only one planet on the average per 1000 stars in the Milky Way, we are looking at 100 million exoplanets.

Our interest is in an exoplanet that can support life. The technical definition of a habitable zone is the distance from a star at which liquid water could exist on the orbiting planets' surfaces. Habitable zones are also known as "Goldilocks' zones, where conditions might be just right for life.

To be habitable, using Earth as the model, a planet must, additional to standing liquid water, have the correct atmosphere, temperature and pressure, not suffer from damaging radiation and a solid and stable surface, possibly under water, with the standard supply of minerals.

Exoplanets are too far and too small to be seen with telescopes. The first exoplanets were in fact discovered only in the 1990s. Since then scientists have identified thousands using a variety of detection methods. Basically, by measuring exoplanets' sizes (diametre) and masses (weight), we can determine their compositions ranging from very rocky (like Earth and Venus) to very gas-rich (like Jupiter and Saturn).

Of the 1,780 confirmed planets so far beyond our solar system, only 16 are located in their star's habitable zone. Size also matters: a planet that is too small cannot maintain an atmosphere; and one that is too large will have a crushing atmosphere.[9]

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[9] See NASA website - https://exoplanets.nasa.gov/faq/43/how-do-planets-form/#:~:text=Scientists%20think%20planets%2C%20including%20the,within%20the%20disk%20to%20collide.

Proxima Centauri b (or Proxima b), 4.24 light years away, is our closest exoplanet orbiting within the habitable zone of the red dwarf star Proxima Centauri, which is our closest star and part of the larger triple star system Alpha Centauri.

Kepler-452b, the first approximately Earth-sized planet to be found in a Sun-like star's habitable zone. It is 1,800 light years away.

Earth

So far, the Earth is the only known planet that is inhabited. And it has evolved the full range of life forms from microbe to man (and human).

Size and Structure

Of the four Internal planets, Earth is the largest, with a diametre of 12,756.2 km and a circumference at the equator of 40,075 km. Because of its rotation, the Earth bulges at the equator and flattens at the poles, creating an oblate spheroid

It is 150 million km from the Sun and about 40 million km from Venus, its nearest neighbour, (the latter depending on their relative locations in orbit). Earth has one Moon, some 384,400 km distant.

Earth is the densest major body in the solar system at 5.52 grams per cubic inch. It's composed of 34.6% iron, 29.5 % oxygen, 15.2 % silicon, 12.7% magnesium, 2.4 %nickel, 1.9 % sulfur and 0.05 % .titanium.

The Earth’s core, 3,470 km, consists largely of nickel and iron. The outer region is liquid and the inner part is solid. The liquid outer part flows around the inner core with the Earth’s rotation, generating a magnetic field that shield’s the planet’s surface from certain kinds of cosmic and solar radiation.

The core is hot That's because it's extremely well insulated. Above the core is a hot layer called the mantle. It's a whopping 1,800 miles thick and has the consistency of caramel, keeping the heat in. "The mantle is basically a thick jacket.

The first source of heat is that left over from the formation of the Earth. The next source is gravitational pressure and the rotation of the Earth. The last known source of heat is the radioactive decay of elements in the inner part of the Earth. If it cooled down, the planet would grow cold and dead.

The body of the mantle is essentially magmatic, viscous molten heavy simatic rock in which convection takes place transferring heat and pressure to the surface.

Above the mantle sits a thin lithosphere or crust of between 5 to 70 km thick. The crust is made up of the “other minerals,” mainly in the form of rock, magma, and soil, The junction or divide between the crust and mantle is partially molten allowing the crust to move around in response to tectonic and volcanic pressures.

Crust

The crust of the Earth is made up of continental and oceanic plates. These tectonic plates are made of lighter sialic rock. They are solid and rigid. When pressure builds up underneath, they fissure, fold and warp, break out in volcanism, and in extreme cases separate by “continental drift.”

Surface Features.

Today, the oceans occupy 71% of the Earth's surface, with deeps going down to 10,000 metres. The land itself is made up of seven continents. The land-surface comprises high fold mountain chains and blocks of old massifs, further sculptured by tectonics and volcanism. The landforms have in turn been weathered by wind, rain and rivers into highlands, lowlands, flood plains and island arcs.

The average surface temperature of the Earth is 14-16^{o} Celsius, including the sea. This is well within the limits for the existence of standing water. The. 23% tilt of the Earth's axis produces the distinctive seasons and the climatic zonings we experience. The polar regions are permanently capped with ice, also the highest peaks. The oceans become progressively colder below, where not heated by thermal vents.

Of the total land surface area of about 149 million square km, some 33% is desert (hot and cold) and 24% is mountainous, leaving only about 43% as habitable land. The latter have great rivers that water and support life in the interior. The oceans are independently teaming with life. The most liveable parts of the Earth are the tropical and temperate regions.

Composition

A planet supporting Earth-type life will have a menu of life-needed minerals.

Table 3 gives a quick comparison of the elements on Earth against the cosmic scale, with the typical composition of terrestrial vegetation to indicate those supporting basic life:

Table 3
Relative abundance of Elements on Earth
(Percentage %)

Element	Cosmic Average	Earth Crust	Earth Atmosphere**	Life (Terrestrial Vegetation)
Hydrogen	87	3		16
Helium	12	0		0
Carbon	0.03	0.1		21
Nitrogen	0.008	0.0001	78	3
Oxygen	0.06	49	21	59
Neon	0.02	0		0
Sodium	0.0001	0.7		0.01
Magnesium	0.0003	8		0.04
Aluminium	0.0002	2		0.001
Silicon	0.003	14		0.1
Sulphur	0.002	0.7		0.02
Phosphorus	0.00003	0.07		0.03
Potassium	0.000007	0.1		0.1
Argon	0.0004	0	0.93	0
Calcium	0.00001	2		0.1
Iron	0.002	18		0.005
Carbon-dioxide Greenhouse gases *** Water			0.03 0.04	

*0=<10^{-6} presence
**including methane, ammonia and trace elements

One could say life on Earth was determined by the materials found on Earth. Some 99% of terrestrial vegetation is made up of oxygen, carbon, hydrogen and nitrogen, with calcium, potassium and silicon forming one-third of the other 10 trace minerals forming vegetable life. Excluding three other trace elements (argon, neon and helium) the total vegetable list of 14 elements make up the same minerals as contained on Earth and in its atmosphere. There is no issue here of significant other constituents of planet Earth (or for that matter the cosmos) being not being used to make life.

Atmospheric Features

The early atmosphere was essentially hydrogen and a combination of the other gases "outgassed" by volcanoes and a cooling Earth, including nitrogen and carbon di-oxide.The hydrogen, being the lightest, progressively escaped into space.

There was no oxygen in the air. It was a "reducing" atmosphere. Oxygen of its nature tends to combine with or "oxidate" minerals, and hence got absorbed into the early Earth. It took life itself in due course to intervene and generate and maintain supplies of (biological) oxygen to support subsequent stages of evolution. The preceding table show that oxygen constitutes 59% of the make-up of vegetable life, and makes up 21% of the present atmosphere. We shall deal with that later. At this point we may wonder whether this provision itself was cosmically pre-determined or a happy chance, and whether it has occurred elsewhere or on Earth only.

Finally we may touch on carbo di-oxide, shown above as making up 0.03% of the present atmosphere. Scientists believe there was much more in the early atmosphere. This was the second area of biological intervention. Photosynthesis, which produced the oxygen, also captured carbon di-oxide directly from the air synthesising the same (by carbon fixation) into sugars and carbohydrates needed to support the whole chain of life. In the process it established the carbon cycle, which has regulated the percentage of carbon di-oxide down to its present levels. Carbon di-oxide has a critical hot house effect (retains solar heat). Failure to retain the planet's temperatures within present life-supporting margins can spell the extinction of all life.

Water

Since the Earth cooled down, it has been amply supplied with standing water. A significant quantum came as hydrates and hydrides in the original minerals and rocks. Over time, volcanoes released massive amounts of water from the inner Earth to the atmosphere. A significant quantum was also delivered as ice-coatings during the early bombardments. By Achaean times. Earth was a water-world before it became a continental planet.

Over millions of years, much of this water has been recycled between the inner Earth, the oceans and rivers, and the atmosphere. This cycling process means that freshwater is constantly made available to Earth's surface . The water that we drink today is the same water that woolly mammoths, dinosaurs, and the first humans ever drank! It was the same water that was the first used and is still used as the reductant in oxygenic-photosynthesis.

The general belief is that much if not most of the water on planets has been delivered from space by bombardments

Organic Compounds

It is increasingly believed that the organic compounds were formed and distributed following cosmogenesis, or if not at least following and as part of stellargenises. Comets, meteorites and asteroids consistently show evidence of organic compounds, in particular amino acids.

It is possible (but still to be confirmed) that organic compounds were delivered to Earth before the origin of life, and formed part of the pre-biotic soup in which life is envisaged to have begun.

Scientists also point out that most organic compounds can today be artificially synthesised in the lab. If the relevant elements were available in the early soup, our proto-microorganism may well have synthesised their organic compounds.

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PART B

Earth-Life Cosmic-Dance

Chapter Three
Emergence of Life

Overview

This part narrates the sequence of events associated with the emergence of life, best grasped as enabling contributions, respectively, by the Earth and the proto-organism involved, towards the currently attained product of evolution.

What we see is more than a partnership. We take a bird's eye swipe across the time-lines of both Earth's physical history and of life evolution, and discover they are very much one story, not two.

The story divides into a long Pre-Cambrian period of 3.5 billion years and a shorter Post-Cambrian period of 500 million years, separated by the Cambrian Explosion, which took place circa 545-525 million years ago.

The formation of the Earth began about 4.54 billion years ago. From different available indications, it took less than 400 million years to settle down and set the stage for the first act of our Earth-Life Cosmic Dance, the emergence of the single-cell microbe. (I work with 4.1 billion years ago as the most reasonable figure for this, for the present.)

Then, it took the latter a whopping 1.5 billion years to develop oxygen-based single-cellular life, and another whopping 1.0 billion years to multi-cellular life and eventually the first animal - altogether about 3.5 billion years to the latter, circa 650 million years ago. **During this period, the Earth would have travelled 16.5 times round the Milky Way.**

The Cambrian Explosion which followed marked the beginning of an amazing diversification and proliferation of life forms, conquest of the land and air, leading to the emergence of the hominid, and man, in the short space of a little more than 500 million years. The Earth would have completed only another 2.4 times round the Milky Way.

Our Carbon Identity

We are a carbon life-form.

Carbon (4.6%) is the fourth most abundant chemical element in the observable universe by mass after hydrogen (73.9%), helium (24.0%), and oxygen (10.6%). It is a non-metal.

Carbon atoms are unique because they can bond together to form very long, durable chains that can have branches or rings of various sizes and often contain thousands of carbon atoms.

Carbon compounds are defined as chemical substances containing carbon. More compounds of carbon exist than any other chemical element except for hydrogen.

The reason is carbon's ability to form stable bonds with many elements, including itself. This property allows carbon to form a huge variety of very large and complex molecules. Silicon and a few other elements can form similar chains; but they are generally shorter, and much less durable. In general bonds of carbon with other elements are covalent bonds, which is a feature of its chemical flexibility.

A covalent bond is a type of chemical bond formed when two or more nonmetal atoms share pairs of valence electrons to achieve a stable, filled outer electron shell. These bonds, which create molecules, are held together by the electrostatic attraction of the nuclei to the shared electrons.

Carbon is pre-eminently a biological construction material, in the form of biochemical organic compounds.

Organic Compounds

An organic compound is a member of a class of chemicals containing carbon atoms bound to one another and to other atoms by covalent bonds. All organic compounds have in common the presence of carbon atoms and hydrogen atoms. In addition, different organic compounds may contain oxygen, nitrogen, phosphorous, and other elements.

Carbon compounds that have no hydrogen are not organic. (Carbon dioxide (CO_2) does not have hydrogen and is therefore not an organic compound.)

Organic carbon compounds are far more numerous than inorganic carbon compounds. They are found in the cells of living organisms and collectively constitute the "living" component of the cosmos. In real life there, are nearly 10 million carbon-based compounds in living things.

By mass, about 96% percent of our bodies are made of four key elements: oxygen (65%) carbon (18.5%), hydrogen (9.5%) and nitrogen (3.3%).

Organic compounds are no longer defined as compounds originating in living things, as they were historically. Many can be and are synthesised nowadays – by abiotic chemistry – and even used as commercial products.

Organic compounds make up, serve and belong to living things, In the natural order of things, they originate or originated in a biological cell. I refer to them as "natural" or "biological" organic compounds, and unless indicated otherwise "organic compounds" mean that.

Pre-biotic availability of Organic Compounds

We shall review the current hypotheses on the above subject further on. At this juncture, we may note the following points:

. (a). It is likely that the carbon (together with hydrogen and the other seed minerals of organic compounds) were widely dispersed in the universe following the big bang, or if not following it, as part of stellar nucleosynthesis,

.(b). They are accordingly widely found in interstellar space and the planets. Experiments have shown that some (many, most?) of our organic compounds may in fact be synthesisable in space (including Earth) under optimal conditions – say with the right spark of lightning.

. ©. Our proto-organism then found a sufficient set of organic compounds in his primordial soup to kick-start life, and sufficient to develop whatever range of organic compounds was needed for evolution.

.(d). The alternative was that our microorganism had to define his biologically needed compounds from scratch, and by trial and error put together the first organic compound.

.(e) Obviously, how far and fast our proto-organism proceeded depended on the pre-biotic availability of organic compounds. If the relevant elements were available in the early soup, our proto-microorganism may well have synthesised the first organic compounds. Our ancestor microorganisms certainly went on to synthesise all the other organic compounds they needed thereafter.

All life on Earth is built from organic molecules, but simply finding organic molecules does not mean these molecules are linked to life. The molecules also can be made in lots of ways that do not involve living organisms.

The Earth was therefore pre-readied for life in this respect. Our proto-organism emerged, came into being, was born, took form and was a **product of the organic world**. Hence. Not surprisingly, we have turned out to be a carbon life-form.

It is now understood that the cosmos went on to synthesise carbon or organic compounds, among others, amino acids. These got distributed through the stellar life cycle and are found in the interstellar medium, on planets and on other objects.

Main Organic Compounds

Organic compounds are assembled by their living things in different forms to serve various functions. There are four major categories as follows. These, and their variants, are the primary corner-stones of the cell world.

.(1) Carbohydrates. A carbohydrate is an organic compound such as sugar or starch, used to store energy. Carbohydrates (cellulose) are the most abundant class of organic compound found in living organisms.

.(2) Lipids are a broad group of organic compounds which include fats, wax, vitamins, and phospholipids. The functions of lipids include storing energy, signalling, and acting as structural components of cell membranes. They also help with moving and storing energy.

.(3) Proteins are bio-polymeric structures composed of amino acids, containing mostly hydrogen, carbon, nitrogen and oxygen, linked together in chains. All proteins contain only 22 different amino acids classified by their properties. The linear number and order of amino acids are coded in our genes, a segment of DNA.

Proteins serve as structural support, biochemical catalysts, hormones, enzymes, building blocks, and initiators of cellular death. They also serve functions like organization, transportation, and defence.

.(4) Nucleic Acids. Nucleic Acids: Store and transfer genetic information necessary for life (eg, DNA, RNA).

Organic molecules

Organic molecules are any molecules containing organic compounds.. Examples include very small molecules like methane (CH4) and very large macromolecules like carbohydrates (glucose), lipids (triglycerides), nucleic acids (DNA), and proteins (the enzyme lactase).

Nucleotides.

Nucleotides are the building blocks of the nuclei acids RNA and DNA, the essential bio-molecules of life. A nucleotide is made up of a nitrogen-containing base (adenine, guanine, thymine, and cytosine in DNA, and adenine, guanine, uracil, and cytosine in RNA), a phosphate group, and a sugar molecule (deoxyribose in DNA, and ribose in RNA). DNA and RNA are polymers made up of many nucleotides

Nucleotides also play a central role in metabolism. They provide chemical energy for the many cellular functions, eg. protein and cell membrane synthesis, moving the cell and cell parts (both internally and intercellularly), cell division etc, and they are important co-factors of enzymatic reactions.

Amino Acids

Amino acids are the building blocks of proteins, which are the main building blocks of life. Amino acids are organic compounds that contain both amino and carboxylic acid functional groups

Although over 500 amino acids exist in nature by far the most important are the 22 amino acids incorporated into proteins. Only these 22 appear in the genetic code of life.

Proteins serve as structural support inside the cell and they perform many vital chemical reactions. Each protein is a molecule made up of different combinations of 22 types of smaller, simpler amino acids.

It has been further established that a variety of amino acids are easily produced under conditions which were believed to have existed on the primitive Earth or in the early solar nebula.

The most critical of the organic compounds for the emergence of life as we know it were the amino acids. The formation of amino acids and peptides[10] are assumed to precede and perhaps induce the emergence of life. Amino acids can form from simple precursors under various conditions. Surface-based chemical metabolism of amino acids and very small compounds may have led to the build-up of amino acids, co-enzymes and phosphate-based small carbon molecules. Amino acids and similar building blocks could have been elaborated into proto-peptides with peptides being considered key players in the origin of life.

While amino acids and consequently simple peptides must have been formed under different geochemical scenarios, the transition from an abiotic world to the first life forms is to a large extent still unresolved.

It is remarkable that our original incipient microorganism selected some 22 specific amino acids to form and sustain life and encoded for them in its (and our) genome. Today, all life depends on these amino acids. These same codes are found in our earliest known ancestors – even in viruses; so the selection happened very early. Some even suggest they were pre-selected

Geological-Evolution Timecope

It is helpful to have a tabulation up front of the stages and the time-lines of evolution, as per Table 3:

Table 4
The Geological-Evolution Timecope

Time*		**Life**
4.54 Ga		**Earth formed**
4.3 Ga	 4.28Ga 4.1 Ga 3.7 Ga	Earliest putative life-signature (hydrothermal). Earliest putative life-signature (land). First Microorganism Earliest fossils
3.5 Ga	3.48Ga 3.2 Ga	Start of Photo-synthesis.
3.2 Ga 2.1 Ga	2.8 Ga 1.8 Ga 1.6 Ga	First Cyanobacteria Great oxidation Event (GOE) Great Oxidation Crisis (GOC) Prokaryote survival Multicellular life Eukaryotic life
900 Ma	840 Ma	Neoproterozoic Oxygen Event (NOE)
650-541 Ma	650 Ma 650-538	First animal life Edicaran biota
541 Ma	**Palaeozoic eon**	
	540-525 Ma 380 Ma 300 Ma	Cambrian Explosion First land Vertebrates First land Plants

[10] - Peptides are short chains of 2 to 50 amino acids that act as essential building blocks for proteins like collagen, elastin, and keratin in the body..

252 Ma	**Mesozoic**	
	240 Ma 230-66 Ma	First Mammals Non-avian Dinosaurs
66 Ma	**Cenozoic**	
	66 Ma	200 Ma -first Hominins
	314 Ma	Homo Sapiens
	50 Ma	Modern Man

(*Ga = billions years ago. Ma=million years ago)

Pre-Cambrian period

We can only know what, where and when first life existed from signatures they left behind in the earliest rocks.

Oldest Rock

The oldest minerals from Earth's crust yet discovered are zircon crystals found (as detritus or "wash") in Archean metamorphosed sedimentary rock from the Jack Hills of southwestern Australia. Analysis of the zircon consistently provides dates over 4.0 billion years ago.

Another report states that the oldest in-place Earth rock is thought to be from the Acasta Gneiss in the Canadian Shield, determined to be about 4.0 billion years.

Earliest Evidence of Liquid Water

In addition, the oxygen isotope compositions of some of the zircons have been interpreted to indicate that more than 4.3 billion years ago there was already liquid water on the surface of the Earth, suggesting at least pockets of surface cooled. The presence of liquid water would indicate that life could have emerged very soon after the oceans began to form, from about 4.41 billion years ago.

Earliest Evidence of Life[11]

Fossilised microorganisms (microfossils) have been found in hydrothermal vent precipitates from an ancient sea-bed in the Nuvvuaqittuq Belt of Quebec, Canada. These may be as old as 4.28 billion years, the oldest evidence of life on Earth, dating back to the Hadean. Biologists now speculate that if life arose relatively quickly on Earth, then it could be common in the universe, a view I find very attractive – and if so, why not in the Solar System.

The possibility that terrestrial life forms may have been seeded from outer space has been considered. In January 2018, a study found that 4.5 billion-year-old meteorites found on Earth contained liquid water along with prebiotic complex organic substances that may be ingredients for life, if not of life elsewhere. We revert to this matter further on.

Other physical evidences of life include specimens of graphite, a biogenic substance, in zircon[12] in 3.7 billion-year-old meta-sedimentary rocks discovered in southwestern Greenland.

The earliest direct evidence of life on Earth is from microfossils of microorganisms permineralised in 3.465-billion-year-old Australian Apex chert rocks, although the validity of these microfossils is debated.

[11] - https://en.wikipedia.org/wiki/Earliest_known_life_forms#cite_note-NAT-20170301-2

[12] The zircon had specks of pure carbon, also known as graphite, preserved within its structure. These inclusions contained a common form of carbon known as carbon-12, along with unusually low levels of its heavier counterpart, carbon-13, possible life signatures..

In May 2017, a report indicated that evidence of microbial life on land may have been found in a 3.48-billion-year-old geyserite in the Pilbara Craton of Western Australia.

In July 2018, scientists reported that the earliest life on land may have been bacteria, around 3.22 billion years ago.

> "The earliest signs of life on a young Earth, around 3.5 billion years ago, have generally come from the ocean in the form of fossilized microbes within ancient rock. Now, scientists working in the Barberton Greenstone Belt in South Africa—where some of the oldest rocks on Earth are preserved—find evidence of terrestrial microbial life that they estimate is about 3.22 billion years old. The results, published today (23 July 2018) in "Nature Geosciences", represent the oldest signs of land-based life on our planet yet discovered."[13]

According to one authority, this work represents the oldest and least ambiguous work that we have so far that life existed on land already 3.2 billion years ago.

What we have above are putative signatures of life previously not thought occurring in the Hadean, encouraging evidence to build on, but far from proof.

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[13] - https://www.the-scientist.com/news-opinion/oldest-evidence-of-terrestrial-life-on-a-young-earth-64537

Chapter Four
A. The Hadean Eon
(4.6 to 4.0 billion years ago)

The Earth took shape as the third of four inner planets of the Solar system. It is generally accepted that the latter formed together, some 10 million years after the four gas and ice giants.

Typical of the internal planets, Earth was, during the first phase, a red hot glowing planet, literally a ball of plasma and molten rock,. There was no atmosphere. The sky was opaque and cloaked by a blanket of toxic gases (ie today's "greenhouse gases"), dust and debris. There was no ozone layer, but thee would have been hydrogen and water vapour. While continued accretion and the additional pressure increased terrestrial temperature, there was no means for heat to escape into space. It was thought therefore that the Earth remained hot for a considerable time. Recent evidence of the possible presence of liquid water and life-signatures in Hadean eon supports a newer hypothesis that the Earth did in fact cool down far more rapidly leading to the formation of the oceans in a little more than 100 million years. Researchers are hurriedly working out al the angles to this dramatic change of view.

Aside from attracting local orbiting stuff, the Earth was exposed to the considerable and sizeable lose matter orbiting the Sun and fighting the competing gravitational attractions of the Solar System. All the planets suffered severed bombardment from meteorites, comets, asteroids and such like. Geophysicists indicate that the Last Heavy Bombardment in the Solar system took place around 4.1 billion years ago. The tumultuous history of the Earth therefore lasted 500 million years. Earlier thought to have inhibited cooling and life-s emergence, the extra-terrestrial bombardments may have contributed to the process by the delivery of water and even life supporting resources, if not life itself. Researchers are working feverishly on this angel as well.

There were no solid landmasses in the early Hadean, and no rocks. The surface was largely molten and continually disrupted by bombardments. This earliest period has therefore been described as "hellish" - hence "hadean" or like Hades.

The earlier view has also been that the land and the oceans were formed only in the next eon, in early Archaean times, and then Earth was at first essentially a "water-world". The would-be crust (comprising both the ocean beds and land surfaces) was affected by the still heating interior, which generated upward convections of magma. As the crust tried to cool, the blocks were shifted about, subducted and re=cycled. Researchers are also feverishly working on the implications for crust formation, of an earlier cooling Earth and the formation of liquid water.

Geophysicists indicate that about 4.257 billion years ago, some 343 million after first formation, a proto-planet the size of Mars, which has been named Theia, collided with the Earth. It is believed that the core of the planet buried itself into the Earth, but the considerable debris of the impact accumulated in the sky and eventually formed the Moon. The latter was 15 times bigger than now and Earth then orbited the Sun once in six hours instead of 24 hours.

These factors changed the Earth's formation history. For one, it blew away the former atmosphere. Secondly, it led to the final adjustments of the Earth's orbit. And thirdly it gave the Earth its tilt – with all its ultimate climatic effects. These factors added to the Earth's ability to cool.

Recent researchers consider that the formation of the Moon may have had another dramatic impact. The early moon produced strong tides, which would have disturbed (stirred) the ocean floors and other water bodies, as they do now but more so. One effect was to accelerate their cooling. The other was to create a molecular soup of carbon and other preferred minerals. These factors would have advanced the beginning of life

Astronomers now believe that the cosmos was significantly hydrated by the second generation of stars (to which the Sun belongs).That being the case, we may speculate that there was water on

Earth in the mid and late Hadean, in vapour form if nothing else released from the interior minerals, as well as delivered as ice-coated missiles. Earth's water could have originated from interactions between the hydrogen-rich atmosphere and magma oceans of the planetary embryo that comprised formative years.

Once the Earth (or parts) began to cool below 100 degrees Celsius, water vapour would have begun to condense, in the lowest places.

There is in fact evidence that life may have existed on Earth in Hadean times. In Western Australia, river-borne relict detrital grains of zircon dating to 4.1 billion years ago have been found containing pure graphite (carbon) with a signature indicating photosynthetic life. The source has still not been found. I could not determine how much ocean or solid crust with riverine surface water there was at that time.

Prior to the Archean eon, Earth was in the astronomical stage of planetary accretion; no rocks are preserved from this stage. The earliest terrestrial materials were not rocks but minerals

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Chapter Five
B. The Archaean Eon
(4.0.to 2.5 billion years ago)

The Physical World

The Archaean eon lasted the longest, a whopping 1.5 billion years. The Archaean gave birth to first life. Geologists have divided the period into four sub-periods of roughly 400 million years each, namely the Eoarchean, Paleoarchean, the Mesoarchean and the Neoarchean. I was not able to particularise all our events of interest by this time-frame, and so refer to the actual dates or to early, mid or late Archaean, unless able.

Ocean World

The first fact of importance is that by the beginning of the Archean, the Earth had cooled significantly. By about 3.8 billion years ago, the water had condensed into rain which filled the basins of our world. Much of Archean oceans were likely created by the condensation of water derived from the outgassing of abundant volcanoes.

The planet was then mostly a "water-world, covered with a huge ocean with little surface land to speak of. Geological evidence has suggested that by 3.5 billion years ago, the oceans temperatures were down to around 85^o to 55^o Celsius. They cooled dramatically even further to the current average temperatures of 15^o Celsius.

The oceans were the first frontier of life. They contained a large number of small organic molecules, which are called "prebiotics", because they were there before life appeared.

Lithosphere

The second fact of importance is that during the beginning of the Archean eon, as the meteorite impacts slowed and the Earth cooled, the crust began to harden around the molten globe, forming both continental and oceanic plates. Together, these comprised the lithosphere. Much of the lithosphere was under an ocean deeper than today's oceans, although there also was continental crust.

The lithosphere was in turn made up of tectonic plates. These were consolidated aggregates formed of lighter rock sitting on the more viscous material of the Earth's mantle below. Heated from the core below, the mantle was (and still is) subject to convection, pushing up hot magma under the tectonic plates, as well as the crust generally. The pressure produced fissures, rifts and folds, and in other places it erupted in volcanic activity. On a larger scale, the convection currents caused the tectonic plates to shift or drift, forming and reforming as continental landmasses and oceans, a process known as "plate tectonics". In the early Archaean, the Earth was a one-plate planet, before the inception of plate tectonics.

Today's oldest continental crust dates back to the Archean. The first supercontinent, Vaalbara, existed between 3.6 to 2.7 billion years ago in the Eoarchean, quite early, followed by Ur around 3.1 billion years ago, and two others in the Neoarchean.

Due to recycling and metamorphosis of the Archean crust, there is a lack of extensive geological evidence for specific continents. It is fascinating though that our first known continental bacterium would have grown up in Vaalbara. It would have been a prokaryote.
.

Anoxic Atmosphere

Fourthly, at this stage of the Earth’s formation, the atmosphere lacked oxygen. There was no ozone layer. The atmosphere was anoxic and reducing, ie oxygen extracting. Although volcanoes “outgassed” (released) much water vapour (H2O) and carbon dioxide (CO2), their breakdown in the atmosphere produced only a small amount of free oxygen, The situation was not very different in both Hadean and Archean times, but this subject is still under review.

The intense volcanism during the Archean caused carbon dioxide to be highly concentrated in the atmosphere. It is theorised that this gave rise to greenhouse effects that kept the Earth’s surface sufficiently warm to prevent the development of glaciation, for which there is no evidence in Archean rocks. Scientists also suggest that methane, another greenhouse gas, could have slowly built up during the Hadean, and by 3.8 billion years ago could have been abundant enough to have helped warm the Earth. At that time, the Sun was shining at 70% of its current brilliance.

Pre-biotic Scenario

All said and done, Earth possessed the primordial pre-conditions for life, namely the right temperature, standing water and the requisite list of minerals. A generally well-behaved Sun supplied all the energy needed. An anoxic atmosphere was not an initial barrier

It is not often realised that without the magnetic shield around it, the Earth would not be able to support life. Besides abating UV, it kept the atmosphere in place.

Finally, the proposition, increasingly accepted , of the initial universal dispersal and availability of organic compounds was a fundamental primordial provision for life, like water.

Emerge Micro-organic Life
- The Prokaryote

Some Technical Information

Bonds

In general, covalent bonds form between nonmetals, ionic bonds form between metals and nonmetals, and metallic bonds form between metals.

An ionic bond is formed when an electron lost by one element is gained by another. In the case of two nonmetals, they both lose electrons so no electron transfer takes place. Thus an ionic bond cannot be formed between two non-metals.

Two metals can't form an ionic bond. The requirements for this bond are the losing of electrons by one element and gaining by another. There is no metal in existence that accepts electrons. So, ionic bond between only metals is not possible.

In ionic bonds, the metal loses electrons to become a positively charged cation, whereas the nonmetal accepts those electrons to become a negatively charged anion. Ionic bonds require an electron donor, often a metal, and an electron acceptor, a nonmetal.

Non-metals attain stability when they attain nobility, ie, a fully filled outer shell. In order to achieve that, they undergo covalent bonding by sharing of electrons. Metals on the other hand have no free electrons in their valence bands unlike non-metals, they do not preferably require covalent bonding.

Genome

A genome is and represents the complete hereditary information of an organism encoded in RNA or DNA. In the latter, the genome comprises both the genes and non-coding sequences. It covers the entire gamut of building, running, maintaining an organism and passing life on to next generation.

Ribosome

A ribosome is an intercellular structure made of both RNA and protein, and it is the site of protein synthesis in the cell. The ribosome reads the messenger-RNA (mRNA) sequence and translates that genetic code into a specified string of amino acids, which grow into long chains that fold to form proteins.

In order for a cell to manufacture these proteins, specific genes within its DNA or RNA system must first be transcribed into molecules of mRNA; then, these transcripts must be translated into chains of amino acid, which later fold into fully functional proteins.

A ribosome is a complex of RNA and protein and is, therefore, known as a ribonucleoprotein.

Ribozyme

A ribozyme is a ribonucleic acid (RNA) enzyme. The ribozyme catalyses specific reactions in a similar way to that of protein enzymes. Ribozymes are found in the ribosome where they join amino acids together to form protein chains.

Proteins

Proteins are bio-polymeric structures composed of amino acids. More simply, a protein is a complex naturally occurring substance that consists of amino acid residues joined by peptide bonds. Proteins are present in all living organisms and include many essential biological compounds such as enzymes, hormones, and antibodies.

A protein molecule is made from a long chain of amino acids, each linked to its neighbour through a covalent peptide bond. Proteins are also known as polypeptides. Each type of protein has a unique sequence of amino acids, exactly the same from one molecule to the next.

Proteins serve as structural support, biochemical catalysts, hormones, enzymes, building blocks, and initiators of cellular death.

Proteins perform a vast array of functions within living organisms, including catalysing metabolic reactions, replication, responding to stimuli, and transporting molecules from one location to another

The chemical synthesis of proteins is now possible because of the prodigious advances in peptide synthesis that have occurred over the last century

Enzymes

An enzyme is a substance that acts as a catalyst in living organisms, regulating the rate at which chemical reactions proceed without itself being altered in the process.

An enzyme is defined as an organic catalyst for biochemical processes. Enzymes are proteins that help speed up metabolism - the chemical reactions in our bodies. They build some substances and break others down. All living things have enzymes.

Definition of Life

All living organisms share several key characteristics or functions: cell order, sensitivity or response to the environment, reproduction, growth and development, regulation, homeostasis, and metabolism. When viewed together, these eight characteristics serve to define life.[14]

[14] https://openoregon.pressbooks.pub/mhccbiology101/part/themes-and-concepts-of-biology/

The Microorganism

The first life form was a microorganism. What is not determined conclusively is whether there were many independent entities that sought to emerge at about the same time in different places.

What we have strong evidence of is that one proto-organism succeeded, and became the first universal common ancestor of all living things. When he replicated himself, then we began. If life sprouted in many places at once, we would not all have inherited the same genes.

Microorganisms today replicate in minutes. Our first ancestor, however, could have, probably would have, taken a few million years to set up a workable energy-capture system (respiration if you like) and probably as much again to set up ribosomes, working metabolics and protein synthesis. It is not unreasonable to suppose he took as long as a few hundred million years before first replication. At that stage evolution operated in cosmic time, and relied on chance for the right factors to come together.

These things would have happened in late Hadaan times, when the Earth was still in formation. There was very little permanent crust, which kept being subducted by sub-surface convections. There were hardly any (land) fossils, the only evidence we can have of early life.

The first trace evidence goes back to 4.1 billion years ago just before the Archean, a carbon tracing embedded in a zircon crystal, which could have been biological produced. The earliest actual fossil we have is the layered macroscopic sedimentary structures known as “stromatolites” deposited by microorganisms, which record their existence dating back 3.48 billion years, say 3.5 billion years, ago. Both have been found in Western Australia of today.

There was a gap of 500 million years (half a billion years) between just the above two happenings. A lot would have happened and disappeared. The Earth went round the Milky Way twice.

And for another **2,500 million years** (2.5 billion years) – almost three-quarters of the history of life on Earth - all organisms were single-celled microorganisms. It must be presumed that they speeded up replication to ensure survival. They would have conquered the oceans, and spread out towards land They would have improved their internal efficiencies, and they would have invented much of Darwin’s catalogue of evolutionary skills, like adaptation, mutation, etc. The mainstream would have evolved, while many off-shoots would have gone extinct.

The microorganisms lived singly and as colonies of cells. They were and still are of very microscopic size, in the micron scale ($1x10^{-6}$). Their relatively complex infrastructure and processes were only revealed with the electron-microscope (a gift of Quantum Mechanics) just after the second world war.

Our microorganism was a prokaryote, ie non-oxygen dependent. The microorganism went on to establish two other prokaryote domains, the Archaea and the Bacteria. The latter would go on to establish the Eukaryote domain, to which all oxygen dependent creatures today belong. Within the prokaryotes, there have been further diversification.

The prokaryote is today the by far the most populous life form on Earth. Allowing for refinements and mutations, the prokaryote is still basically the single-celled microorganism - as invented by the first microorganism. Bacteria are by far the most abundant prokaryotic species today. We shall hear more about them later.

Primary Responses of Our Proto-Organism.

Re-winding the clock, we arrive at the spot and the hour when our proto-organism had assembled itself. The cosmos was either hard-wired to surface a proto-organism at the right time, or we owed it all to chance.

The rich soupy environment in which our proto-organism lay would have conditioned it to test, try, respond and react to various stimuli, creating gradients of preferential actions unconsciously stored - and built upon with increasing sentience into life-management information

Our proto-organism's efforts would have boiled down to three issues: (1) to harvest energy, (2) to construct a cell with the functions of a self-sufficient living entity, and (3) to establish a platform for perpetuation of itself

Energy

Energy was the first requirement. As we start, we place our proto-organism in an inorganic environment looking closely at the inorganic compounds around; and we must assume it knew nothing yet about organic compounds. Our proto-organism's practical option was to chew on the surrounding inorganic minerals for energy.

As it turned out, our proto- organism invented "anaerobic" respiration, an extraordinary feat in electro-chemical micro-engineering even by today's standards. It is the process in which a molecule (serving as an electron donor), is oxidised or oxidated15 by another inorganic compound as oxidising agent16 into simpler compounds, at the same time releasing an electron and a wee quantum of free chemical energy.

Our microorganism further developed an electronic transport chain to move (relay by redox) this energy to yet another inorganic molecule (a final electron acceptor) for use or storage.

In time, with the availability of organic compounds, our proto-organism would develop enzymes, pathways and metabolic processes to maximise the production, storage, management and deployment of energy.

In time, it would increasingly rely on use of its own stored energy, and develop the apparatus and machinery both to make and consume its energy, oxidising organic compounds

In time, our microorganism would develop oxygenic-photosynthesis trapping sunlight to oxidate water for energy, and releasing oxygen with dramatic effect.

And, in time, it would manufacture carbohydrates by fixation of carbon di oxide from the atmosphere, and store these for food (and energy).

The energy saga will be completed ultimately with aerobic respiration, when its descendants (animals and humans) breath in oxygen to oxidise our food to release the stored energy for our use.

It will be easily realised that our proto-organism could not have gone very far without constructing both a physical and a biochemical infrastructure. Whereas someone building a star would need inorganic minerals (only), someone building live-cell needed organic compounds to create metabolic pathways, etc; or it would get nowhere. To my mind, it is not without significance that the organic compounds were actually provided to our proto-organism in situ. It just needed to invent the necessary biochemistry.

Cell

Our proto-organism went on to construct a cell as the home and repository of life, with the necessary features, functional entities and biochemical systems. They are the specifications of a prokaryote. They are still substantially the identification features of the present day descent of the microorganism.

[15] "Oxidise" or "oxidation" means a transfer of an electron, in or out. "Oxidation" is defined as the addition of oxygen to the substance or the removal of hydrogen from the substance.

[16] An "oxidising agent," (also known an oxidiser or oxidant) is any substance that oxidises another substance (in or out) An oxidising agent" is "oxidated" when it loses an electron, and is known as the "electron donor".. An oxidising agent is "reduced" when it gains an electron, and it known as the "electron acceptor".

.– Firstly a simple cell wall and membrane, defining it and mediating between it and the outside world.

. – Secondly, cytoplasm, a gel-like continuum within the cell, composed mainly of water, which also carries enzymes, salts, sugars, cell components, and various organic molecules.

.– Thirdly, a basic platform of ribonucleotides, containing ribose, the molecular precursor of nucleic acids. Ribonucleotides were themselves the building blocks of RNA. Quite simply, our little monster invented the RNA world.

.- Fourthly, our microorganism needed a working tool, and invented the ribosome of which there are many in a cell. Ribosomes are “macro-molecular” machines that perform protein synthesis.

Ribosomes are themselves composed of special proteins and nucleic acids. One of them is ribose. The naturally-occurring form, d-ribose, is a component of the ribonucleotides from which RNA is built, and so this compound is necessary for coding, decoding, regulation and expression of genes.

Generally, ribosomes manipulate organic and inorganic compounds to make enzymes, which manage and regulate metabolism.

.- Fifthly, our microorganism formulated the universe’s first biological language, first genome, storing the information in RNA without a nucleus – precursor of our present day DNA genetic code,

. - And lastly, our first microbe learnt to maintain homeostasis, and replicate itself by binary fission.

Prokaryotes are small, single-celled organisms that have a relatively simple structure. A striking feature is that their specialised parts or working components are not enclosed within organelles, as in eukaryotes, but reside in the cytoplasm. Prokaryotes (even today) are organisms whose cells lack a nucleus.

More Technical Information

Metabolism

Metabolism is that set of chemical reactions that together capture energy and enable application of the same to activate, orchestrate, maintain and evolve the various life processes.

These are orchestrated by enzymes, catalysts, hormones, and other biochemicals in chemical sequences, pathways, and cycles.

These are too numerous to list, but include the energy transport and storage chain, glycolysis and the Krebs cycle - the food breakdown system, protein building, genetic coding, waste disposal and replication.

At a later stage, there will be photosynthesis and the Calvin cycle. It is incredible how many activities were packed within a single cell of a micron or less.

RNA World

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The “RNA world” hypothesis suggests that the prokaryote began as a simple RNA molecule that could copy itself without help from other molecules. It proceeded to use RNA both to store genetic information, and create enzymes to catalyse chemical reactions.

The outcome was its choice of RNA as the first platform to build life on, founded on the base molecule, RiboNucleicAcid (RNA), made up of ribonucleotides

RNA is not made from amino acids. They are genetic material that are made up of nucleotides, containing nitrogenous bases, just like DNA.

Nucleotides are ribose sugars attached to nitrogenous bases and phosphate groups. The nitrogenous bases include adenine, guanine, uracil, and cytosine.

By trial and error, our proto-organism established RNA as its first platform and cell-operating system. The primary activities of the latter were namely (1) boosting and regulating energy production, (2) the synthesis of amino acids into requisite proteins for various functional needs, (3) cell-building and replication, and (4) maintaining homeostasis and waste disposal.

For its working tool, our proto-organism evolved the ribosome – in fact many copies of them. Besides being the macro-molecule to manufacture proteins, the ribosomes serviced most other functions by creating enzymes to catalyse their activities, including respiration.

RNA-DNA Genetic Code

For its information management system (mis), our proto-organism used the ribonucleic acids inherent in RNA to create a proto genome or genetic code to identify the growing list of body-parts and other supplies to be programmed, manufactured and moved about - which code system the whole living world has adopted since.

The RNA operating system comprised three sub-systems. Firstly, there was the messenger-RNA (mRNA), which delivered the genetic code (stored in mRNA) to the ribosomes for translation into working specifications. Secondly, there was the transfer-RNA (tRNA). which transferred the selected amino acids (or raw materials) to the ribosomes. And thirdly, there were the ribosomal-RNA (rRNA) molecules themselves, the core (50%) of the ribosome macro-molecule, which did the production work. All the latter activity took place in the cytoplasm or body of the cell. The RNA-ribosome system (together with the genetic code) proto-typed the human brain, and our original microorganism might be thought of as the first programmer. It is not possible to say at what stages these functions grew, but they would have been put in place early - certainly before viruses branched off.

The evolution of the cell-operating system would become complete in time by the upgrading with a universal genetic code and a DNA-based hereditary data base management system (like a dbms). These got transferred to eukaryotes in time, and are now used today by humans and almost all living things. Components of RNA have in fact been subsumed into our DNA system, eg. the messenger-RNA transcript, while the RNA genome is still being used by some microorganisms, including viruses.

RNA is generally single-stranded. Like DNA, each RNA strand has the same basic structure, composed of nitrogenous bases covalently bound to a sugar-phosphate backbone. However, for those who are particular, the sugar in DNA is deoxyribose, whereas RNA contains ribose. Furthermore, DNA uses the bases adenine, thymine, cytosine, and guanine, while RNA uses adenine, uracil, cytosine, and guanine.

RNA and DNA are both naturally occurring nucleic acids. The repeating units of all nucleic acids are called nucleotides.

Prokaryotic cells do not have a membrane-bound nucleus. Instead, their genetic material can be found in a region of the cytoplasm called the nucleoid. A prokaryotic cell typically has only a single, coiled, circular chromosome.

The Deoxyribose-Nucleic Acid (DNA) is found in the cytoplasm of the more evolved prokaryote. It is a single circular strand or chromosome, also called a plasmid. It contains the genetic code of the prokaryote, which can be transcribed by a messenger-RNA (mRNA), to synthesize proteins.

I floated a number of enquires whether there was evidence that nucleic acids could also have been pre-biotically synthesised and distributed around the cosmos, but failed to get a clear answer.

Homeostasis

Our microorganism was our first doctor. He established the first principles of good health, ie homeostasis. Select your food carefully, do not over eat, empty your waste products regularly, keep your lungs free, build up your muscles, keep your metabolic functions in good repair, maintain good energy reserves, and keep external bodily threats at bay. Finally, as a backup, reproduce yourself at the appointed time

In short, the purpose of homeostasis is to maintain the established internal environment without being overcome by external stimuli that exist to disrupt the balance.

Our microorganism, being the simplest of all beings, namely a prokaryote, had a straight-forward job, only a single cell to deal with. The primary defence was its plasma membrane, which allowed traffic both-ways, ejecting waste and injecting nutrients. The rest of it was a matter of internal management.

I quote this paragraph as the last delicious words on the subject.

> "Cellular homeostasis is maintained in coordination with extracellular cues (such as growth factors and nutrients) and intracellular metabolite concentrations. The interplay among all these factors coordinate complex signal transduction networks that perpetuate the information and rewire the metabolism of the cells."

Unfortunately, I lost the reference. It means the same thing as the first paragraph above.

Reproduction

Prokaryotes reproduce asexually through binary fission. The cell cycle consists of three distinct but short phases: first, a growth phase in which the mass of the cell is increased, then the chromosomal replication phase, and finally the chromosomes are separated and the cells are physically split into two independent daughter or new cells.

Bacteria divide somewhere between once every 12 minutes and 24 hours. So, the average lifespan of a prokaryote is usually taken at around 12 hours or so.

The primary concern of cell division is the maintenance of the original cell's genome. Before division can occur, the genomic information that is stored in chromosomes must be replicated, and the duplicated genome must be cleanly divided between progeny cells. It requires replication of the cell's chromosomes, segregation of the copied DNA, and splitting of the parent cell's cytoplasm. Duplication of DNA is followed by elongation of the bacterial cell, which results in the creation of two infoldings, two new plasma membranes, and a cell wall. Increases in the size of prokaryotes (cell growth) and their reproduction by cell division are tightly linked.

In unicellular organisms, binary fission is reproduction. In the course of time, binary fission became cell division or mitosis as practised by the multicellular life form descendants of the prokaryote. In the human being, cell division goes on all the time in all individual cells for growth, repair, and replacement - in addition to sexual reproduction of the whole person. A typical proliferating human cell divides on average every 24 hours.

How Life Began

The following is as realistic a picture of what happened at the beginning as we might get:

How Life Began

> "Around 4 billion years ago, primordial cells began to form in a hot, chemical-rich broth. One credible line starts inside erupting geysers in a thermal region on land, similar to present-day Yellowstone National Park. Minerals on geyser walls catalysed the formation of simple types of fat molecules and spewed them into nearby pools. As the molecules collected and interacted, these pools became hatcheries of microscopic spheres called vesicles. Meanwhile, RNA molecules arose through other chemical reactions and began to self-replicate inside vesicles. Heat fluctuations and turbulence in the environment eventually kick-started a primitive cellular life cycle and these proto-cells began to divide and reproduce. Those were the first microbes; that was the first life on Earth.[17]"

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[17] https://www.statnews.com/2017/12/21/microbes-human-life/#:~:text=Heat%20fluctuations%20and%20turbulence%20in,the%20first%20life%20on%20Earth.

LUCA

It has been established that the prokaryote microorganism was the common ancestor of all living things. We have been able to trace, through the genetic code that our Last Universal Common Ancestor was (LUCA) was a single-cell prokaryote microorganism,

In 2016, Madeline C. Weiss and colleagues genetically analysed 6.1 million protein-coding genes and 286,514 protein clusters from sequenced prokaryotic genomes representing many phylogenetic trees and identified 355 protein clusters that were probably common to the LUCA.

LUCA is an inferred evolutionary intermediate, that links us to the first traces of microbial life in rocks that are 3.5–1.5 billion years of age. It is an hypothetical individual, a composite of the earliest microorganisms found sharing our genetic code. To keep up with the fiction, they would all have to be traced back to our proto-organism.

Several DNA-binding proteins trace to LUCA, so it would appear that LUCA possessed DNA. But it is unresolved whether LUCA could actually replicate DNA. For LUCA, DNA might just have been a chemically stable repository for RNA-based replication.

We know that LUCA had hundreds of genes encoded. That implied a suite of cellular machinery including messenger-RNA, transfer-RNA, and ribosomes. to translate the code into proteins Those proteins included enzymes, to operate its anaerobic respiration.

For our purpose, suffice it that LUCA was most likely a single-celled organism that lived between three and four billion years ago. It may have used RNA both to store genetic information and to catalyse chemical reactions.

FUCA

The First Universal Common Ancestor (FUCA) is a hypothetical microorganism that was the actual earliest ancestor of the Last Common Universal Ancestor (LUCA) - and its descendants. FUCA would also be the ancestor of ancient sister lineages of LUCA, none of which have modern descendants.

It is increasingly the accepted view that the common presence among the earliest microorganisms of both a biological translation mechanism and a genetic code strongly indicates a common or unique origin for all the early biological systems, including viruses. By definition, FUCA would have had these features.

One view is that the pre-FUCA scenario was populated by many nascent open systems. It has been called the Progenote era. They would have with increasing success used RNA. This caused the pre-cellular open systems to start to accumulate information and to self-organise biochemical pathways.

One can think of FUCA as a front runner among these open biological systems. Our own microbe would have been the first FUCA

FUCA would have been originally generated without a genetic code, directly from the ribosome. FUCA would have appeared when the RNA world replicators started to be capable to catalyse the bonding of amino acids

The first genetic system would have been assembled together with a primeval, possibly error-prone, genetic code. When its genetic code was completely established, FUCA would have matured, and be set for all generations to come.

Viruses

From the preceding, viruses might (must) have evolved after FUCA and before LUCA. Viruses by and large belong to the RNA world. They use the same genetic code (and ribosomes) as FUCA – and therefore other living things, They have nucleic acid genomes. Their nucleotides codons encode for same amino acids used in the synthesis of proteins. There is however much debate on the subject of when they took off.

One thought stream is that viruses may have been the earliest or early levels of “self-assembly” of living things on the main line of evolution, but went up a cul-de-sac. They may even have been non-oblate (independent) and non-parasitic.

Some people view them as an intermediate or “failed” stage in the development of the living cell. Like the neutrino, they might be classed as the “waste material” of evolution, the bits that did not make it.[18] The tiniest viruses are only 20 nm in diameter, smaller than a ribosome.

But it is not known how much they have modified since nor what route or routes they took from their ancestral forms to today. Even their phylogenetic (family tree) relationships with the other micro-organisms including bacteria have yet to be established. Today, they are oblate non-cellular biological non-living things.

A virus is called a DNA virus or an RNA virus, according to the kind of nucleic acid that makes up its genome. It interesting that the retrovirus[19] Covid-19 is an RNA virus, which may or tell us when it failed to complete its evolution and developed pathogenically.

Hypotheses on Origin of Life.

When did life appear on Earth?

For many millions of years, early Earth was pummelled by asteroids and other celestial objects. Temperatures would have been very high (with water taking the form of a gas, not a liquid). The first life might have emerged during a break in the asteroid bombardment, between 4.4 and 4.0 billion years ago, when it was cool enough for water to condense into oceans. A second bombardment happened about 3.9 billion years ago. It’s likely after this Earth became capable of supporting sustained life.

Oparin-Haldane Hypothesis

In the 1920s, Russian scientist Aleksandr Oparin and English scientist J. B. S. Haldane separately proposed that life on Earth could have arisen step-by-step from non-living matter through a process of “gradual chemical evolution.”

Oparin and Haldane thought that early Earth had a reducing atmosphere (an oxygen-poor atmosphere) in which molecules tend to donate electrons. Under these conditions, simple inorganic molecules could have reacted (with energy from lightning or the sun) to form building blocks like amino acids and nucleotides, which could have accumulated in the oceans, making a "primordial soup."

The building blocks could have combined in further reactions, forming larger, more complex molecules (polymers) like proteins and nucleic acids, perhaps in pools at the water's edge.

The polymers could have assembled into units or structures that were capable of sustaining and replicating themselves. Oparin thought these might have been “colonies” of proteins clustered together to carry out metabolism, while Haldane suggested that macro-molecules became enclosed in membranes to make cell-like structures.

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[18] I have done a separate review on Virus* (Biological Predator), ISBN 978-981-18-3046-4 (PDF). https://geraldpillay.wordpress.com

[19] - A retrovirus isa type of RNA virus that replicates by using an enzyme called reverse transcriptase to convert its RNA genome into DNA within a host cell. This newly created DNA is then integrated into the host's genome, allowing the virus to replicate alongside host cells. Other notable examples include HIV and HTLV.

The details of this model are debatable. But the basic idea – a stepwise, spontaneous formation of simple, then more complex, then self-sustaining biological molecules or assemblies – is still at the core of most origins-of-life hypotheses today.

Stanley Miller and Harold Urey Experiment

In 1953, Stanley Miller and Harold Urey did an experiment to test the Oparin and Haldane ideas. They found that organic molecules could be spontaneously produced under reducing conditions thought to resemble those of early Earth.

Miller and Urey built a closed system containing a heated pool of water and a mixture of gases that were thought to be abundant in the atmosphere of early Earth. To simulate the lightning that might have provided energy for chemical reactions in Earth's early atmosphere, Miller and Urey sent sparks of electricity through their experimental system.

After letting the experiment run for a week, Miller and Urey found that various types of amino acids, sugars, lipids and other organic molecules had formed. Large, complex molecules like DNA and protein were missing, but the Miller-Urey experiment showed that at least some of the building blocks for these molecules could form spontaneously from simple compounds.

Scientists now think that the atmosphere of early Earth was different than in Miller and Urey's setup, inter alia, not reducing, and not rich in ammonia and methane. However, a variety of experiments done in the years since have shown that organic building blocks (especially amino acids) can form from inorganic precursors under a fairly wide range of conditions.

From these experiments, it seems reasonable that at least some of life's building blocks could have formed abiotically on early Earth. However, exactly how (and under what conditions) remains an open question.

Experiments conducted later showed that the other RNA and DNA nucleobases could also be obtained through simulated prebiotic chemistry with a reducing atmosphere.

The University of Waterloo and University of Colorado conducted simulations in 2005 that indicated that the early atmosphere of Earth could have contained up to 40 percent hydrogen—implying a much more hospitable environment for the formation of prebiotic organic molecules. The escape of hydrogen from Earth's atmosphere into space may have occurred at only one percent of the rate previously believed. One of the authors, Owen Toon notes: "In this new scenario, organics can be produced efficiently in the early atmosphere, leading us back to the organic-rich soup-in-the-ocean concept. I think this study makes the experiments by Miller and others relevant again." experiment.

Abstract

> "We show that the escape of hydrogen from early Earth's atmosphere likely occurred at rates slower by two orders of magnitude than previously thought. The balance between slow hydrogen escape and volcanic outgassing could have maintained a hydrogen mixing ratio of more than 30%. The production of prebiotic organic compounds in such an atmosphere would have been more efficient than either exogenous delivery or synthesis in hydrothermal systems. The organic soup in the oceans and ponds on early Earth would have been a more favourable place for the origin of life than previously thought."
> A Hydrogen-Rich Early Earth Atmosphere Feng Tian, Owen B. Toon, Alexander A. Pavlov,H. De Sterck4"[20]

From building blocks to polymers

The problem facing scientists was how monomers (building blocks) like amino acids or nucleotides could have assembled into polymers, or actual biological macro-molecules on early Earth. In cells today, polymers are put together by enzymes. But, since the enzymes themselves are polymers, this was a kind of a chicken-and-egg problem.

[20] https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=cdb2f0801f80db1e49f88d08a81c5b359f2238a6

In the 1950s, biochemist Sidney Fox[21] and his colleagues found that if amino acids were heated in the absence of water, they could link together to form proteins. Fox suggested that, on early Earth, ocean water carrying amino acids could have splashed onto a hot surface like a lava flow, boiling away the water and leaving behind a protein.

Additional experiments in the 1990s showed that RNA nucleotides can be linked together when they are exposed to a clay surface. The clay acts as a catalyst to form an RNA polymer. More broadly, clay and other mineral surfaces may have played a key role in the formation of polymers, acting as supports or catalysts. Polymers floating in solution might have hydrolysed (broken down) quickly, supporting a surface-attached model. A type of clay known as montmorillonite in particular has catalytic and organising properties that may have been important in the origins of life, such as the ability to catalyse formation of RNA polymers (and also the assembly of cell-like lipid vesicles).

If we imagine that polymers were able to form on early Earth, this still leaves us with the question of how the polymers would have become self-replicating or self-perpetuating, meeting the most basic criteria for life.

The "genes-first" (RNA) hypothesis

In the genes-first hypothesis, one possibility is that the first life forms were self-replicating nucleic acids, such as RNA or DNA, and that other elements (like metabolic networks) were a later add-on to this basic system.

Many scientists think that RNA, not DNA, was likely the first genetic material. This is known as the RNA world hypothesis. Scientists favour RNA as the first genetic molecule most importantly because RNA can, in addition to carrying information, act as a catalyst, which no known DNA. molecules can do.

RNA catalysts are called ribosomes (ribozymes) and they could have played key roles in the RNA world. A catalytic RNA could, potentially, catalyse a chemical reaction to copy itself. In fact, researchers have been able to synthetically engineer small ribozymes that are capable of self-replication.

Some scientists think that an even simpler “RNA-like” molecule with catalytic and information-carrying capacity might have come first, and might have catalysed or acted as a template for RNA synthesis. This is sometimes called the "pre-RNA world" hypothesis.

The "metabolism-first" hypothesis

An alternative is the metabolism-first hypothesis, which suggests that self-sustaining networks of metabolic reactions may have been the first simple life (predating nucleic acids).

These networks might have formed, for instance, near undersea hydrothermal vents that provided a continual supply of chemical precursors, and might have been self-sustaining and persistent (meeting the basic criteria for life). In this scenario, initially simple pathways might have produced molecules that acted as catalysts for the formation of more complex molecules. Eventually, the metabolic networks might have been able to build large molecules such as proteins and nucleic acids. Formation of "individuals" enclosed by membranes (separate from the communal network) would have been a late step.

Self-Sustaining and Self Replication Requirements

A basic property of a cell is the ability to maintain an internal environment different from the surrounding environment. Today’s cells are separated from the environment by a phospholipid bilayer. It is unlikely that phospholipids would have been present under the conditions in which the first cells formed, but other types of lipids (ones that would have more likely been available) have also been shown to spontaneously form bilayered compartments.

[21] https://en.wikipedia.org/wiki/Sidney_W._Fox

In principle, this type of compartment could surround a self-replicating ribosome or the components of a metabolic pathway, making a very basic cell. Though intriguing, this type of idea is not yet supported by experimental evidence.

So far, no experiment has yet been able to spontaneously generate a self-replicating cell from abiotic (non-living) components.

Organic Molecules from Outer Space

Organic molecules might have formed spontaneously from inorganic ones elsewhere, as on early Earth.

The idea that organic molecules might have travelled to Earth on meteorites is supported by reasonable evidence. Scientists have found that organic molecules can be produced from simple chemical precursors present in space, under conditions that could exist in space (high UV irradiation and low temperature). We also know that some organic compounds are found in space and in other star systems.

Most importantly, various meteorites have turned out to contain organic compounds (derived from space, not from Earth). One meteorite, ALH84001, came from Mars and contained organic molecules with multiple ring structures. Another meteorite, the Murchison meteorite, carried nitrogenous bases (like those found in DNA and RNA), as well as a wide variety of amino acids.

One meteorite that fell in 2000 in Canada contained tiny organic structures dubbed "organic globules." NASA scientists think this type of meteorite might have fallen to Earth often during the planet's early history, seeding it with organic compounds.

The majority of organic compounds introduced on Earth by interstellar dust particles have helped to form complex molecules, thanks to their peculiar catalytic activities.

Studies of organic compounds in the Murchison meteorite suggest that the RNA component uracil and related molecules, including xanthine, were formed extra-terrestrially. NASA studies of meteorites suggest that all four DNA nucleobases (adenine, guanine and related organic molecules) have been formed in outer space.

The cosmic dust permeating the universe contains complex matter that could be created rapidly by stars. Glycolaldehyde, a sugar molecule and RNA precursor, has been detected in regions of space including around proto-stars and on meteorites.

Organic compounds in space

Observations with radio waves carried out in the seventies proved that interstellar space is not only full of hydrogen and dust, but also contains complex chemical compounds, or gaseous molecules, such as water (H20), ammonium (NH3) and methanol (CH3OH).

It has been further established that a variety of amino acids are easily produced under conditions which were believed to have existed on the primitive Earth or in the early solar nebula.

The most critical of the organic compounds for the emergence of life as we know it were the amino acids. The formation of amino acids and peptides are assumed to precede and perhaps induce the emergence of life. Amino acids can form from simple precursors under various conditions. Surface-based chemical metabolism of amino acids and very small compounds may have led to the build-up of amino acids, coenzymes and phosphate-based small carbon molecules. Amino acids and similar building blocks could have been elaborated into proto-peptides with peptides being considered key players in the origin of life.

Since then, scientists have discovered a range of ways and components by which the potentially pre-biotic formation and chemical evolution of peptides may have occurred, such as condensing agents, the design of self-replicating peptides and a number of non-enzymatic mechanisms by which amino acids could have emerged and elaborated into peptides.

While amino acids and consequently simple peptides must have been formed under different experimentally proved geochemical scenarios, the transition from an abiotic world to the first life forms is to a large extent still unresolved.

Overall, it is clear that organics are a widespread component of Solar system material. The most primitive and least processed meteorites —the so-called carbonaceous chondrites — contain ample organic material

Lab-based studies reveal how carbon atoms diffuse on the surface of interstellar ice grains to form complex organic compounds, crucial to revealing the chemical complexity in the universe.

Meteorites recovered in Antarctica and Australia lead scientists to believe DNA building blocks exist in space. NASA's Michael Callahan led a team that found molecules on meteorites that form the basis of DNA.

A sample extracted from an asteroid far from Earth has confirmed that RNA nucleobases can be found in space rocks.

The James Webb Space Telescope may have discovered tentative evidence of a sign of life on a faraway planet. It may have detected a molecule called dimethyl sulphide (DMS). On Earth, at least, this is only produced by life.

Some scientists have long suggested that a substantial fraction of the organic compounds that were the precursors to amino acids—and perhaps some amino acids themselves—on early Earth may have been derived from comet and meteorite impacts.

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The question of why organisms on Earth consist of L-amino acids instead of D-amino acids is still an unresolved riddle.[22] Some scientists have long suggested that a substantial fraction of the organic compounds that were the precursors to amino acids—and perhaps some amino acids themselves—on early Earth may have been derived from comets and meteorite impacts.

One such organic-rich meteorite impact occurred on September 28, 1969, over Murchison, Victoria, Australia. This meteorite is suspected to be of cometary origin because of its high water content of 12%. Dozens of different amino acids have been identified within the meteorite, some of which are found on Earth. Some compounds identified in the meteorite, however, have no apparent terrestrial source. Most intriguing are the reports that amino acids in the Murchison meteorite exhibit an excess of L-amino acids. An extra-terrestrial source for an L-amino acid excess in the Solar system could predate the origin of life on Earth and thus explain the presence of a similar excess of L-amino acids on the pre-life Earth.

Tryptophan is one of the 22 amino acids essential for forming key proteins for life on Earth. Astronomers have discovered high amounts of the amino acid tryptophan in interstellar material throughout a nearby star-birthing region of space

It is not clear at this point whether our proto-organism started anaerobic metabolism with inorganics or waited until amino acids were available, if in fact there was any meaningful time lapse.

The PAH world hypothesis

This is a speculative hypothesis that proposes that polycyclic aromatic hydrocarbons (PAHs) - known to be abundant in the universe, including in comets, and assumed to be abundant in the primordial of

[22] - -L-amino acids and D-amino acids are stereoisomers (enantiomers) that differ in the orientation of their amine group around the alpha-carbon, visualized as left (L) or right (D) in a Fischer projection. L-amino acids are the building blocks of proteins in all living organisms, while D-amino acids are primarily found in bacterial cell walls, antibiotics, and specific regulatory molecules

the early Earth - played a major role in the origin of life, by mediating the synthesis of RNA molecules, leading into the RNA world. However, as yet, the hypothesis is untested.

PAHs are said to be the most common and abundant polyatomic molecules in the observable universe, and are a major store of carbon. They seem to have formed shortly after the Big Bang, and are associated with new stars and exoplanets. PAHs have been detected in nebulae, in the interstellar medium, in comets, and in meteorites.

The Kauffman & Co Hypothesis

In Ju 2018, Stuart A. Kauffman, David P Jelenh and Gabor Vattay of Cornell University published some exciting new research. Because it is potentially so ground breaking, I reproduce its title and Abstract in full:

"**Theory of chemical evolution of molecule compositions in the universe, in the Miller-Urey experiment and the mass distribution of interstellar and intergalactic molecules**"[23]

Abstract

"Even computer simulations of the origin of life have never yielded clear evidence of how the step can be taken from amino acids to auto-catalytic chemical networks and then to self-reproducing molecules of life.

Chemical evolution is essential in understanding the origins of life. We present a theory for the evolution of molecule masses and show that small molecules grow by random diffusion and large molecules by a preferential attachment process leading eventually to life's molecules. It reproduces correctly the distribution of molecules found via mass spectroscopy for the Murchison meteorite and estimates the start of chemical evolution back to 12.8 billion years following the birth of stars and supernovae. From the Frontier mass between the random and preferential attachment dynamics the birth time of molecule families can be estimated. Amino acids emerge about 165 million years after chemical elements emerge in stars. Using the scaling of reaction rates with the distance of the molecules in space we recover correctly the few days emergence time of amino acids in the Miller-Urey experiment. The distribution of interstellar and extragalactic molecules are both consistent with the evolutionary mass distribution, and their age is estimated to 108 and 65 million years after the start of evolution. From the model, we can determine the number of different molecule compositions at the time of the emergence of Earth to be 1.6 million and the number of molecule compositions in interstellar space to a mere 719 species."

Cornell University, Journal of Theoretical Biology, June 2018,

MIT Technology Review[24,] in reporting and reviewing the preceding findings, had this to say, which conveniently captures the situation:

'That has significant implications for our thinking about the origins of life. "The results suggest that the main ingredients of life, such as amino acids, nucleotides and other key molecules, came into existence very early, about 8-9 billion years before life," say Kauffman and co.

Since the precise conditions in which life evolved on Earth took another eight to nine billion years to emerge, amino acids cannot be a sign of life potential at all, as had been thought after the Urey-Miller experiment." Their existence in samples is by no means an immediate precursor of life," say Kauffman and co.

This also explains why attempts to extend experiments like Urey and Miller's over months and years have never yielded anything interesting.

Even computer simulations of the origin of life have never yielded clear evidence of how the step can be taken from amino acids to auto-catalytic chemical networks and then to self-reproducing molecules of life.

That places some dampers on the idea that the universe could be teeming with life. Instead, biologists who study the origin of life will need to look much more closely at the special conditions in which biological—or, as Kauffman and co put it, "post-chemical"—evolution occurs. "Life's secrets are coded in the interactions and post-chemical evolution of these molecule families," they say'.

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23 https://arxiv.org/abs/1806.06716v2
24 https://www.technologyreview.com/2018/07/09/141564/first-evidence-that-amino-acids-formed-soon-after-the-big-bang/

Clearly, there is much work to be done."
Extracted from MIT Technology Review 9 Jul 2018

Assessment

The big bang may have been a chance event or otherwise, but once it happened, the physical constituents of the universe were determined, right down to the last atom.

It seems, at the incipience stage, that our proto-life somehow perceived that there was a higher organisation of things to be found by harnessing the chemicals floating in the universe.

Putting it differently, after messing arounds with everything (possibly for some million years), his incipience stumbled on biology as the way forward.

The universe naturally includes laws of chemical evolution which incorporate the progressive aggregation and build-up of molecules, compounds and organic compounds. In particular, I am satisfied that, like water, organic compounds came into being as part of this process soon after stellar-nucleuses, and got distributed to the planets in much the same way

It is clear that the Solar system had organic compounds, from the bombardments we have received. There undoubtedly were organic compounds on Earth when our proto-organism came alive.

The growing scientific consensus seems to be that the transition from non-living to living entities on Earth was not a single event, but a process or chain of increasing complexity. Most importantly. after the trigger of life, they included the emergence of molecular self-assembly, self-direction, auto-catalysis, and the emergence of cell membranes, all of which happened spontaneously..

Our proto-organism had no example to follow or competition to beat. Somehow he chose options coherently favouring this objective. After some zillions of years, there were several zillions of descendant microorganisms pushing the biological boundaries in all environments.

Contrary to cosmic thermodynamics, our biology seems imbued with a drive to build and "upgrade" itself, opting for the next most favourable step along its line of upgrade options

As far as I can see, the actual "happening" was by a series of trials and errors. Our proto-organism sought out different energy options and experimented with different fermentations and combinations, and moved from one "success" to finding the next "necessary" (if indeed it could rationalise) sequence. It did take a couple of billion (million million) years, though.

If, in the cosmic order of things, quarks, electrons, ions and anions have been hard-wired to respond to the laws of quantum mechanics to form matter, anti-matter, etc, I do not see why minerals and organic molecules should not by the same operation of chance respond to further tiers of laws to activate biochemical cellular life. I am comfortable that, allowing for such chance, biochemical life could have happened abiogenetically.

The existence of organic compounds does not mean life automatically exists. Life still has to be triggered in an organic body. An energy charge on inorganic matter to produce an organic compound could be, probably is, within the realms of chemical evolution. But an energy charge on an organic or inorganic compound to produce the characteristics of life, on our present understandings, would be a "quantum leap".

At some point, our proto-organism found a need to store, retrieve and apply information from an increasing span of variables, as well as organise (sync) activities across its multiple intra-cellular functions. It had a management work-load. Most importantly, it had to choose reproductive adaptations and mutations allowing for the best possible options for advance. The RNA/DNA system was the quantum leap. Before that, the big bang was essentially in degenerative mode, ie unfolding and unwinding. This was the first physical signal of intentionality for the provision of evolution, the basis of increasing complexity.

At the same time, our proto-organism banked on rapid and mass replication, with a high rate of mutation and horizontal transfers. This resulted in zillions of himself out there testing various options across all environments. There was no central feedback and control and the mortality rate was phenomenal, but the ones that took a step forward took the lead, perhaps more than one.

And yet, given the epochs of time involved, the RNA/DNA system could have been put together by trial and error. I invite you to calculate the odds at which our microorganism was working: a million microbes working a million years x 365 days x 24 hours x 60 minutes divided by 12 minutes per life span = $43{,}800 \times 10^{12}$ which gives 0.000000000438-to-1 as the fantastically good odds for striking .a winning combination – in fact for a million microbes, once every 6 minutes around the globe. Yet the choice of direction in each case was a quantum leap.

What seems to me clear is that the universe laid down several pathways (and possibly locations) for the emergence of our form of life. In retrospect a proto-microorganism on Earth with a high replication rate and short lifespan became the front-runner to start the process. Time was not initially an issue. A cool billon years, or more, would not have been too long. Even if it had a notion of what it wished to evolve, the timing would largely be determined by the chances and circumstances to be..

I go by what some call the “biogenesis” route, which from the overall design and processes-in-place of the universe seems targeted towards establishing the right conditions for life. Life is not an accident, but enabled as a cosmic objective. Chance is assigned a major role in all stages of actuation. If chance did not choose the specific routes of advancement, it was the eliminate device. One could say Earth was pre-selected, or again it was thrust into the role by chance.

The premise that the cosmos intended the universe to have life opens the door to life being similarly intended (and prepared for) in other realms of the cosmos. When we break the time-barrier, we shall find out. I very much incline to the idea.

Abiogenesis is the term used to convey that life originated by natural processes from non-living matter. It leaves open how non-living matter started, including that the latter may have started from nothing – which admits the proposition that life could have originated from nothing. Needless to say, abiogenesis has been neither proved nor disproved.

I prefer to think of each new discovery as revealing another step in the design of the cosmos, and the role of science is to discover the total plan or design of the cosmos. I accept that it is beyond science to dissolver who designed the cosmos

Diversification of Prokaryotes

Prokaryotes were unicellular from the beginning, and lived in colonies. Today, they are essentially the same, but have grown bigger with more internal sophistication and in myriads of classifications. They live in every liveable habitat in every corner of the planet - in every ocean, in soil, on land, on and in plants and animals, and in the human body.

Very early in its evolution, the original microorganism diversified into two main domains; Eubacteria (bacteria) and Archaea, with bacteria often standing in as the continuation of the main-stream. In that sense, the original microorganism is often referred to as a bacterium. The archaea are often thought to have branched out first, and adapted to living in extreme environments. Both branches have contributed in their respective ways to the evolution of the eukaryote, but by far the largest has been bacteria.

The earliest fossils of bacteria and archaea are found in the stromatolites structures in the Apex chert formation in Western Australia, both approximately 3.5 billion years old. Both took off very early.

Prokaryotes further diversified in this early period into fungi, lichen, molds, protists, various algae, prions and viruses., while still microorganisms, These are nowadays classified in separate domains. Most of these organisms survive outside of a host, in the air, water or soil, with the exception of viruses, which can only survive for a brief time outside their host cells – and which may in fact have preceded the bacteria and archaea. It Is not clear which branched out of the original mainstream, and which from the two sub-domains.

The only way we can know our past is from fossil records. The Hadaan and the Archaean were physically turbulent times, and very little was preserved. One group of bacteria, the cyanobacteria, have left traces that extend back nearly 3.5 billion years. The oldest undisputed evidence of cyanobacteria dates to be 2.1 billion years ago. They represent a clear new stage in the evolution of the prokaryote. Suffice it to say that all higher life forms on Earth evolved because of the evolutionary leap made by the cyanobacteria.

Most microorganisms can freely exchange genes, even between widely divergent species. This horizontal gene transfer, coupled with a high mutation rate, allows them to swiftly evolve and adapt to diverse environments. This is the basis of their survival.

and the continents and to extremes of environments.
These microorganisms have remained steadfastly single-celled, which facilitates adaptation and replication. They do so by binary fission – division straight down the middle. As a result, they can double their numbers a few times a day – especially bacteria in the human body – and move with the oceans.

Biosphere

The Earth's biosphere extends down to at least 10 km below the seafloor, up to 41–77 km into the atmosphere and includes soil, hydrothermal vents and rock The biosphere has been found to extend the deepest parts of the oceans.

Under certain test conditions, life forms (bacteria in particular) have been observed to survive in the vacuum of outer space.

Multi-cellular Organisms

Some microorganisms did experiment with multi-cellular arrangements. Evidence of this includes a two billion-year-old, coil-shaped fossil of what may be blue-green or green algae found in the US and Asia, named Grypania spiralis, or some 2.5 billion-year-old microscopic filaments recorded in South Africa representing the first true evidence of multicellular life.

It \would be two billion years after life emerged on Earth, that complex life emerged in the form of large, multi-cellular nucleated cells with membrane-bound organelles The evolution of fungi, plants and animals followed this path.

Classification of Living Things

The classification or taxonomy of living things generally in use is that originally proposed by Carl Linnaeus in 1753. It is a hierarchical system, which works like a series of nesting boxes. The top classification is the domain, followed by kingdom, phylum, class, order, family, genus, and species.

There are three domains that include all the living things on Earth. The domains are Bacteria, Archaea, and Eukarya. Bacteria and Archaea are all single-celled microorganisms that do not have DNA contained within a nucleus. Most of the Archaea live in extreme environments. The Bacteria and Archaea were once grouped together as a single kingdom (called Monera), but scientists later discovered that the Archaea were distinctly different. Archaea are more similar to Eukarya than to Bacteria.

All plants and animals, including humans, belong to the domain Eukarya, the distinguishing features being they are multi-cellular and aerobic, ie oxygen-dependent,

Classification of Prokaryotes

The classification of prokaryotes has presented many problems. due to the fact that most of its history took place from nearly four million years ago, and we lack even fossil records. However, with breakthroughs in DNA technology, it has been possible to know more about them, and line them alongside the others.

There have been several classifications, and the subject is still open.
The List of Prokaryotic Names with Standing in Nomenclature (LPSN of 2018) of the Microbiology Society25 gives a total of 116 Classes, 7 Sub-classes, 196 Orders, 24 Sub-orders,415 Families, 2930 Genus, 15,448 Species, and 581Sub-species, with a total of 19,717 categories of prokaryotes in all.

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[25] https://www.microbiologyresearch.org/content/journal/ijsem/10.1099/ijsem.0.002786

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Chapter six
C. Early Proterozoic Eon
(2.5 to 1.6 billion years ago)

Third Definitive Formation Eon

The Proterozoic was the third and **longes**t of the Earth's four geologic eons, spanning the time interval from 2.5 billion years ago to 538.8 million years ago. It was the last third of the Pre-Cambrian "super-eons", following the Archaean and the Hadaan before it. The Proterozoic eon is divided in the following eras in geological time:

. - The Paleoproterozoic, 2.5 to 1.6 billions years ago (@ **Early Proterozoic**)
. – The Mesoproterozoic, 1.6 to 1.0 billion years ago, and (@ **Late Proterozoic**)
. – The Neoproterozoic , 1.0 to 0.538 billion years ago (@ **Late Proterozoic**).
Due to their startlingly different histories, this chapter deals with the Paleoproterozoic, and the next with the other two.

The Proterozoic eon was followed by
. – The Cambrian Explosion, 538 to 485 million years ago, and
. - The Phanerozoic eon, 485 million years ago, and on-going.

Earlier Formative eons

It is good to re-cap what took place up to the Archaean eon just before this:

. 1 – The Earth was already two billion years old
. 2 – The Last Heavy Bombardment (LHB) took place 1.3 billion years ago
. 3 – The average surface temperature was down to 40 degree Celsius.
. 4 – The waters had condensed in the lowest places. It was an ocean world.
. 5 – The hardening crust was still being substantially subducted by magmatic currents
. 6 – Five continental masses, and one supercontinent, formed and reformed at various times[26].
. 7 – The atmosphere was a reducing one (no oxygen) before the Oxygen Explosion (2.2 to 1.9 bya),

Earth's Magnetic Field

The Earth's magnetic field was established 3.5 billion years ago. The solar wind flux was about 100 times the value of that of the modern Sun, so the presence of the magnetic field helped prevent the planet's atmosphere from being stripped away, However, the field strength was lower than at present and the magneto sphere was about half the modern radius. The atmosphere has played a key role in our evolution.

(i) Paleoprotozoic Era
Early Proterozoic Physical World

Plate Tectonics

Beginning from the Early Proterozoic, plate tectonics became the dominant factor in the evolution of the planet's surface. The outer layers of the Earth were crinkling like the skin of a shrinking apple, forming rigid tectonic plates.
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[26] Portions of these, known a cratons, would survive forming the continental cores of future landmasses,

The outer layers of the Earth are divided into the lithosphere above and the asthenosphere below. Tectonic plates are formed in the lithosphere. The latter is overlain by oceanic crust or continental crust.

The lithosphere is cooler and more rigid, while the asthenosphere is hotter and flows more easily. The lithosphere therefore exists as separate and distinct tectonic plates, which ride on the fluid-like solid asthenosphere.

The continental lithosphere is typically about 200 km thick, though this varies considerably. The average oceanic lithosphere is typically 100 km, and because it is formed at the mid-ocean ridges it spreads outwards.

The term “mantle” geologically refers to the planet’s solid outer envelope surrounding its core, to an average depth of 2,900 km. It includes both the asthenosphere and lithosphere.

Within the lithosphere, the mantle is differentiated from the crust per se by the “Mohorovic discontinuity” (some 10 – 90 km deep), a seismic feature, usually thought of as the boundary of the Earth’s crust.

During the Early Proterozoic, the tectonics plates began to form as a result of the cooling of the planet. The oceans lost more heat than the landmasses. The uneven heating from the core below, the uneven build-up of temperature and pressure beneath the surface masses combined with the uneven loss of surface temperature generated convection currents within the mantle, and the tectonic plates began to move.

The ancient cores of the continents (gratons) in fact moved over wide areas of the globe, forming and reforming, accumulating smaller fragments of crust and sometimes colliding with other large landmasses. The opposite also happened, leading to continental rifting, and the opening up of oceans

Continents

The start, the land masses of the Proterozoic were in a state of dispersal, with 10 disparate continental pieces, fragments of the earlier supercontinent Kenorland - rather like today. Columbia became fully assembled only by about 1.82 billion years ago.

The Early Proterozoic was dominated by the supercontinent Columbia. It existed approximately 2.5 to 1.5 billion years ago coming together during this period of global-scale collisional events.

Other independent pieces included the continental scale Laurentia and Baltica and the two cratons of North and West Australia. Over its long life, these and others merged with it and separated, including cratons now forming India, China, Siberia, Amazonia and Antarctica.

We therefore have to imagine zillions of prokaryotes on each block and in the waters in between, and yet they together produced an extraordinarily coherent community and evolutionary story, as this and subsequent chapters will describe..

In terms of the physical scenario, except for the tectonic, volcanic and magmatically active areas, the land and the oceans were now stable for sufficient periods (say for 300-500 million years at a time) to enable our microorganisms to indulge in longer stretches of evolution. The land was a limit but the oceans facilitated growth and dispersion. The atmosphere was the physical frontier being directly changed by the new biology.

Glaciation

As the Earth progressed towards the Proterozoic, the planet cooled to the temperatures sustaining liquid water, with the possibilities of ice. The first glaciation of which there is trace evidence was Pongola, some 2.9 billions years ago. The glacial episode in fact occurred in the Mesoarchean era, over some 150 million years

The next glaciation was the Huronian glaciation which occurred from approximately 2.5 to 2.2 billion years ago I the early Proterozoic. It was a period where at least three ice ages occurred.

The Rhyacian glaciation was the third in the era, and lasted from 2.3 to 2.05 billion years ago. The Huronian began at the start of the Rhyacian and lasted 100 million years or about 80% of this period.

Early Proterozoic Atmosphere

As the Earth cooled, an atmosphere formed mainly from gases spewed from volcanoes. These included hydrogen sulfide, methane, and ten to 200 times as much carbon dioxide as today's atmosphere.

The geological perspectives treat the atmosphere as mainly outgassed from the solid Earth. It was an atmosphere of nitrogen (N_2) and carbon di oxide (CO_2) with trace amounts of water (H_2O), methane (CH_4), carbon monoxide (CO), and hydrogen (H_2). This is described as a weakly reducing atmosphere. Such an atmosphere contains practically no oxygen. Oxygen (O_2), was present in the atmosphere at that time at just 0.001% of its present atmospheric level..

Recent research indicates that the early atmosphere contained ammonia (NH_3), water vapour (H_2O), hydrogen (H_2), and methane (CH_4).3

The Sun shone at about 70% of its current brightness 4 billion years ago, but there is strong evidence that liquid water existed on Earth at the time; a warm Earth, in spite of a faint Sun. Carbon dioxide levels were much higher at the time, providing enough of a greenhouse effect. The other factor sustaining the temperature was most likely the gas methene, which is a powerful greenhouse gas and was produced by early forms of life known as methanogens.

GOE

As will be described in the following section, our prokaryote microorganisms, and cyanobacteria in particular, had from perhaps before the Palaeozoic, been engaged in oxygenic photosynthesis as the means of harvesting energy, which process produced free molecular oxygen as a by-product released into the atmosphere. By the early Proterozoic, this resulted in an unprecedented increase in oxygen levels to above 10% (of present-day) in the atmosphere, turning it into an oxidative atmosphere.

The increasing free oxygen caused oxidative damage to organic compounds making up our microorganisms, and caused the near extinction, the first and longest lasting such event in the Earth's history, of the anaerobic microbial mats which dominated the Earth’s surface and the shallow seas. The latter would survive and eventually re-oxygenate the atmosphere permanently.

Early Proterozoic Biosphere

Finally, in the In Early Proterozoic, lasting nearly one billion years, our original microorganism evolved to be a totally competent entity: the single-celled prokaryote. It occupied the oceans, all corners of the continents, and it adapted itself to live in all the extremes of climate.

By the early Proterozoic, our microorganism had mastered the use of the available range of nutrient resources and physical resources, including sunlight. Within its single-cell structure, it had developed a metabolic system which served not only its energy production, but also its food acquisition, processing and digestion, as well as cell maintenance, growth and reproduction.

After a while, our microorganisms doubled their numbers daily, if not faster. They were the first hordes of cosmic evolution, the rampaging “earthlings”. They were not visible, but existed in the zillions.

They constituted the entire biosphere of this planet, in fact the first beings of the entire cosmos as far as we know: microscopic, unicellular and a sexual.

Our microorganisms had taken all the necessary time to get to this point. They took about two billion years, give or take a few million. They would have been two billion times round the Sun, and beginning their tenth circuit round the Milky Way.

Our lead prokaryotes, were on the frontiers of pushing evolution to its next stage. They would transform (oxygenate) the atmosphere, and had begun the evolution of the next higher life-form: the multi-cellular eukaryote.

Before the Huronian Ice Age, most organisms were anaerobic, relying on chemosynthesis and retinal-based anoxygenic photosynthesis. for production of biological energy and bio-compounds. The front runners were dabbling in the oxidation of water. With the beginning of the Huronian glaciation, as will be related in the next section, cyanobacteria (the main population of our microorganisms) began to oxygenate the atmosphere

I searched but found no comment made anywhere whether the Huronian gladiation did or did not enhance, slow, stall or affect the our evolving microorganisms, both prokaryotic or eukaryotic, or the GOE for that matter. I imagine it slowed things down. It was not the cold but the oxygen that did it.

After the Huronian Ice Age ended, the Earth was swelteringly for a hot a billion years with little or no ice even in the coldest places. The warm seas hosted an ever-increasing diversity of life. The primary life-form was the prokaryote. After over a billion years of constant heat, after the Huronian, around 850 million years ago, a gradual change started to occur.

This is the time when the first microorganic eukaryotes are thought to have originated from the symbiosis between the asgardarcdaea and the alphaproteobacteria, as well as sexual production - found within the eukaryotes only.

Huronian Glaciation

The Huronian glaciation occurred from approximately 2.5 to 2.2 billion years ago in the Early Proterozoic. The Huronian glaciation was a period when at least three ice ages occurred. The Huronian was located in the region north of Lake Huron, in Canada. Its geographic spread is not clear, but it is referred to as a. “global glaciation”.

The Huronian glaciation broadly coincided with the Great Oxygen Event (GOE). The oxygen reacted with the methane to form carbon di oxide and water, both much weaker greenhouse gases than methane, especially as water vapour readily precipitated out of the air with dropping temperature.

This caused an icehouse effect, possibly compounded by the low solar radiation (70%) at the time as well as the formation of an ozone layer, and the reduced geothermal activities at that time.

The Huronian-Rhyacian glaciations were the longest in the history of the Earth, Popular perception is that one or more of the glaciations may have been “snowball” Earth events, when all or most of Earth's surface was covered in ice. However recent evidence contests this, indicating temperate climates in low latitudes, providing scant evidence for global glaciation.

Saga of the Cyanobacteria

In the latter half of the Paleoproterozoic, the cyanobacteria[27] were the front-runners among the prokaryotes, that literally changed the world. They were responsible for oxygenating the planet, enabling the evolution of the eukaryote.

This family or phylum emerged very early, in fact not long after the bifurcation of the prokaryotes into the two domains of the Archaea and the Eubacteria @ Bacteria. The cyanobacteria belonged to the latter.

[27] - The singular is “cyanobacterium”, but the microorganism is invariably referred to in the plural “cyanobacteria”, both in the singular and the plural according to context.

We know that cyanobacteria had appeared as early as 3.4 billion years ago as stromatolites. Recent research suggests that the "crown group"[28] of the phylum cyanobacteria branched off around 2.9 billion years ago. Some think they might in fact have been the original microorganism.

Scientists believe prokaryotes were dabbling with and acquiring the ability to trap sun-light to supplement their meagre supplies of energy. from somewhere before 3.0 billion years ago, Before that, prokaryotes obtained their energy from inorganic matter, ie chemo lithographically.

Photosynthesis – Sunlight Energy

It was the cyanobacteria who successfully harnessed sunlight to deliver usable energy.

At that point, oxygen was not involved. The Earth's atmosphere contained no oxygen to speak of (0.004%). This break-through became known as "anoxygenic photosynthesis."

Scientists believe that at about 2.7 to 2.5 billion years ago, the cyanobacteria led in a second major break-through by using sunlight additionally to oxidise water. One commentator referred to this as using water as a fuel. This released the considerable energy binding the constituents of water.[29] With Earth being a "water world", this was the great learning. It was a huge turning point in our evolution.

Our cyanobacteria had in fact now established nothing less than a transfer link between a soggy Earth and a limitless source of energy, the Sun. This second process has now become known as "oxygenic-photosynthesis". With abundant energy, our cyanobacterium were fuelled to grow more complex, enabling us to evolve eventually to humans. We would not be here otherwise.

The evolutionary strategy of the prokaryote (and therefore the cyanobacteria) was (and is) truly ferocious. A conservative figure is that they doubled (and still do) every hour or less, with no fuss or foreplay, by binary fission. With minimal internal architecture and a short life span, they were capable of quick horizontal transfer, adaptation and mutation. And they reproduced by the zillions. They swamped the oceans and then the land. With oxygenic photosynthesis, their energy draw-down potential was limitless.

The waste product of the oxidation of water was oxygen. The cyanobacteria had no use for it, and it was simply released into the atmosphere. And, the rate of oxygen release must also have doubled by the hour. It is interesting that in the original cosmic scheme of things, free oxygen was a minor gas distributed around the galaxies mainly by stellar-nucleosyls. Its main role was as the element together with hydrogen forming water, and with a friendly propensity to bond with most of the other elements as inorganic and organic compounds. Unlike sunlight, water, amino acids and the other organic compounds, oxygen was not specifically pre-provided as a necessary constituent of life support. The cyanobacteria made it so.

With zillions of cyanobacteria releasing oxygen, after much of the rocks of the Earth's surface had become oxidised, the oxygen began to accumulate in the atmosphere. The latter progressively transformed from a reducing to an oxidising atmosphere. Solid geological and scientific evidence indicates that this began around 2.1 billions years ago and culminated around 1.8 billion years ago with oxygen reaching up to 10% of the atmosphere.

Great Oxidation Event

This event is known as the Great Oxidation Event. Our cyanobacteria had changed the ecology of the planet. **One might even say they transformed the Earth into a planet for a new kind of earthling not previously possible.** The change was biologically added to the standard cosmic design.

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[28] The "crown group" encompasses all the species (known to exhibit photosynthesis capabilities) living today, their most recent common ancestor, and all (extinct) descendants of the most recent common ancestor. It is a way of defining a clade,

[29] Oxidation of one molecule of water involves transfer of four electrons to the oxidant, a high redox potential.

Great Oxygen Crisis

And there was a second turning point that occurred simultaneously. Our world was anoxygenic and our microorganisms oblate anaerobics. Oxygen was basically poisonous to the prokaryote. The excited single oxygen molecule was very reactive and biologically damaging. Among other things, it produced free radicals and a poisonous by-product named "reactive oxygenic species (ROS)". Anaerobes do not possess the defences against the latter, and therefore cannot survive in oxygenated air.

In transforming the world, the cyanobacteria spawned the adder of their own extinction. Even as the oxygenation of the planet took place, the prokaryote populations began to diminish, capping off the oxygen supply, the rate of which dropped and stopped growing. Scientists estimate that about 90% of the population of prokaryotes (that is of all earthlings) went extinct, by about 1.6 billion years ago. This even is known as the Great Oxygen Crisis. It was also the first extinction event, although outshone by others later and generally not counted. Oxygen levels fell, but remained in the low digital percentages.

Fight for Survival

As they were throttled by oxygen, our cyanobacteria, and the other front runners, decided to survive and evolve. They would master the oxygen world and become aerobic.

Their first defence was to produce the necessary enzymes to counteract the ROS, which they did/

Their second strategy was to take advantages of the many valuable features of oxygen by incorporating its use in their metabolism,

And the third was to retain oxygenation-photosynthesis for the continued supply of oxygen. In future, they would control the supply.

The total cyanobacterial population would have been much reduced in numbers in the meantime, with the experimental group still smaller. The turn-a-round would have been very slow. At no point was there any equilibrium reached until nearly 90% of all life was lost.

Adopting oxygen

And our prokaryotes did successfully incorporate oxygen into their metabolic procedures to optimise their internal efficiencies in progressive related steps, preparing the way to evolve to eukaryotic.

Scientists speak mainly of cyanobacteria leading, but I would include the other front runners. I like to think there was a high level of collective or shared effort in the whole advancement.

Tthe prokaryote was at that stage was (and still is) a single-cell microorganism, of less than an micron (0.000001m). Everything that was engineered happened inside it.

Various parallel developments took place. We list these, simplified, to purely impress the reader with their extraordinary and comprehensive bio-technical capability.

.1 They added a Photosystem II to their original chlorophyll centre to expand the frequencies of trappable sunlight .

.2 They re-organised their (water-oxidising) Oxygen-Evolving Centre to deliver a higher throughput of electron energy, while continuing to supply oxygen to the atmosphere

.3 They were still dependent for their food supplies from the external environment, and upgraded their intake and digestive systems to increase the availability of glucose, including glycolysis.

.4 They perfected the Krebs cycle, their "digestion" molecular machine, which consumed the outputs from the preceding two processes to produce the first line biological energy carrier in the ADP30.

.5 They earlier evolved the Electron Transfer Chain (ERC) to channel the latter into the ATP31 Synthase, a biological "molecular machine" (an enzyme) where the terminal electron receptor was located. For the latter, the early prokaryotes used various inorganic compounds (involving phosphorous) and the ATP Synthase proceeded to produce (by phosphorylation) modest quantities of ATP, the final biological energy required.

ATP synthase works by "chemiosmosis," using the energy of protons flowing down an electrochemical gradient, not by direct chemical bonding.

Adenosine diphosphate (ADP) isa vital organic compound composed of adenine, ribose, and two phosphate groups, acting as the lower-energy byproduct when ATP releases energy for cellular processes. Through phosphorylation, ADP acts as a "discharged battery" that binds a third phosphate to become ATP, powering metabolic activities, muscle contraction, and active transport.

The game-changer came when the prokaryote adopted oxygen as the terminal electron acceptor, to generate APT, by oxidative phosphorylation. With oxygen, the organism could break down glucose all the way to carbon dioxide. This released the maximum energy available. The waste products were water and carbon dioxide.

For all practical purposes, the conversion of one molecule of glucose to 34-38 units of ATP was the system maximum under all the above processes. This became the metabolic equilibrium for their one-cell operation. It has continued to be the ceiling per cell even in human cells today. This was the break-through for evolution of eukaryotic oxygenic respiration and the higher rates of metabolism necessary for the higher level animal life of the future

.6 All the above originally took place in the prokaryote's open-ended cytoplasm. It went on to developed the mitochondrion (or "mitochondria" for there are many in a cell) to house the principle functions of the above including ATP Synthase. This organelle is the identification mark of all eukaryotic cells. Scientists believe one strain, the proteobacteria, modelled the organelle mitochondria, the all-important oxygen-based energy power-house that even humans use today.

The prokaryotes would have recognised the extreme metabolic value of oxygen. It combined easily with water and everything else. Oxygen could and did extend the range of their own biochemistry, in the range and functionality of their enzymes, in ways we know not. And lastly, it was available everywhere on the planet.

Carbon Fixation

Chlorophyll that started anoxygenic-photosynthesis was adapted to give them carbon-fixation, and became the evolutionary backbone of plant life.

Carbon fixation was invented by prokaryotes (bacteria and archaea) billions of years before eukaryotes existed. to fix CO2 in anoxic environments. Cyanobacteria later perfected oxygenic photosynthesis (Calvin cycle), which provides the foundation for almost all primary biomass production.

A way was found for the surplus energy to be used to oxidise the carbon di oxide in the atmosphere, to create starch (carbohydrates) which could in turn be stored and metabolised when needed. So the necessary machinery was set up, including the Calvin cycle, for the production and consumption of stored reserves.

[30] - ADP= Adenosine diphosphate (ADP) isa vital organic compound composed of adenine, ribose, and two phosphate groups, acting as the lower-energy carrier.
[31] - ATP = Adenosine Triphosphate), the final biological energy carrier, also referred to as the unit of the "energy currency" of all living things.

The prokaryote, including the cyanobacteria, added carbon fixation to oxygenic-photosynthesis, . Our microorganisms had now coupled the two skills known together today simply as ”photosynthesis”, as exemplified today in plants and plankton who continue to generate the oxygen in sunlight (“light dependent function)” and carry out carbon fixation at night (“light independent” function), in turn storing the carbohydrates for later consumption.

Self-Sufficiency

The liberation here achieved was that our microorganism could now both draw down its stores of food and building materials, as well as switch on the energy taps, at will, no longer tied to hours of sunlight, or location. It was mobile and **self-sufficient**. At this point our cyanobacteria had become photoautotrophs. Having successfully survived to become aerobic, the procaryote possessed the resources to take evolution forward at its own pace, scale, and direction.

The human model is based on the complete portability and mobility of energy and internal resources first enabled by the cyanobacteria. The human body comprises 30 trillion cells, each (except red blood-cells) essentially a working copy of our original microorganism

We need to remind ourselves that the prokaryote (and therefore the cyanobacterium) was up to this stage a single cell entity, in which all the preceding (and many others including RNA and DNA) happened.. In conditions of “surplus energy’, the prokaryote grew by living in colonies. This permitted greater interaction and sharing.

Prokaryotes, that is cyanobacteria, never really took the route of multicellular specialisation. One reason given is that microorganisms stayed small to maximise surface area to volume for maximum internal-external exchange. For a long time, mats of co-existing single-cell bacteria and archaea were the dominant form of life on earth.

Evolving to eukaryotic

Ultimately, one of the early eukaryotic cells engulfed a single-celled cyanobacterium and evolved a chloroplast-bearing lineage, the ancestor of modern plants, which have carried on the proud dual function tradition of photosynthesis started by their single-celled forebears.

Today, we know that the eukaryote was eventually born by the endosymbiosis of multiple generations of front line prokaryotes, making the latter clearly our ancestors.

It took another billion years before the eukaryote became the lead front of evolution. The oldest known fossil of an eukaryote is 1.6 billion years ago.

The overall consensus is that the cyanobacteria was a lead, if not the leader in the development of oxygenic-photosynthesis. As they recovered, they went on to re-oxygenate the world, evolve the eukaryote, and establish full photosynthesis as the basis of the ecological world of all future living things.

Cyanobacteria Today

Scientists estimate that some 28% of the world’s oxygen today is supplied by plants and the rest (about 72%) by phytoplankton32 in marine and aquatic environments.

The latter comprise various microorganisms both eukaryotes and prokaryote. The line between the single-cell eukaryote and the aerobic prokaryote can be very thin. The later are the most abundant phytoplankton in open, nutrient-poor oceans, often outnumbering eukaryotic phytoplankton in those environments. The cyanobacteria are the most significant, being the principal if not the sole prokaryote phylum carrying out oxygenic-photosynthesis today.

[32] - Phytoplankton = Microscopic photosynthetic organisms—essentially tiny, floating plants or plant-like bacteria (cyanobacteria)—that inhabit the upper, sunlit layer of oceans and freshwater. They are fundamental primary producers, forming the base of the aquatic food web, sustaining all living things from zooplankton, up.

Prokaryotic phytoplankton (primarily cyanobacteria) account for a massive share of the total phytoplankton cell abundance and, in some regions, constitute a significant portion (20–30% or more) of the total primary producer biomass.

One reports states that Prochlorococcus, a genus of marine cyanobacteria, is the single largest microscopic oxygen producer, responsible for up to 20% (Wikipedia says up to 50%) of the oxygen in Earth's biosphere. These microscopic organisms, often termed "ocean pastures," produce more oxygen than all tropical rainforests combined
.
Despite their prominence, they are not the only, or even the most numerous, bacterial phylum (other major phyla include Proteobacteria, Firmicutes, etc.). However, their role as the primary oxygen-producers makes them uniquely significant.

Cyanobacteria were previously known as green-blue algae, until the latter were reclassified eukaryotes. Cyanobacteria have also come to play important roles in the Earth's nitrogen and carbon cycles.

Great Oxidation Event (GOE)
(A Technical Reprise)

The Great Oxidation Event (GOE), also called the Oxygen Catastrophe, Oxygen Revolution, Oxygen Crisis or Oxygen Holocaust, was an interval during the early Paleoproterozoic era when the Earth's atmosphere and the shallow ocean first experienced a rise in the concentration of oxygen. Allowing for some disputes, it was dated from about 2.460, with the main interval between 2,300 and 1,900, billion years ago

The overall story of how the cyanobacteria accomplished this is told in the preceding section. It can be imagined that, given the standing count at any one time of zillions of cyanobacteria, oxygenic phototrophs, multiplied geometrically several times a day, the numbers involved and the oxygen release would have been be phenomenal. The latter would first saturate ("oxidate") the Earth's minerals, and then accumulate in the atmosphere.

Geological, isotopic and chemical evidence suggests that biologically produced molecular oxygen (O_2) started to accumulate in Earth's atmosphere and changed it from a weakly reducing atmosphere practically devoid of oxygen into an oxidising one containing abundant free oxygen, with oxygen levels being as high as 10% of their present atmospheric level by the end of the GOE.

The composition of the Earth's earliest atmosphere is not known with certainty. The bulk was likely nitrogen (N_2), and carbon di oxide (CO_2), which are also the predominant nitrogen-and-carbon-bearing gases produced by volcanism today. These are relatively inert gases. Oxygen, meanwhile, was present in the atmosphere at just 0.004% of its present atmospheric level.

The Sun shone at about 70% of its current brightness 4 billion years ago, but it was a warm Earth in spite of a faint Sun. Either carbon di oxide levels were much higher at the time, or other greenhouse gases were present, most likely methane, which is a powerful greenhouse gas and was produced by early forms of prokaryotic life known as methanogens

A number of hypotheses have been put forward offering alternative factors accounting for or contributing to the GOE. I stay with the main consensus. My argument: when the cyanobacteria nearly went extinct, the oxygen levels dropped, and did not recover for the next billion years until the arrival of the first plants. In. fact, a more meaningful question is why the rise was so delayed after the firs discoveries of oxygenic-photosynthesis by the prokaryotes now known to have begun a billion years earlier.

Eventually, oxygen started to accumulate in the atmosphere, with major consequences:

. 1. - Oxygen likely oxidised atmospheric methane (a strong greenhouse gas) to carbon dioxide (a weaker one) and water. This weakened the greenhouse effect of the Earth's atmosphere, causing planetary cooling, which triggered the Huronian glaciation.

. 2 - The GOE triggered an explosive growth in the diversity of minerals, with many elements occurring in one or more oxidised forms near the Earth's surface. It is estimated that the GOE was directly responsible for deposition of more than 2,500 of the total of about 4,500 minerals found on Earth today.

. 3. - Life had remained energetically limited until the widespread availability of oxygen. The oxygen greatly increased the free energy available. For example, the prokaryotes made significant improvements to (oxidised) their cellular respiratory systems. Mitochondria was evolved about then.

. 4- Saturation of the environment with oxygen led to the near-extinction of nearly all prokaryotes, but precipitated the evolution of eukaryotic life.

Lomagundi-Jatuli event

The rise in oxygen content was not linear: instead, there was a rise in oxygen content around 2.3 billion years ago, followed by a drop around 2.1 billion years ago. This rise in oxygen is called the Lomagundi-Jatuli event or Lomagundi event (named for a district in Zimbabwe and the time period has been termed Jatulian). During the Lomagundi-Jatuli event, oxygen amounts in the atmosphere reached heights similar to modern levels, before returning to low levels during the following stage. This drop in oxygen levels is called the Shunga-Francevillian event. Evidence for the event has been found globally Oceans stayed rich in oxygen for some time even after the event ended.

It has been hypothesised that eukaryotes first evolved during the Lomagundi-Jatuli event.

Oxygenic Effects on the Biosphere

Isotopic chemistry data from sulfate minerals have been interpreted to indicate a decrease in the size of the biosphere of over 80% associated with changes in nutrient (organic compounds) supplies at the end of the GOE.

The increasing oxygen level eventually depleted the reducing capacity of ferrous compounds, hydrogen sulfide and atmospheric methane and, compounded by the global glaciation, devastated the archaean microbial mats around the Earth's surface. The subsequent adaptation of surviving archaea, via symbiogenesis with aerobic proteobacteria, led to the first developments of eukaryotic microorganisms and multi-cellular life forms.

Oxygenic Effects on Physical Environment

The current scientific understanding of when and how the Earth's atmosphere changed from a weakly reducing to a strongly oxidizing atmosphere emerged when it was observed (in the 1970s) that sediments older than about 2 billion years all contained minerals in reduced forms of iron or uranium that are not found in younger sediments, because they are rapidly oxidised in an oxidising atmosphere. Further red beds, which get their colour from the oxidised ferric mineral (hermatite) began to appear in the geological record at about this time.

On the other hand, banded iron formations largely disappeared from the geological record at 1.850 billion years ago. These can form only when dissolved ferrous iron transported into ocean depositional basins are oxidised by an oxygenating ocean to form insoluble ferric iron compounds. The end of the deposition of banded iron formation is therefore interpreted as marking the oxygenation of the deep ocean. .

By way of balance, the increasing quantum of oxygen produced the ozone layer, which acted as a shield against UV radiation, not that it did much to counter act the poisonous effect of the oxygen on our indefatigable microorganisms

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(Back to TOC)

Chapter Seven
D. Late Proterozoic Eon
(1.6 billion – 538 million years ago)

BORING BILLION YEARS
(ii) Mesoproterozoic era
(iii) Neoproterozoic era

Geologic Time-Frame

The Late Proterozoic (eon), also known as the "Boring Billion Years" comprised the Mesoproterozoic era (1.6 -1.1 bya) and the Neoproterozoic era (1.1 bya – 538 mya). The first was a longer quiescent period which took nearly 700 million years. It was followed by a shorter turbulent period, the Neoproterozoic, which took 562 million years.

The first Mesoproterozoic era was essentially a period of survival and establishing improved routes for evolution. By the latter Neoproterozoic era, microorganic life had achieved several stages of development and proficiency. They needed less time for trial and error, and became increasingly interactive with and even able to modify the environment.

The Earth-Life evolutionary Dance became progressively time-foreshortened, and dependent on direct geo-physical factors, including tectonic activity, climate, the availability of nutrients, and the efficiency of bio-physical processes. .

The primary modus operandi of evolution became quick adapt, quick mutate, and rapid reproduction of multiple optional species , allowing for a wide trail of extinctions, both naturally failed and caused by external calamities..

In the second Neoproterozoic era, our microorganism would acquire mitochondria, transfer to eukaryotic respiration, develop carbon fixation and full photosynthesis, and evolve the first plants. – with traces of the next stage, animals.

The following table captures the essential facts:

Table 5
Late Proterozoic Eon
(1.6 -0.538 bya)

Geological Time frame	**Physical World**	**Evolution**
Mesoproterozoic 1.6 -1.0 bya	Great Oxygenation Event GOE)) Oxygen increase to 10.0% 1.8 bya Great Extinction Crisis GOC) Oxygen drops to 1.0% 1.6 bya Supercontinent Columbia fragments 1.5 -1.3 bya	Anaerobes, extinction rate 80-90%
Stenian period (1.2 – 1.0. bya)	Supercontinent Rodinia assembled 1.23 bya	

Neoproterozoic era 1..0 bya – 538 mya ***Tonian period*** 1.0 bya 720 mya ***Cryogenian period*** 715 - 535 mya ***Edicaran period*** 635 – 538 mya	Break up of supercontinent Rodinia 8.25-650 mya Formation of craton-continent Gondwana from Rodinia 800 – 150 mya Sturtian glaciation (Snowball Earth) 717-670 mya Neoproterozoic Oxidation Event (NOE) 700-541 mya Marinoan glaciation (Snowball Earth) 654 to 632 mya Formation. Of supercontinent Pannotia 650 -550 mya Gaskiers glaciation 579.6 - 579.9 mya	Recovery and adaptation of prokaryotes to oxygenated environment Internal use of oxygen Muti-cellular prokaryotes Eukaryotic faculties First eukaryotic microorganisms Multicellular eukaryotes Edicaran biota (soft-bodied animals)
Paleophanezoic era 538 – 252 mya Cambrian Explosion 545 – 525 mya	Formation of Supercontinent Pangaea 335 – 175 mya	

Plate tectonics and the composition of the atmosphere were the two dominant factors affecting our planet during the preceding Early Proterozoic era (2.5 to1.6 billion years ago)..

Great Oxidation Crisis (GOC)

The bio-oxygenation of the atmosphere in the Early Proterozoic beginning from 2.4 to 1.8 billion years ago, known as the Great Oxidation Event (GOE), would become a major determinant of the course of evolution.

By the Mesoproterozoic era that followed (1.6 billion years ago), It produced a major reactive biological consequence. Firstly, the dominant anaerobic prokaryote population nearly went extinct – as oxygen was poisonous to it. Scientists estimate that over 90% of prokaryotic life (at that point it meant all life) died out. Simultaneously the oxygen levels fell as the prokaryotes disappeared in what has been called the Great Oxidation Crisis (GOC) to 1% of present day levels.

In the ensuing 900 billion years (roughly from 1.4 billion to 0.538 million years ago) both plate tectonics and the climate stabilised and oxygen levels reach its lowest levels about the turn of the billennium.. The period became known as the Boring Billion Years. On the surface, it was a period of low-oxygen during which nothing much happened evolutionarily. But it allowed our prokaryotic ancestors the time to struggle for our survival.

Firstly they created the necessary enzyme defences against the harmful effects of oxygen. This meant the survivors could continue to produce oxygen. This proved to be vital to re-supplying the atmosphere for the future. Secondly the prokaryotes were able to adapt themselves to an oxygenic environment while remaining anaerobic, so much so that they have continued to exist as such to this day and still constitute the largest component of living things. Thirdly, as the re-oxygen began, the eukaryotic evolution could take place. The Boring Billion would see the emergence of the aerobic eukaryote to become the dominant form of life on Earth..
It was thought that the "Boring Billion" marked a delay in the evolution of complex life, primarily due to low levels of oxygen in the atmosphere. Earlier studies highlighted the remarkably low trace element

trends during the so-called stasis period (1.8–1.4 bya), caused by prolonged nutrient, climatic, atmospheric and tectonic stability.

Physical World

Tectonic Stasis

The evolution of the atmosphere, hydrosphere and biosphere is linked to the supercontinent cycle, where the continents aggregate and then drift apart. The Boring Billion saw the evolution of two supercontinents, Columbia (or Nuna) and Rodinia.

The supercontinent Columbia formed between 2.0 and 1.7 billion years ago and remained intact until at least 1.3 billion years ago, while Rodinia was formed around 1.23 billion years ago.

Geological evidence suggests that Columbia underwent only minor changes to form the supercontinent Rodinia. In the Stenian period from 1.1 to 0.9 billion years ago, reconstruction studies suggest that the supercontinent was located in equatorial and temperate zones.

The Boring Billion ended by the breakup of the supercontinent Rodina during the Tonian period, 1000–720 million years ago.

Climate Stability

There is little evidence of significant climatic variability during this time period. The Sun was 5–18% less luminous than it is today, but there is no evidence that Earth's climate was significantly cooler. In fact, the Boring Billion lacked any evidence of significant glaciation until near the end.

Atmospheric methane produced by prokaryotes probably contributed their greenhouse effects. Carbon di oxide levels were , perhaps 7 to 10 times higher than modern levels and contributed their effect.

Based on presumed greenhouse gas concentrations, equatorial temperatures during the mid Proterozoic may have been 22–27 °C in the tropics, 17 °C; at mid-latitudes and -23 to -2 °C at the poles, with a global average temperature about 19 °C which was 4 °C warmer than today.

Not much oxygen is necessary to sustain the ozone layer. It seems the levels during the Boring Billion may have been high enough for it, However, the Earth was probably more heavily bombarded by UV radiation than today.

Oxygen levels during the Boring Billion are thought to have been markedly lower than during the GOE, perhaps 0.1% to 1.0% of pals (present atmospheric levels).

An brief re-oxygenation event is said to have occurred from 1.59 to 1.36 billion years ago, during which oxygen rose transiently to about 4% of pals at various points. I could find no details about this event or of any significant impact.

But widespread suboxic and anoxic conditions likely lasted until about 540 million years ago corresponding with Edicaran period and the ensuing Cambrian Explosion.

Oceanic composition

The oceans may have been oxygen-poor, nutrient-poor and sulfidic (euxinic), populated by mainly anoxygenic purple bacteria, a type of bacteriochlorophyll-based photosynthetic bacteria which uses hydrogen sulfide instead of water and produces sulfur as a by-product instead of oxygen. This composition may have caused the oceans to be coloured black and turquoise.

The oceans are thought to have had low concentrations of key nutrients necessary for complex life, namely molybdenum, iron, nitrogen, and phosphorus, in large part due to a lack of oxygen and the resultant oxidation necessary for these geochemical cycles.

Nutrients could have been more abundant in terrestrial environments, such as lakes or nearshore environments closer to continental runoff.

In general, the oceans may have had an oxygenated surface layer, a sulfidic middle layer, and suboxic[33] bottom layer. The latter was possibly maintained by levels of hydrogen (H2) and hydrogen sulfide (H2S) output by deep sea hydrothermal vents.

Atmosphere

Oxygen

The sudden drop in oxygen after the GOE - indicated to have been a loss of 10 to 20 times the current volume of atmospheric oxygen - is known as the Lomagundi-Jatuli Event and is the most prominent carbon isotope event in Earth's history. Oxygen levels may have been less than 0.1 to 1% of modern-day levels.

The low oxygen levels in the atmosphere was associated with widespread anoxic waters. Even in the shallowest waters, significant quantities of oxygen may have been restricted mainly to areas near the coast.

Thus, widespread suboxic and anoxic conditions likely lasted until about 500 million years ago corresponding with the arrival of the Edicaran biota and the Cambrian Explosion.

During the Boring Billion, open ocean productivity was very low compared to the Neoproterozoic and Phanerozoic as a result of the absence of planktonic nitrogen fixing bacteria.

The low rate of nitrogen fixation, which only ended during the Cryogenian with the evolution of planktonic nitrogen fixers, meant that free ammonium was in short supply across this time interval, severely constraining the evolution and diversification of multicellular biota
lifeforms

Life Forms

Life in the Mesoproterozoic

Recent studies have pointed to a high level of variability, rather than scarcity, of bio-essential trace elements in the oceans. They have revealed several critical biological evolutionary events, such as the appearance of eukaryotes, origin of multicellularity and sexual reproduction. They have also pointed to the first major diversification of eukaryotes (crown group) which occurred during this period.

They suggest, therefore, that the period of low nutrient trace elements caused evolutionary pressures which became an essential trigger for promoting biological innovations. They then argue that the later periods of stress-free conditions, with relatively high nutrient trace element concentration, in fact facilitated diversification.

They conclude that the Boring Billion was a period of sequential stepwise evolution and diversification of complex eukaryotes, triggering evolutionary pathways that made possible the later rise of micro-metazoans[34] and their subsequent macroscopic descendants. By the late Mesoproterozoic eukaryotic organisms had become moderately biodiverse. The Boring Billion Years formed the backdrop to what was really going on – the rise of the eukaryotes.

At the same time, prokaryotes had overcome their threat of extinction and would go on to evolved for life in an oxygenated world. We will catch up with our prokaryotes after looking at their descendants, the eukaryotes.

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[33] The suboxic zone is defined as the region where concentrations of oxygen and sulfide are both extremely low and had no perceptible gradient

[34] - Metazoans are all animals belonging to the kingdom Animalia, characterized as multicellular, eukaryotic organisms that develop from an embryo with distinct tissue layers, heterotrophic, usually capable of active movement, and have cells specialized into tissues and organs. This group includes all animals except sponges and Protozoa

Evolution of the Eukaryotes

By the beginning of the Proterozoic, around 2.5 billion years ago, some one billion years down the road, we find the prokaryote had occupied the whole planet, both the oceans and the land. They were in the zillions. They had earlier diverged from their common stream , the archaea domain from before 3.1 billion years ago and the eubacteria from before. 2.5 billion years ago,

Prokaryotic advancements

At that point, there was no oxygen in the atmosphere. Our microorganisms were anaerobic. And they proceeded in that mode to discover chemolithotrophy, anoxic respiration, chlorophyll (to trap sunlight) and, among other things, oxygenic photosynthesis, which produced oxygen. The last two would have been in the order stated.

Scientists believe the discovery of oxygenic synthesis took place quite early among the front runners in their quest for more energy, perhaps even before 3 billion years ago. The oxygen levels of the atmosphere are thought to have risen from about 2.4 billion years, reaching a maximum of 10%[35] around 1.8 billion years ago (GOE).

As oxygen levels rose in the atmosphere, our prokaryote would have (1) immediately realised its poisonous effects. and (2) perhaps more slowly its metabolic efficacy in certain functions, particularly respiration. The counter-offensive was therefore on two fronts.

As we know in retrospect, the prokaryote responded successfully on both fronts – but not achieving a turn-a-round before 90% of its population had been decimated about 1.6 billion years ago.

On the first front, the prokaryotes incorporated oxygen directly into a number of its light-dependent and light independent functions. The most important of these was oxidative phosphorylation, the actual creation of ATP energy packages. The other was adopting oxygen as the terminal electron acceptor in the energy transport chain, which maximised the energy output per molecule of glucose. These were the foundations of survival.

The prokaryotes began to grow in size and develop functional improvements. These included cell walls, and possibly flagella. The DNA was sequestered in a nucleus and the photosynthetic suite got packaged as a chloroplast and placed in an organelle known a plastid,. And, most importantly, the energy production and respiratory functions were grouped in another organelle called a mitochondrion (usually referred to as “the mitochondria”).

The single-cell prokaryote took the oxygen off the air. Although the standard prokaryote does not have mitochondria, the cell membranes of some advanced prokaryotes were and are able to perform aerobic respiration.

With these enhancements some prokaryotes became facultative (ie. aerobic or anaerobic as necessary) and some fully aerobic (oblate anaerobe.)

There was increasing sharing of functions and growth in size among those living in colonies. In the next stage, prokaryotes began to merge, and the eukaryote was born

Eukaryotes

It is now generally accepted that mitochondria originated from free-living oxygen-metabolising (aerobic) bacteria that were engulfed by an ancestral eukaryotic cell that did not make use of oxygen (that is, was anaerobic)[36].

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[35] There is some ambiguity among sources. I read this as percentage of our current atmosphere.

[36] The leading theory is they were created by symbiogenesis between an anaerobic Asgard archaean and an aerobic proteo-bacterium, which formed the mitochondria. A second episode of symbiogenesis with a cyanobacterium created the chloroplasts, which led to the emergence of plants.

Given the many forms and functions they would evolve, let us be clear that the essence of a eukaryote organism is that it can live is the presence of oxygen. It is internally compartmentalised by organelles, has mitochondria and chloroplast, and can carry out photosynthesis. Mitochondria evolved before chloroplasts. Advanced entities are aerobes.

The early formation of eukaryotes was by endosymbiosis of prokaryotes. Scientists believe the eukaryote emerged when a large archaean prokaryote engulfed another smaller eubacterian one, with one of them having the mitochondria. Evidence indicates that eukaryotic mitochondria and chloroplasts in their organelles originated in prokaryotes that lived inside other, larger prokaryotic cells.

Mitochondria arose through endosymbiosis more than 1.45 billion years ago . Many mitochondria make ATP without the help of oxygen.

Chloroplasts are thought to have similarly developed from photosynthetic bacteria, such as the cyanobacteria. A chloroplast is an organelle within the cells of certain eukaryotes (plants and certain algae) that is the site of photosynthesis.

Plastids are double-membrane organelles and found in the cells of plants and algae . Plastids are responsible for manufacturing and storing food. They often contain the pigments that are used in oxygenic-photosynthesis.
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A unique aspect of mitochondria is that they have their own genetic material, called mitochondrial DNA . It is derived from the DNA of the alpha-proteobacteria, which were parasitic endosymbionts that evolved into mitochondria, as permanent organelles of the cell.

Eukaryotic cells would also contain other membrane-bound organelles, such as the endoplasmic reticulum and Golgi apparatus. They would be typically unicellular and reproduce asexually.

The front-line eukaryotes would soon become multi-cellular, with increasing cell specialisation and levels of organisation, system integration, and functional capability. At some point, they transferred and anchored their evolution in sexual reproduction through fertilisation.

These and other features would enable life to build into entities of visible to gigantic scale, leading to the current peak of the human, possessing both incredible physical dexterity and a range of abstract faculties

The blossoming of eukaryotes did not preclude the expansion of cyanobacteria; in fact, stromatolites reached their greatest abundance and diversity during the Mesoproterozoic, peaking roughly 1.2 billion years ago, after the eukaryote arrived on the scene.

Protists

Unicellular eukaryotes are sometimes called protists. Scientists hypothesise that the first protists evolved from prokaryotes .Protists may be aerobic or anaerobic.

Protists are simple eukaryotic organisms that are neither plants nor animals, nor fungi. Protists are unicellular in nature but can also be found as a colony of cells. Most protists live in water, damp terrestrial environments or even as parasites

Protists are either autotrophic or heterotrophic. Photosynthetic protists (photoautotrophs) are characterised by the presence of chloroplasts. Other protists are heterotrophs and consume organic materials (such as other organisms) to obtain nutrition. Most heterotrophs protists lack chloroplast.

Today protists are a group of all the eukaryotes that are not fungi, animals, or plants. The eukaryotes that make up the kingdom Protista do not have much in common besides a relatively simple organism, and are autotroph or heterotroph. Protists can look very different from each other.

Algae

Algae might be regarded as the second generation of the eukaryote. One could think of them as evolving from (or after) protists, although their actual origins could be diverse. They are classified as belonging to the kingdom Protista. The algae are however not closely related in an evolutionary sense, and their phylogeny is still being delineated

Algae is a broad term used to categorise all the eukaryotic organisms that are not true plants but can carry out photosynthesis on their own, producing oxygen as a result of it. Algal organisms can either be unicellular or they can be multicellular and complex.

They lack the specialised multicellular sexual reproductive structures of plants. Algae also lack true roots, stems and leaves – like avascular lower plants (e.g. mosses). They are classified within the of the kingdom Protista.

Algae can range in size from microscopic to giant kelps that reach 60 metres (200 feet) in length. Their photosynthetic pigments are more varied than those of plants. In ecological terms, they constitute a major oxygen producer for the planet and food base for almost all aquatic life,

Algae have been classified into major groups based on colour—e.g., red, brown, yellow and green. The colours are a reflection of different chloroplast pigments. Many more than three groups of pigments are recognised. Originally, cyanobacteria were thought to be algae because of their green-blue pigmentation, but have since been retained as prokaryotes.

Algae are a group of predominantly aquatic photosynthetic organisms, naturally occurring in aquatic habitats like ponds, rivers, and lakes. The simplest of algae, the unicellular phytoplanktons, are found in every drop of water in these water bodies.

Algae survive and grow by producing their own food via photosynthesis, using inorganic materials as a source. These inorganic materials are derived from waste material like fertilisers that run off into the streams from nearby human settlements.

Algae are eukaryotic organisms and thus are made up of cells that are compartmentalised. Algal cells are surrounded by a cell wall that is primarily composed of cellulose.

They contain all the important cell organelles of the eukaryotes, i.e., nucleus, endoplasmic reticulum, mitochondria, ribosomes, Golgi complex, etc. Apart from these, they also contain the plastids, specifically the chloroplast, the origin of which is different in the case of different sub-categories of the algae.

Most algal organisms are unicellular, but some higher forms are found as aggregates of these single cells, forming one single, highly functioning multicellular organism.

In the case of multicellular algae, the main body of the organism is called the thallus. This body can be branched and individual branches are flat and called blades. Most of these multicellular algae are immobile and often attached to a solid surface. The part of the thallus that anchors the body to the support is called the holdfast. The main body and the holdfast are connected via a stem-like structure called the stipe. Lamina is the leaf-like photosynthetic part of the thallus.

The specialised cell organelles, plastids, contain the photosynthetic pigment called chlorophyll. The various sub-categories of algae are made depending upon the type of chlorophyll pigment.

Specific groups of algae share features with fungi and protozoa. Some algae appear to have a closer evolutionary relationship with the protozoa or fungi than they do with other algae.

Fungi

Fungi (singular fungus) are eukaryotic organisms that are multi-cellar. with a rigid cell wall. However, fungi are neither plants nor animals, but rather organisms that form their own kingdom. These organisms are classified under the kingdom fungi. Fungi include yeasts, molds and mushrooms .

Many people mistakenly believe fungi are plants. However unlike plants, fungi are non-photosynthetic. Theya re unable to source their energy from the Sun. Instead, most fungi release enzymes into the environment that digest organic matter and then absorb it. They are therefore further classified as heterotrophs.

The way they feed themselves is different from other organisms. They do not ingest their food like animals. Fungi obtain the nutrients they need by digesting their food externally, and then absorbing it. They feed on various dead and dying plants and animal matter, and some feed off a living host.

Fungi appear to have diverged from plants and animals around one billion years ago, at the start of the Neoproterozoic era.

Fungi do include symbionts of plants, animals, or other fungi and also parasites. Lichens for example are a complex life form that is a symbiotic partnership of two separate organisms, a fungus and an alga. The kingdom fungi includes molds and yeast.

Fungi perform an essential role in the decomposition of organic matter and have fundamental roles in nutrient cycling and exchange in the environment.

Fungi share most of the key features of eukaryotes, including the mitochondria organelle and DNA nucleus, but they lack chloroplast. With plants they do share a cell wall and vacuoles. Unlike plants, fungal cell walls do not contain cellulose. Fungi produce several secondary metabolites that are similar or identical in structure to those made by plants.

They reproduce by both sexual and asexual means, and like plant groups (such as ferns and mosses) produce spores. Some species grow as unicellular yeasts that reproduce by budding or fission

Like animals they are heterotrophic organisms, and so require preformed organic compounds for food.

The oldest confirmed fungi fossils have been as between 715 and 810 million years old, They represent eukaryotic evolution a little further down the road.

Lichens

Lichen are the outcome of symbiotic relationships between fungi and (photosynthetic) algae or cyanobacteria. The photosynthetic partner is referred to in lichen terminology as a "photobiont".

The evolutional lifestyle is known as “mycorrhiza”. The photobiont provides sugars and other carbohydrates via photosynthesis to the fungus, while the fungus provides minerals and water to the photobiont. They function almost as a single organism; in most cases the resulting organism differs greatly from the individual components.

The lichen community call this this mode of cohabitation “lichenisation”. This “trans” or extra-special association is common among fungi; around 27% of known fungi—more than 19,400 species—are lichenised. Their issue of course are polyglot and heterous.

Lichens occur in every ecosystem on all continents, play a key role in soil and the initiation of biological succession, and are prominent in some extreme environments, from polar to semi-arid They are able to grow on inhospitable surfaces, including bare soil, rocks, tree barks, wood, shells, barnacles and leaves.

Protozoa (Ancestor of animals)

Protozoa are unicellular eukaryotes . As in all eukaryotes, the nucleus is enclosed in a membrane. They are heterotrophic organisms. They are either free-living or parasites.

Protozoa are unicellular, heterotrophic, eukaryotic organisms comprising four organisation types: amebae, flagellates, ciliates, and parasitic sporozoans.

Protozoa are a specific group of single-celled organisms, like Amoebas and Paramecia, that move around and feed on other tiny organisms.

Unicellular animals are classified as protozoa .Animal-like protists are commonly called protozoa (singular, protozoan).

They are animal-like because they are heterotrophs, and are capable of moving. Although protozoa are not animals, they are thought to be the ancestors of animals.

Most protozoa are not classified in the animal kingdom because they are unicellular organisms, which means they are made of only one cell . All animals, which belong to the animal kingdom, are multicellular. There are no animals that are microscopic.

Most species are free living, but all higher animals are infected with one or more species of protozoa

Three types of animal like protists are paramecium, euglena , and amoebas. Euglena are special in that they are both animal-like and plant-like. They are referred to as mixotrophs.

Historically, the protozoa were regarded as "one-celled animals", because they often possess animal-like behaviour, such as motility and predation, and lack a cell wall, as found in plants and many algae.

Protozoa are considered to be a subkingdom of the kingdom Protista , More than 50,000 species have been described, most of which are free-living organisms; Protozoa are found in almost every possible habitat.

Protists, on the other hand, are a larger category that includes various single-celled and multicellular organisms, like algae with diverse characteristics.

Of those alive today, some 21,000 species occur as free-living organisms in aquatic or terrestrial environments, whereas the remaining 11,000 species are parasitic in vertebrate and invertebrate hosts .

They were called unicellular as they were observed as single cells. However, now it is known that protozoans can form functional multicellular aggregates. Thus a better reason to call them unicellular will be - they can survive as single cells in their niche.

Life in the Mesoproterozoic - Comment

It is clear that endosymbiosis symbiosis was a primary technique of evolution among prokaryotes and eukaryotes. The transition to multicellularity that launched the evolution of animals from protozoa marks one of the most pivotal, and poorly understood, events in life's history.

(iii) Turbulent Neoproterozoic Era (1.0 to 0.538 bya)

The Neoproterozoic era comprises three geological periods:

. 1 - the Tonian period (1.0 0.72 bullion years ago),
. 2 - the Cryogenian period (720 to 635 million years ago), and
. 3 - the Edicaran period (635 -525 million years ago)

The “Boring Billion Year” (of the Late Proterozoic) crossed over into and ended in the Tonian period, in the Neoproterozoic era,

Tonian period

(1.0 – 0.72 billion years ago).

Physical World

In physical terms, surface tectonics became active leading to the breakup of the supercontinent Rodinia. It was formed in the mid-Stenian In the preceding era. It drifted apart during this period, starting from 900 to 850 million years ago.

As the central part of Rodinia reached the Equator around 750–700 Ma, a new pulse of magmatism and rifting continued the disassembly in western Kalahari, West Australia, South China, and most margins of Laurentia.

By 650–550 million years ago, several events coincided, including the opening of the Lapetus Ocean and the Pan-African orogeny (mountain building).One important result was the formation of the continental scale Gondwana.

Climate

The Earth’s atmosphere was largely devoid of oxygen after the GOC. Concentrations of atmospheric oxygen seem to have begun to rise during the interval. It increased to 1 % relative to present-day concentrations, sometime between 900 to 800 million years ago.

Life forms

During the Tonian (1.0 – 0.72 billion years ago), very early multicellular organisms may have evolved and diversified in oxygen "oases" in the deep oceans, which acted as cradles in these early stages of eukaryote evolution.

The ancestors of green algae and seaweed first appeared as unicellular and primitive multi-cellular multicellular forms near the end of the Tonian. Scientists suggest that these organisms survived the end-Tonian glaciation in isolated habitats on the seafloor before diversifying during the Cryogenian Period.

Tonian rocks preserve some of the earliest fossils of macroalgae, and the first large evolutionary radiation of acritarches, another (assorted) group of microfossils..

Vase-shaped microfossils abound in late Tonian sediments and represent the earliest testate amoebozoans

Finally the first putative metazoan (animal) fossils are dated to the middle to late Tonian The fossils (Otava antiqua) have been described as a primitive sponges. Some recent studies have concluded that the base of the animal phylogenic tree is in the Tonian. This incredible finding places animal evolution **before** plants.

Cryogenian period
(720 – 635 mya)

Plate Tectonics

Before the start of the Cryogenian, the supercontinent Rodinia started to drift apart. The super-ocean Mirovia began to close while the super-ocean Panthalassa began to form. The break-up of Rodinia was global, in the sense it affected almost all the cratons and sub-continental tectonic blocks.

Climate-Atmosphere

The increasing concentration of oxygen in the atmosphere is often cited as the major contributor to the large-scale evolutionary phenomena that began in and followed the Cryogenian.

There was a rapid increase in organic carbon burial as a result of the increased rates of global photosynthesis.

Glaciation

The name of the geologic period refers to the very cold global climate of the Cryogenian. The Earth suffered the most severe ice ages in its history during this period.

There seem to have been two distinct Cryogenian ice ages: the so-called Sturtian glaciation between 717 and 660 million years ago, followed by the Varanger (or Marinoan) glaciation, 654 to 632 million years ago

The principial causes of the glaciations were tectonic, due to the break-up of Rodinia. Scientists also point out that the Sun's radiation had decreased during this period due to higher reflection of the white surface, and the recovery of photosynthetic, ie carbon fixation, activity must have reduced the greenhouse effects significantly.

The Cryogenian was a time of drastic climatic and biosphere changes. After the previous years of stability, the severe **Sturtian glaciation** (717 to 660 million years ago), began freezing the entire planet in a state known as the Snowball Earth.

Some scientists believe the Sturtian glaciation kicked in due to a double whammy: a plate tectonic reorganisation brought volcanic degassing to a minimum, while simultaneously another continental volcanic province (in Canada) started eroding away, consuming atmospheric carbon di oxide.

After the latter's short time-span of 57 million years, it was immediately followed by the **Marinoan glaciation** (654 to 632 million years ago). This even shorter glaciation possibly covered the entire planet in a Snowball Earth.

There is controversy over whether these glaciations covered the entire planet, or if a band of open sea survived near the equator They were contrastingly multiple regional glaciations, and together constituted the longest and most severe glaciation suffered by the planet since the Huronian, over a billion years before, and they hold this record up to now.

Between the Sturtian and Marinoan glaciations was a so-called "Cryogenian interglacial period" marked by a relatively warm climate but still anoxic oceans.

Glaciogenic deposits have been found from all the continents. They provide evidence of the most widespread and long-ranging glaciation on Earth. Several glacial episodes were evident, interspersed with periods of relatively warm climate, with glaciers reaching sea level in low paleolatitudes

Other Cryogenian glaciations were probably small and not global as compared to the Marinoan or Sturtian glaciations.

In the case of the Cryogenian ice age, the glaciers extended and contracted in a series of rhythmic pulses, possibly reaching as far as the equator. The glacial evidence occur in places that were at low latitudes during the Cryogenian, a phenomenon which has led to the hypothesis of deeply frozen planetary oceans as well in the so called Snowball Earth. New research suggests that towards the end of this period, Earth may not have been fully frozen.

Mention should be made here of the Milankovitch cycles, a contribution from astronomy. The Earth's orbit varies between nearly circular and mildly elliptical (its eccentricity). When the orbit is more elongated, there is more variation in solar radiation at different times in the year. In addition, the rotational tilt of the Earth (its obliquity) changes slightly. A greater tilt makes the seasons more extreme. Finally, the direction pointed to by the Earth's axis changes (axial precession), while the Earth's elliptical orbit around the Sun rotates (apsidal precession). The combined effect of the preceding is that the proximity to the Sun, and hence solar radiation, changes during different astronomical seasons.

Milankovitch emphasised land masses changed temperature more quickly than oceans, because of the mixing of surface and deep water and the fact that soil has a lower volumetric heat capacity than water. I did not see any more incisive data relating the Milankovitch cycles to the Cryogenian ice age.

The end of the Cryogenian ice age was caused by (world-wide) volcanic release of carbon di oxide and dissolution of gas hydrates. It might have been further hastened by the release of methane from equatorial permafrost. These phenomena were brought about by the continental tectonic upheavals.

Life Forms in the Cryogenian

During the glaciations, life was basically on survival terms. Between the Sturtian and Marinoan glaciations, global bio-growth and biodiversity remained at low levels. Evolution picked up after the glaciations. The evidence is from fossils found.

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Fossils of shelled (testate) amoeba first appeared during the Cryogenian period. Some of the oldest known fossils of sponges, and therefore animals, were found. However, it is unclear whether these fossils represented proto-sponges or complex microbial precursors to sponge-grade organisms.

Other findings suggest that new groups of life evolved during this period, including the red algae and green algae and some fungi.as the testate amoeba. The end of the period saw **the origin of heterogenic plankton, which would feed on unicellular algae and prokaryotes, ending their bacterial dominance of the oceans**

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Fossils identified as seaweed unearthed in black shale in Wuhan, in central China's Hubei Province indicate that habitable marine environments in Cryogenian times were more widespread at the time than previously known. A multi-national team under China's Geosciences University of Wuhan undertook a detailed study entitled and published its findings on 4 Apr 2023, from which I quote[37]

> "The key finding of this study is that open-water - ice-free - conditions existed in mid-latitude oceanic regions during the waning stage of the Marinoan Ice Age"
> "
> "It is fair to say that the 'Snowball Earth' events were significant challenges to life on Earth," Xiao added. "It is conceivable that these 'Snowball Earth' events could have driven major extinctions, but apparently life, including complex eukaryotic organisms, managed to survive, attesting to the resilience of the biosphere."
>
> **Mid-latitudinal habitable environment for marine eukaryotes during the waning stage of the Marinoan snowball glaciation**
> Nature Communications, 4 Apr 2023
> (cited by Reuters, 23 Apr 23)

The findings support the idea that it was more of a "Slushball Earth" where the earliest forms of complex life - basic multicellular organisms - endured even at mid-latitudes.. The world's oceans were not completely frozen and that habitable refuges existed.

37 - https://www.reuters.com/lifestyle/science/study-explains-how-primordial-life-survived-snowball-earth-2023-04-04/

Life is thought to have survived near hydrothermal vents, in meltwater ponds near volcanoes, or in shallow marine areas where light for photosynthesis penetrated through cracks in the ice. certainly prokaryotes.

The end of the period also saw the origin of heterotrophic plankton, which would feed on unicellular algae and prokaryotes and end the bacterial dominance of the oceans The unicellular algae themselves went through diversification, and their population went up by a factor of a hundred to a thousand.

Edicaran Biota

Edicaran Period
(635 – 525 mya)

The Cryogenian period was followed by the brief but extraordinary Edicaran period (545 - 525 million years ago), which lasted only 20 million years.

Plate Tectonics

After the supercontinent Rodinia broke up, most of its cratons and continental blocks reassembled into another supercontinent called Pannotia, in the Edicaran period.

Pannotia remained intact until about 550 million years ago when it too began to rift, breaking apart into the continental blocks of Laurentia, Siberia, Baltica, and Gondwana.

The break-up of Pannotia was accompanied by sea level rises, dramatic changes in climate and ocean water chemistry - and an upsurge of new life.

The Lapetus Ocean started to open while Pannotia was being assembled, This opening of the ocean and other Cambrian seas coincided with the first steps in the evolution of soft-bodied metazoans, for they made a myriad of fresh habitats available for them.

Glaciations

The **Gaskiers glaciation** lasted a short 340,000 years, between 579.6 and 579.9 million years ago - late in the Edicaran period. making it the last major glacial event of the Pre- Cambrian. It was also the last and the least of three major ice ages in the Neoproterozoic, and did not lead to global glaciation.

One bed in the Gaskiers (Newfoundland) lies just below some of the oldest fossils of the Edicaran biota, leading to early suggestions that the passing of the glaciation and the subsequent sharp rise in the ocean oxygen levels may have paved the way for the evolution of the odd organisms of the Edicaran.

The **Bou-Azzer glaciation**, was another Ediacaran glaciation that could have been similar to the Gaskiers glaciation, and with similar evolutionary effects.

Climate - Atmosphere

A second rapid rise in atmospheric oxygen levels occurred between 700 - 541 million years ago. This coincided more or less with the Snowball Earth glaciations occurring around 715 and 635 million years ago.

Over the course of the Edicaran period, the oceans gradually became better oxygenated, with the time interval immediately after the Gaskiers displaying evidence of significantly increasing marine oxygen content.

Life Forms in the Edicaran

Over the course of the Edicaran period, the oceans gradually became better oxygenated, with the period immediately after the Gaskiers glaciation displaying evidence of significantly increasing marine oxygen content.

The rapid diversification of multicellular life during this geologic period, known as the Edicaran biota, has been attributed to the increases in oxygen content.

The Ediacaran marks the **first widespread** appearance of complex **multicellular fauna** life. The relatively sudden evolutionary radiation event, known as the Avalon, is represented by now-extinct relatively simple soft-bodied animal phyla.

Oxygen-consuming **multicellular eukaryotes became ubiquitous and widespread**. Initially restricted to deeper, colder waters that possessed the most dissolved oxygen, metazoan (animal) life gradually expanded into warmer zones of the ocean as global oxygen levels rose.

The biota were typically enigmatic tubular and frond-shaped, mostly sessile (lacking independent motive capability) organisms. Fossils of these organisms have been found worldwide, and represent the earliest known complex multicellular organisms.

Most of these organisms died out during the extinction event 539 million years ago. Forerunners of some modern animal phyla also appeared during this period.

The biota largely disappeared with the rapid increase in bio-diversity during the Cambrian. The Cambrian biota appears to have almost completely replaced the organisms that dominated the Ediacaran fossil record

Determining where Ediacaran organisms fit in the tree of life has proven challenging; it is not even established that most of them were animals or hypothetical intermediates between plants and animals.

Avalon Explosion

The Avalon explosion is named from faunal trace fossils discovered the Avalon, Canada. It is a proposed taxonomic identification of this prehistoric faunal (animal) evidence, about 575 million years ago . This evolutionary event is believed to date in the Edicaran, some 33 million years earlier than the Cambrian Explosion.

Scientists are still unsure of the full extent behind the development of the Avalon explosion, which resulted in a rapid increase in metazoan diversity.   Many of the Avalon explosion animals are sessile soft-bodied organism living in deep marine environments,

Scientists are still unsure of the full extent behind the development of the Avalon explosion, which resulted in a rapid increase in metazoan biodiversity, including some first appearances.

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Chapter Eight
E. Phanerozoic Eon (Visible Universe)
(538 million ya to present)

The Phanerozoic is a time in Earth's history when active complex life forms evolved, took their first foothold on dry land, and when the forerunners of all multicellular life on Earth began to diversify.

Nothing we have described and cogitated upon so far was actually visible. All of life we have examined, both prokaryotic and eukaryotic, has been microorganisms. it happened a long time before, and there was very little evidence to work with.

Phanezoic means “visible life”. With the Phanerozoic, life evolved to larger sizes, achieved extra-ordinary levels of biological organisation and diversify, on land into plants, animals and human, and in the oceans into myriads of marine species.

Rate of Evolution

The most outstanding feature of the Phanezoic era is the rapid and steep rate of evolution. It took over a billion years to produce a single-celled prokaryotic, and another billion years to produce the single celled eukaryote. On the other hand, in the 538 million years of the Phanezoic, we have plants, animals, fish and humans, the last with incredible physical dexterity and a range of abstract faculties.

It is estimated that there are currently around 8.7 million species of eukaryote globally, and possibly many times more of prokaryotic microorganisms. More than 99% of all species that ever lived on Earth, amounting to over five billion species, are estimated to have died out. The latter include those who disappeared in the five extinction events of the Phanezoic

Changing Technology

More things have happened in a shorter time in the Phanezoic. This could be because much more of the recent evidence is preserved. We now have quantum technology to probe down to the sub-atomic level. We also have much more resources to deploy on exploration and research. We have much more information to work with.

While scientists continue to unravel the workings of increasingly complex biology, the common man wonders where the impulse for this progressive evolution is coming from and where il leading to.

Life has had to survive over 20 catastrophic events, of which no less than five have been extinction events. The Earth has also revved up both its tectonic and climatic activity.

The Phanezoic eon

The Phanerozoic eon is divided into three eras, largely on the basis of the common assemblages of life-forms: the Palaeozoic era (538 million to 252 million years ago), Mesozoic era (252 million to 66 million years ago), and Cenozoic era (66 million years ago to the present) eras.

The eras themselves comprise several geological periods. A whole lot of evolution takes place in each period.

. 1 **The Palaeozoic era**
Cambrian Explosion period (538 to 485 million years ago)
Ordovician period (485 to 445 million years ago)
Silurian period (445 to 423 million years ago)
Devonian period (419 to 368 million years ago)

Carboniferous period (328 to 303 million years ago)
Permian period (303 to 251 million years ago)

. 2- The Mesozoic era
Triassic period (251 to 201 million years ago)
Jurassic period (201 to 152 million years ago)
Cretaceous period (145 to 72 million years ago)

. 3 **The Cenozoic era** comprised the following:
Paleogene period, including the Palaeocene, Eocene, Oligocene epochs (66 to 23 million years ago),
Neogene period, including the Miocene and Pliocene ages (23 to 2 million years ago), and
Quaternary period, including the Pleistocene and the Holocene ages (2 million years ago to now.)

Palaeozoic Era
(538 - 251 million ya)

Physical World

The Proterozoic eon saw the full impact of the biological on the physical world, namely the oxygenation of the planet. This led to beginnings of eukaryotic, or oxygen-based life.

The last quarter however saw the break-up of the supercontinent Rodinia, and the onset of a series of short-term glaciations. The latter formed the backdrop to a series of extinction events, which in turn pushed evolution to produce the first pro-metazoans (animals).and plants.

Continents

The short-lived supercontinent Pannotia (633–573 million years ago) hosted the Edicaran period. By about 550 million years ago, Pannotia had separated into four continental blocks, leaving an ancient continental block Gondwana to be the main landmass hosting the Cambrian Explosion (541 to 381 million years ago), together with two smaller blocks Battica and Laurentia.

Soon after the Cambrian Explosion ended, these and other blocks would re-converge to form Pangaea (335-200 million years ago), which would break up again by the Jurassic in the late Mesozoic to form the present continental configuration.

Gondwana

Gondwana (550–175 million years ago) was an ancient supercontinent that incorporated present-day South America, Africa, Arabia, Madagascar, India, Australia and Antarctica, but has not been given that title because it never quite complied with the agreed definition.

Gondwana was formed by the accretion of several cratons[38] in the Tonian, beginning from 800 million years ago.

The remnants of Gondwana make up around two-thirds of today's continental areas. Its continental land area extended from the south pole to north of the equator. Around it were extensive shallow seas and numerous smaller land areas.

Gondwana would have been covered with green forests. Regions that were part of Gondwana shared floral and zoological elements that persist to the present day.

Pangaea

[38] - “cratons” = large stable blocks of the Earth's crust,

Pangaea (335-175 million years ago) was a supercontinent that existed during the late Palaeozoic and early Mesozoic It was fully assembled by the Early Permian period (some 299 million to about 273 million years ago).

Pangaea was C-shaped, with the bulk of its mass stretching between Earth's northern and southern polar regions. It was surrounded by a global super-ocean Panthalassa, and eventually by the Tethys ocean as well.

On the eastern periphery of Pangea was Cathaysia, a smaller continent comprising the landmasses of both North and South China, at the eastern end of the Paleo-Tethys Ocean.

The supercontinent began to break apart about 200 million years ago, during the Early Jurassic (201 million to 174 million years ago), eventually forming our present-day continents and the Atlantic and Indian Oceans.

Current Continental Configuration

According to modern definitions, a supercontinent does not exist today; the closest in existence to a supercontinent is the current Afro-Eurasian landmass which covers approximately 57% of Earth's total land area. All evolution in the Cenozoic era, including humans, took place on the current continents.

A future supercontinent, termed Pangaea Proxima, is projected to form within 250 million years.

Terrestrial Factors

For our purposes, suffice it to say that evolutionary environments are set, at any one time, by a combination of the following geomorphological factors, most of which in turn are determined by the tectonics of the place:

Land
.- terrain, mountains, shields, shorelines, lakes, rivers, plains, and soil,
.- volcanism, magmatic floods, gaseous outages, minerals,
.- atmospheric composition, oxygen, hothouse gasses, solar conditions
.- climate, temperature and seasons, glaciation, weathering

Oceans
.- Sunlight,
.- Ridges and rifts, shorelines, deeps, thermal vents,
.- Currents, stratification temperatures, etc
.- Nutrients
.- Oxygenation
.- Acidification,. carbonation
.- Mineral composition: hydrogen, sulfur, phosphorous, nitrogen

The above impact evolution, dispersal, diversification and speciation, as well as extinction. It is not possible in a reprise of this nature to say what factors determine each evolutionary event at this rapid stage of happenings, nor even by location. We can only highlight factors on the macro scale.

Ocean Tectonics

It is known that the sea level is generally low when the continents are together and high when they are apart. It is also known that the sea level also drops when there is extensive gladiation.

In the early and mid Phanezoic, much of the burgeoning new species emerged in the shallow waters of the shorelines. They were accordingly most exposed to the changing water levels.

The rifting of continents creates new oceans and sea floors. These produce a warmer, less dense oceanic lithosphere, which do not lie as deep as old, cool oceanic lithosphere. In periods with relatively large areas of new lithosphere, the ocean floors come up, causing the sea level to rise. The result is a greater number of shallower seas.

The increased evaporation from larger areas of ocean increases rainfall, which, in turn, increases the weathering of exposed rock, including fresh volcanic rock. It is thought that this increased rainfall may have reduced greenhouse gases levels to below the threshold required to trigger the period of extreme glaciation known as Snowball Earth during the Cryogenian.

Mass Extinctions/Diversifications

After the relative stability of the Proterozoic, the planet's tectonic cycles revved up in the Phanezoic. The geological periods are in the low hundreds of millions of years and less, while the epochs break down into the mere millions and the tens of thousands.

The environmental stage foreshortened and became more differentiated over both the land and within the oceans. In the table below, we reflect the major extinction/diversification events that form the backdrop to the saga of and drove evolution of life;

Table 6
Mass Extinction/Diversification Events

Geological time	Mass Extinction/Diversification Event	Date mya
Palaeozoic	Cambrian Explosion	538-485
	Cambrian Arthropod Radiation Cool Event (CARCE)	521-517
	Archaeocyathid Extinction Warm Event (AEWE), Redlichiid-Olenid Extinction Warm Event	511 to 510.5
	Great Ordovician Biodiversification Event (GOBE).	485 to 443.8
	Late Ordovician-Silurian Extinction Event	445-to 440
	Silurian-Devonian Terrestrial Revolution	428 to 359
	Late Devonian Extinction Event	372 to 359
	Carboniferous Explosion. Perm-Carboniferous glaciation - Carboniferous Rainforest Collapse	359 ton 299 300 to 305
	Permian-Triassic Extinction Event (The Great Dying)	251.9 to 251.8
	Triassic-Jurassic Extinction Event	201
Mesozoic	**Cretaceous- K-Pg Extinction Event (cooling, meteor)**	66
Cenozoic		
Palaeogene	Eocene-Oligocene Extinction Event (minor)	33.9
Neogene	Pliocene-Pleistocene Extinction Event ice ages (Med)	5.33 to 2.58
Quaternary	Pleistocene 4 glaciations Major extinction event ?	2.0 (supernova)
	Holocene 6th extinction	10.012 (11,200 years)

Life Forms

At the start of the Phanerozoic Eon, the climate became warm and humid. Since then, Earth's climate has gone through four cycles of frigid glaciers and warm tropical seas.

Early Palaeozoic

Cambrian Explosion (538-483 mya)
Ordovician period (483-445 mya)
Silurian period (445-423 mya)

Climate

The early Cambrian (541-385 million years ago) climate was moderate at first, becoming warmer to hot over the course of the Cambrian, as the second-greatest sustained sea-level rise in the Phanerozoic got underway, into the early Ordovician.

The early Palaeozoic climate was strongly zonal. While the "climate" in an overall abstract sense, became warmer, the habitat of most organisms of the time – the continental shelf marine environment – became steadily colder.

The Ordovician (485-445 million years ago) and Silurian (445-423 million years ago) were warm greenhouse periods, with the highest sea levels of the Palaeozoic (200 m above today's).

The warm climate was interrupted by the Early Palaeozoic "icehouse" ice age (460-420 million years ago) culminating in the Himantian glaciation, 445 million years ago, at the end of the Ordovician into the Silurian.

This cold spell caused the **Ordovician-Silurian** glaciation. It was the first, and the **second-greatest mass extinction** of the Phanerozoic Eon. Over time, the warmer weather moved back into the Palaeozoic Era.

As plants took hold on the continental margins, oxygen levels increased and carbon di oxide dropped.

Cambrian Explosion
(538-485 million years ago)

The Cambrian period (538-485 million years ago) was the first period of the Palaeozoic era and it lasted 53 million years.

The Cambrian was a period of transition between tectonic modes, and continents were scattered by fragmentation of Rodinia. Some theorists suggest the Cambrian explosion occurred during the last stages of Gondwanan assembly.

Lowland areas such as Baltica were flooded and much of the world was covered by epeiric[39] seas . This event opened up new habitats where marine invertebrates, such as trilobites, radiated and flourished. Plants had not yet evolved, and the terrestrial world was devoid of vegetation and inhospitable to life as we know it.

Global climate during Cambrian time was probably warmer and more equal than today . An absence of either land or landlocked seas at the Cambrian poles may have prevented the accumulation of polar ice caps.

This period sparked a rapid diversity of animals, in an event known as the Cambrian Explosion, during which the greatest number of animal body plans evolved in a single period in the history of Earth. It

[39] - "epeiric seas" = shallow waters of continental shelves and adjacent inland seas.

resulted in the divergence of most modern metazoan phyla. The event was accompanied by major diversification in other groups of organisms as well.

Some point to the increase in oxygen during the NOE that began around 700 million years ago as a primary cause of the Cambrian Explosion, providing fuel for movement and the evolution of more complex body structures. Others propose that an extinction of life just before the Cambrian opened up ecological routes or "adaptive spaces" and yet others suggest predator-prey interactions and competitive pressures reaching a point where they spurred fast animal evolution

The Cambrian marked a profound change in life on Earth. Prior to it, the majority of living organisms were small, unicellar, and simple, with notable Tonian and Edicaran exceptions. Multi-cellular organisms had selectively emerged preceding the Cambrian, but it was not until this period that mineralised – hence readily fossilised – organisms became common. The Cambrian Explosion produced the first representatives of most modern animal phyla.

Most animal life during the Cambrian was aquatic. Complex algae evolved, and the fauna was dominated by armoured arthropods. Trilobites were once thought to be the dominant life form but is has since been found that anthropoids were by far the most dominant animals in the ocean,

Before Cambrian, while diverse life forms prospered in the oceans, the land was thought to have been comparatively barren – with nothing more complex than a microbial soil crust (mats), and a few molluscs and anthropoids that emerged to graze on the microbial mats and biofilms on the Cambrian tidal flats and beaches.

However, by the end of the Cambrian, mynapods, arachnids and hexapods started adapting to the land, along with the first plants

Following a steep rise from the late Edicaran, the early Cambrian was still relatively cool, with the period between 521 and 517 million years ago being known as the **Cambrian Arthropod Radiation Cool Event (CARCE).**

However, the Earth grew generally very warm down to the turn of the century. Its climate was comparable to the hot greenhouse conditions (still to come) of the Late Cretaceous and Early Palaeogene, The **Archaeocyathid Extinction Warm Event (AEWE),** lasting from 511 to 510.5 million years ago, was particularly warm, and another warm event, the **Redlichiid-Olenid Extinction Warm Event,** followed a close million years or so after . It became even warmer towards the end of the period, and sea levels rose dramatically. This trend continued into the Early Ordovician the start of which was characterised by an extremely hot global climate.

The late half of the Cambrian was surprisingly barren and showed evidence of several rapid extinction events.

In contrast to later periods, the Cambrian fauna was somewhat restricted. Free-floating organisms were rare, with the majority living on or close to the sea floor; and mineralising animals were rarer than in future periods. Some Cambrian organisms ventured onto land, producing trace fossils, eg. slugs.

Ordovician period
(485 to 443.8 million years ago)

The Ordovician was a time in Earth's history, lasting about 41 million years, in which many groups still prevalent today evolved or diversified. This process is known as the **Great Ordovician Biodiversification Event (GOBE).**

The most common forms of life, however, were trilobites, snails and shellfish. Invertebrates, namely molluscs and arthropods, dominated the oceans, with members of the latter group starting their establishment on land during this time, becoming fully established by the Devonian. The trilobites were gradually replaced by arthropods.

The first land plants are known from this period. Fish, the world's first true vertebrates, continued to evolve, and those with jaws may have first appeared late in the period.

A group of freshwater green algae, the steptophytes, began to colonise the flood plains and riverine zones giving rise to primitive land plants.

By the end of the Ordovician, Gondwana had moved from the equator to the South Pole. The glaciation of Gondwana resulted in a major drop in sea level, killing off all life that had established along its coast.

The glaciation caused an “icehouse[40] Earth” leading to **the Ordovician-Silurian Extinctions (@ OS)**, Some 60% of marine invertebrates and 25% of families became extinct. Though one of the deadliest mass extinctions in earth's history, the extinction did not cause profound ecological changes.
.
The Ordovician-Silurian extinction refers to two extinction events The first extinction event occurred (445-443 million years ago) in the late Ordovician. The second occurred (443-440 million years ago) in the early Silurian, also known as the Himantian glaciation and extinction. The Britannica states that the OS extinctions eliminated an estimated 85% of all species.

Overlapping the preceding, there was also an Andean–Saharan ice age which lasted 30 million years during the Ordovician and Silurian periods, from 460 to 430 million years ago. Volcanic activity and weathering related to extensive mountain building caused carbon di oxide levels to plummet, chilling the planet.

Silurian period
(443.8 to 419.2 million years ago)

The Silurian is the shortest period, only some 22 million years, beginning from the second OS extinction event, which Itself lasted for 3 million years.

One important event in this period was the initial establishment of terrestrial life, in what is known as the **Silurian-Devonian Terrestrial Revolution**. Vascular plants emerged from more primitive land plants. The appearance of vascular plants allowed plants to gain a foothold on land. These early plants were the forerunners of all plant life on land.

Fungi started expanding and diversifying, and three groups of arthropods became fully territorialised.

Another significant evolutionary milestone was the diversification of jawed fish which produced cartilaginous fish and bony fish. The latter divided into lobe-finned and ray-finned fishes. Jawless fish declined.

The first freshwater fish evolved, though arthropods were still the apex predators. Fully terrestrial life evolved, including early arachnids, fungi, and centipedes.

During this time, there were four continents: Gondwana (Africa, South America, Australia, Antarctica, Siberia), Laurentia (North America), Baltica (Northern Europe), and Avalonia (Western Europe). The rise in sea levels allowed many new species to thrive in water.

Plants mostly remained aquatic until the Silurian period, when they began to transition onto dry land.

Late Palaeozoic era
Devonian period ((419.2 -358.9 million years ago)
Carboniferous Period (358.9 to 298.9 million years ago)
Permian Period (298.9 to 251.9 million years ago)

[40] “icehouse” means ice caps at both poles

Devonian period
(419.2 -358.9 million years ago)

The middle Palaeozoic was a time of considerable stability. Sea levels had dropped with the preceding ice age, but slowly recovered over the course of the Silurian to Devonian.

The slow northward movement of bits and pieces of Gondwana created numerous new regions of relatively warm, shallow sea floor. The north–south temperature gradient moderated and the far southern continental margins became increasingly less barren.

The **Silurian-Devonian Terrestrial** th **Revolution,** also known as the Devonian Explosion, was a period of rapid colonisation and radiation of land plants and fungi on dry land, with most critical phase occurring during the Late Silurian and Early Devonian

Diversity of plants increased greatly during the Silurian and Devonian periods, comparable in scale and effect to the explosion of animal life during the Cambrian. On land, plant groups diversified rapidly. The first trees and seeds evolved.

These new habitats led to greater arthropod diversification. The first amphibians appeared and fish occupied the top of the food chain.

The Devonian featured a huge diversification of fish, including armoured fish and lobe-finned fish, which eventually evolved into tetrapods (four-footed folk)

This diversification of terrestrial photosynthetic florae had vast a impact on the Earth’s atmosphere and biosphere, by oxygenation and carbon fixation.

Their roots eroded into the rocks, creating rich water-holding organic soil, known as the pedosphere, significantly altering the chemistry of the lithosphere and hydrosphere.

The floral activities also exerted significant changes in the water-cycle and climate, as well as creating diverse layers of vegetation that provided sustenance and refuge in both upland and wetland habitats.

Vertical growth of vascular plants allowed for expansive canopies to develop, forever altering the plant evolution that followed.

The Devonian witnessed the widespread greening of the Earth's surface, with many modern vascular plant clades originating during this period.

As plants evolved and radiated, arthropods, the first animal terrestrials, evolved independently among themselves, together with molluscs, insects and tetrapod vertebrates, , causing plants to in turn develop defences against foraging animals.

The Silurian and Devonian terrestrial florae were largely spore-bearing plants (ferns) and significantly different in appearance, anatomy and reproductive strategies to most modern florae, which are dominated by fleshy seed-bearing species that evolved in the Cretaceous. Much of these Silurian-Devonian florae had died out in subsequent extinction events.

The **Late Devonian Extinction Event** consisted of several events which collectively represent one of the five largest mass extinctions in the history of life on Earth. The term primarily refers to a major extinction, the Kellwasser event, which occurred around 372 million years ago. Overall, 19% of all families and 50% of all genera became extinct. A second mass extinction occurred 359 million years ago, bringing an end to the Devonian, as the world transitioned into the Carboniferous. Some consider the extinction to be as many as seven distinct events, spread over about 25 million years, with massive loss of biodiversity.

Carboniferous Period
(358.9 to 298.9 million years ago)

The Carboniferous spanned from 359–299 million years ago. The Carboniferous is the period during which both animal and plant life were well established on land. The early half is sometimes referred to as the **Carboniferous Explosion.**

During this time, average global temperatures were exceedingly high; the early Carboniferous averaged at about 20 degrees Celsius (but cooled to 10 °C during the Middle Carboniferous).Oxygen levels were as high as 30% of the atmosphere, the highest ever.

Tropical swamps dominated the Earth, and the lignin-stiffened trees grew to greater heights and number. As the bacteria and fungi capable of eating the lignin had not yet evolved, their remains were left buried, which created much of the carbon that became the coal deposits of today (hence the name "Carboniferous").

Perhaps the most important development of the time was the evolution of amniotic eggs, which allowed amphibians to move farther inland and remain the dominant vertebrates for the duration of this period. The period is sometimes called the Age of Amphibians because of their diversification.

Also, the first synapsids (proto-mammalians) and sauropods (which include modern reptiles and birds) evolved in the swamps.

Land arthropods and insects also underwent a major evolutionary radiation during the late Carboniferous.

Throughout the Carboniferous, there was a cooling trend, which led to the **Perm-Carboniferous glaciation** and the **Carboniferous Rainforest Collapse.** Gondwana was glaciated as much of it was situated around the south pole.

The late half of the period experienced glaciations, low sea level, and mountain building as the continents collided to form Pangaea.

Permian Period
(298.9 to 251.9 million years ago)

At the beginning of this period, all continents joined together to form the supercontinent Pangaea, which had formed due to the collision of Euramerica and Gondwana during the Carboniferous.

The land mass was very dry during this time, with harsh seasons, as the climate of the interior of Pangaea was not regulated by large bodies of water. The Carboniferous Rainforest Collapse left behind vast regions of desert within the continental interior.

Amniotes, which could better cope with these drier conditions, rose to dominance in place of their amphibian ancestors. The Permian witnessed the diversification of the two groups of amniotes, the synapsids and the sauropsids (reptiles). Creatures such as dimetrodon and the edaphosaurus ruled the new continent.

The first conifers evolved, and dominated the terrestrial landscape.

Near the end of the Permian, however, Pangaea grew drier. The interior was desert, and new taxa filled it.

Eventually, some 95% of all life on Earth disappeared in a cataclysm known as **The Great Dying**, the third and most severe Phanerozoic mass extinction.[a] Various authors recognise at least three,] and possibly four extinction events in the Permian.

The first extinction event saw a major faunal turnover, with most lineages of primitive synapsids becoming replaced by more advanced therapsids. The next was associated with the eruption of the Emeishan Traps41 in South China (262-259 million years ago)

The Permian ended with the **Permian-Triassic Extinction Event** (251.9-251.8 million years ago). It lasted under one hundred thousand years. It was the largest mass extinction in Earth's history and was the last of the three (or four) crises that occurred in the Permian. It was associated with the eruption of the Siberian Traps.

The scientific consensus is that a major cause was the flood volcanic eruptions of basalt that created the Siberian Traps, which release sulfur di oxide and carbon di oxide, resulting in euxinic (oxygen-starved and sulphurous) and acidifying oceans, and high global temperatures.

It was the Earth's most severe known extinction event, with the extinction of 57% of all biological families, 83% of genera, 81% of marine species and 70% of terrestrial vertebrate species. It was also the greatest known mass extinction of insets.

It was the greatest of the "Big Five" mass extinctions of the Phanerozoic. It took well into the Triassic for life to recover from this catastrophe, and on land, the ecosystems took 30 million years to recover. The Great Dying) formed the boundary between the Permian and Triassic geologic periods.

(ii) Mesozoic era
(251 – 66 mya)

The Mesozoic era is the penultimate era of Earth's geological history lasting about 179 million years. It is characterised by the dominance of gymnosperms[42] and archosaur[43] replies, a hot greenhouse climate; and the tectonic break-up of Pangaea.

The Mesozoic era is not subdivided into Early and Late, and its main features are most comfortably seen as a whole. In detail, it comprises three periods as follows:

. – 1 Triassic period (251.9 to 201.4 million years ago)
. – 2 Jurassic period (201.4 to 145 million years ago), and
. – 3 Cretaceous period (145 to 66 million years ago)

Terrestrial flora reached its climax in the Carboniferous, when towering lycopsids and rain forests dominated the tropical belts. Climate change caused the Carboniferous Rainforest Collapse which fragmented this habitat, diminishing the diversity of plant life in the late Carboniferous and Permian periods.

Physical World

Continents

The vast supercontinent Pangaea dominated the globe during the Triassic, but in the following Jurassic period it began to rift into two separate landmasses, Laurasia in the north and Gondwana to the south.

Compared to the vigorous convergent plate mountain-building of the late Palaeozoic, Mesozoic tectonics was comparatively mild. The sole major Mesozoic orogeny occurred in what is now the Arctic, Siberia, and in Manchuria, related to the opening of the Arctic

[41] |Traps" in geology refers to massive volcanic outpourings or floods of basaltic lava on a near continental scale.
[42] Gymnosperms are a group of seed-producing plants that includes conifers, cycads, gingko and gnetophyes.
[43] Archosauria (lit. 'ruling reptiles') or archosaurs is a clade of diapsid sauropsid representatives. tetrapods, with birds and crocodilians being the only extant (includes dinosaurs)

Geologists contend that Pangea’s formation was partially responsible for the mass extinction event at the end of the Permian period, particularly in the marine realm. As Pangea formed, the extent of shallow water habits declined, and land barriers inhibited cold polar waters from circulating into the tropics. This is thought to have reduced the dissolved oxygen levels in the warm water habitats that remained, and contributed to the 95 % reduction of diversity in marine species.

In contrast, the era also featured the dramatic rifting of the supercontinent Pangaea. By the end of the era, the continent had rifted apart, into nearly their present forms, though not their present positions.

Laurasia became North America and Eurasia, while Gondwanan split into South America, Africa Australia, Antarctica and the Indian subcontinent. The latter collided with the Asian plate during the Cenozoic, forming the Himalayas.

Climate

The Triassic was generally dry, a trend that began in the late Carboniferous and highly seasonal, especially in the interior of Pangaea. Low sea levels may have also exacerbated temperature extremes.

Land areas near large bodies of water—especially oceans—experience less variation in temperature. Because much of Pangaea's land was distant from its shores, temperatures fluctuated greatly, and the interior probably included expansive deserts.

But there is some evidence that the generally dry climate was punctuated by episodes of increased rainfall. The most important humid episodes were the Carmian Pluvial Event and one in the Rhaetian, a few million years before the Triassic–Jurassic extinction event.

Sea levels began to rise during the Jurassic, probably caused by an increase in seafloor spreading. The formation of new crust beneath the surface displaced ocean waters by as much as 200 m above today's sea level, flooding coastal areas.

Pangaea began to rift into smaller divisions, creating new shoreline around the Tethys Ocean. Temperatures continued to increase, then began to stabilise. Humidity also increased with the proximity of water, and deserts retreated.

Different studies have come to different conclusions about the amount of oxygen in the atmosphere during different parts of the Mesozoic, with some concluding oxygen levels were lower than the current level (about 21%) throughout the Mesozoic, some concluding they were lower in the Triassic and part of the Jurassic but higher in the Cretaceous, and some concluding they were higher throughout most or all of the Triassic, Jurassic and Cretaceous.

The era began in the wake of the Permian-Triassic Extinction, the largest mass extinction in Earth's history, and ended with the Cretaceous-Paleogene Extinction Event.

The Earth had just witnessed a massive die-off in which most of all life became extinct. Of the creatures that managed to survive the Permian extinction, temnospondyls reached peak diversity during the early Triassic.

The Middle Triassic, from 247 to 237 million years ago, featured the beginnings of the breakup of Pangaea and the opening of the Tethys Ocean. Ecosystems had recovered from the Permian extinction. Algae sponge, corals, and crustaceans all had recovered, and new aquatic reptiles evolved, such as ichthyosaurs.

Life Forms

Flora & Fauna

Flora

Conifers were the dominant terrestrial plants for most of the Mesozoic, with grasses becoming widespread in the Late Cretaceous. Flowering plants appeared late in the era, but did not become widespread until the Cenozoic.

The dominant land plant species of the time were gymnosperms, which are vascular, cone-bearing, non-flowering plants (such as conifers) that produce seeds without a coating. This contrasts with the earth's current flora in which the dominant land plants in terms of number of species are angiosperms. Modern conifer groups began to radiate during the Jurassic.

The earliest members of the genus Ginkgo first appeared during the Middle Jurassic. This genus is represented today by a single species, Ginkgo biloba.

Bennettitales, an extinct group of gymnosperms with foliage superficially resembling that of cycads gained a global distribution during the Late Triassic, and represented one of the most common groups of Mesozoic seed plants.

Flowering plants radiated during the early Cretaceous, first in the tropics but the even temperature gradient allowed them to spread toward the poles throughout the period. By the end of the Cretaceous, angiosperms dominated tree floras in many areas, although some evidence suggests that the biomass as still dominated by cycads and ferns until after the Cretaceous–Paleogene extinction.

Fauna

Dinosaurs were the dominant terrestrial vertebrates throughout much of the Mesozoic.
The extinction of nearly all animal species at the end of the Permian period allowed for the radiation of many new lifeforms.

In particular, the extinction of the large herbivorous pareiasaurus and carnivorous gorgonopsians left those ecological niches empty. Some were filled by the surviving cynodonts and dicynodonts, the latter of which subsequently became extinct

Recent research indicates that it took much longer for the reestablishment of complex ecosystems with high biodiversity, complex food webs, and specialised animals in a variety of niches, beginning in the mid-Triassic, 4 million to 6 million years after the extinction, and not fully proliferated until 30 million years after the extinction.

Animal life was then dominated by various archosaurs: dinosaurs, pterosaurs, and aquatic reptiles such as ichthyosaurs, plesiosaurs, and mosasaurs.

Pseudosuchians, relatives and ancestors of modern crocodiles, and some archosaurs which specialised in flight becoming the pterosaurs, were the first time among vertebrates. Therapsids, the dominant vertebrates of the preceding Permian period, declined throughout the period

The climatic changes of the late Jurassic and Cretaceous favoured further adaptive radiation. The Jurassic was the height of archosaur diversity, and the first birds and eutherian mammals also appeared.

Triassic period
(251.9 to 201.4 million years ago)

The Triassic lasted roughly 50 million years ago, preceding the Jurassic period. The period is bracketed between the Permian–Triassic extinction event and the Triassic-Jurassic Extinction event, two of the "big five".

At the dawn of the Mesozoic, ocean plankton communities transitioned from ones dominated by green archaeal-plastidans (prokaryotic) to ones dominated by endosymbiotic algae with red-algal-derived plastids (eukaryotic).

A specialised group of archosaurs, called dinosaurs, first appeared in the Mid-Triassic, and became the dominant terrestrial vertebrates in the Late Triassic or Early Jurassic, occupying this position for about 150 or 135 million years, until their demise at the end of the Cretaceous.

Archaeopteryx lithographica, from the Late Triassic, is usually considered the earliest known avialan which may have had the capability of powered flight. True toothless birds appeared in the Cretaceous.

The first mammals also appeared during the Mesozoic, but would remain small—less than 15 kg (33 lb)—until the Cenozoic

On land, groups of insects flourished, like mosquitoes and fruit flies. Reptiles began to get bigger and bigger, and the first crocodilians and dinosaurs evolved, which sparked competition with the large amphibians that had previously ruled the freshwater world, and the mammal-like reptiles on land.

Following the bloom of the Middle Triassic, the Late Triassic, from 237 to 201 million years ago, featured frequent heat spells and moderate precipitation (10–20 inches per year). The recent warming led to a boom of dinosaurian evolution on land as the continents began to separate from each other,

All this climatic change, however, resulted in a large die-out known as the **Triassic–Jurassic extinction** event, in which many archosaurs (excluding pterosaurs, dinosaurs and crocodymorphs), and almost all large amphibians became extinct, as well as 34% of marine life, in the Earth's fourth mass extinction event.

The cause is debatable, and flood basalt eruptions in the central Atlantic are cited as one possible cause.

Jurassic
(201.4 to 145 million years ago)

The Jurassic lasted 55 million years and featured three major epochs: The Early Jurassic, the Middle Jurassic, and the Late Jurassic.

The Early Jurassic climate was tropical and much more humid than the Triassic, as a result of the large seas appearing between the landmasses.

In the oceans, plesiosaurs, ichthyosaurs and ammonites were abundant.

On land, dinosaurs and other archosaurs staked their claim as the dominant race, with theropods at the top of the food chain. All-in-all, archosaurs rose to rule the world.

The first true crocodiles evolved, pushing the large amphibians to near extinction.

Meanwhile, the first true mammals evolved, remaining relatively small, but spreading widely. The castorocauda had adaptations for swimming, digging and catching fish. One was able to glide for short distances, like modern flying squirrels.

The Middle Jurassic spanned 23 million years. Dinosaurs flourished as huge herds of sauropods filled the fern prairies, chased by many new predators.

Conifer forests made up a large portion of the forests. In the oceans, plesiosaurs were quite common, and ichthyosaurs flourished. This epoch was the peak period of the reptiles.

The Late Jurassic spanned 18 million years. During this epoch, the first avians, , the archaeopteryx evolved from small dinosaurs.

The increase in sea levels opened up the Atlantic seaway, which has grown continually larger until today. The further separation of the continents gave opportunity for the diversification of new dinosaurs.

Cretaceous period
(145 to 66 million years ago)

The Cretaceous is the longest period of the Mesozoic, and has two epochs: Early and Late Cretaceous.

The Early Cretaceous spanned over 45 million years. The Early Cretaceous saw the expansion of seaways and a decline in diversity of sauropods, stegosaurs, and other high-browsing groups, with sauropods particularly scarce.

Some island-hopping dinosaurs evolved to cope with the coastal shallows and small islands of ancient Europe. Other dinosaurs rose up to fill the empty space that the Jurassic-Cretaceous extinction left behind.

Seasons came back into effect and the poles got seasonally colder, but some dinosaurs still inhabited the polar forests year round. The poles were too cold for crocodiles, and became the last stronghold for large amphibians. Pterosaurs got larger as new genera like evolved.

Mammals continued to expand their range: eutriconodonts, wolverine-like predators, and early therians began to expand and become common in the fossil record.

The Late Cretaceous spanned 34 million years. It featured a cooling trend that would continue in the Cenozoic.

Eventually, tropics were restricted to the equator and areas beyond the tropic lines experienced extreme seasonal changes in weather.

Dinosaurs still thrived, as new taxa such as tyrannosaurs, ankylosaurs, triceratops and hadrosaurs dominated the food web.

In the oceans, mosasaurs ruled, filling the role of the ichthyosaurs, which, after declining, disappeared.

Flowering plants, possibly appearing as far back as the Triassic, became truly dominant for the first time.

Pterosaurs in the Late Cretaceous declined for poorly understood reasons. Birds became increasingly common and diversified into a variety of enantiomithe and omithurine forms.

Though mostly small, marine hypobromites became relatively large and flightless, adapted to life in the open sea.

At the end of the Cretaceous, the Deccan Traps and other volcanic eruptions were poisoning the atmosphere.

As this continued, it is thought that a large **meteor** smashed into earth 66 million years ago, creating the Chicxulub Crater in an event known as the **K-Pg Extinction**, the fifth and most recent mass extinction event, in which 75% of life became extinct, **including all non-avian dinosaurs.**

After the dinosaurs died out, nearly 65 million years passed before people appeared on Earth. However, small mammals (including shrew-sized primates) were alive at the time of the dinosaurs

Pangea's breakup had the opposite effect: more shallow water habitat emerged as overall shoreline length increased, and new habitats were created as channels between the smaller landmasses opened and allowed warm and cold ocean waters to mix. On land, life-forms on the newly isolated continents developed unique adaptations to their new environments over time, and biodiversity increased.

(iii) Cenozoic era
(66 to now mya)

The Cenozoic (66 to now, million years ago) means ”new life, comparable to the preceding Mesozoic which means “middle life” and Palaeozoic which means “old life” Eras, while the Proterozoic meant “earlier life”.

The Cenozoic era is divided into
. - 1 Paleogene period (66 to 23 million years ago),
. – 2 Neogene period(23 to 2.6 million years ago), and
. – 3 Quaternary period, (2.6 million years ago to now.)

Evolution diversified and sped up even further and the period breaks down even further as follows:

- The Paleogene period, into the Palaeocene, Eocene, Oligocene epochs (66 to 23 million years ago) as follows:
  Palaeocene epoch (66 to 56 mya)
  Eocene epoch (56 to 33.9 mya)
  Oligocene epoch (33.9 to 23.3mya)

- The Neogene period, including the Miocene and Pliocene ages (23 to 2.6 million years ago),
  Miocene epoch (23.03 to 5.33 mya)
  Pliocene epoch (5.33 to 2.58 mya), and

. -The Quaternary period, including the Pleistocene and the Holocene ages (2.6 million years ago to now.)
  Pleistocene epoch (2.58 to 0.012 mya)
  Holocene epoch (0.012 to 0 mya)

Physical World

Continents

The Cenozoic is the era when the continents moved into their current positions. India collided with Asia 55 to 45 million years ago creating the Himalayas. Arabia collided with Eurasia, closing the Tethys Ocean and creating the Zagros Mountains around 35 million years ago. The break-up of Gondwana in the Late Cretaceous and Cenozoic times led to a shift in the river courses of various large African rivers.

Climate

The **Cretaceous–Paleogene (K–Pg) Extinction Event**, also known as the Cretaceous–Tertiary (K–T) extinction, was a sudden mass extinction of three-quarters of the plant and animal species of the Earth. approximately 66 million years ago. The event caused the extinction of all non-avian dinosaurs. Most other tetrapods weighing more than 25 kilograms (55 pounds) also became extinct. Excepting some species such as sea turtles and crocodiles.

It is now generally thought that the K–Pg extinction was caused by the impact of a massive asteroid, 10 to 15 km (6 to 9 mi) wide, 66 million years ago, which devastated the global environment, mainly through a lingering impact winter which halted photosynthesis in plants and plankton.

In the Cretaceous that survived and followed, the climate was hot and humid with lush forests at the poles, there was no permanent ice and sea levels were around 300 metres higher than today. This continued for the first 10 million years of the Palaeocene, culminating in the **Palaeocene-Eocene Thermal Maximum** around 55.5 million years ago.

Around 50 million years ago Earth entered a period of long term cooling. This was mainly due to the rise of the Himalayas. The upraised rocks eroded and reacted with carbon dioxide in the air causing a long-term reduction in the proportion of this greenhouse gas in the atmosphere.

Around 35 million years ago, permanent ice began to build up on Antarctica. The cooling trend continued in the Miocene, with relatively short warmer periods.

When South America became attached to North America creating the isthmus of Panama around 2,8 million years ago, the Arctic region cooled eventually leading to the glaciations of the Quintenary ice age/, of which the current Holocene epoch is an interglacial

Life Forms

Fauna and Flora

Early in the Cenozoic, following the K-P Extinction Event the planet was dominated by relatively small fauna, including small mammals, birds, reptiles, and amphibians. From a geological perspective, it did not take long for mammals and birds to greatly diversify in the absence of the dinosaurs that had dominated during the Mesozoic. Some flightless birds grew larger than humans, and were formidable predators.

During the Cenozoic, mammals proliferated from a few small, simple, generalised forms into a diverse collection of terrestrial, marine and flying animals, giving this period its other name, the **Age of Mammals**.

Mammals came to occupy almost every available niche, and some also grew very large, attaining sizes not seen in most of today's terrestrial mammals.

The ranges of many Cenozoic bird clades were governed by latitude and temperature and have contracted over the course of this era as the world cooled.

The Cenozoic is just as much the age of savannahs, the age of co-dependent flowering plants and insects, and the age of birds.

Grasses also played a very important role in this era, shaping the evolution of the birds and mammals that fed on them.

One group that diversified significantly were snakes, following the evolution of their primary prey source, the rodents.

In the earlier part of the Cenozoic, the world was dominated by a handful of primitive large mammal groups. But as the forests began to recede and the climate began to cool, other mammals took over.

The Cenozoic is full of mammals both strange and familiar, from mastodons, mammoths, three-toed horses and sabre-tooth tigers to marsupials, whales and primates. Mammal evolution was predominantly shaped by climatic and geological processes.

Nannoplankton experienced rapid speciation and reduced species longevity, while suffering prolonged declines in diversity, during the Eocene and Neogene. Diatoms, in contrast, experienced major diversification over the Eocene

The climate during the early Cenozoic was warmer than today, However, the Eocene-Oligocene transition and the Quaternary glaciation dried and cooled the Earth.

Knowledge of this era is more detailed than any other era because of the relatively young, well-preserved rocks associated with it.

Palaeogene period
(66 to 23 million years ago)

The Palaeogene period (66 -23 million years ago) spans from the extinction of non-avian dinosaurs to the dawn of the Neogene era. It features three epoch: the Palaeocene, Eocene and Oligocene.

Palaeocene epoch (66 to 56 mya)

The Palaeocene epoch lasted 10 million years. Modern placental mammals originated during this time. The K-Pg extinction had included the large herbivores, which permitted the spread of dense but usually species-poor forests.

The Early Palaeocene saw the recovery of Earth. The continents began to take their modern shape, but all the continents and the subcontinent of India were separated from each other.

This epoch featured a general warming trend, with jungles eventually reaching the poles. The oceans were dominated by sharks as the large reptiles that had once predominated were extinct. Archaic mammals filled the world such as creodonts (extinct carnivores).

Eocene epoch (56-33.9 mya)

In the Early Eocene, which lasted 22.1 million years, species living in dense forest were unable to evolve into larger forms, as in the Palaeocene. Among them were **early primates**, whales and horses along with many other early forms of mammals.

At the top of the food chains were huge birds, such as Paracrax. Carbon dioxide levels were high. The temperature was 30 degrees Celsius, with little temperature gradient from pole to pole.

In the Mid-Eocene, the Antarctica Circumpolar Current between Australia and Antarctica formed. This disrupted ocean currents worldwide and as a result caused a global cooling effect, shrinking the jungles. This allowed mammals to grow to mammoth proportions, such as whales which, by that time, had become almost fully aquatic. Mammals like were at the top of the food-chain.

The Late Eocene saw the rebirth of seasons, which caused the expansion of savanna-like areas, along with the evolution of grasses.

The end of the Eocene was marked by the **Eocene-Oligocene Extinction Event** occurring between 33.9 and 33.4 million years ago. It was marked by large-scale extinction and floral and faunal turnover, although it was relatively minor in comparison to the large earlier mass extinctions.

The boundary between the Eocene and Oligocene epochs was marked by the glaciation of Antarctica and the consequent beginning of the Late Cenozoic ice age as well as the end of the greenhouse climate of the Early Palaeogene. The global cooling also correlated with marked drying conditions in low-latitudes Asia.

Oligocene epoch (33.9-23.03 mya)

The Oligocene epoch lasted 10.9 million years and featured the expansion of grasslands which had led to many new species to evolve, including the first elephants, cats, dogs, marsupials and many other species still prevalent today.

Many other species of plants evolved in this period too. A cooling period featuring seasonal rains was still in effect. Mammals still continued to grow larger and larger.

Neogene period
(23.03-2.58 million years ago)

The Neogene featured 2 epochs: the Miocene, and the Pliocene.

Miocene epoch (23.03-5.33 mya)

The Miocene epoch lasted 17.7 million years and was a period in which grasses spread further, dominating a large portion of the world, at the expense of forests.

Kelp forests evolved, encouraging the evolution of new species, such as sea otters. During this time, perissodactyls thrived, and evolved into many different varieties. **Apes evolved into 30 species.**

The Tethys Sea finally closed with the creation of the Arabian Peninsula, leaving only remnants as the Black, Red, Mediterranean and Caspian Seas. This increased aridity. Many new plants evolved: 95% of modern seed plant families were present by the end of the Miocene.

Pliocene epoch (5.33 -2.58 million years ago)

The Pliocene epoch lasted 2.75 million years and featured dramatic climatic changes, which ultimately led to modern species of flora and fauna.

The Mediterranean Sea dried up for several million years, because ice ages reduced sea levels, disconnecting the Atlantic from the Mediterranean, and evaporation rates exceeded inflow from rivers.

The isthmus of Panama formed, and animals migrated between North and South America during the American interchange, wreaking havoc on local ecologies.

Climatic changes brought savannas that are still continuing to spread across the world;
Indian monsoons, deserts in central Asia - and the beginnings of the Sahara desert.

The world map has not changed much since, save for changes brought about by the glaciations of the Quaternary, such as the Great Lakes, Hudson Bay and the Baltic Sea.

The **Australopithecus** evolved in Africa, beginning the human branch.

Quaternary period
(2.58 million years ago to now)

The Quaternary spans from 2.58 million years ago to present day, and is the shortest geological period. It features modern animals, and dramatic changes in the climate. It is divided into two epochs: the Pleistocene and the Holocene.

Pleistocene epoch (2.58 to 0.012 mya)

The Pleistocene lasted from 2.57 million years This epoch was marked by ice ages as a result of the cooling trend that started in the Mid-Eocene. There were at least four separate glaciation periods marked by the advance of ice caps as far south as 40° N in mountainous areas.

Meanwhile, Africa experienced a trend of desiccation which resulted in the creation of the Sahara, the Namib and the Kalahari deserts.

Many animals evolved including mammoths, giant ground sloths, dire wolves, sabre-toothed cats, and **Homo Sapiens**. 100,000 years ago marked the end of one of the worst droughts in Africa, and led to the expansion of primitive humans.

As the Pleistocene drew to a close, a major extinction wiped out much of the world's megafauna, including some of the hominid species, such as Neanderthals. All the continents were affected, but Africa to a lesser extent. It still retains many large animals, such as hippos.

Holocene epoch

The Holocene began 11,700 epoch and is on-going. Human activity is blamed for a mass extinction that began roughly 10,000 years ago, though the species becoming extinct have only been recorded. This is sometimes referred to as the “sixth extinction” It is often cited that over 322 recorded species have become extinct due to human activity since the Industrial Revolution, but the rate may be as high as 500 vertebrate species alone, the majority of which have occurred after 1900.

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Chapter Nine
Evolutionary Fronts

Scale and Biodiversity

Species

When a species is born, the event is evolution. Species is therefore the basic unit of evolution. Knowing how many species inhabit the Earth is among the most fundamental questions in science.

The most outstanding feature of life on Earth is its biodiversity. When a new species is born, we have a family relationship between the two. As new species evolve from succeeding generations, we have a chain of varying relationships within an enlarging framework, going back to the. original set. This principle provides the basis for their classification and a sane framework for enumeration.

A species may be defined as comprising related organisms that share common characteristics, and are capable of inter-breeding and creating fertile offspring. The evolution of a new species (from an old) is called speciation

A species which is no longer present in its original range or as a distinct species any longer is called an extinct species. It was previously living and existing but has now vanished from Earth. eg. dinosaurs, the dodo bird.

An extant species, on the other hand, describes one that has survived to the present day

Three Domains of Evolution

Until the advent of microbiology, scientists grappled with various theories how and along what courses the early microorganism evolved. It has been only since 1990 that the scientific fraternity adopted the three domain structure of evolution.

The substantive view now is that very early in its life, the original anaerobic (prokaryotic) microorganism split into two species, Eubacteria and Archaea.

Not long after, as has been detailed earlier in this book, one or/and the other began to acquire oxygenic photosynthesis capabilities – leading to the oxygenation of the planet followed by the near extinction of all prokaryotes. It is from their survival struggles that both categories evolved the necessary defences and/or faculties to continue and succeed in what has eventually become an oxygenated or aerobic world.

The latter world went on to foster the third most successful domain of evolution, oxygen-based living things or eukaryotes, which have been able to grow to visible even gigantic proportions, biological complexities and facultative development, and now dominate the planet.

Biodiversity

Biodiversity refers to every living thing in these three domains, including eubacteria, archaea, plants and animals - and humans

Eukaryotes encompass all the categories that evolved out of the Phanezoic era, aerobic and belonging to the visible world – overwhelmingly plants and animals.

Unless specified otherwise, we refer to the first two together as bacteria, and to plants and animals as synonymous with eukaryotes.

Taxonomic Classification of Living Things

Classification is the basis of any system of enumeration. The science of biological classification is commonly called taxonomy.

Linnaus Taxonomic Classification of Living Things

A system for classification of plants and animals was first propounded by Carolus Linnaus, a Swedish scientist, in 1753. With modifications, the Linnaus Taxonomic Classification of Living things is still in common use. It provides the framework, but not the criteria.

The basis of defining and identifying a species was initially, and still remains substantially, by their physical characteristics, ie morphology and other disenable attributes. The seven characteristic features of living organisms most used still are nutrition, excretion, movement, respiration, reproduction, growth, and sensitivity.

The Linnaus system is a seven-tier hierarchical system, and it works like a series of nesting boxes. The three domains have been added making it an eight-tier classification as seen in the following schematic:

Table 7
Linnean Taxonomic Classification of Living Things

	Domain						
1	Kingdom						
2		Phylum (Division)					
3			Class				
4				Order			
5					Family		
6						Genus	
7							species

The Linnean taxonomic system is applicable for the three domains separately. The dominant application is the Eukaryotic domain, as the latter encompasses the visible world which constitutes almost the whole of living reality.

In the nature of evolution, older species go extinct as they are replaced by new species There are also mass extinctions caused by natural disasters. There are specialised databases of extinct botanic and zoological species, but we need not be concerned with these.

The Linnaus System deals mainly with the plant and animal kingdoms. The bacterial domains remain basically minimal and untouched (see later).

The eukaryotic domain itself comprises five distinct kingdoms, as follows: protozoa, chromista, fungi, plantae and animalia, each kingdom further subdivided by Linnean classifications.

International Code of Phylogenetic Nomenclature (PhyloCode)

Since the advent of electronic microscope(circa 1934) and molecular biology, scientists have had increasingly to take into account DNA and other genetic features in allocating specimens and defining species. DNA sequencing has in fact now enabled scientists to trace the lineages of individual specimens far back, even to their ancestries in prokaryotic times. The new stream of quantum-level information (and not just genetic information) does not sit comfortably on hitherto traditionally constructed classifications.

There is a definite movement towards a phylogenic classification of all living things, now made possible by the tools of sub-sub atomic research. They speak of a Tree of Life approach, with roots in the evolutionary past. They have gone so far as to frame an International Code of Phylogenic

Nomenclature, or PhyCode. The embrassive notion is the top-down **clade,** in which species may be seen relationally in their ancestral context as well – if not primarily.

A clade, in biology, is a group of organisms that consists of a common ancestor and all of its descendants. Because clades consist of all the modern descendants of a common ancestor, clades they are considered monophyletic. A **clade** is a group of descendants of a common ancestor

The Linnean system, which is "poly-phyletic", must evolve along phyletic lines – if for nothing else to take advantage of the power of the quantum computer. Much remains to be done. For the time being, let us look at what we have got.

..

Overview

There are varying attempts to estimate the number of species, depending on when the estimate was made and the taxonomy used. Most approximate quite closely to the one which I have selected below:

Table 8[44]

Overview of Evolution

(Superkingdom = Domain)

8

(Super)Kingdom	When evolved	Structure	Number of species (total)	Number of species (marine)	Number of species (terrestrial)
Superkingdom Prokaryota					
Bacteria	3–4 Gyr	Unicellular	1,250,000 (0.8–1.7 million)	NA	NA
Archaea	3–4 Gyr	Unicellular	105,000 (70,000–140,000)	NA	NA
Superkingdom Eukaryota					
Protozoa	1.5 Gyr	Unicellular	36,400	36,400	0
Chromista	1.2 Gyr	Unicellular	27,500	7,400	20,100
Fungi	1 Gyr	Unicellular or multicellular	611,000	5,320	605,680
Animalia	700 Myr	Multicellular	7,770,000	2,150,000	5,620,000
Plantae	500 Myr	Multicellular	298,000	16,000	281,400
Total species			**10,100,000**	**2,210,000**	**6,540,000**

Estimates for eukaryotic species are from Reference 34; estimates for prokaryotic species (operation taxonomic units) are based on Global Prokaryotic Census (39). Total marine and terrestrial species estimates are for eukaryotes only (34). Species numbers for protozoa are very likely to be largely underestimated.
Abbreviation: NA, not applicable.

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The crude estimated total figure for all **species** for all the three domains is 10.1 million. Of this eukaryotes make up 8.8 million, while the two bacterial domains make up 1.3 million. There are many more species of eukaryotes than bacteria. Of the latter eubacteria (bacteria per se) are estimated to comprise 93% while archaea make up the small balance. No breakdown is given for the bacterial domains vis-a-vis their marine component.

One research group suggests that some 86% of the species on Earth, and 91% in the ocean, still await description.

In the context of the preceding, it is sobering that more than 99% of all species hat ever lived on Earth, amounting to over five billion species, are estimated to have become extinct. This is due to evolution itself which adapts and upgrades all the time, and also to mass extinctions and natural disasters. .

[44] Copied from https://www.researchgate.net/figure/Estimated-total-number-of-species-on-Earth-in-the-seven-kingdoms-of-life-29-30_tbl1_363252151 (content may be subject to copyright. Provided here for pointer to the source. Users of the data should check independently for copyright.)
36,400

I have not tried to analyse the figures in this section. The number of species (say in a classification) unless otherwise indicated means and includes the number extant (living and known) and those extinct but known (from fossils, etc) and classified.

Catalogue of Life

The Catalogue of Life is an online database that provides an index of known species, including microorganisms. It is maintained by Species 2000, a federation of database organizations around the world in partnership with the Integrated Taxonomic Information System (ITIS) of US federal agencies. It publishes a update list annually.
.
The Catalogue currently compiles data from 165 peer-reviewed taxonomic databases that are maintained by specialist institutions around the world. As of September 2022, the COL Checklist listed 2,067,951 of the world's 2.2m extant species

About 18,000 new species are catalogued a year, mainly newly discovered rather than newly emerged. The gestimated number of the latter varies widely from 5 to 91.
.
According to the 2019 Global Assessment Report of the Intergovernmental Science Platform on Biodiversity, the biomass of wild mammals has fallen by 82%, natural ecosystems have lost about half their area and a million species are at risk of extinction - all largely as a result of human actions. Twenty-five percent of plant and animal species are threatened with extinction.

Eukaryotic Domain

Eukaryotic organisms range from a single-cell protist to multicellular beings as large as the African elephant or the red wood tree. They are all made up in common of units of the eukaryotic cell, the distinguishing features of which are that it possess a nucleus and a mitochondrion (ie is oxygen-dependent). All eukaryotes belong in the domain Eukaryia.

In the Linnean system, the top classification of a domain is kingdom. After several revisions, since 1998 we have five kingdoms into which eukaryotic species fall:

Table 9
Eukaryotic Kingdoms

Kingdoms	Description	Species (Number of)	Phyla
Protozoa	Earliest single-celled eukaryotes	36,400	
Chromistan	Photosynthetic eukaryotic microorganisms (with chlorophyll), including many algae	27,500	
Plantae	All plants	298,000	14
Fungi	Heterotrophic (non-photosynthetic) eukaryotic microorganisms, including. mushrooms, yeast, molds, etc.	611,000	8
Animalia	All Animals, including humans	7.770.000	31
Total		10,100,000	

It emerges that 7.7 million (77%) of all eukaryotes belong to the kingdom animalia, with fungi at 611,000 coming second ahead of plantae at 298,000 third. There are many many more species of animals than plants.

The evolution of microorganisms, including eukaryotic organisms, has been dealt with in detail earlier. Therefore, we shall omit looking here at the kingdoms protozoa, chromista and fungi, except where they form part of the plantae story.

Depending on definitions, the animal kingdom contains about 31 subdivisions or phyla, the plant kingdom contains about 14 phyla, with the fungus kingdom about 8 phyla. All phyla are further divisible into class, order, family, genus and species. We shall not be concerned with these except to note the number of species in a kingdom, which gives the size of a kingdom

Kingdom Plantae

Plants

The Kingdom Plantae is the kingdom of plants, The latter includes organisms that range in size from tiny mosses to giant aspen. The neatest definition I could find is from Britannica, which I. quote[45]:

> "Despite this enormous variation, all plants are multicellular and eukaryotic (i.e., each cell possesses a membrane-bound nucleus that contains the chromosomes).
>
> They generally possess pigments (chlorophyll and b and carotenoids), which play a central role in converting the energy of sunlight into chemical energy by means of photosynthesis. Most plants, therefore, are independent in their nutritional needs (autotrophic) and store their excess food in the form of macromolecules of starch. The relatively few plants that are not autotrophic have lost pigments and are dependent on other organisms for nutrients.
>
> Although plants are nonmotile organisms, some produce motile cells (gametes) propelled by whiplike flagella"

The evolution of plants has resulted in a wide range of complexity, from the earliest unicellar algae mats through multicellular marine and freshwater green algae, to spore-bearing terrestrial ferns, and eventually to the complex seed-bearing flowering plants of today.

The Plantae includes all land plants: mosses, ferns, conifers, flowering plants—an amazing range of diverse forms. With near 300,000 species, they are second in size only to the animal phylum anthropoids (insects). Only fungi outnumber them. Land plants are also known as embryophytes

Classification of Plants

The plant kingdom is further classified into subgroups. Classification is based on the following criteria:

. - Plant body: Presence or absence of a well-differentiated plant body. E.g. Root, Stem and Leaves.

. - Vascular system: Presence or absence of a vascular system for the transportation of water and other substances. E.g. Phloem and Xylem.

. - Seed formation: Presence or absence of flowers and seeds and if the seeds are naked or enclosed in a fruit.

The plant kingdom has been classified into five subgroups according to the above-mentioned criteria:
. - Thallophyta
. - Bryophyta
. - Pteridophyta
. - Gymnosperms
. - Angiosperms

[45] - https://www.britannica.com/plant/plant/Definition-of-the-kingdom

Thallophyta (algae)

Thallophytes lack a well-differentiated body structure and is not properly differentiated or distinguished into root, stem and leaves . They may be filamentous, colonial, branched or unbranched. This includes algae, bryophytes and pteridophytes.

Bryophyta (mosses)

Bryophytes is the informal group name for mosses, liverworts and hornworts . They are non-vascular plants, which means they have no roots or vascular tissue, but instead absorb water and nutrients from the air through their surface (eg. their leaves).

Bryophytes are terrestrial plants but are known as “amphibians of the plant kingdom” as they require water for sexual reproduction. They may reproduce both sexually and vegetatively.Mosses comprise more than 10,000 species in 700 genera almost twice as diverse as mammals.

Pteridophyta (ferns)

Pteridophytes are vascular plants with xylem and phloem. The plant body has true roots, stem and leaves. They are cryptogams, seedless and vascular. They reproduce through spores.Ferns, spike-mosses, quillworts are a few pteridophytes

Pteridophytes are considered as the first plants to be evolved on land: Before the flowering plants, the landscape was dominated with plants that looked like ferns for hundreds of millions of years.

The fern crown group is estimated to have originated in the late Silurian period 423.2 million years ago.

Gymnosperms (Conifers)

Gymnosperms have a well-differentiated plant body and vascular tissues. They bear naked seeds, i.e. seeds are not enclosed within a fruit. Gymnosperms consist of four main phyla:

. - Coniferophyta,
. - Cycadophyta,
. - Gingkophyta,and
. - Gnetophyta

Conifers are the dominant plant of the gymnosperms, having needle-like leaves and living in areas where the weather is cold and dry.

Angiosperms flowering plants)

The key difference between angiosperms and gymnosperms is how their seeds are developed . The seeds of angiosperms develop in the ovaries of flowers and are surrounded by a protective fruit.

Angiosperms are seed-bearing vascular plants with a well-differentiated plant body. They produce flowers during their life-span. The seeds of angiosperms are enclosed within the fruits.

Angiosperms are further divided into monocotyledons and dicotyledons according to the number of cotyledons present in the seeds. Some of the common examples are mango, rose, tomato, onion, wheat, maize, etc.

Nowadays clades is increasingly the preferred taxonomic term. In the kingdom Plantae, the Angiospermae or Magnoliophyta (flowering plants) are the most diverse group of land plants. Within them, the Eudicots constitute over 70% of the angiosperm species.

The three largest flowering plant families containing the greatest number of species are the sunflower family (Asteraceae) with about 24,000 specie, the orchid family (Orchidaceous) with about 20,000 species, and the legume or pea family (Fabaceae) with 18,000 species.

A form of flowering plant that the largest organism on earth in breadth is the giant marine plant, **Posidonia australis** , living in Shark Bay, Australia. Its length is about 180 km and it covers an area of 200 km square The area is protected as a World Heritage site.

Pando is the world's largest tree. It is a quaking aspen (an angiosperm) located in Utah USA, A male clonal organism, Pando has an estimated 47,000 stems that appear as individual trees, but are connected by a root system that spans 106 acres.

Pando is the largest tree by weight and landmass. Pando is estimated to weigh collectively 6,000 tonnes (6,000,000 kg), or 13.2 million pounds, making it the heaviest known organism. Pando is often characterized as an "organism". Pando is a tree.

The angiosperms originated about 250 million years ago and comprise 80% of earth's plant life. They are also a major source of. food for humans and animals.

Kingdom Animalia

Animal evolution began in the ocean over 600 million years ago in the Edicaran period, with tiny creatures that probably did not resemble any living organism today. Since then, animals have evolved into a highly-diverse kingdom.

Although over one million extant (currently living) species of animals have been identified, scientists are continually discovering more species. The number of extant species is estimated to be between 3 and 30 million. It is separately estimated that around 9 or 10 million species of animals inhabit the earth; the exact number is not known and all estimates are rough

Animals first appear in the fossil record in the late Cryogenian period, and diversified in the subsequent Edicaran. Nearly all modern animal phyla became clearly established in the fossil record as marine species during the Cambrian explosion began around 538 million years ago and most classes during the Ordovician radiation around 485.4 million years ago.

Some 6,331 groups of genes common to all living animals have been identified; these may have arisen from a single common ancestor that lived during the Cryogenian period.

What is an animal

All animals[46] are members of the kingdom Animalia, also called metazoa. All are multicellular, and all are heterotrophs (that is, they rely directly or indirectly on other organisms for their nourishment). Most ingest food and digest it in an internal cavity.

Animal cells lack the rigid cell walls that characterise plant cells. The bodies of most animals (all except sponges) are made up of cells organised into tissues, each tissue specialised to some degree to perform specific functions. In most, tissues are organised into even more specialized organs.

Most animals are capable of complex and relatively rapid movement compared to plants and other organisms.

Most reproduce sexually, by means of differentiated eggs and sperm. Most animals are diploid, meaning that the cells of adults contain two copies of the genetic material.

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[46] https://animaldiversity.org/accounts/Animalia/

The development of most animals is characterised by distinctive stages, including a zygote, formed by the product of the first few division of cells following fertilization; a blastula, which is a hollow ball of cells formed by the developing zygote; and a gastrula, which is formed when the blastula folds in on itself to form a double-walled structure with an opening to the outside, the blastopore.

Animals range in size from no more than a few cells to organisms weighing many tons, such as blue whale and giant squid.

By far, most species of animals are insects, with groups such as molluscs, crustaceans an nematodes also being especially diverse. The vertebrates are relatively inconsequential from a diversity perspective.

Animals form a clade, meaning that they arose from a single common ancestor

Animal Classification

The animal classification system characterises animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup.

All animals require a source of food and are, therefore, heterotrophic: ingesting other living or dead organisms. This feature distinguishes them from autotrophic organisms, such as most plants, which synthesize their own nutrients through photosynthesis. As heterotrophs, animals may be carnivores, herbivores, omnivores, or parasites.

Most animals reproduce sexually with the offspring passing through a series of developmental stages that establish a fixed body plan. The body plan refers to the morphology of an animal, determined by developmental cues.

Animal Phyla

Within the animal kingdom there are 35 total phyla, although nine of them are the most well-known and understood. Within the animal kingdom, animal species usually fall into one of nine different phylum or **phyla**:

.1 - Porifera – Marine animals more commonly known as sponges and found in every ocean.

.2 - Cnidaria – Mostly marine animals that include over 11,000 species. Examples include coral, jelly-fish and anemones

.3 - Platyhelminthes – Typically parasitic flatworms. Lacking in any respiratory or circulatory system, oxygen passes through their bodies instead in a process known as diffusion. Examples include tapeworms and flukes.

.4 - Nematoda – The nematodes are roundworms or eelworms Most species are free-living, feeding on microorganisms but there are many that are parasitic Unlike nematodes have a tubular digestive system, with openings at both ends. Nematodes have successfully adapted to nearly every ecosystem..

. 5- Annelida – More complex than platyhelminthes, these are segmented and symmetrical worms containing a nervous system, respiratory system, and sense organs. Examples include the common earthworm and leeches.

.6 - Arthropoda – Invertebrate animals with an exoskeleton and segmented bodies. Contains insects, crustaceans, and arachnids. This is the largest phylum by species count. Examples include scorpions, butterflies, and shrimp

.7 - Mollusca – The second largest phylum by species count, and the largest marine phylum. Invertebrates with soft unsegmented bodies. It is estimated almost a quarter of marine life falls in this category. Examples include clams, mussels, and snails

. 8 - <u>Echinodermata</u> -An echinoderm includes starfish, sea urchins, and sea cucumbers, as well as the sessile sea lilies. Echinoderms are recognisable by their usually five-pointed radial and are found on the sea bed at every ocean depth. The phylum contains about 7,600 living species making it the second-largest group of deuterostomes after the chordates, as well as the largest marine only phylum.

. 9 - **<u>Chordata</u>** – Vertebrates. Animals that develop a notochord, a cartilaginous skeletal rod that supports the body in the embryo and can often become a spine. Most animal, including dogs, horses, birds, and humans, fall into this category

Animal Classes

The phylum group is subdivided into smaller groups, known as animal classes. The **Chordata phylum** splits into these seven animal classes

.1 – <u>Agnatha</u> (jaw-less fish) – Primitive jawless fish including lampreys, hagfishes, and extinct groups.

.2 - <u>Chrondrichtyes</u> (cartilaginous fish) – Composed of fish with skeletons composed of cartilage. Includes rays and sharks)

.3 - <u>Osteichthyes</u> (bony fish) – Includes saltwater and freshwater fish with bony skeletons like eels, anglerfish, clown fish, swordfish, and catfish, carp, trout, and salmonids.

.4 - <u>Amphibia</u> (amphibians) – Four-limbed, ectothermic vertebrates, including frogs, toads, salamanders, and newts.

.5 - <u>Reptilia</u> (reptiles) – Vertebrates with dry skin and scales such as snakes, turtles, lizards, and crocodilians.

.6 - <u>Aves</u> (birds) – Warm-blooded, egg-laying animals characterised by two wings, two legs, and feathers.

.7 - **<u>Mammalia</u>** (mammals) – Warm-blooded four-legged (or two-armed, two-legged) animals that breathe with lungs and give birth to live young.

Animal Orders

Each class is divided into small groups known as orders. There is no universally accepted breakdown for the class Mammalia. Some outline as many as 26 different orders for the class **Mammalia.** Some of the most popular examples include::

. 1 – <u>Artiodactyla</u>. Even-toed hoofed animals – Examples include moose, camels and giraffes.

.2 – <u>Carnivora</u>. Animals that specialise in mostly eating meat, but also contain some omnivores and herbivores. Examples include bears.

.3 – <u>Rodentia</u>. Gnawing mammals Examples include bears, mice and squirrels.

.4 - <u>Chiropptera</u> (bats) – The only mammals that can fly. Examples include free-tailed and vampires

.5 --<u>Cetacea</u> (porpoises and whales) – Examples include killer whales, dolphins and humpback whales.

.6 -**<u>Primates</u>** – Includes prehensile hands and feet, commonly with opposable thumbs. Examples include gorillas, chimpanzees and humans.

Animal Families

In every order, there are different animal families which are defined by groups that have very similar features. Animal families are basically sub-divided into **two main groups–vertebrates and invertebrates.**

Animal Genus

Every animal family is further divided into smaller groups known as genera, or genuses. Each genus contains animals that have very similar features and are closely related.

For example, the Felidae (Cat) family contains **genuses** including: Small Cats and domestic Cats, Panthera (Tigers, Leopards, Jaguars and Lions), Pumas (Panthers and Cougars) etc.

Animal Species

Each species within the genus is named after its features and characteristics. The names of animals are based in Latin and consist of two words. The first word in the name of an animal will be the genus, and the second name indicates the specific species. As an example, a dolphin species name is Delphinus Delphis.

Animal Classification Example – Orang-Utan

Kingdom: Animalia (Animal)
Phylum: Chordata (Vertebrate)
Class: Mammalia (Mammal)
Order: Primates
Family: Hominidae (Great Apes)
Genus: Pongo
Species: Pongo pygmaeus (Orang Utan)

Summary (Kingdom Animalia)

The overwhelming majority of the estimated 8.7-million species under the Kingdom Animalia are thought to be anthropoids.

A recent estimate of the number of arthropods on Earth today is 3.7 million species. Arthropoda is the largest and most diverse animal phylum. The arthropods include beetles, crustaceans, insects, centipedes, millipedes, spiders, scorpions, and the extinct trilobites. Their species richness or diversity surpasses any other group of organisms

Over 1.5 million extant animal species have been documented, of which around 1.05 million are insects, over 85,000 are molluscs and around 65,000 are vertebrates.

Most living animal species belong to the infra-kingdom Bilateria: a clade whose members have a bilateral symmetric body plan

Prokaryotes Again

Scale and Diversity

Our current knowledge about bacterial categories is largely based on study of those species that can be propagated under laboratory conditions (in vitro). However, applications of molecular techniques and direct sequencing of environmental samples indicate that only a small fraction of bacterial species can be grown in pure cultures, and their actual diversity is largely underestimated.

Available estimates suggest the existence of over 10 million species of bacterial categories, in about 1,300 phyla.

It is estimated that only 1.2 million species of bacteria are known in 40 phyla, and 105,000 species of archaea known in 30 phyla . Wikki states that only 2% of all bacterial species are known. So far, only about 10,000 species of (presumably of both categories) have been formally described. Estimates vary widely. The figures here are indicative only.

On 13 June 2012, a major milestone of research the US National Institute of Health announced that their researchers calculated that more than 10,000 microbial species occupy the human ecosystem, and they have identified 81–99% of the genera – presumably they still have to work out the phyla groupings.

Recap

We last left off our prokaryotic microscopic communities in the early Proterozoic, around two billion years ago.

When they invented photosynthesis for their energy, the oxidation of water as the resource, they inadvertently released oxygen to the atmosphere as a by-product. It was poisonous to them, and scientists report that more than 90% of them went extinct.

At that point, they were all (life was) invisible. The good news was that the surviving 10% struggled successfully to survive the Great Oxygen Crisis (dated about 1,8 billion years ago). A proportion did so by (a) developing the necessary defences against oxygenic poisoning to continue, and the rest (b) evolving and becoming aerobic, ie eukaryotic.

As a result of the above extinctions, the oxygen levels of the atmosphere dropped back to near nothing. However, by the Cambrian period (538-525), the planet had got re-oxygenated, this time re-enforced by the enhanced oxygenic photosynthesis of the plant kingdom.

The eukaryotic world took advantage of the enhanced energy creating potential of oxygen to grow physically bigger, become more sophisticated organisms, and to diversify – hence produce our visible world. The latter went on to survive five mass extinctions, leading to the emerge of man in the Cenozoic starting (from 66 millions year ago.).Very little is known of the prokaryote world during this period, except that they too survived.

In fact today, prokaryotes numerically outnumber the eukaryotes, still invisible. They are to be found in all environments on land in the soil and in the oceans, both free-living and permanently resident in plants, fish, animals and humans

Bacterial-Archaeal Relationship

The only life form in the beginning was the single-cell anoxic prokaryote. Early in their evolution, they diversified into two branches, the Eubacteria and the Archaea The latter lived in the more extreme environments, and the former (generally known as Bacteria) established themselves as the main stream. The latter have always been by far the larger number, even today, and have had the more overriding impact on the evolutionary scene.

Bacteria was first seen under a microscope in 1676, but the first Archaea was identified only in 1977 and classified as a separate Domain Archaea in the 1990s.

Given their taxonomic differences and specialised adaptations, bacteria and archaea share a wide range of features arising from their common origin. Both are microorganisms. While, on both sides, many have evolved to become eukaryotic and aerobic, both collectively remain single-celled prokaryotes.

Both can be photosynthetic, oxygenic and carbon-fixing, and both can be heterotrophic. Both can be land based or marine. Both are free-living, fill the air, and populate plants, fish and animals, and the soil.

Both reproduce asexually, by binary fission, although bacteria do produce endospores (allowing hibernation) and archaea do not. Both have incredibly short life spans, from as short as 4 – 20 minutes, and they engage extensively in horizontal transfers. Thes factors make the standard concepts of species difficult to apply to them. In one actual example, the category or species of bacteria equates the entire phylum of primates down to man.

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Both bacteria and archaea are endosymbionts. Those with complementary features tend to engulf and merge into the next level of complexity and specialisation, and move towards multicellularity. **It is now widely accepted that eukaryotes represent the fruit of a symbiosis between an archaeal host and at least one bacterial lineage, the former likely giving rise to the cell proper and the latter giving rise to mitochondria**.[47]

A major difference is that archaeans include inhabitants of some of the most extreme environments on the planet. Some live near rift vents in the deep sea at temperatures well over 100 degrees Celsius. Others live in hot springs or in extremely alkaline or acid waters.

Both populate the oceans and make up plankton, forming the base of the organic food chain of all living things.

Both also provide much of the Earth's oxygen by photosynthesis, thereby constituting yet another necessary foundation for life. Having evolved from them and into their world, we live in their universe.

For both bacteria and archaea the term "lifespan" has no practical meaning. They double continuously several times a day, and do not die. I have not found any meaningful discussion how this continuous multiplication of their numbers will balance out in the end. Already, they out-number us.

They can of course be killed, by heat, cold, fire, poisons, and anti-biotics. Bacterial cell lysis or cell death only occurs when their cell wall is ruptured and their cellular contents leak into the surroundings. Exposure to ionizing radiation can also kill bacteria as it creates free radicals that can damage DNA cellular components leading to death or cell lysis..

About 40% of all microbes living in the ocean are archaea with the rest of the microbes being bacteria, protists, and fungi (the last two are eukaryotes) This means that there are more archaea in the oceans than there are bacteria .

Bacteria

Bacteria occupy all living and non-living niches on Earth including arctic, antarctic and alpine regions, deserts, deep rock sediments, marine environments, and even thermal vents. They occur in water (fresh and salty) and in the air. **One cubic metre of air holds around one hundred million bacterial cells.**

We have already mentioned that through photosynthesis, bacteria (together with plants) sustain life on this planet by the supply of oxygen. They are also the major primary producers at the base of the .food chain.

The soil is a rich source of bacteria and a few grams contain around a thousand million of them. They are essential to soil ecology, breaking down toxic waste and recycling nutrients.

Some types of bacteria live as saprophytes (living on dead organic material), while other are parasites in and on plants , animals and humans, causing diseases.

Insects have become so dependent on bacteria that they have developed new organelles to house them – so called bacteria factories. The nutrients provided by bacteria have enabled insects to survive on highly unbalanced diets and exploit new types of food resources.

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47 - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4413235/

As for total numbers, Wikki[48]i states that there are thought to be approximately 2×10^{30} bacteria on Earth, In the same article it states that the oceans and seas harbour around 3×10^{26} bacteria, which provide up to 50% of the oxygen humans breathe. I could not tell whether there was a double-count. I also could not tell if the figures here are inclusive of archaea

Bacteria-Human Relationship

Bacteria in the human gut break down certain complex carbohydrates and dietary fibers that humans cannot but need. They produce short-chain fatty acids, an important nutrient, as by-products. They also provide the enzymes necessary to synthesize certain vitamins.

The human body contains a total of some 3.9×10^{13} (39 trillion) bacteria resident in and on the body. . Multiplied by 8.7 billion people presently on the planet, we get into some very heavy calculations of total numbers.

It is estimated that 500 to 1,000 species of bacteria live in the human gut alone, but belong to just a few phyla. Most are harmless, even co-operative and (made) beneficial to human life. A report indicated that there were only 1,513 bacterial pathogens are known to infect humans pre-2021.

Also, they play an essential role in the defence against infections by protecting colonised surfaces from invading pathogens.

Yet, 7.7 million deaths around the world were found linked to bacterial infection. That is 13.6%, or 1 in 8, of all global deaths. This makes bacterial infections the second-leading cause of death globally.

The number of bacterial cells in the human body is estimated to be around 39 trillion, while the estimate for human cells is around 30 trillion. The number of bacterial genes is estimated to be 2 million, 100 times the number of approximately 20,000 human genes.

Archaea

Archaea and bacteria are generally similar in size and shape, although a few archaea have very different shapes. Despite this similarity to bacteria, archaea possess genes and metabolic pathways that are more closely related to those of eukaryotes, notably for the enzymes involved in transcription and translation. Other aspects of archaeal biochemistry are also unique, such as their reliance on ether lipids in the cell membrane.

Archaea use more diverse energy sources than eukaryotes, ranging from organic compounds such as sugars, to ammonia, metal oils or even hydrogen. Marine archaea use sunlight as an energy source, and other species of archaea fix carbon, but no known species of archaea does both.

The first observed archaea were extremophiles, living in extreme environments, such as hot springs and salt lakes. Improved molecular detection tools have led to the discovery of archaea in almost every habitat, including soil and marshlands. **Archaea are particularly numerous in the oceans, and the archaea in plankton may be one of the most abundant groups of organisms on the planet.**

Most taxonomists agree that within the archaea, there are currently five major phyla. There are likely many other archaeal groups that have not yet been systematically studied and classified.

Like bacteria, archaea are essential to soil ecology, breaking down toxic waste and recycling nutrients. They are abundant in lakes and oceans, in arctic ice, and geothermal springs, where they provide the nutrients needed to sustain life by converting dissolved compounds, such as hydrogen sulfide and methane to energy.

They live on and in plants and animals. Most do not cause diseases, are beneficial to their environments, and are essential for life. Archaea are a part of the microbiota of all organisms. In the

48 - https://en.wikipedia.org/wiki/Bacteria

human microbiome, they are important in the gut, mouth, and on the skin. Archaea have been associated with some diseases, but so far no archaea has been classified as a pathogen.

Archaea are present in the human gut, but, in contrast to bacteria, the numbers of archaeal species are much more limited. The dominant group are the methanogens, but colonisation is variable, and only about 50% of humans have easily detectable populations of these organisms.

The majority of gut-associated archaea have a unique metabolism: they perform methanogenesis, that is, they consume end-products of fermentation, such as hydrogen, carbon dioxide, formate, acetate, methanol and probably ethanol, as well as methyl compounds to produce gaseous methane.

Viruses

And we have not yet mentioned viruses, who pre-existed[49] bacteria, out-number them, and are indestructible. I reviewed the subject in my second book at the height of Covid -19.[50] I reproduce the first paragraphs of the first part to identify who they are:

> “Viruses are incomplete biological entities. They are encoded to replicate, but are not endowed with the reproductive machinery and resources to do so. They must therefore acquire these by hunting and taking over the cells of living beings to fulfil their reproductive need. Born with the urge but without the necessary genitalia, they hunt to replicate. This is their core identity.
>
> Viruses are constitutional predators. They target different species of living things, and different cells in these. They stay dormant or latent in a living entity until they find the right target. Then they go active, become fully “infectious agents” and “pathogenic[7].” It is in this active form that we know them, sadly as in HIV or SAR-Covid-2.
>
> The increasing belief, indeed new evidence, is that they co-existed with the first life forms, which were the micro-organisms, around 3.7 billion years ago, and of which bacteria are today the most abundant kingdom extant.
>
> One thought stream is that viruses may have been the earliest or early levels of “self-assembly” of living things on the main line of evolution, but went up a cul-de-sac.
>
> It is not known how much they have modified since nor what route or routes they took from their ancestral forms. Today, they are oblate (non-independent), non-cellular biological non-living things.
>
> Some people view them as an intermediate or “failed” stage in the development of the living cell. Like the neutrino, they might be classed as the “waste material” of evolution, the bits that did not make it.”

Whatever it is, they have since established their own core identity and mode of survival. They have been taking over and inhabiting living cells, including bacteria and archaea, since the beginning.

Bacteriophage

A bacteriophage, also known as a phage, is a virus that infects and replicates within bacteria.

Following infection, the bacteriophage hijacks the bacterium's cellular machinery to prevent it from producing bacterial components and instead forces the cell to produce viral components.

They only target prokaryotes and concentrate where the latter are most , including the oceans (marine cyanobacteria) and in humans. The human immune system actively reacts to some phages while simultaneously tolerating the vast majority of them. Their place in our future is still an open question.

The bacteriophage could be given the tag of deadliest being as it devours mercilessly numerous bacteria every second. But they are equally important for conservation and sustenance of life.

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[49] - Some scientists believe that viruses could have evolved from self-replicating RNAs. This possibility would mean that viruses may have appeared before bacteria.

[50] - See my book “Virus* Biological Predator”, published in 2021, at, https://geraldpillay.wordpress.com/

They are ubiquitous in the environment and recognised as the earth's most abundant biological agent. Phages are incredibly diverse and exist everywhere in the environment, including in our bodies; in fact, humans contain more phages than human cells. These viruses cannot infect human cells.

Bacteriophages (phages) are abundant outside the human body, found in virtually every environment where bacteria exist, including soil, water, and even food products. They are the most common biological entities on Earth and are crucial in regulating bacterial populations in natural ecosystems, demonstrating their activity and function in diverse external environments.

Archaeal Viruses or Phages

Achaea are infected by their own group of viruses, called archaeal viruses or archaeal phages, which are analogous to bacteriophages that infect bacteria. While the term "phage" historically included viruses that infect both bacteria and archaea due to their shared prokaryotic nature, archaeal viruses generally have distinct structures and genetics from bacterial phages.

Chain infection

The replication cycle of a bacteriophage can create approximately100 to 200 new bacteriophages within a single host bacterium before the cell bursts to release the new virions. This number varies depending on the specific type of bacteriophage and the conditions of the host cell, but a typical yield from a single infection is in this general range.

A new bacteriophage can go on to infect another (host) bacterium within the human body after replication in a bacterium. Bacteriophages (phages) can also exit the host bacteria through cell lysis, dispersing into the surrounding environment like other bacteria. Once outside the infected cell, phages can travel through the bloodstream, be excreted in urine, or translocate from the gut to other areas, potentially spreading to different locations within and even outside the body. As far as I can make out archaeal phages can do the same.

Phages are made of nucleic acids and proteins, which are not inherently toxic to humans. They have specific receptors that only allow them to bind to and infect certain types of bacteria. They cannot bind to or replicate in human cells because human cells lack these specific receptors Bacteriophages are therefore not dangerous to humans.

Phages are even a normal and beneficial part of the human microbiome and are being explored for use in therapies harmful to bacteria.

Presumably, being viruses, they are not biological

Insects

(Not microbes).

Anthropoids

It would be an omission not to look at man’s co-travellers, some might say next closest societally co-competing co-travellers, the **Insects**.

They constitute the major species of the phylum Anthropodia. The latter are one of the **nine** phyla making up the Kingdom Animalia, accounting for more than 80% of all known animal species.

Besides Insects, anthropoids include spiders and relatives, crustaceans , and centipedes. Insects comprise approximately half of all known eukaryotic (animal, plant, and fungal) species on Earth.

Insects

The largest group of arthropods is i**nsects** (Class Insecta, Order Hexapoda), Insects are smallish eukaryotes. They are characterised by their three-part body (head, thorax, abdomen), three pairs of legs, and one pair of antennae, compound eyes and (not all) wings. The are invertebrates.

Insects are found in almost every habitat on Earth, from forests to aquatic environments
Insects are the most diverse group of animals

Typical terrestrial members of the Order Hexapodia include bees, beetles, butterflies, flies, mosquitoes, cockroaches, silverfish, termites **and ants**.

Evolution

Insects began 480 million years ago, around the same time as the earliest land plants. The first insects took to land from marine or coastal habitats. Their ability to fly developed much later, about 400-406 million years ago, making them the first animals to do so. The major insect lineages present today were established by about 375 million years ago, allowing for extensive diversification. The development of wings was a crucial evolutionary innovation that enabled them to dominate terrestrial and aerial environments. The most diverse insect groups appear to have co-evolved with flowering plants.

Many insects, but not all, have wings, allowing for flight. They play crucial roles in ecosystems as pollinators (eg, bees, butterflies), scavengers (eg, termites), and food sources for other animals.

Eusociality

Eusociality is the highest level of organisation of sociality. It is defined by the following characteristics: cooperative care (including care of offspring from other individuals), overlapping generations within a colony of adults, and a division of labour into reproductive and non-reproductive groups. The division of labour creates specialised behavioural groups within an animal society, sometimes called **castes.** Eusocial groups can be viewed as superorganisms, also colonies.

Eusociality has evolved to different extents and degrees in the animal kingdom. It is most widespread in the insect world, among the sub-Classes Hymenoptera (ants, bees and wasps) and Isoptera (termites). All ants are **social insects and live in colonies.**

Reproduction Life-Cycle

An insect colony's is organised by a caste system consisting of a queen, workers (drones), and male ants, The queen is the primary egg-layer, ensuring reproduction, while workers (sterile females) perform tasks like foraging, nest construction, brood care, and defence. The male ants are reproductive and die after mating with a queen to start new colonies.

Pheromones

Pheromones are chemical substances, released into the environment, that trigger a social or behavioural response in other members of the same species. These chemical signals are used by a wide range of organisms, from insects to some mammals, for purposes such as attracting mates, marking territories, raising alarms, or forming social bonds. In insect colonies, the queen coordinates efforts through pheromones.

In large colonies, queen pheromones are crucial for communicating the queen's health and status. A lack of queen pheromone can trigger workers to build queen cells, indicating the colony's need for new queens.

When a threat is detected, the communication network within the colony allows for a coordinated response, recruiting specialised defenders or initiating collective actions like swarming an intruder.

Although chemical communication via pheromones is a dominant and widespread form of communication, these societies incorporate other communication methods, like sound and touch.

The vast majority of insect species are solitary and do not live in colonies; While ants, termites, and honey bees and wasps are well-known for their social behaviour and complex colonies, most other insects and many solitary wasps live independently and raise their young on their own.

Ants

There are no solitary ants. Every ant species is a social insect. Unlike some wasps and bees, all ant species are social insects that live in colonies, which is a defining characteristic of the ant Family.

While some ants, like nomadic army ants, do not build permanent nests, they still live in large, mobile aggregations that function as temporary colonies.

Different pheromones help ants recognise members of their own colony, identifying castes, and even deceased colony members

Evolutionary Competitors and Threats

Army Ants

Army ants are defined as a nomadic species of ants that lack a permanent nest, alternating between a stationary phase for egg-laying and a migratory phase in search of food, primarily preying on other ants and a variety of insects. They may be thought of as
temporary nomadic colonies that move together as a functioning unit.

Army ants are predators that travel in columns to hunt for food, which includes other insects and invertebrates. During these raids, the colony streams out of its nest in huge numbers, searching for food across the forest floor.

Besides moving, army ants colonies grow rapidly. Some ant species form new colonies through a process called budding, where a group of queens, workers, and brood leave the parent colony to establish a new one.

The largest insect colony is the Argentine an super-colony (Linepithema humile) in the Mediterranean region, which spans over 6,000 km (3,700 miles) from northern Italy to the Atlantic coast of Spain. This massive interconnected network of nests contains billions of worker ants and millions of queens, forming a single, unified super-colony . An invasive "tramp" species, when introduced to new regions, they lose their territorial instincts and form super-colonies by uniting with other colonies.

Another vast super-colony exists in California, extending for hundreds of miles. They have also been documented in Japan, Australia, and New Zealand.

The Argentine ant army engages in collective foraging behaviour or raids that clear their path of other living organisms to sustain the colony.

This often displaces most or all native ants and can threaten native invertebrates and even small vertebrates. Their primary goal is protein from other invertebrates.

Their predatory raids "denude" their foraging corridors of such prey, although they do not directly remove or eat vegetation itself. This however imperils native plants that depend on native ants for seed dispersal, or lizards that depend on native ants or invertebrates for food, and flowering plants who depend on pollinators.

During spring and summer, when nests are expanding, they have an insatiable appetite for protein and sweet foods such as honeydew and nectar invading the supplies of many animals and birds.

Out of some 14,000 described ant species, super-colonialism is found in less than 1% of all ants.

Conclusion

I do not see that ant armies constitute any major destructive or threat potential to mankind or evolution. Rather, they are a hangover of an obsolete egg-reproduction biology operated by a low-level chemical-olfactory system of communication, socially designed as a caste system. They show no facultative development as I define it. but I their societal development, they show a tight level of organisation and a high level of differentiation and efficiency. They will grow to be bigger pests, well within mankind's ability to manage them. The important thing is that they do not eat our vegetation.

Round-Up

The Earth contains an estimated one trillion species of microbes — with 99.999% of them remaining undiscovered. A human can house 100 trillion microbes, creating a microbiome that serves an ecosystem of microbes. Microbes connect and transform in myriad ways, creating and combining and separating microbiomes anew.

Following present classification, there are a little less than 9,300 known species of prokaryotes, which includes bacteria and archaea; but attempts to estimate the true number of bacterial diversity have ranged from 10^7 to 10^9 total species—and even these diverse estimates may be off by many orders of magnitude.

There are an estimated 4-6 x 10 30 prokaryotic cells on earth whose total carbon mass represents about as much as the total carbon mass of plants on earth.

Scientists now estimate that 80% of Earth's species live on land, 15 % in the ocean, and the remaining 5% in fresh-wate habitats. The oceans however cover 71% of the Earth's surface, Insects make up the largest percentage of the animal kingdom.

With more than 10,000 species alive today, birds constitute the most diverse group of land vertebrates (backboned animals) on Earth.

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(Back to TOC)

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Chapter Ten
Evolution of Homo Sapiens

Homo Sapiens is the taxonomic name for humans, We are a species of Primates in the order of Mammals under the kingdom Animalia in the phylum Cordata. Primates are further subdivided into sub-orders, which include the Lesser Apes (gibbons) and the Great Apes (orang utans, gorillas, chimpanzees, and humans.)

First Emergence

First Animals

The first animal life-forms (soft-bodied) appeared just before the Cambrian Explosion (538-525 million years ago).By the end of the Mesozoic, some 470 million years ago, we had birds, fish, insects - and the dinosaur and giant reptiles.

At the Cretaceous- Paleogene (K-P) boundary (also known as the Cretaceous-Tertiary or K-T boundary),- 66 million years ago, a sizable asteroid struck the Earth in Mexico, massively disrupting the ecology of the planet for several years, in particular interfering with photosynthesis. It caused a mass extinction of the dinosaurs and many other organisms. It is believed 75% of life was wiped out and noting above 25 kg survived. Plant life was similarly affected, with flowering plants surviving better.

Tertiary - Cenozoic

The K-P boundary marked the beginning of the final evolutionary stretch, the Cenozoic or “New Life” era, taking advantage of the vacant niches created by the K-P event. It culminated in the emergence of the human, in the relatively short space of 65 million years.

The Cenozoic is crowded with a whole host of dramatic happenings of interest to evolution, and I need no excuse to set out the picture in some detail. It is broken down into several geological periods and epochs. To help avoid confusion, I summarise again the picture here for reference::

Table 10
Cenozoic Era

Period	**Epoch**	56 - 33.9**Million Years Ago (mya)**
Tertiary Paleogene	Palaeocene Eocene Oligocene	65 -56 56 - 33.9 33.9 - 23.09
Tertiary Neogene	Miocene Pliocene	23.09 – 5.33 5.33 – 2.58
Quaternary	Pleistocene Holocene	2.58 – 11,700 years ago 11,700 – now, years ago

Tectonics

In early Cenozoic covering the Palaeocene and early Neogene (periods (65-23 million years ago), the continents moved into their current positions and evolved their present configurations, viz.

. - About 55 to 45 million years ago, India collided with Asia, creating the Himalayas, the Monsoons and the high plateaus;

. - About 35 million years ago Arabia collided with Eurasia creating the Mediterranean, the Caspian and the smaller seas; and from

. - About 25–22 million years ago the mighty East African Rift System (EARS) developed, and the break-up of Gondwana led to the final positioning of the large African rivers, and finally

. About 2’8 million years ago, South America became attached to North America creating the Isthmus of Panama, the Arctic region cooled, eventually leading to the glaciations of the Quaternary Ice Age - which Is still on-going and of which the current the current age, the Holocene epoch, is but an inter-glacial phase.

Climate/Life

In the **Palaeocene,** the Cretaceous climate continued, ie. hot and humid with lush forests at the poles. There was no permanent ice, and sea levels were around 300 metres higher than today The temperature was 30 degrees Celsius with little temperature gradient from pole to pole. This culminated in the Palaeocene-Eocene Thermal Maximum, about 55.5 million years ago.

The climate was hot. Forests and animals re-established themselves with vigour. The first placentals appeared, and launched the age of mammals. They evolved to fill virtually all the niches vacated by dinosaurs.

From the **early-Eocene** began a period of long term cooling, inter alia due to the Himalayas. Around 35 million years ago permanent ice began to build up on Antarctica. The cooling trend continued, with relatively short warmer periods, through to the late Miocene

In the early-Eocene, species living in dense forest were unable to evolve into larger forms, as in the Palaeocene. Among them were early primates, whales and horses along with many other early forms of mammals. At the top of the food chains were huge birds.

In the **mid-Eocene**, disrupted ocean currents worldwide caused a global cooling effect, shrinking the jungles. This allowed mammals to grow to mammoth proportions

The **late-Eocene** saw the rebirth of seasons, which caused the expansion of savanna-like areas, along with the evolution of grasses.

The end-Eocene was marked by the **Eocene-Oligocene extinction event**, occurring between 33.9 and 33.4 million years ago, also called the Eocene-Oligocene transition (EOT)’ It was marked by large-scale extinction and floral and faunal turnover (changes), although it was relatively minor in comparison to the earlier mass extinctions.

The event was marked by the glaciation of Antarctica. It was the beginning of the Late Cenozoic Ice Age, which continues to today, and the end of the greenhouse climate of the early Palaeogene. The global cooling correlated with marked drying conditions in low-latitudes Asia.

The **Oligocene** featured the expansion of grasslands which led many new species to evolve, including the first elephants, cats, dogs, and marsupials among others. Many other species of plants evolved in this period too. Mammals continued to grow larger and larger.

In the **Miocene** epoch, grasses spread further, dominating a large portion of the world, at the expense of forests, including 95% of seed plants, Apes evolved into 30 species.

The **Pliocene** epoch, 5.33 to 2.58 million years ago, featured fresh tectonic and climatic changes. The ice age continued, sea levels fell, and he Mediterranean dried up.

Thus, the Tertiary (Neogene) period ended with the replacement of vast areas of forest by grasslands and savannahs that are still continuing to spread across the world. As aridity increased, deserts grew in central Asia, including the beginnings of the Sahara.

New food sources and niches on the grasslands and savannahs fostered further evolution of mammals and birds.

Mammals came to occupy almost every available niche (marine, terrestrial and flying), and some grew very large, attaining sizes not seen in most of today's terrestrial mammals. giving this period its other name, the Age of Mammals. Needless to say everybody was carnivores, herbivores, or omnivores.

The Cenozoic is just as much the age of savannahs, as the age of co-dependent flowering plants and insects, and the age of birds. Grasses also played an important role shaping the evolution of the birds and mammals that fed on them. Many new plants evolved: 95% of modern seeding-plant families were present by the end of the Miocene.

One group that diversified significantly in the Cenozoic were the snakes. Whales diversified in the seas, and sharks reached their largest size during the Miocene.

The earliest known direct ancestor of man, the Australopithecus, emerged in Africa in the middle of the Miocene, about 8-9 million years ago.

Evolution[51]

The first primate-like mammals or **proto-primates** (Plesiadapiformes) evolved in the early Palaeocene epoch (66-56 million years ago) at the beginning of the Cenozoic era.

They were roughly similar to squirrels and tree shrews in size and appearance. They were adapted to an arboreal way of life in warm, moist climates.

The first true **primates** evolved by 55 million years ago, near the beginning of the Eocene epoch (56-34 million years ago). They were the pro-simians, like the lemurs of today.

Monkeys evolved near the end of the Eocene or during the early Oligocene (34-23 million years ago). Their ancestors were most likely pro-simians.

Apes evolved from monkeys from the early Miocene (23-5 million years ago). One of the earliest of the monkey to ape transitional primates was Proconsul It lived in African forests 21-14 million years ago.

Apes are distinguished from monkeys by the complete absence of a tail and the presence of an appendix, and by their larger and more complex brains. Apes do not have tails due to a mutation of the TBXT gene.

By 14 million years ago, the group of apes that included our ancestors was apparently in the process of adapting to life on the edges of the expanding savannahs. They were very likely similar in appearance to modern African apes.

In mid-Miocene, about 8-9 million years ago, their descendants in Africa diverged into two lines--one that led to **gorillas** and another to humans, chimpanzees, and bonobos.

In late-Miocene, around 5-7 million years ago, a further divergence occurred which separated the ancestors of **modern chimpanzees and bonobos** from the mainstream, the early hominins (human-like primates) that were our direct ancestors.

During the Pliocene (5-2,58 million years ago), flora and fauna spread among the continents with the final juxtaposition of the continents as at present. **Early hominids** in Africa evolved into some 19-20 distinctly different hominin species, all of whom have gone extinct, except one**, Homo Sapiens**, which has survived to the present day as modern human.

51 https://www.palomar.edu/anthro/earlyprimates/early_2.htm

The Pleistocene was a time of global cooling and warming with ice ages and interglacial periods occurring about every 100,000 years. We are right now in the Holocene, at the beginning of an interglacial period (as of 2020).

Taxonomy Hominoidea

Apes (collectively **Hominoidea)** are a clade of primates (simians) native to Africa and Asia who together with their sister group the Cervopithecidas form the catarrhine clade, making them genetically **monkeys**.

There are two extant branches of the superfamily Hominoidea or apes:- the gibbons or family Hylobatidae, the lesser apes; and the **Hominidae also called Hominids,** or the great apes.

. 1 -The family **Hylobatidae** or the lesser apes include four genera and a total of 20 species of gibbon, all native to Asia, and

. 2 The family **Hominidae or** Hominids or the great apes, include four genera comprising three extant species of orang-utans and their subspecies, two extant species of gorillas and their subspecies, two extant species of panins (bonobos and chimpanzees) and their subspecies, and humans in a single extant subspecies.

The Hominidae, or Hominids, are the taxonomic family of Primates that includes modern humans (Homo Sapiens).

The family Hominidae had speciated earlier from the family Hylobatidae (gibbons) about 15 to 20 million years ago, while the latter had itself speciated from the original line, the super--family Hominoidea (apes), about 20 million years ago.

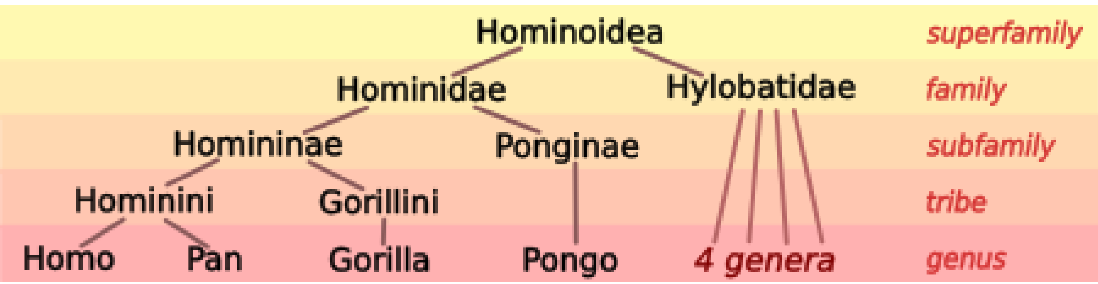
Within the taxon Hominidae, a number of extant and extinct genera are grouped with the humans, chimpanzees, and gorillas in the sub-family **Homininae**, while others are grouped with the orangutans in a separate sub-family **Ponginae** which branched off earlier.

The sub-family Homininae next speciated the tribe Gorillini (gorillas), leaving the chimpanzees and humans as a tribe of the Homininae.

In a final step the chimpanzees branched off to form the genus **Pan.** The time frame is disputed, and muted to be as long ago as 7 to 3 million years ago.

The closest living relatives of Homo Sapiens are those of the genus Pan, namely chimpanzees, who branched away in the late Mesozoic. The following precious diagram says it all

Table 11
Taxonomy of Hominoidea



The term “Homini”, also “”, is now adays used to include all members of the human clade after the split from the chimpanzees (Pan), while "Hominid" includes all the great ape sub-families from orang-utan to humans. - including chimpanzees.

Quaternary

The Quaternary is the current and most recent of the three periods of the Cenozoic era, and spans from 2.58 million years ago to the present.

The Quaternary Period is divided into two epochs: the Pleistocene (2.58 million years ago to 11,700 years ago) and the Holocene (11,700 years ago to today). A proposed third epoch, the Anthropocene was rejected in 2024 by the governing body of the ICS

The Quaternary Period is typically defined by the cyclic growth and decay of continental ice-sheets related to the Milankovitch cycles[52] and the associated climate and environmental changes that they cause.

It has been demonstrated that there were several periods of glacial advance and retreat and that past temperatures on Earth were very different from today.

The Australopithecus who first evolved in the mid-Miocene (14 million years ago) speciated several species during the Pleistocene. Our own Home Sapiens, modern humans, are believed to have evolved in the late Pleistocene, about 314,000 years ago.

During the Quaternary Period, mammals, flowering plants, and insects dominated the land.

Genus: Homo

The evolution of man is told by the Smithsonian Museum of Natural History at in their outstanding interactive presentation, which I urge readers to look at53.

On the physical side, the practice of bi-pedalism (walking upright) when in "terrestrial mode" marks the beginning of our evolution (as apes). From their earliest evolution most if not all animals have had a "brain " of some sort, eg. the planarian flatworm. An increasing brain size marked the progressive evolution of our bi-pedalling brethren. They were also distinguished by two other features, namely they used objects (stones) as tools, and they began to live increasingly as a social group.

Following their split with chimpanzees and bonobos, the hominins diversified into many species and at least two distinct genera. All but one of these lineages – representing the genus Homo and its sole extant species Homo Sapiens – are now extinct.

The earliest record of Homo is the 2.8 million-year-old specimen LD 350-1 from Ethiopia and the earliest named species are Homo54 habilis and Homo rudolfensis evolved by 2.3 million years ago. H. erectus evolved 2 million years ago and was the first archaic human species to leave Africa and disperse across Eurasia. H. erectus also was the first to evolve a characteristically human body-plan.

Homo Sapiens emerged in Africa around 314,000 years ago from a species commonly designated as either H. heidelbergensis or H. rhodesiensis, the descendants of H. erectus that remained in Africa.

H. Sapiens migrated out of the continent, gradually replacing or interbreeding with local populations of archaic humans. Humans began exhibiting behavioural modernity about 160,000–70,000 years ago, and possibly earlier.

The extent of Neanderthal admixture varies significantly between contemporary racial groups. The extent of archaic admixture is of the order of about 1% to 4% in Europeans and East Asians, and highest among Melanesians (the last also having Denisova hominin admixture) at 4% to 6% in addition to Neanderthal admixture).

52 - It hypothesises that variations in eccentricity, axial tilt and precession result in cyclical variations in the intra-annual and latitudinal distribution of solar radiation at the earth's surface, and strongly influences the earth's climatic patterns.
53 - https://humanorigins.si.edu/evidence/human-evolution-interactive-timeline
54 - Homo" is customarily shortened to "H."

Cumulatively, about 20% of the Neanderthal genome is estimated to remain present spread in contemporary populations.[89]

Homo Ancestors Mainstream

Evolution of man included 7 stages – Dryopithecus, Australopithecus, Ramapithecus, Homo habilis, Homo erectus, Homo neanderthalensis, and Homo Sapiens.

The following species are generally thought of as constituting the ancestral line of Homo Sapiens.

By 7 million years ago
The ancestral line of the chimpanzees and bonobos (Pan) separated out from the pre-superfamily Homonini leaving the latter as the ancestral mainstreams leading to the genus Homo and ultimately to its sole extant species Sapiens

By 6 million years ago
The oldest evidence for **walking on two legs** comes from one of the earliest humans known, Sahelanthropus, an extinct genus of hominid dated back to about seven million years ago during the Miocene . Walking upright may have helped this species survive in the diverse habitats near where it lived—including forests and grasslands.
. 1 - Sahelanthropus tchadensis, Chad, 7-6 mya,
. 2 - Orrorin tugenensis, Kenya, 6.2-5.8 mya
. 3 - Ardipithecus kadabba, Ethiopia,5.8-5.2 mya

By 4 million years ago
During this time, early human species lived near open areas and dense woods. Their bodies had evolved in ways that enabled them to walk upright most of the time, but still climb trees. As a result, they could take advantage of both habitats.

.4 - Ardipithecus ramidus, Ethiopia, 4.4 mya
.5 - Australopithecus anamensis, Ethiopia, 4.2-3 mya
.6 - **Australopithecus afarensi**s, Ethiopia, Kenya, Tanzania,3.8-2.9 mya
.7 - Kenyanthropus platyops, Kenya, Turkana, 3.5 mya
.8 - Australopithecus africanus, South Africa, 3.3-2.1 mya
.
By 2.6 million years ago
The earliest **tools** were simple stone flakes and cores. For more than 2 million years, early humans used these tools to cut, pound, crush, and access new foods—including meat from large animals.

. 9 - Paranthropus aethiopicus, Turkana, Kenya, Ethiopia, 2.7-2.3 mya
.10- Australopithecus garhi, Ethiopia, 2.5 mya
.11- Homo habilis Southern Africa, 2.4-1.4 mya
.12- Paranthropus boisei, Ethiopia, Kenya, Tanzania, Malawi, 2.3-1.2 mya
.13- Australopithecus sediba, Southern Africa, 1.9 mya
.14- Homo rudolfensis, Kenya, Tanzania, Malawi, 1.9-1.8 mya

By 800,000 years ago
Control of **fire** provided a new tool with several uses—including cooking, which led to a fundamental change in the early human diet. Early humans probably gathered around campfires to socialise, to find comfort and warmth, to share food and information, and to find safety from predators.

.15- **Homo Erectus**, Southern Africa, Georgia, China, Indonesia,1.9 mya – 110,000 years

From 800,000–200,000 years ago
Human brain size evolved most rapidly during a time of dramatic climate change. Larger, more complex brains enabled early humans of this time period to interact with each other and with their surroundings in new and different ways. As the environment became more unpredictable, bigger brains helped our ancestors survive.

.16- Homo heidelbergensis Hoo Naladl, Africa, Europe, Asia (China),700-200 years ago

.17- Homo neanderthalensis, 400-40,000 years ago
.18- Homo floresiensis, Asia (Indonesia), 100-50,000 years ago
.19- **Homo Sapiens**, evolved in Africa, worldwide, 314,000-now years ago

From 2,000,000 Years Ago
Eventually, humans found they could control the growth and breeding of certain plants and animals. This discovery led to farming and herding animals, activities that transformed Earth's natural landscapes—first locally, then globally.

Origin of Genus Homo

Our human ancestors are believed to have originated in Ethiopia and Africa from the family Sahelanthropus (and/or its sub-tribes), some 7 million years ago.

Ardipithecus is the earliest known **genus** of the human lineage and the likely ancestor of Australopithecus, a group closely related to and often considered ancestral to modern human beings. Ardipithecus lived between 5.8 million and 4.4 million years ago.

Our first ancestors to qualify as "anatomically modern man" are believed to have been the genus Homo habilis, with Homo rudolfensis contesting for the honours, around 2.4 million years ago.

The species Homo erectus, who emerged around 1.9 million years ago or later, is generally recognised as the last ancestor, leading to the emergence of our own species, .

The divergence of the lineage leading to the first Homo sapiens, also known as the "early modern humans", out of the ancestral the Homo erectus (or an intermediate species) is estimated to have occurred in Africa, roughly 500,000 years ago.

Finally, Homo sapiens emerged from Homo heidelbenrgensis around 314,000 years ago in Africa, and then spread The earliest fossil evidence of early modern humans appears in Africa around 300,000 years ago,

Terminology

"Anatomically modern humans" (AMH) and "Early modern humans"(EMH), are terms used to distinguish species that were/are anatomically consistent with the features (range of phenotypes) seen in contemporary humans and distinct from archaic humans. species. The term "modern man" means our current Homo Sapiens.
.
Dispersal of Homo Sapiens

Homo sapiens began dispersing "out of Africa" as is popularly known, in several waves from possibly as early as 250,000 years ago, and certainly by 130,000 years ago. A southern dispersal began about 70,000 years ago leading to the permanent colonisation of Eurasia and Oceania by 50,000 years ago.

By 50,000 – 40,000 years ago, the first humans set foot in Australia. By 45,000 years ago, humans lived at 61°N latitude in Europe. By 30,000 years ago, Japan was reached, and by 27,000 years ago humans were present in Siberia above the Arctic Circle. By the end of the Upper Palaeolithic Age humans had crossed Bering and expanded throughout the Americas

Archaic Humans

Homo Neanderthalensis

A parallel group, also extinct, were the Homo Neanderthalensis who emerged in Europe and West Asia around 430,000 years ago, and included the Homo Denisovans (around 285,000 years ago)

The two (together with related tribes) are called “archaic humans”. They overlapped with the Homo Sapiens and there was significant inter-breeding with the latter.

The genus Homo heidelbergensis, dated 600,000 to 300,000 years ago, has long been thought to be a likely candidate for the last common ancestor of the Neanderthal and modern human lineages. However, genetic evidence published in 2016 seems to suggest that Homo heidelbergensis in its entirety should be included in the Neanderthal lineage, as "pre-Neanderthal" or "early Neanderthal", while the divergence time between the Neanderthal and modern lineages has been pushed back to before the emergence of Homo heidelbergensis, to close to 800,000 years ago.55

Modern humans met and interbred with archaic humans in Africa and in Eurasia between about 100,000 and 30,000 years ago. Archaic human species including Neanderthals are thought to have survived until around 40,000 years ago.

The extent of Neanderthal admixture varies significantly between contemporary racial groups, being absent in Africans, of the order of about 1% to 4% in Europeans and East Asians, and highest among Melanesians (the last also having Denisovan admixture at 4% to 6% in addition to Neanderthal admixture)

Cumulatively, about 20% of the Neanderthal genome is estimated to remain presently spread in contemporary populations.

Cro-Magnons

Cro-Magnons were the first “early modern human” (EEMH) Homo Sapiens, to settle in Europe, migrating from western Asia, continuously occupying the continent possibly from as early as 56,800 years ago. They interacted and interbred with the indigenous Neanderthals - who went extinct 40,000 to 35,000 years ago.

From 37,000 years ago a second wave succeeded in forming a single population, from which all subsequent Cro-Magnons descended and which contributes ancestry to present-day Europeans

Cro-Magnons were anatomically similar to present-day Europeans, West Asians, and North Africans; but were more robust, having larger brains, broader faces, more prominent brow ridges , and bigger teeth, compared to the present-day average. The earliest Cro-Magnon specimens also exhibit some features found in Neanderthals. The first Cro-Magnons would have had darker skin tones than most modern Europeans;

The Cro-Magnons had expansive trade routes stretching as long as 900 km (560 mi), and hunted big game animals. . The Cro-Magnon arsenal included spears, spear-throwers, harpoons and throwing sticks, and possibly dogs.

Cro-Magnons are well renowned for creating a diverse array of artistic works, including cave paintings, figurines, and geometric patterns. They also wore decorative beads, and plant-fibre clothes dyed with various plant-based dyes. For music, they produced bone-flutes, whistles, and other instruments.

They also buried their dead, though possibly only people who had achieved or were born into high status.

Apparently the Cro Magnons went extinct about 10,000 years ago, after the Neanderthal. None of the regular sources could offer me an explanation. The best position appears to be: "Cro-Magnon" is the name scientists once used to refer to what are now called Early Modern Humans or Anatomically Modern Humans—people who lived in our world at the end of the last ice age (ca. 40,000–10,000 years ago); they lived alongside Neanderthals for about 10,000 of those years.

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55 - https://en.wikipedia.org/wiki/Early_modern_human

Another source states: Cro-Magnons, sometimes called “European early modern humans,” were members of our species, Homo sapiens, who lived in Europe at the end of the last ice age.(I take it this means they are extinct.)

Another commentator pointed out that Cro Magnon man had the highest cranial capacity among all the evolutionary species of humans. Thus, they are considered more intelligent than modern men. Cro Magnon had a larger forehead and a well-developed chin along with a semi-circular jaw and orthognathous face.

Another source states: their DNA sequences match those of today's Europeans, suggesting that “Neanderthal hybridisation” did not occur. I am fascinated by the underlying syllogism: that, therefore, Europeans have larger brains.

Early Modern Human

Early modern human (EMH), or Anatomically modern human (AMH), are terms used to distinguish Homo sapiens species that were anatomically consistent with the range of phenotypes seen in contemporary humans, from extinct archaic human species. This distinction is useful especially for times and regions where anatomically modern and archaic humans co-existed,

Range from AMM to BM

Basically, our early modern humans emerged with the species Homo Sapiens. The latter in turn emerged from the species Homo erectus. The Homo erectus species emerged as early as 1.9 million years ago,

it is believed that early humans (as defined) – and therefore Homo Sapiens - arose between 350,000 and 260,000 years ago through a merging of populations in East and South Africa, while the Neanderthals emerged slightly earlier in Europe and West Asia.

Homo erectus was a human of medium stature that walked upright. The braincase was low, the forehead was receded, and the nose, jaws, and palate were wide. The brain was smaller and the teeth larger than in modern humans. Homo erectus appears to have been the first human species to control fire, going back some 1,000,000 years ago.

Early humans therefore lived during the Palaeolithic era, also known as the “pre-historic era”, while contemporary humans live in the modern era. The cut-over is broadly with the invention of writing.

The early humans first lived in small, nomadic groups and were primarily hunter-gatherers, from their emergence 1.9 million years ago to the Middle Palaeolithic. This term is used to mark the emergence of behavioural modernity roughly by 50,000 years ago, corresponding to the start of the Upper Palaeolithic. There were several species, which have all since gone extinct.

Homo sapiens evolved from the genus Homo Habilis, very broadly between 50,000 and 12,000 years ago (the beginning of the Holocene), ushering in the Upper Palaeolithic Revolution

Pre-Historic Ages

The Palaeolithic Age

The Palaeolithic Age, also called the Old Stone Age, coincides broadly with the Pleistocene. It is the period distinguished by the development of stone tools by hominins. It is the time when we began to develop communally. It extends from about 3.3 million years ago, to about 11,650 years ago, into the present Holocene,

During the Palaeolithic Age, hominins grouped together in bands (small societies) and subsisted by gathering plants, fishing, and hunting or scavenging wild animals.

The Palaeolithic Age is characterized by the use of knapped stone tools, In time, they used wood and bone tools.
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With emergence of the species Homo sapiens, about 50,000 years ago in the late Pleistocene, there occurred a marked increase in the diversity of artifacts. In Africa, bone artifacts and the first art appeared in the archaeological record. The first evidence of human fishing also noted, Archaeologists classify artifacts of this period into many different categories, such as projectiles, engraving tools, sharp knife blades, and drilling and piercing tools.

Upper Palaeolithic Revolution

From the evidence, advancements in human intelligence and technology changed radically in the course of the Palaeolithic, between 60,000 and 30,000 years ago, presaging the advent of behavioural modernity, sometimes described as the “Upper Palaeolithic revolution.”

The latter term (behavioural modernity”) comprise a set of traits that distinguish Homo Sapiens from extinct hominid lineages and reflect a highly developed brain capable of reasoning, language, introspection and problem-solving.

Tools, such as stone-bladed tools, tools made of antlers, and tools made of bone were created during this period. People began creating clothing. What appear to be sewing needles were found around 40,000 years ago and dyed flax fibres dated 36,000 year ago have been found. Human beings may have begun wearing clothing as far back as 190,000 years ago.

Cultural aspects emerged, which included cave paintings, sculpture, carvings, and engravings on bone and ivory. The most common subject matter was large animals that were hunted by the people of the time.

Towards the end of the Palaeolithic Age, humans began to produce the earliest works of art and to engage in religious or spiritual behaviour, such as burial and ritual.

The Palaeolithic Age went through a set of glacial and inter-glacial periods in which the climate periodically fluctuated between warm and cool temperatures.

By 50,000 – 40,000 years ago, the first humans set foot in Australia. By 45,000 years ago, humans lived at 61°N latitude in Europe. By 30,000 years ago, Japan was reached, and by 27,000 years ago humans were present in Siberia above the Arctic Circle.

By the end of the Upper Palaeolithic Age humans had crossed Bering and expanded throughout the Americas.

A view increasingly supported by archaeologists is that there was indeed some kind of "human revolution" but that it occurred in Africa and spanned longer, over tens of thousands of years. It was not a sudden mutation but a historical development along the lines of the industrial revolution. it was a relatively accelerated process. Also, some archaeologists point to the relatively explosive emergence of ochre crayons and shell necklaces, apparently used for cosmetic purposes. dated within a time-window of 70,000–160,000 years ago in the African Middle Stone Age, suggesting that the emergence of Homo sapiens then coinciding with the earlier transition to modern cognition and behaviour..

The Mesolithic Age

The Palaeolithic Age preceded the Mesolithic Age, although the date of the transition varies geographically by several thousand years.

The type of culture associated with the Mesolithic varies between areas. It is associated with a decline in the group hunting of large animals in favour of a broader hunter-gatherer way of life, and the development of more sophisticated and typically smaller lithic tools and weapons.

Depending on the region, some use of pottery and textiles may be found in sites allocated to the Mesolithic, but generally indications of agriculture are taken as marking transition to the Neolithic.

The more permanent settlements tend to be close to the sea or inland waters offering a good supply of food. Mesolithic societies are not seen as very complex, and burials were fairly simple.

The Neolithic Age

The Neolithic Revolution was the first agricultural revolution, representing a transition from hunting and gathering nomadic life to an agricultural existence. It evolved independently in six separate locations worldwide around 10,000–7,000 years ago (8,000–5,000 BC E). The earliest known evidence exists in the tropical and subtropical areas of southwest Asia, northern-central Africa, and Central America.

It resulted in a shift to more sedentary lifestyles, and the use of agricultural tools. Animals were domesticated (including dogs).

Another defining characteristic was the emergence of pottery, and, in the late Neolithic period, the wheel for making pottery.

Neolithic architecture included houses and villages built of mud- and the construction of storage facilities, tombs and monuments.

Copper metal-working was employed as early as 9000 BCE in the Middle East. A system of counting using small clay tokens was began in Sumer about 8000 BCE Grandiose burial mounds are a mark of the Neolithic.

Behavioural modernity grew as part of the Neolithic revolution. which involved radical changes in agricultural technology, animal management, and the adoption of permanent settlements.

Bronze Age

The Stone Age developed into the Bronze Age after the Neolithic revolution,

The Bronze Age was characterised by metal smelting of copper and bronze, an alloy of tin and copper, to create implements and weapons. This technological trend began in the Fertile Crescent and spread outward.

The Bronze Age lasted from approximately 3300 to 1200 BCE. It was characterised by the use of bronze, the use of writing in some areas, and other features of early urban civilisation.

Iron Age

The Iron Age involved the adoption of iron or steel smelting technology, either by casting or forging. Iron replaced bronze.

Iron was smelted in Egypt about 6000 BCE. and iron replaced bronze in the Middle East about 1500 BCE. The Chinese began casting iron about 5000 BCE. and their methods for casting iron was the precursor to modern steel manufacturing methods.

In Europe, iron was introduced about 1100 BCE. and had replaced bronze for creating weapons and tools by 500 BCE. Iron was extracted from metal ore starting about 2000 BCE in Africa.

Other societal changes often accompanied the introduction of iron, including changes in art, religion and agriculture. The Iron Age ends with the beginning of the historic periods, generally marked by the development of the written language

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Chapter Twelve
Modern Man

Behavioural modernity

Behavioural modernity is a suite of behavioural and cognitive features that distinguish modern man from other AMHs, hominins and primates.

Most scholars agree that modern human behaviour can be characterised by a number of "human universals". These include abstract thinking, planning depth, symbolic behaviour (art, ornamentation), music, and dance, scale in exploitation of resources, and in the development and application of technology. These attainments pre-suppose the prior acquisition of language and writing,

Finally, language, written language, morality and religious features would spell communities who have reach the civilised stage.

Other criteria, differentiating stages of economic development, include clothing, tools (stone, flint, bones, et), weapons (hunting, fishing), agriculture, collective labour, trade, transport over long distances, control of fire.

Social criteria include, community living (size of), social practices and protections, cultural features, ritual practices (burial), homes and hearths and social learning.

Scientists observe that although human communities lived in separate locations and environments through prehistory, they evolved with broadly common features. This suggests they developed these features before they broke off, probably before the exodus from Africa.

Ascent to Modernity

The modern human is deemed generally to have emerged at the invention of writing. Human affairs thereafter becomes more a matter of history than evolution. The further transformations of man have been more man's own doings.

In the modern age, our further development has been phenomenal and rapid. Homo Sapiens have gone from agriculture to space tourism in 10,000 years, while it took 50,000 years to become modern man. All of it is man-made.

It is not possible to say whether we are the terminal objective or whether there are further stages of physical evolution, or whether man must now find and establish its continuing or a new destiny. The point is of course the central interest of this book.

The earliest writing system comes from Mesopotamia (present-day Iraq), where shaped clay tokens were used for accounting purposes between 8000 and 3500 BCE. Based on the surviving evidence, humans invented writing in Mesopotamia sometime between 3400 BCE and 3300 BCE. Proof of writing in Egypt has been found that dates back to 3200 BCE, and in what is now China around 1300 BCE.

While our focus is on contemporary man, it provides some perspective to mention briefly the major stages how we got to today.

From 8000 BCE

The “cradles” of civilisation emerged independently in six location Sumer-Mesopotamia, Egypt, Indus-India, China and the Minoan-Greeks, were peoples in separate locations with distinct cultures, economies, political organisation, religious beliefs and their own philosophical and scientific attainments. They established the ethnic-language-cultural patterns of the world’s population till today.

From 3000 BCE to 1500 CE

The age of empires, including the Minoan, the Akkadian-Babylonian, the Persian, the Greek, Hellenic Greece, the Mauryan, the Han, the Gupta; and of course Roman-Byzantine empire, the Arab-Ottoman caliphates and the Ming-Qing dynasties.. The populations were still agricultural, but with increasing urbanised, maritime and militarised-naval components. The effect of these empires was to spread knowledge, culture and trade, regionally and in known world.

Aristotle(384-322 BCE) was Alexander the Great’s (336-323 BCE) tutor. Apart from being the landmark philosopher of all time, Aristotle was the father of modern science. The emperor sent him specimens from all parts of this empire. The Roman empire (753 BCE to 476 CE) gave us the Christian religion to which 30.7% of the world belong. The Caliphates gave us Islam with a world membership of 24.9%

From 1500 to 1900 CE

This is the era of the nation states, the “discovery” that the world was round, the colonisation and exploitisation by European states of the underdeveloped world, but also the expansion of trade and culture and the spread of education, and common values.

1700 to 1900 CE

Overlapping the preceding, this time-frame began the great age of enlightenment, the scientific revolution, and the industrial revolution in Europe , leading to large scale production of raw materials to supply the industries, and the export of goods to the new markets. The need for stability, infrastructure and an increasingly educated workforce in the colonies resulted in benefits of the reverse flow of investments, education and religion.

This period also saw greater economic integration and trade, the railway, the great sailing ships and first steam and then electric power.

1900 to today

The beginning of the 20th century saw the world effectually become a global economy. There was increasing turmoil as the industrial powers vied for market supremacy, territorial possession and raw materials, while the lesser nations sought a fair share of the pie and there was nascent unrest in the colonies for freedom.

It took the two World Wars, with weapons verging on the threat of extinction, to bring mankind to the realisation that their survival and prosperity, that of the entire species depended on peace and co-operation.

The formation of the United Nations (1945) and adoption of the Universal Declarations of Human Rights (1948) marked the turning points. The first attested to the common desire for survival, while the latter laid down the principles of development. The world has struggled but successfully maintained global peace since. The right to life, health, liberty and education are among the foundations of human civilisation.

The beginning of the 20$^{th.}$ century saw the Quantum revolution, which opened the door to the sub-atomic physics of the universe. With Einstein’s’ Theory of Relativity, we now even understand how the cosmos (and the Earth) might have been formed I and where we ae heading.

The peace has been vital to the technological revolution that followed. With electronics, telecommunications, the computer and the internet, we have moved into the information age. Contemporary man is increasingly . a “knowledge worker”.

The Contemporary Age.

Within my lifetime (I am 91 years old), contemporary man has effectually mastered the physical environment, establishing an alternative basis for further evolution.

On a cosmic scale, we can tell what is going on in galaxies zillions of light-years away, hypothesise how the universe began, and how it may end. On a sub-atomic level, we can study the anatomy of a virus and take preventive action against it. On a biological level, we breed good bacteria and market them to help improve our health, while we have anti-biotics to deal with the bad ones.

At the terrestrial level, contemporary man is totally mobile, with GPS. We have conquered the air and the seas. We have been to the Moon, we have robots on Mars, and in what must the supreme feat of integrated science and engineering, we haves the James Webb Space Telescope some 1.3 million km away in space in gravitational equilibrium between the Sun and the Moon. It is poised to discover other planets (exoplanets) that support life. and to look almost directly at how the big bang began .

At the human level, man’s living environment is almost wholly engineered. We have created a sophisticated technological world, urbanised and with luxurious standards of living. Manual labour has been replaced by automation and robotised equipment. We farm our staples, meat and fish with advanced technology, and manufacture the rest of our needs.

Until our original prokaryote leant to trap sunlight to oxidise water for energy, we had no future. Our present technological edifice requires mountains of energy and any future destiny will require even more. We may note that man has replicated what the Sun does for its energy and is producing our energy by nuclear fission and nuclear fusion.

The power, capacity and potential of man’s cognitive and intellectual faculties have been incredibly enhanced by information technology,. The human’s capacity to inquire and investigate, process and analyse data, think, communicate, take decisions and manage have all been geometrically increased, most recently by artificial intelligence. When we manage to couple the latter with a quantum computer, the potential will be frightening.

Contemporary man is increasingly a “knowledge worker”. Everybody carries a smartphone or other device in instant contact with others, and netted to Google with all the data and information resources on tap. One may wonder whether our original microorganism had any such creature I mind when it started evolution, or whether it is all the Homo Sapiens’ doing, or chance.

At the biological level, today, we know the complete Human Genome, can modify it and affect evolution. Through DNA sequencing we can trace our evolution back to our first universal common ancestor, the evolution of the different species, extinct and extant, by family trees, and classify them.

With man’s mastery of biology, the average person is assured of essential medical care and health support. We know each stage of evolution from the first microbe, and where we stand in the sweep of evolution.

By law education is universal. Some 40% of the global adult population have some kind of tertiary education. Homo Sapiens today are therefore a species of educated Individuals, with a growing intelligentsia. We may contemplate with some awe the situation when we max the intellectual potential of the whole world.

At the same time mankind is inter-dependent and must remain unified. The destiny of the collective depends the behaviour of the individual. The sinews of our civiliisation therefore lie in the behavioural norms of our ethics and morality. Man’s ultimate success will depend on the aspirations of the collective.

sapiens stands at the apex of the biological evolution that began on Earth. Some 19 species of the genus Homo came down the line with him but have all gone extinct, leaving him the dominant species on the planet. He is the most advanced outcome or product of this biological evolution. He exercises de facto hegemony over all other life forms, and is at the top of the food chain.

And, finally, he is possessed of a set of the most extraordinary intellectual faculties, with which he has mastered his own living environment and even stepped into space - to the extent that it raises the question whether he is in fact the intended terminal objective of evolution and whether evolution intends that hereon he discover and determine his own destiny.

In the natural order of things, life has evolved on an individual entity basis, as well as members of a species. Mutation, reproduction, speciation and evolution take place at the individual level. Nothing is more individual than a mammalian mother. At the societal level, there have been two extremes of models, the insect army modal and the individuality of human society. The evolution of the human brain made the latter the choice. Man's intellectual faculties distinguish him from all other creatures.

Human: The Person

In my review of evolution, one thing stands out. Evolution takes place at the individual level. Likewise, the output of evolution is represented by the next individual - with the new elements added. The human individual or man is the current outcome of our long evolution, but with the extraordinary addition of a set of intellectual and qualitative faculties, coupled with the freedom and the free will to use them according to choice.

It suggests that the destiny of the individual is the primary objective of evolution and the destiny of the species is at one with it.

As individuals will think, desire and behave differently, this effectually differentiates each human as an person. Each person is unique. Each person will have its own identity. and each person will have different behavioural responses to the real world.

The immediate pre-occupations of the individual will the well-being and “happiness” of self and persons of immediate interest. It so happens that they are tied to the destiny of the species in the long term. To that extent, the individual is concerned with the latter.

The preceding suggests that the destiny of the species is hereon no longer set and ordered by the evolutionary process. It is in the hands of the individual, taking decisions in the interests of himself and the collective.

If so, the preceding mark a turning point, and even possibly the terminal point, in the saga of evolution. The added faculties represent the “quantum leap” for the Kingdom Animalia.

The development of the person becomes a necessary end for both the individual and the collective, for the best possible social framework (civilisation) to ensure the future of the species.

Terminology.

To maintain clarity, I use the following terms with the meanings assigned.

.- “sensory inputs”. Inputs to the brain via vision, hearing, touching, feeling, smell, or taste from the external environment, or internally from within the body.

.- ”cognitive faculties”. The brain's assimilation and response to sensory inputs, mainly at a routinised or reflex level and of a functional nature, possessed by all animals, including man.

.- “intellectuals faculties”. That set of faculties, only possessed by man, that enable him to find out, think and decide how to fulfil his personal satisfactions, and safeguard the species.

.- “extrasensory faculties”. That set of faculties that enable the individual to sense things beyond the physical world. Anthropological indications exist of it from and across early modern man’

.- “mind”. That conscious totality of a person that controls and directs the entity that is the individual human. The mind, the person and the individual are indistinguishable. .

.- “consciousness”, A state of total awareness of self, body, intellectual and qualitative faculties and the external environment, in which state the mind is ready to think. The ambient state of man is consciousness. When asleep or otherwise less than fully conscious, the brain’s functions hardwired into the human continue, but the mind is not conscious.

. – “think”. The act of engaging the intellectual faculties in rational activity, usually the first step in other activities.

Human Brain

The intellectual faculties are lodged with the human brain, and the intellectual functions are performed through the instrumentation of the brain. The latter in turn co-ordinates all their activities and maintains their on-line and memory banks.

Man has the largest brain (1,300 cm) of all animals, with its own uniquely structured architecture, and has massive processing and multi-tasking power.

Essentially, the brain performs all the functions of a computer.(in fact the computer is modelled on the brain), executing the programmes and tasks through the intellectual faculties.

It would appear that the brain also possesses some functions extra to the intellectual faculties. Drawing from all levels of input and the memory banks, including evolutionary and cosmic memory, the brain delivers exotic psychic and paranormal phenomena like dreams, and visions, and extra-sensory experiences like awareness of the supernational.

The brain resides with an individual, and is under his total control. It is said men use only a fraction of their brain power. It is also said that one madman can destroy the world.

Man’s Intellectual Faculties

Man’s intellectual faculties comprise a set of brain skills and functions, possessed individually and in common by all, and therefore can be used individually, complementarily, or by agreement collectively.

The ability to abstract and think in the abstract has been man’s vital capability. By the efficient communication systems developed, two men are able to conceive precisely the same thing His intellectual faculties have been the engine of his stupendous achievements.

These have been at both the Personal and the Collective levels:

.- (a) At the Personal level: for (i) provision of the everyday requirements at our very high standards of living and for the conduct and enjoyment of life, and (ii) for the discharge of his societal duties and responsibilities, and

.- (b) At the Collective level : for the (i) better management of human society, (ii) developing a better world through technology, (iii) enlarging man’s Knowledge-base, and (iv) understanding the purposes and direction of evolution so as to fulfil the individual’s and the species’ destiny better.

Key Intellectual Features

The key intellectual features became possible only when modern man had fully developed language, writing, speech and mathematics. It is incredible that this happened only some 8,000 years ago.

The central faculties are conceptual ability and reason, in all their variations according to the subject on which the mind is applied , whether scientific, philosophic, religious, or social, and whether personal, societal or research. The important complementary core faculties include needs analysis, problem-solving, judgement or choice, and design and planning.

Key Intellectual Functions

The. intellect functions in four dimensions
.- (i) Qualitative, which are essentially self-definitional
.- (ii) Information assembly
.- (iii) Decision making and action
.- (iv) Knowledge building

The first forms the parametres of choice, eg, possible, preferences, priorities and ethics, the second comprise the inputs for decision making, and the third is the reasoning and choice, following by action. The fourth is represented by the (insatiable) inquiring habit of man, increasingly his "lead" faculty in this evolutionary role.

Qualitative Operations

The qualitative operations are generally regarded as inputs and. outputs of the intellectual faculties, which indeed they are. They provide inputs about the self. I prefer therefore to identity them as separate sets, as they relate to the individual's personality and desires, and map out his self-image, rather than his activities.

<u>Establish Lifestyle</u>.-
.- Establish targets and norms of satisfaction at the personal level
.- Establish the targets and norms of satisfaction at the societal level
.- Adopt personal values (right, wrong, justice, goodness, caring)
.- Adopt behavioural norms (including ethics and morality)
.- Decide personal destiny
.- Plan life in implementation of preceding

<u>Cultivation of Qualitative faculties</u>
.- Cultivate the personal virtues (love, caring, justice and generosity)
.- Cultivate the social virtues (responsibility)
.- Maximise learning and skills
.- Master the emotional faculties (indulgence and restraint)
.- Cultivate the aesthetic faculties (appreciation and skills)
.- Cultivate one's imagination, intuition and ratiocination
.- Cultivate one's feelings, convictions and beliefs

<u>Recognise and Develop Other faculties</u>
.- Psychic abilities
.- Awareness of the spiritual or super-natural
.- Conviction and belief in a creator
,- Conviction and belief in an afterlife

The qualitative operations establish the potential and parametres of the person, and his choice of lifestyle.

These set the framework of his behaviour. On the other hand, it is a man's intellectual faculties, acting with free will, that determine his decisions and actions, and therefore his character.

Information Input Processes

To carry out its routinised functions, as well as to serve the intellectual faculties, the brain carries out various input activities

.- Perception, interpretation, storage and retrieval of information from sensory inputs

.- .Perception, interpretation, storage and retrieval of information from bodily inputs
.- Perception, interpretation, storage and retrieval of information from intellectual outputs
.- Perception, interpretation, storage and retrieval of information from educational sources

Personal Planning Framework

The following would be some of the objectives for which the intellectual faculties could and should be used in a well-planned life:

Strategise and implement
.- Programmes of satisfaction at personal level
.- Programmes of satisfaction at the societal level
.- Programmes of satisfaction at the species level

Activities (personal)
.- Self-development, physical, mental, educational and behavioural
.- Emotional development and enjoyment
.- Aesthetic development and enjoyment
.- Intellectual development and enjoyment
.- Well-being and safety of self and the family

Activities (societal)
.- Help the community establish norms for the well-being of the community
(order, safety health, work , education, standard of living)
.- Fulfil duties and responsibilities in respect of the above.
.- Contribute to development of the social infrastructure
.- Contribute to knowledge and technological development.

Cradles of Civiliisation

At some point, man is deemed to have become civilised. Among other things, this is measured by the increasing unification of peoples as one society, sharing their Intellectual heritage and technology, and living (as peacefully as possible) within a common set of ideals, standards and aspirations.

The earliest humans communities grew into complex societies from around 7000-5000 years ago and were defined by the emergence of urban centres, organised governance, surplus food production, and specialised labour.

Key characteristics included writing systems, monumental architecture, social hierarchies, with religion playing a crucial role in unifying populations and legitimising power. These societies arose in areas with geography favourable to intensive agriculture, leading to population growth and economic stability . They grew from states, to countries, to empires, and to civilisations.

The earliest was Sumer in Mesopotamia. The other cradles of civiliisation included Egypt, China, India, and (less known) the Olmec civilisation in Mesoamerica and the Norte Chico civilisation of Peru.

I tend to think man's future evolution lies in his civilisation, in his further development in the above dimensions, perhaps critically in the moral sphere.

Frontiers of Modernity

Behavioural modernity is a suite of behavioural and cognitive features that distinguish modern man from other EMHs, hominins and primates.

Frontiers of Modernity

I see modern man emerging in three dimensions: (1) facultative (or intellectual) development, (2) societal development and (3) moral development.

Most scholars agree that modern human behaviour can be characterised by a number of “human universals” in facultative development. These include abstract thinking, planning depth, symbolic behaviour (art, ornamentation), music, and dance, scale in exploitation of resources, and the development and application of technology, These attainments pre-suppose the acquisition of language and writing.

Collectively, man has built up and shares a massive structure of comprehension of the world he lives in. This incorporates two streams: (i) empirical or scientific knowledge and (ii) deductive or metaphysical thought. Besides his own reservoir of the preceding, man is also equipped with his own bank of experiential inputs, and his own emotions and passions.

At the societal level, there has emerged the social and legal framework evolving towards statehood, division of labour and craftsmanship evolving towards social hierarchy, and trade and economics evolving towards urbanisation. The family has remained the unit of the community and society.

At the morality level, there has been increasing order and personal and collective responsibility for the family, the community and the state. This has been accompanied by increasing education as well as self-awareness of the individual’s responsibilities in his choices and decisions in the exercise of free will.

But, moralists also generally. agree that man is both self-gratifying and caring. There is a sense that while evolving his desirable societal attributes, man has not yet completely lost some of his primitive instincts of survival. While on balance, his overall moral performance has been good, man needs to watch this front.

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Chapter Twelve
Evolutionary Status of Man

Turning Point

Whereas evolution has up to now been self-piloted, whether by chance or on a pre- programme, with intelligent man and free will, evolution adopted a new formula. It has placed the future in man's hands. This is a turning point, and possibly a terminal point.

The preceding represent a quantum leap for which there was no prior preparation. it raises the question whether man is the intended terminal objective of evolution (period), or whether evolution's intention is that hereon he discover and determine his own further evolution and destiny.

The Homo sapiens stands at the dominant species on the planet. He exercises de facto hegemony over all other life forms, and is at the top of the food chain.

Among other things, he can self-drive himself through different emotional states from self-gratification to desire for the common good. And lastly, he is endowed with the free will to do so.

Man is today in a position to change the course of evolution. It is in fact thought of as mankind's responsibility.

Man, the Person

With intelligence and free will, man is an individual person, an independent being in his own right. Each person will have different behavioural responses to the real world. He shares mankind's responsibility through his decisions as an individual, in that they collectively determine the course of events.

At the same time, it is thought that he is individually responsible and accountable for his decisions and actions. If they fail moral scrutiny, he can square out and make amends over a life-time. If he does not, we have a metaphysical issue whether his accountability extends into an after-life, or whether he can just get away with anything.

Each individual person is defined by **his own identity.** Identity is a reality that exists in a combination of his mind in his body. It manifests itself in his decisions, and commands the body through the brain. It resides in the mind. It encapsules the sum of his past history, his present thoughts, his emotional suite, and his future aspirations. It shoulders his responsibilities, exults in his achievements, and shares his guilt. Man's identity is the living entity (some say "soul") of his being.

By incorporating identity into man's being, evolution has brought into existence a non-corporeal component in human nature. It is this view of identity that provokes the issues of life after death, reincarnation, etc. When the body dies, what happens to the non-corporeal being? An alternate view is that this is all fiddle-faddle. He has an identity while alive as a sociological reality, but once he does dies, that is it. He was just another intermediate. This is another aspect of the metaphysical enquiries going on.

iI just may be that evolution will carry on whether the man-experiment succeeds or fails, and it will stand ready to test another formula – if indeed man has left sufficient of the planet Earth for it to do.

Purpose of Man

The answer to the question why man exists at all must await further metaphysical work – on which we comment further on.

For the present, in so far as man is concerned, his purpose (mission) is and must be to progress (evolve further) as far as he can go using his intellectual capabilities, at the same time safeguarding the species, the planet and its other life-forms. Evolution hereon means civilisation.

Every human action has three levels of application and fulfilment: (1) personal objectives, (2) societal objectives, and (3) the safeguarding of the species. The underlying requirements is that this must not compromise the vitality of the planet and its other living creatures.

Th best human actions are those in which all three levels are in sync. The best human person assumes responsibility and adopts the most favourable norms of attainment and behaviour for each, and acts accordingly, and further influences the collective to do the same. Where the majority of the latter do, the species is saved, while the person is said to have achieved the most desirable personal moral behaviour.
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Achievements So Far

To appraise where we could be heading, it is meaningful to look at what man has achieved so far.

In the Knowledge sphere

We have united and institutionalised our efforts, achieving a collective mountain of knowledge
.- In the physical sciences, we understand matter from the sub atomic to the cosmos.
.- In the biological sciences, we understand evolution and living organisms, from microbes up
.- In the psychological and sociological sciences, we have studied individual and social behaviour,
.- In the “earth sciences”, we have studied the complete Earth history and anthropology of man
.- In the philosophical disciplines, we have studied existence and identity, mortality and immortality.
.- In the metaphysical domain, we have studied existence, reality, knowing and casualty, including our intellectual faculties themselves,
.- In In the theological domain, we have studied the existence and nature of a creator, including human accountability, and
In the religious sphere, we have studied belief systems, myths and revelation,

Man has inter alia developed our moral and ethical codes, and accumulated much **wisdom** in the process, ie. how to live well.

In the Technology sphere

.- With the computer, the internet and telecommunications, we have transformed mankind into an integrated society, functioning globally as one.
.- We have substantially mastered our living environment (except the climate)
.- We have conquered the air, the sea and space
.- We have mechanised, automated and robotised our work process and food production
.- Our medical and educational services are all high-tech.
On the obverse side
.- We have not (yet) conquered death (if we do, we shall have other problems.)

In the Information sphere

.Man is today an information-based or knowledge-based species. The cutting edge of evolution is no longer biological but information

Our brain capability will increase rapidly by hitherto unimagined scales by technological inventions such as the quantum computer.

In the Social and Political sphere

.- We have taken concrete steps towards and institutionalised world consultation, cooperation, international law and world government,
.- And, for the first time, we have a fragile global, if not sector, peace.

On the obverse side,
.- We also have Incredible weapons of mass destruction, and political leaders who threaten to use them.

In the Metaphysical front

Man's domain is our world and our reality, which for convenience I refer to as materiality. Beyond materiality lies the unknown

Yet there are some things external to his present world that rational man sooner or later circles round wanting to know, in particular who made the cosmos and the universe, including man (by evolution) and in the case of the latter what is his purpose. I call these the "metaphysical issues". Man has developed a whole set of disciplines exploring these issues; As yet there is no break-through. it is generally recognised that enlightenment will greatly strengthen man's life focus and organisation, and stabilise his moral development.

Shortcomings

Mortality

The first limit of the human is that he is mortal, with a lifespan of more or less a century.
Death is incorporated in his biology, a functional part of reproduction, speciation, and evolution. Every individual man is a sackful of cells (10 trillions to be exact). While he commands the totality, the individual cells are aging and dying, and new ones being born. At some point the man dies.

It is said that a short life-span for an individual is inconsistent with his being a person with a creative and cumulatively expandable intellect, and one whose personal "wisdom" and enjoyment of life is achieved with age and experience. It becomes increasingly incongruous as the evolutionary environment transfers increasingly to a man-made world through technology and mental application. Not surprisingly, man is constantly exploring the extension of life. Mortality remains a major frontier of evolution for man to break.

Morality

Moral means good for society, good for the species and or good for the man. Moralists have found that individuals in this world are from to time driven by a common set of emotional failings, the most prominent of which are pride or vainglory, envy, wrath, sloth, avarice, greed, and inordinate sexual desire or concupiscence. Where they dominate, they become passions, overriding good sense and caution.

As against the preceding, moralists point out that the larger part of humanity do control these passions by the practice of the virtues, namely prudence, temperance, fortitude, diligence and justice. Combined with other positive emotions, like love, kindness, generosity, etc, they foster the high character, attained by much of humanity.

It is recognised that one of the reasons for the open-endedness of individual moral behaviour is that humanity as a species lacks of knowledge of what the individual's role and responsibilities are. This vacuance drives the metaphysical enquiries of man.

Fortunately, man has been developing along democratic lines, allowing for collective sanity to apply in social governance. By and large, man's responsibilities, relationships, rewards and resources remain in balance. Improving the moral behaviour (perfectibility) of man remains a major area constant attention and tweaking.

Other Dangers

The evidence so far suggests that our human destiny will be tied in with three factors:

.- (i) How far we go in science and technology (physical and biological) without crossing human limits or creating uncontrollable means of our own destruction

.- (2) How well we structure and manage our civil society, including enforcement of our laws and ethics, without resorting to wars.

.- (3) The standards of behaviour of the people, which is closely related to their espousing and practising some kind of moral code, if not perfecting the individual.

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Our Record - Good

Societal Development.

Humans began to recognise the full extent and oneness of their species after the explorations and colonisations that followed Christopher Columbus in 1492. And the front-end soon began to function as a global community sharing their culture, including their languages and religion. The period was characterised by the struggles of the colonial powers for territory and raw materials. At home, they faced social revolution due to the widening gap between the rich and poor.

The scientific revolution which began in the 17th century transformed man's capabilities intellectually, in terms of his mastery of the environment, and in unifying the peoples of the Earth as a single community. It also more clearly separated the known from the unknown and unknowable.

Mankind has since developed an essentially unified civil society or civilisation while respecting and fostering national and cultural differences. We are an educated species and are able to access the different streams of knowledge and their institutions, whether scientific, philosophical, religious or traditional, with equal openness. Mercifully most people can communicate in common languages that have become international.

Fortunately, the world is now networked by a growing number of co-operating international institutions and associations, whether for education, research, professional development and surveillance. or managing our technological and supplies infrastructure. The multinational industries also cement our countries, where they were once primarily exploitative.

Finally, after two world wars, we have a declaration of human rights which enshrines the sanctity and freedom of the individual, and we have a UN system that governs us in common domains, sets the necessary ethics in relevant areas, and even arbitrates in an international court of justice.

The UN has done great things in health, education, trade and economic development, the foundations of our civil society. It is sufficient to look at the outstanding role the World Health Organisation (WHO) played during the recent Covid-19 pandemic, to appreciate the critical role of the UN system in our future survival.

However, an even closer look will reveal how inadequate the present system still is. Given the scale of our advances in (and the increased dangers of) our sciences and technologies, the whole UN is overdue for a complete revamp. They do not have authority within national boundaries. They have no enforcement powers, only limited "peace-keeping" roles with voluntary forces. They would be powerless to stop a nuclear war if one erupts between two super powers today.

If evolution has cast its lot with the individual human for its future, then the individual human must be able to exercise his choices within a framework of civic freedom. Of the two global systems tried out, democracy permits the better exercise of choice. On a hopeful note, the world collectively is leaning towards democracy as the standard political format for countries. According to the World Forum on Democracy, electoral democracies now represent 120 of the 192 existing countries and constitute 58.2% of the world's population.[56] However, the practice of democracy is still flawed in many countries. Of the seven countries with the largest populations in the world, totalling 51.3%, only China, 17.39%, is not a democracy.[57]

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[56] - https://www.coe.int/en/web/world-forum-democracy
[57] - https://www.worldometers.info/world-population/population-by-country

Finally, the distribution of income is another indicator of progress towards universal equality. The World Bank data for 2022 gives only 39 countries out of a total of 177 countries (22.0%) with a per capita GDP of $25,000 or above, the criterion of a developed country. Some 53 had less than USD 3,000. The distribution of Income and wealth within countries is another matter. Income inequality is at the heart of aberrant human behaviour. The hopeful note is that countries are increasingly tempering the extremes of capitalism with socialist policies, and vice versa.

The Technological Front

The European Space Agency (ESA) 's astrometry spacecraft (satellite) Gaia has already mapped and catalogued 1,7 billion stars in and around the Milky Way, The James Webb Space Telescope is currently looking at the universe some 200 light years from the big bang.

Man has been to the Moon. We have remotely been surveying Mars for some years, and our proto-type starship has made its first successful (reuseable) take-off and landing on Earth. All we need is to re-invent quantum physics to get round the time barrier, and we shall be poised for the first step to long range space.

Today, a scanning transmission electron (STED) microscope has reached resolutions down to 0.5 nm (50 picometres) level and can provide magnifications of up to 10,000,000. Today, we can magnify our original prokaryote (of 1 micron) one 100 times.. At the quantum level, we are studying the boson, the gravity carrier, the last unknown frontier of space, and quasiparticles that are transparent in photons.

We have gone into the second quantum revolution with nanotechnology. We are now employing quantum mechanics to alter the quantum face of our physical world. We can create states of quantum coherence or entangled matter and energy that are not likely to exist anywhere else in the universe. These new man-made quantum states have novel properties of sensitivity and non-local correlation which defy our logic.

An equal revolution has taken place in biology and biotechnology. We know the complete architecture of a virus. We can trace our heredity through DNA to our first common ancestors. We have unravelled the complete genetic code of the human being. Technically, we are near to be able to clone ourselves. In biotechnology, scientists are talking of nanomedicine, ie diagnosing and delivering medication at nano levels even possibly using nano robot doctors.

We have replicated the nuclear fission of the Sun. We have 620 nuclear reactors supplying energy all round the world. We are on the point of launching fusion reactors, replicating the even more powerful process of nucleosynthesis that fuelled the primeval expansion of the cosmos and provides the energy of the stars.

The Information Age

The development of the Information Technology (IT) is perhaps the most profound directional change to evolution brought about by technology. Homo Sapiens have evolved into an information-based species.

As the decisions he makes have more and more to do with the world of his own construct, the more he is dependent more and more on processed information, and less and less on the physical inputs of his senses. The latter is increasingly technically sensored.

A typical human today is a knowledge-worker. He is highly "instrumentalised" even in his daily life, checking his smartphone or computer for stock prices or talking (giving instructions) to a robot or his car to carry out a function. All automated functions are information based.

We have now multiplied our data processing and computing powers and our memory banks zillionfold. The world's libraries and transactional records are substantially digitised, enlarging our span of the understandable. All the information is stored or accessible somewhere and can be downloaded by anyone with a smartphone. This enables us, collectively ad individually, to think with wider spans of information and in further depth in the abstract, to take better decisions and manage our civilisation more efficiently.

With Artificial Intelligence (AI) programming of our existing computer capabilities (for example the top 500 supercomputers today in tandem) we can interrogate our data resources, simulate, and programme extensive and intensive information analysis beyond the wildest imagination.

We are already proto-typing the quantum computer, which is geometrically more powerful, with IBM's Osprey with 433 qubits in the lead. The technology is still shaky. With Artificial Intelligence (A!) married to a quantum computer we shall be able to re-write quantum mechanics and GPS the Milky Way (at least), and when we get there we shall also have our favourite books and operas with us.

Human Well-being

Mankind goes forward with the expectation that with increasing civilisation man improves as a moral creature. By giving man free will, evolution is banking on this.

And the features of civilisation that apply here include education, health, improved standards of living, and equal enjoyment of resources and opportunity. These promote greater understanding and peace. They develop responsibility. Finally, they enable people to adopt philosophies of life based on inter-human compassion (caring), and the transfer of life's satisfactions to the practice of the virtues rather than personal passions.

The mis-exercise of free, on the other hand, is managed and secured against by controls within social development, inter alia the ethical and legal frameworks.

In this sector we have a long way to go. Taking education, the most fundamental requirement, as at 2023, while the world literacy figure is 87.4%, the figure of the average years schooling of adults (+25 years) is only 8.8 years and the expected only 13 years. In high-income countries, nearly 84% of young people complete upper secondary education over their lifetime. In contrast, in low-income countries, approximately 61% of youth are completely **out** of upper secondary school. Gloriously, basic education is compulsory, and most chidden have primary education.

The bottom is our life-span. In 1950, the average global life expectancy was around 46 years, a significant jump from earlier periods. By 2023-2024, it had risen dramatically to roughly 73 years , with projections for 2025 hovering around 73-73.5 years. This increase in longevity has been due to health and living standard improvements.

Our Record - Not So Good

Wars and Conflicts

In our time, peoples have come together with nationalist or ideological aspirations to wage war or cause societal subversion on a global scale. Perhaps our greatest achievement is that we survived the 20th century.

Driven fist by territorial aggrandisement and then by race superiority ideology, one country launched two world wars and exterminated six million people. World War II was the largest and most violent military conflict in human history. It was a technological war, dominated by new generation aircraft, battleships, submarines and radar, and ended with the world's first "WMDs" (weapons of mass destruction). Official casualty sources estimate battle deaths at nearly 15 million military personnel and civilian deaths at over 38 million.

Driven by dialectic materialism (an evolutionary ideologic travesty) and led by megalomaniac political leadership, the communist revolutions near crippled the world, Any attempt to estimate a total number of killings under communist regimes depends greatly on definitions, ranging from a low of 10–20 million to as high as 110 million if one includes all nine countries and deaths from famines, gulags, deportations, etc. China alone top scored with 66 millions and the USSR with some 20 million58.

In the last three quarters of a century there has not been another world war. This is not to say we have been living peacefully.

The Cold War lasted from 1945 to 1989, and has left a legacy of nuclear missiles. Even today, believe it or not, there are some 12,100 nuclear warheads, mostly shared by US (5,748) and Russia (5,580). They in turn have some 1,479 and 1,509 respectively strategically deployed at any one time on nuclear submarines, intercontinental ballistic missiles, heavy bombers and forward bases. The other countries with nuclear warheads include China (500), France (290), UK (225) India (172), Pakistan (170), Israel (90) and North Korea ((90).[59] Despite valiant efforts to disarm, the nuclear threat remains the greatest danger to the survival of mankind.

There has always been some war or conflict going on. Data collected by the Uppsala University in Sweden60 identifies 285 distinct armed conflicts having taken place since 1946.

One research group, the Global Peace Index (GPI), estimates that some 13.5% of the world's GDP is going into armament and war, 92 countries are currently involved in conflicts beyond their borders, and 110 million people are either refugees or internally displaced due to violent conflict. 61 Not to be outdone, we have inter alia the Russian invasion of Ukraine, and Israel doing battle with Palestine.

It takes great faith to believe that human nature will improve as we grow more civilised, as would appear to be the position taken by evolution if it believes we shall survive. The philosophic stream however points out that man is inherently capable of and does exercise the necessary virtues to do the right thing

Destruction of the Planet

The highly developed human species uses proportionately much more energy (including the brain), requires much more territorial space, and therefore consumes far more natural resources per individual than other species.

A growing group of scientists argue that the current age of man should be described as the Anthropocene Epoch, and began in the year 1950, which is when human activity started to have a significant impact on the planet's climate and ecosystems.

Around 10,000 years ago, some 57% of the world's habitable land was covered by forest. We have lost one-third since, half in the last century. Scientists estimate that only about 5% of the environment remains unaffected by humans, in floral and faunal terms.

The current rate of extinction of species is estimated at 100 to 1,000 times higher than the natural background extinction rate. We could be losing from 1,500 to 10,000 species a year, from microorganisms up. Biodiversity loss and species extinction have accelerated to the point that human activity is either on the cusp of or has already produced a 6th mass extinction

This has been accentuated by the rise in pollution, in carbon dioxide (57%), methane (10%) and other "greenhouse" gases. Unless checked, the world's temperature will cross the critical threshold of 2 ^{o} Celsius above pre-industrial levels, in 10-15 years. The ice-caps are already melting, despite the fact that we are supposed geologically to be in the Holocene ice age.

There are signs of biological instability. The human body is becoming susceptible to increasing stress and aberrations. We have cancers and mental disorders. Most alarming, we have the emergence of viruses, by nature predatorial, that diversify rapidly and multiply almost infinitely in human hosts, who are almost indefensible against them.

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58 -https://en.wikipedia.org/wiki/The_Black_Book_of_Communism

59 - https://www.armscontrol.org/factsheets/nuclear-weapons-who-has-what-glance

60 - https://ucdp.uu.se/downloads/index.html#armedconflict

61 - https://www.visionofhumanity.org/highest-number-of-countries-engaged-in-conflict-since-world-war-ii/

Mankind has developed close to limits to the point of adversely affecting the planet and evolution. This has to be taken into account in considering the future of the human race.

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Chapter Thirteen
Quo Vadis?

Definitions

Unless the context otherwise requires,

“moral” means that which is right or good (as against wrong or bad) in relation to the individual’s well-being, the collective welfare and/or the safety of the species.

“moral code” describes the set of behavioural precepts and norms sanctioned by society, while “ethics” relate to approved behaviour in specific areas, eg. the professions.

“religious domain”, appertains to the teachings and practices of a religion, generally including the worshipful and spiritual activities of its followers, while “spiritual” refers to any human interaction with the paranormal or unknown.

“reality”, that which exists, physical and non-corporeal, but excludes the unknown and the speculated

“Non-corporeal”, that part of evolved **reality** which is **not physical, but is known about reality** such as information, knowledge, systems, data, history.

“non-material”, a word I use for “spiritual”, to avoid possibly confusing connotations of the latter.

“beyond materiality”, beyond (known) reality both physical and non-corporeal

“Identity”, the sum total of a human being, a non-corporeal reality, an entity sometimes referred to as the “soul”.

“reason”, embraces the total range of man’s abstract thinking abilities in application

“knowledge” ,what is known of a reality, or the sum total of all relevant information about a reality appropriately organised, stored and retrievable.

“information” relevant human constructs of knowledge (facts) derived from processing data

“information gap”, the knowledge gap beyond reality and the unknown or the speculated, that lies beyond man’s ability to perceive or find out
Upper Palaeolithic Revolution

The Quest

It is in man’s nature that he must know, if possible to the point of proof (as per scientific principles) whether there is a supreme being and his intentions in creating man; or to the same points of proof that there Is nothing; or that there is no way of knowing either through our reason alone.

We may or may not recognise that, there is an orientation within man’s intellect which finds it necessary to ask the questions, as though nature needs and intends that he should look for if not find the answers.

It is clear that the answer, some answer, would be fundamental to man’s ultimate understanding of. his purpose, whether now or in future. We have further to remind ourselves that, here, man is looking beyond this cosmos, beyond his own reality.

It seems contrary to “common sense” that, after establishing man with abstract thinking to master the universe, it does not matter (to evolution) whether man pushes himself further or destroys the Earth and himself. The very same abstract thinking tells us that man’s purpose is to take evolution forward, whether to the stars, beyond space-time, and even to discover the unknown, even beyond materiality.

There is a sense that life this our temporal existence is not a perfect paradise. It is too short and imperfect, too wrapped in obligations and restrictions, and riddled with morality, to be the end-all of everything.

There could be somewhere beyond a higher plane, a more perfect existence, non-corporeal, possibly in an afterlife where mortality would have no meaning. And, this could well be the quest of evolution from the start, or the idea would not have emerged in us.

Evolution has worked to a series of overall algorithms, with the widest possible choices at each point, using the opportunities presented along the route. They allowed for corrections, adaption and mutations, and seizing new advantages as they arose. It is an open question at which stage man, in the form of ourselves, emerged as a possible final prototype, possibly after the split of the genus Pan.

The future lies with us. Evolution has passed the baton on to us. Our primary temporal objectives are three-fold and pretty clear: (1) well-being of the individual, (2) welfare of the our society, and (3) perpetuation of our species. We could add two others: namely (4) live longer and (5) preserve the planet.

There is a sense that in relation to our capabilities, our known objectives are incomplete. Therefore, we lean towards our promptings to ask the metaphysical questions, and seek to qualify for a more perfect life in the hereafter.

At this stage of evolution, the destiny of the individual is the destiny of the species Homo sapiens. This has not been so up to now. We are the turning point. If man goes immortal, the species will go immortal – for the first time, and probably finally in evolutionary history. It is not unreasonable for us to perceive this as the probable ultimate terminal objective of evolution, and that we have been designed with that end in view.

Until the preceding is resolved, man’s immediate evolutionary route forward is the temporal pathway.

The Temporal Pathway

By way of explanation, I use the term ”temporal” to refer to the here and the now. All life will terminate when this universe terminates, and therefore nothing in this temporal time is immortal. Only existence beyond materiality is immortal;

My focus here is on how man, the individual, evolves further in our temporal time, both on Earth and in possibly In space.

Further on, I look at whether there is an alternative or parallel path for him beyond materiality (after death) in addition to his temporal function of safeguarding the species.

In The Short-Term
Stay on Earth

For the time being, this is the only option. Long-distance travel into space must realistically await until we have re-configured our science. Purely for conceptual purposes, we might give ourselves a time-frame of say about 500 years or so still substantially here. The break-through could however come earlier, or take longer.

The technological advances will apply, but overcoming our shortcomings will be our priorities. We may state these as our macro-objectives to ensure our long-term survival.

.(1) A unified global society with a shared information and knowledge base, culture and moral values, coupled with tight international control over individual aberrant behaviour, will be the best assurance of survival.

.(2) The best investments will go into improving the standards of health, education, and well-being, in conditions of growing equality of incomes and shared affluence, freedom of choice, better distribution of wealth and equal opportunity, and.

.(3) As house-keepers, we must cater equitably for the needs of (a) the human population and (b) the other living creatures, while (c) we manage and preserve the resources of this planet..

Human Population

Fertility

The world's population is now about 8.2 billions, and will peak at 10.3 billions in the 2080s. It looks like we will be declining rather than increasing after that.

What we shall definitely have to do, after taking into account all other needs and concerns, is to project, plan for and **manage** a desirable level of population over our chosen time-frame. We shall have to achieve that by behavioural and cultural management, the bottom line of which will be by control of the net reproduction rate.

Fertility will be the Achilles' heel of mankind. China went in for an enforced one child family at one stage. But, enforcing the reverse has been quite another matter; instead they are now paying extensive bouses for more chidden.. Life enhancement and extension, and longevity, will introduce further layers of complication.

Structural Imbalance

The vast majority of the world's population lives in the developing countries, some 6.7 billions, totalling 84%. Yet developed countries, totalling 1.1 billion people, hold about 69% of the global wealth. The developed world accordingly earns much more per capita. The gap between rich and poor is continuing to widen.

Disparity in wealth and income are the fundamental causes of global discontent, instability and conflict. The poor communities also rely more on natural resources, exploiting these without conservation, to the point of destruction.

Led by international institutions, the world has seen an enormous flow of financial and technical assistance to support developing countries. And the latter countries have struggled on their own to close the technological and income gaps. The transfer of China, India and Indonesia to the middle income groups has significantly tipped the balance forward.

It has to be added that the principles of socialism, expensively won in human lives, have had a significant role to play in tempering the excesses of capitalistic maldistribution. The structural imbalance can be expected to reduce, progressively removing a serious threat to survival. But maldistribution of resources remains a time-bomb that can trigger a war of mass destruction.

Life-Style

As man increasingly depends on technology, this will reduce the call per capita on natural resources, at the same time consuming the latter more efficiently and more sparingly. Man will increasingly have to forgo the natural product for the manufactured one on the supermarket shelf.

Man could also develop new habits and tastes, Already a paperless society saves a lot of forests, crab-meat saves a lot of sharks and artificial crab-meat saves a lot of crabs.

Human habits can be trained. In Singapore, a meal in a food court would be incomplete without sugar-cane juice. In Mauritius, which is covered with sugar-cane plantations, one could not find a single glass of it anywhere. The population has been drilled that it is almost sacrilegious to cut it, as sugar-cane (sugar) is the backbone of their national economy.

Conserving the Environment

Mankind has developed close to limits to the point of severely adversely affecting the planet's ability to support the human species. We have a human-induced triple planetary crisis of climate change, ecological threat and biodiversity loss, caused by pollution and waste. Serious behavioural corrections are needed.

Climate Change

The Earth's average temperature has risen steadily. Unless checked, the world's temperature will cross the critical threshold of 2º Celsius above pre-industrial levels before the end of this decade. In 2024-25, it was 1.47º C above baseline.

The above has primarily due to atmospheric pollution, in carbon dioxide (CO2), methane and other "greenhouse" gases (GHGs). This rise reflects the increased energy generation by burning fossil fuel - in transport (cars, aircraft), electricity generation, and industrialisation. Estimates from the Energy Institute and Statista placed fossil fuels' share still at around 82% of the global energy mix in 2023.

The world has been addressing these issues since 1995, under the UN Framework Convention on Climate Change (UNFCCC), which meets annually (COP). At its latest meeting at Belem, Brazil in November 2025, the COP30 notably failed to secure a binding commitment to phase out fossil fuels.

The agreed-upon target established at Paris i(2015) is to limit the global temperature rise this century to **well below 2º Celsius** above pre-industrial levels, while **actively pursuing efforts to limit it to 1.5°C** . This latter goal requires deep emissions cuts to reach net-zero CO2 by mid-century, which the world is currently also on track to overshoot.

The UN Environmental Programme (UNEP) reported that the world has so far failed to meet the lower climate change target. Governments' latest pledges to cut emissions in the future, if met, would still see the world face 2.3º to 2.5º C rise in warming.

The principle issue is that the developing countries disagree to meet the costs involved on a proportionate basis, arguing that the developed countries have been largely responsible for the pollution and. should bear the burden of restoring the environment.

The carbon footprint is an index of the total amount of greenhouse gases (GHGs) etc , released by an individual, organisation, event, or product, directly and indirectly, measured in CO2 equivalents The global average is 4 to 5 metric tons. To achieve the Paris global warming target, it must drop to under 2 tons by 2050. The current US average is 16 to 17 metric tons. Mankind remains in danger.

Conserving the Eco-Systems

Oxygen makes up 21% of the atmosphere. Any serious disruption to breathable air could be fatal to all life. Most of Earth's oxygen (50-80%) comes from ocean photosynthetic organisms like phytoplankton, algae, and cyanobacteria, with land plants contributing the rest (around 20-28%).

Mankind must conserve the oceans and all marine life. The latter is also our greatest reservoir of fresh food, as well as the major physical factor influencing our climate and water supply. Currently, stable, the main threats will be pollution (plastics!) and overfishing of popular and endangered species.

On the other hand, the forests (all plant habitats in fact) require serious continued attention. Scientists say that only 5% of our terrain remains unaffected by man and we have lost one-third of our forest cover since industrialisation. They also represent the remaining living space available for our wild life and fauna

Too little carbon dioxide and other greenhouse gases in the atmosphere and the Earth would be frozen. Too much would turn the atmosphere into a furnace. The carbon cycle is Earth's natural system for recycling carbon atoms, moving them between the atmosphere, oceans, land (living organisms and soil), and rocks. The processes include photosynthesis and respiration, as well as rock weathering. Besides regulating climate, it is crucial for sustaining life. Plants and insects play crucial roles in the carbon cycle.

Most of the Earth's atmosphere is made up of the inert gas, nitrogen (78%). Nitrogen compounds are essential for all living things. The nitrogen cycle converts nitrogen is into multiple chemical forms. Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers and the release of nitrogen in wastewater have dramatically altered the global nitrogen cycle, negatively affecting the natural environment system and also human health. The nitrogen cycle is another critical parameter of human evolution.

Biodiversity

Generative AI gives me this alarming report on biodiversity loos. " We are losing living organisms at an accelerated rate, estimated to be**1,000 to 10,000 times higher** than the natural background extinction rate, with some scientists calling it the Sixth Mass Extinction driven primarily by human activities like habitat loss, pollution, and overharvesting…We could already be losing from 1,500 to 10,000 species a year from microorganisms up."

In the animal kingdom, there are about 10 million other species, besides man. There are over one million species of insects alone.

Scientists estimate Earth hosts around one trillion microbial species, but only a tiny fraction (perhaps thousands to a few million) have been formally identified. These include our bacteria, archaea, fungi, and viruses,

Viruses are the most numerous, adapt and multiply with ferocious speed, and are the only ones who are both indestructible and immortal62. By evolutionary design, they must replicate in another biological organism and are therefore biological predators. Man will no doubt bear in mind he could be overpowered by viruses alone, at any time. And I would not vouch for his immortality if he should take them into space with him at some time in the future.

On the other hand, microorganisms (cyanobacteria) are our oxygen suppliers. Ultimately, man will have to operate a viable and responsible biodiversity policy.

Since he is In charge, he may decide to eliminate certain species altogether, ie. tailor-make his universe, perhaps kill off his rivals as does with weeds in his garden.

All in all, man has a reasonable prospect of surviving on this planet, provided he disciplines himself and masters climate change.

In The Long-term
Extraterrestrial Habitation

If our population stabilises and we manage Earth properly, we may not need to migrate to an extraterrestrial habitation. But we shall still want to take in the universe as part of our living space.

We have been to the Moon. We are currently exploring Mars. It is likely we shall have at least temporary habitations there by the end of this decade, and begin to build up our space know-how and technology.

Space Travel

[62] - See my e-book "Virus* Biological Predator" (2021) SBN 978-981-18-3046-4 (PDF) at https://geraldpillay.com/

The problem is long distance space travel. Firstly, space is big and distance is measured by light-years. Secondly, nothing within it can travel faster than the speed of light , ie 300,000 km/sec; and any matter attaining that speed becomes light. The radius of the observable universe, on the other hand, is said to be 46.5 billion light years.

Astronomers estimate there are possibly 2 trillion galaxies in the universe. We are part of the nearest galaxy, the Milky Way. There could be as many as 300 million Earth-sized habitable exoplanets within just the Milky Way. The nearest is 4.2 light-years away, orbiting the red dwarf Proxima Centauri.

Mann's ability to visit space is severely limited by first by the speed he can attain, and ultimately by the speed of light. Voyager 2 ,which entered the interstellar medium on November 5, 2018, would take about 75,000 years to get there, travelling as it does at 17 km/sec. Our own galaxy centre is 26,000 light -years away.

On our present science, **even if we attained half the speed of lightning** (150,000 km/sec), we would need 8.4 light years to get to Proxima Centauri, probably 12 years to allow for the long acceleration needed and the equally long deceleration at the end. On the same basis, we would take 60,000 earth-years to get to the Milky Way centre, and about 7 million earth-years to get to Andromeda the next nearest galaxy.

Even if we achieve half-light speed, we shall be going nowhere outside our Solar System. Realistically, space travel is meaningless unless we can travel **upteen times faster than light.** It means a new science and a new technology. The break-through could happen all at once, or it could take thousands of years, if ever.

Living in Space

There are zillions of third-generation exoplanets, even if we limit ourselves to the Milky Way. In the long-term, if we can get there, it does not matter if they do not have the atmosphere or food we need. With the right portable energy and resources, we can make or bring our own requirements At this point, it appears man will be able to sustain himself extra terrestrially by technological means. Man is already essentially non-corporeal, living on the mental plane in an information-based environment of his own making.

And there will still be the question of life-span. A century or so would hardly be enough to just raise a human to maturity in his new world. Man would strive for as much longevity as possible, in this temporal time, to enjoy his enhanced life-estate. It would be great if over 500 years, he lived to an expectancy of the same.

Living in space would still require that man fulfil his first obligation, to perpetuate the species by reproduction. He would undoubtedly retain his sexual proclivities, and in the best environments and circumstances he should be able to reproduce naturally. However, he may continue to have difficulties with maintaining the net reproduction rate, judging by the growing disinclination of women to have children. As we all live In into longevity, the burden of reproduction will fall on a narrowing band of the younger.

The burden of reproduction can be further narrowed by cloning, using surrogate mothers. Cloning produces identical genetical twins, but not the person. The clone is a new born baby, and will grow up to be a new person (like a son). It is also possible man will in the very very long run seek to reproduce by artificial (technological) gestation. That would terminate one cardinal function of evolution, namely natural reproduction.

As a declining proportion actually die, the number of children needed will be less, unless to populate new planets. We shall then have just a bunch of old fogies and grumpy old ladies, and few children. Man may of course by then have learnt to re-pair, re-style, renew and rejuvenate themselves, and remain looking perpetually young. Thus, whether on Earth or in space, we shall become a “designer people”.

There is no question but that we shall have created our physical utopia, possibly travelling around in space with ease, returning to mother Earth for the holidays and visiting relatives (If we still have them), and skiing on the slopes of a planet in Andromeda.

Human capabilities technologies can make significant improvements to the quality of life, if focussed on improvement of the “normal” central human capabilities referred as the “normative framework”. The aim must be better human individuals and a better society. It can help equalise society. In the long-term, when everybody is clone corrected and engineered from the start, this will be less of a problem

Whatever the reproduction system, it is to be hoped that by then man would have lost or mastered his primeval emotions and passions, and instead have fully developed his incipient virtuous qualities, such loyalty, fairness, caring, and love. Perhaps, these qualities could be bio-engineered in or out as enhancements independently of, before, during or even after cloning. In terms of human management, perhaps these sets of qualities could be added to the menu for cloning, and as criteria for deciding on the early demise (euthanasia) of the unsuitable or the longevity of the future elite. Currently we are close to identifying all the specific genes that control various traits, and may well be able to do these things as normal therapy.

The problem will be who controls the menu for cloning, and who lays down the criteria of essentials to qualify the output as man. Extreme changes may affect overall normality to the point of the person being (still) Homo Sapiens. Needless to say, we could create monstrosities who could endanger the world (and other planets), worse still if someone made them immortal. .

The prospects of creating a biological or bionic “superman” also seem utterly remote. But, by life extension, an individual could achieve considerable longevity.

There is one other way, so far only conjectured, for perpetuation, and that is to “download” the personality of a man (ie his brain and everything in its memory banks) on to a computer, and for him to function therefrom in a suitably robotised environment. Such a transfer to a technological “body” would spell the last severance from evolutionary biology, and might be the only case of achieving immortality in this temporal time – for as long as the technological environment exists. Sex would however be a memory.

The Parallel Pathway
Evolution Beyond Materiality?

Our rational endowments operate in two modes (1) the empirical, the basis of the sciences and (2) the enquirial and deductive, the basis of the metaphysical. There is a (3) third faculty, awareness of the unknown, which is accompanied by other arcane faculties (not present every one). It is extra-rational, is expressed generally in the religious domain, and is the subject of separate attention further on. In our first mode, man has streak away and is today master of the Earth, with a significant presence in space.

The Metaphysical Frontier

In our second mode, man has probed and queried whether there exists a beyond, beyond the universe. Hence we have the various disciplines of metaphysics, and their crystallisation in philosophies and religion.

The Metaphysical Issues

Ultimately, all enquiry beyond materiality boils down to what I have described as the “metaphysic issues”. These are (1) is there a supreme being, transcendental or external to the cosmos; (2) who, if anyone, created the universe (evolution); and why; (3) the purpose, responsibilities, and the fate of man, and (4) life-beyond death.

A positive answer to the first admits of the second. A negative answer leaves the second open to another round of speculation – since we exist, a negative answer to the latter would be irrational.

The third issue underlies personal behaviour. Since man is in the end individually responsible for the well-being and perpetuation of himself and the specifies, he must strive to achieve moral perfectibility The problem is the human, who is notoriously "imperfect" and still enwrapped by his instincts, emotions and passions. We still rely on rewards and punishments in our social systems.

On the fourth issue, life is said to be too short for full accountability or expiation of our conduct. A set of "moral laws" from "above" coupled with rewards and punishments extended into after-life would provide for this, as well as eternally rewarding the good. It would help keep a lot of people in line.

There is a growing incongruity between a fully intelligent creature with free will, capable of conquering space, purely to exist as an evolutionary intermediate, and then subjecting him to senescence and death. The fulfilment of earlier creatures was the evolution and reproduction of the next generation. In this case, man is himself a terminal (albeit intermediate) objective, made responsible for continuation of his species. Having the responsibility means he stands to be judged.

The fulfilment of man must be in terms of his intellectual and moral attainments The shortness of the present life span is thought of as inconsistent with all he can and needs to do or achieve. This impels man to extend his life, seek longevity and if possible conquer death, ie seek immortality.

The Temporal Conundrum

in the long-term (say 1,000 years from now), when every need, pleasure and wish had been satisfied, when he could hit a hole-in-one every time, and every cause was attended to, unless the metaphysical issues are cleared up, we shall still have a bunch of old fogies no wiser, and asking the same questions. Like the crows on the tree in Disney's Jungle Book, they would be sitting around and asking: "what shall we do next?"

They will ask why do we exist, what is the point of being eternally good, is there a better form of longevity, something more or more worthwhile to do, a higher quality of life, what comes after temporal time, and what exactly is our ultimate destiny. Finally they will ask is this happiness?

They will still be looking for the next template for evolution, since this is no longer left to chance but is their responsibility. But then, they will also ask who they are responsible to, and if none why bother. They could become very bored.

Unless evolution (we) bio-engineer some kind of superman, a long life will not be so great if we were to be forever stuck in some artificial machine-body. To enjoy immortality, man will want to be fully incorporeal (free of his body) and transfer beyond materiality.

Metaphysics has been able to explore the subject rationally and formulate the issues in depth but cannot produce the answers, as it has come up against the natural limits of the knowable as against the unknowable.

The Religious Frontier

Up to now, man's answers to the metaphysical questions have come mainly from the third set of his faculties, namely his awareness of the unknown, incorporating his arcane abilities, and expressed historically and societally as religious development.

Man has so far relied on the teachings of religion to fill the gap and has carried civilisation forward, (successfully we may add) bridging the knowledge and psychological gap by what has been called reasonable belief.

The initial stirrings about the metaphysical emerged from the clouds of unknowing about his environment surrounding early man. Responding to an innate need for some answers, man proceeded to believe in and ascribe the unexplainable variously to higher beings (spirits and deities) and began to worship them. This was the start of religion.

As science cleared up much of the unknown, the metaphysical issues remain. The major religions themselves proceeded to develop considerable corpus(es) of metaphysical understandings.

Review of Religion

Every cradle of civilisation developed its own religion. I have proceeded to review the major religious and philosophic developments. Their history, metaphysics and philosophy are generally closely intertwined. My review has therefore been basically historical,

The report will appear in the next volume: Cosmos III*** - Evolution, Beyond Materiality? Here I only allude to those features bearing on our present discussion.

The Abrahamic religions subscribe to a supreme godhead, of varying attributes: omniscient, omnipotent, immortal, morally perfect, creator of the universe and man, and arbiter of the latter according to his moral code, in other words divine. The Dharmatic religions on other on the other hand conceive of Being as transcendent and immanent in the universe, of which man is a part through re-incarnation according to the morality of his life. Central to their teachings is the doctrine that man's life on Earth is some kind of trial, and if he gets it right his rewards and destiny lie in some kind of immortality.

Traditional Chinese culture recognises Shangdi, their godhead, the Mandate of Heaven to govern the peoples, and an afterlife with ancestor worship. In a world crowded with folk-deities, their philosophic focus has been less on the metaphysical and more on social order and a proper way of life. Currently, they have adopted dialectic materialism (communism) "with Chinese characteristics": as their political ideology.

One set of religious teachings incorporate revelation. The others have developed from the enlightenment of holy individuals, mystics and philosophers. They all prescribe a way of life, which generally include a moral code for the individual which may be extended comprehensively for the management of society. Revelation and enlightenment serve as sufficient proofs, and religious adherents reside in their belief and faith of their truth.

Modern Western philosophy emerged from the Greco-Roman and Christian cultures. It is the mainstream within which metaphysics has taken shape, among the other current secular disciplines of philosophy. One main line of thought seems to be that man can by the use of his intellect establish a credible probability in the existence of a prime mover or supreme being, and that it is reasonable to believe in him. But the knowledge gap is there and it requires faith and belief to do so. One further line of thought is that the latter must be given (or revealed) from above. The term commonly used for the supreme being or prime mover is God. Western civilisation has given us two political modes of societal development: the democratic with freedom of religion, and atheistic communism.

Western democratic civilisation took an important turning point when it went separated religion from politics. As a result, religion today, although institutionalised, is essentially an individual matter. However, religion's contributions to man's civilisational ideals and his moral and ethical development have been substantial, some would say pivotal. In the communist world, religion generally struggles but continues.

The belief in a higher order of being remains a basic anchor to a majority of the peoples of the Earth. A 2020 survey showed that world-wide 75.8% of the world's people believed in God a with about 24.2% identifying as unaffiliated to a religion. While it probably reflects some less developed peoples, the overall proportions cannot be ignored.

Religion has been taken advantage of by leaders, even abused by tyrants, to control the population, based on fear of the unknown and punishment for misdeeds. As the mysterious and misinformation got cleared away, this domain has contributed many important qualities to the matrix of human life. Besides the moral code, they include the right to life, equality, justice, and fairness. They have made significant contributions to the moral and behavioural development of man, in fact opening the routes for man to progress to the next qualitative higher plane of behaviour, namely virtuous conduct. In human terms, we have qualities like kindness, charity and love. Afterlife, a feature of some theologies, also adds continuity, depth and meaning to man's otherwise short existence.

Historically it was thought that religion would fade away with scientific and philosophic development, but this has not happened This study finds religion to be a sector of emerging rather than decreasing importance.

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Chapter Fourteen
The Way Forward

Metaphysics in in the large Space-Time

If evolution has been heading man towards a non-corporeal and immortal existence, as there is much evidence to suggest, then our next immediate (metaphysical) step is acquiring extra-rational muscularity and extra information

Our disciplines have gone a long way, crossed-backed by the sociological, neurological and psychological sciences. Our ability to prognosticate and speculate will widen as we revise and re-write our sciences, as we discover new information about our (hitherto) arcane abilities, and as mainstream metaphysics assimilates with the metaphysics and theologies (including revelation) of the various religions, and vice-versa. We should increase our perspicuity in all domains over time.

Mine own feeling is that once we get out into space, our perspectives of the universe will change dramatically and the unknown will look quite different We are likely to have an enlarged understanding of the cosmos, maybe “get nearer” to the origin of things. Belief may then be more automatic, with knowledge. People may decide to opt for immortality rather than longevity.

The recent visit of comet 3i/Atlas, in June-December 2025, prompted a number of scientists to speculate that we were being robotically observed by a more highly developed alien species, possibly an emissary of a guardian federation of alien civilisations. I have no doubt they exist, possibly evolved in the same way, earlier. Our first questions, when we meet, will undoubtedly be whether they know the answers to our metaphysical issues and what they did do following that.

Systematic Exploration of Human “Spiritual” Experience.

I have avoided use of the word “spiritual’ because of its association of ideas. I use it here specifically to mean the contact, communication, mediation and state of awareness (holiness) with the world beyond materiality. These are usually experienced by people with arcane faculties, such as mystics, sadhus, contemplates, visionaries, re-incarnates, saints, and even people in prayer or with a sixth sense. The phenomena may include oracles, appearances and events as well as states of mind. This field has not been systematically recorded, but includes a long history, their context and content mainly associated with religion.

The subject area is subjective, experiential and generally behaviour beyond rationality. To the extent it is factual, (ie it happens,) it should at this point be comprehensively studied to understand if nothing else the faculties and skilled involved. These could perhaps become standardised human skills, like yoga, etc. practised in time by everyone in space and at home.

This field must be explored. It is widely assorted and largely unclassifiable. The best approach is a convergence of scientific and religious intellectuals, working with agreed lists of information sought, definitions and criteria for selection of subjects. With goodwill, co-operation and collaboration there will be much to obtain in the way of empirical output. These will serve to provide the next platform for further stages of study.

it would be a breakthrough if we could isolate the **gene** that triggered this faculty, in fact any gene that could double our metaphysical range. We could then apply it in gene therapy, and our descendants could add it to the options on the menu for cloning. We shall have made progress if we broke new ground, sharpened our common vision of the unknown and enlarged the basis of man’s beliefs.

The Last Divide

Presently, societal development is proceeding in two political formats, the democratic system, and the communist planned society. It is likely we shall coalesce and emerge as a single global society with a common bill of human rights and sharing an increasingly common technology-based culture, including freedom of religion. Religion will then be the last divide.

At that point, the “evangelical” role of the religions may be reversed. Instead of, as necessary in the beginning, combating each other to increase their flock, they may find greater fulfilment in coming together to enlighten the people on the common elements of their teachings in relation to the metaphysical issues. They would still have separate roles offering and guiding their flock as to their respective teachings and different paths to immortality.

The final step would be a voluntary convergence among the religions themselves, and then conjointly with the scientific and metaphysical disciplines, to study both the arcane faculties of man and the sum total of man’s spiritual experiences within religion.

If we can extract (and share) from man’s spiritual experience commonly agreed information, I wound say we could be edging more than a few steps towards strengthening our reason base, and closing the information gap.

Whatever the information package we extract from the above, the mere fact that it will represent added or new or refined collective information previously unavailable and now commonly agreed means that we shall be better placed to postulate our questions and focus nearer the truth, ie ask better questions. It does not mean we will be able to answer ourselves. To the extent the results debunk earlier misinformation and mistaken views, the exercise will have improved the total understanding of things. There will still be a gap, albeit a more focussed one. Man will ultimately have to believe something, even that there is nothing to believe.

In the happiest of situations, it will be left to the religions in the end mainly to offer their respective ways of life and serve a humanity increasingly enlightened as to its destiny.

Evolutionary Strategy

From this study, I find that there is a unifying direction and purpose combining the pre-biotic and the biotic stages of our evolution. Evolution has been a single programme in two parts which brought about the existence of man as we have him.

The overwhelming evidence is that man was and is the culmination of physical evolution. All parallel proto-types have been phased out. The infusion of intelligence marked a quantum leap and a turning point. Iti is equally clear that the next stage of evolution has been placed in the hands of man, through civilisation. With individual free will, man must achieve the objectives of evolution collectively for the species and individually for himself. He has been given total hegemony over the planet Earth.

Evolution has passed the baton on to us. Again from all the evidence, we are in an intermediate phase of an on-going relay, on our way to finding the terminal post. Our immediate objectives are three-fold: (1) well-being of the individual, (2) welfare of the our society, and (3) perpetuation of our species. We could add two others: namely (4) live longer and (5) preserve the planet. As far as we can perceive, the ultimate terminal objective of evolution is apparently something for man to identify, set course for and achieve.

There is a sense that in relation to our capabilities, our immediate objectives are incomplete. There is a sense that, despite our increasing well-being, life in this our temporal existence is not a perfect paradise. It is too short and imperfect, too wrapped in obligations, restrictions and moral issues, and riddled with morality, to be the end-all of everything.

There could be somewhere beyond a higher plane, a more perfect existence, non-corporeal, possibly in an afterlife where mortality would have no meaning. Therefore, we lean towards our promptings to ask the metaphysical questions, and seek a more perfect life in the hereafter. And, this could well be the quest of evolution from the start, or the idea would not have been implant in us.

Judging by the strong continuing belief that a or some kind of supreme being exists and is the source of all life, we must conclude that the metaphysical issues remain our paramount intellectual quest.

But, as certain knowledge lies beyond our physical reality, we can only go so far as to conclude that such a belief is reasonable or unreasonable. Because of free will, man is divided.

The study perceives that inculcation of man's abilities to ask the metaphysical questions as significant of an objective within evolution for him to reach out beyond materiality, to pose the question if not obtain the answers rationally. This latter leaves the implanted awareness of the unknown in him and his arcane faculties, the foundations of man's religious development, as the source of his metaphysical understandings so far, including revelation. If this is indeed man's passage of knowledge to the unknown, then evolution requires that, having established the metaphysical reasonableness thereof, man must believe in the metaphysical answers by the routes available to him, in essence in a supreme being and an immortal afterlife. Belief becomes fulcral to evolution's own terminal objective of gaining immortality through man.

One would have thought that belief was the vital step, and all should be plain sailing after that. In fact, man's overall understanding is that he is also required to successfully manage his passions in a moral life to qualify for the aspired afterlife,. These passions he inherited as part of his evolution; and it seems their control has become a second qualification, and the decisive one, for immortality. In effect, evolution has put man a "double spin" -metaphysics is not enough.

Two Stream Temporal Evolution

Our prognosis is that man is on course to achieving the continuation of the species in temporal time. Mankind will continue as a series of generations who live to a ripe old age (say 500 years each), in an increasingly technological environment here and in space.

Overall, it seems that if evolution is working toward another quantum leap, it would most likely be in t he direction of immortality, which means the afterlife.

It would appear that it is the design or intention of evolution that the alternate path (to an afterlife in association with the supreme being) is left open-ended, for individual discovery and choice

Given the above scenario, we could express evolution's strategies to achieve its current objectives as follows:

. (1) That individual man continues to self-evolve as a technological creature, living progressively longer from generation to the next, perpetuating Homo sapiens as such, on Earth and in space. If he finds no other path, each man dies satisfied with what he has done. The species ends when the last man dies. In this scenario, the species is carries on, but each man is an intermediate.

.(2) That if man collectively answers the metaphysical issues in the positive, particularly that there is an accountable afterlife, then more (if not all) individuals will orientate their values and lives accordingly, with significant changes in societal arrangements. The ideal is everyone transfers to immortality. Man begins an immortal stream, and so does the species. In the short-term, this is unlikely; perhaps it will become more so as man grows older (500 years) in age and "wiser", perhaps in space in a thousand years.

.(3) And there is the status quo: that the majority of the peoples of the Earth, through religion, believe in various answers to the metaphysical issues, predominantly the existence of a supreme being and an afterlife. As a great evolutionary achievement of its own, mankind has secularised societal development, allowing for individual freedom of belief. In this scenario man is both a terminal objective if he chooses to go for the afterlife, and an intermediate otherwise. The species survives on both planes, while it continues the quest in temporal time.

(4) When the last man dies, the species remains immortal.

In future man may achieve a sharper insight into things-beings beyond materiality. Everyone will then understand better what they do not believe in and what they do believe in, and in the case of the latter make their transition to the afterlife. Perhaps all paths will converge, and man will then represent the species wholly and solely in immortality

It is hard to tell what will happen to the atheist stream; in this scenario, the non-believers will go extinct. The only unresolved point then is that the “bad guys” on Earth may think that they will “get away” with their misdeeds if they simply do not believe in a supreme being. On the face of it they will vanish forever. Evolution may, however, have other plans for them. and for those believers who do not qualify for eternal bliss: re-incarnation would be one.

Where Are We

Let us not beat about the bush. If we have two positions or options, and free choice, then, we shall have two streams of human evolution: (1) life here and now only, in temporal time, mortal, and (2) life after death, in association with the supreme being, immortal. We might note that , until he actually dies, man has a choice which way to go. It almost seems evolution is hedging its bets. Perhaps we are still in an intermediate stage, and current man is still a developing prototype, to see how far he can go; when he gets his metaphysical answers, all will be revealed

We may take that those who adhere to a religion implicitly or explicitly think it reasonable to believe, and order their lives accordingly.

On the other hand, atheists are people who have concluded that such belief is unreasonable, and order their lives accordingly. So far no one can or has proved that a supreme being cannot exist, and so their faith is in their unbelief. An agnostic is like an ostrich with his head in the sand.

In the interim two stream scenario, all unbelievers, with their personalities and identities, will die and vanish forever. They will become the discards that did not make it. The believers shall enjoy immortal life after death for their good, but (on present rationalisations) may be punished eternally if their evil outweighs their good and they remain unrepentant.

In the two stream scenario, however, each generation will grow “wiser” with increased longevity, and they will progressively eradicate their troublesome passions. Their knowledge-base will also grow. Overall, their moral conduct is likely to improve, and they will register a higher proportion of believers and as immortals. Perhaps by then, religion will play more of a facilitative role, while people naturally incline towards immortality after death. They may play a part in guiding the believer which version of immortality to. go for.

It is my expectation that man’s evolution will continue intellectually and technological, as his societal development stabilises through increasing civilisation. I see his intellectual evolution specifically in these directions: (1) to re-configure science to break the time barrier,(2) to gain further control of both the non-biological and biological nano-worlds - the latter including his body, and (3) to answer the metaphysical issues more cogently and help resolve the loose-ends

Concluding Remarks

It seems contrary to “common sense” that, after establishing man with abstract thinking to master the universe, it does not matter (to evolution) whether man pushes himself further or destroys the Earth and himself. The very same abstract thinking tells us that man’s purpose is to take evolution forward, whether to the stars, beyond time-space, and even to discover the unknown, even beyond materiality.

There is a sense that life this our temporal existence is not a perfect paradise. It is too short and imperfect, too wrapped in obligations and restrictions, and riddled with morality, to be the end-all of everything.

There could be somewhere beyond a higher plane, a more perfect existence, non-corporeal, possibly in an afterlife where mortality would have no meaning. And, this could well be the quest of evolution from the start, or the idea would not have been implant in us.

My feeling is that we shall progressively acquire enhanced, perhaps additional, intellectual faculties. We shall then know and believe what we need. We should be there by the time we move into space. We should have a clearer picture of things by then.

Meanwhile, let us move on technologically. And manage our collective morality as best we can to stay in business and not go extinct.

I close the study with a high sense of optimism about further study of the arcane and the religious domain. On the one hand, on the religious side, I found in Teilhard de Chardin63, the distinguished scientist-priest, the kind of convergent visionary we need, who caused a stir among his fellow Jesuits by identifying his Omega Point as both the ultimate objective of human evolution and the apex of his religion. At the same, on the secular side, there are many advances on many fronts at different levels, and I can do no better than reproduce the following Google AI generated summary as an indication:

> "Main advances in metaphysics include new approaches to established questions such as the mind-body problem, causation, and personal identity, and a renewed focus on topics like physical cosmology, the nature of physical laws, and the metaphysics of modality (possibility and necessity). Other advances include shifting from purely unchanging concepts to understanding the reality of changing things , a process sometimes called the "new metaphysics".

As I see it, we have awesome information technology to deploy. And the already well-laid metaphysical platforms look like the best common ground for solid forward footholds. The key is quantum-level AI programming, with their potential of multi-layered assembly and interrogation on cross informational and cross-religious fronts.

My own feeling is that if evolution is working toward another quantum leap, it would most likely be in the direction of the non-corporeal, until we are embroiled in beyond materiality. My feeling is that we shall progressively acquire enhanced, perhaps additional, intellectual faculties. We shall then know and believe what we need. We should be there by the time we move into space. We should have a clearer picture of things by then..

We should remember that with a convergence of effort, we could get breakthroughs from both sides. Thus, a major religious leader recently issued an encyclical stressing the safeguarding of the environment as a moral responsibility. And there is this delightful 1953 story of Arthur C Clarke, entitled "The Nine Billion Names of God". The traditional Tibetan wisdom believed that once all the nine billion names of God had been discovered, the purpose of existence would be fulfilled, and the universe would end. Some monks decided to hire two programmers to programme the newly invented computer to do just that. One day, not long after, it was found that everything had disappeared.

We need new thinking, new vision, and like the eukaryotes of old, new synthesis and new courage. Somewhere in the Late Jurassic, there were dinosaurs (archosauria) . When one of them was told his descendants would one day fly, he said :"That would be a quantum leap". We are in the same position.

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END

[63] - https://en.wikipedia.org/wiki/Pierre_Teilhard_de_Chardin

About Gerald F Pillay

(Extracted from Academia, at https://geraldpillay.academia.edu/)

Biography

Gerald Francis Pillay was born in Melaka on 2 Dec 1934. The family migrated to Singapore in 1949. He graduated with the B.A. Honours Upper II in Geography (1957) from the University of Malaya (then in Singapore).

Mr. Pillay served 33 years in the Singapore public service. In 1957, he joined the Administrative Service, rising to Deputy Secretary. In 1974 he was transferred to the newly-created Industrial Training Board as Secretary. In 1989, he retired as Deputy Director (Dy CEO) from the board, which has since become the Institute of Technical Education (ITE).

In 1989, he formed GFP Consultancy. He practised as a policy consultant in Technical Education (TVET)), serving international agencies such as the World Bank, UNESCO and ILO, employers and employers' organisations. In 1992-3, Mr. Pillay served on Botswana's Presidential National Commission on Education, nominated by the Singapore Government. He retired from practice in 2006.

HIS RECENT RESEARCH INTERESTS have been in the major frontiers of science and technology, probing the origin of things. He hopes next to explore the material-spiritual duality of human nature.

He releases these technical self-briefs on Academia.com, so far on "Quantum Mechanics" (2021), "Virus -The Biological Predator" (2022), and the "Cosmos - An Historical Survey and Exploration of the Future" (2023).

He has also e-published "the Chitty Melaka Story" (second edition) (2013) and "Japanese Conquest of Malaya and Singapore, 1941-2" (2019).(check Google).

Full CV available at "About Me" ,at the WordPress publications site.at https://geraldpillay.wordpress.com

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