

EVOLUTION IN LIVING FORMS: DETERMINISM, CHANCE, PURPOSEFUL DESIGN

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ABSTRACT:

The fact of evolutionary change taking place across the full range of plant and animal life is imposed on us by the fossil record from the most primitive single-cell organisms of 3.5 eons ago to the amazing variety of present-day life on Earth. There is no evidence either in Science or in Theology to lead us to think otherwise. We could even argue that a direct creation of each species with the subsequent elimination of ancient forms, to be replaced *in toto* by new unrelated ones, would be almost tantamount to a deceptive stratagem on the part of an intelligent and truthful Creator.

Once evolution is admitted, it becomes necessary to give a sufficient reason and a believable mechanism to explain how it actually took place. While the way life evolves is mostly a problem for Biology to solve, with basic knowledge of genetic variability and transmission providing the general framework, the detailed process for change that leads to improved fitness for the environment and survival or extinction is still debatable and far from satisfactory.

The basic sufficient reason for the development of specialized organs within each species, and for the specific evolutionary jumps, can be sought either in the laws of material interactions: necessity of an outcome given the initial conditions and the chance coincidence of unrelated events at the quantum or macroscopic level, or in the development of a purposeful plan by an Intelligent Creator who uses the forces given to matter at the beginning of the Universe, foreseeing the development of structures for all the future history of nature at all levels.

Both approaches to find a reason are based upon philosophical considerations that cannot be proved or disproved by any scientific methodology that seeks experimental checks. The discussion of their respective merits should be reserved for a forum where

the Philosophy of Science, not Physics or Biology, can use the appropriate methodology to detect finality or its absence. To expect an answer from an equation or a numerical measurement is to establish a false opposition between Science and the Humanities (including Philosophy and Theology)

EVOLUTION IN LIVING FORMS: DETERMINISM, CHANCE, PURPOSEFUL DESIGN

I – The overall environment: EVOLUTION, AS DESCRIBED BY MODERN SCIENCE

We live in an evolving Universe, not in a static one. Not only is our own experience a constant succession of changing events and internal states, but even the large scale structure of the Universe, during so many years considered as infinite, eternal and static, is now recognized as evolving from a state of high density and temperature –the Big Bang- until the present. We cannot explain what we now observe except in terms of eons of physical changes in galaxies, stars and planets. And the same is applied as well in the realm of living structures found in the planet Earth.

The basic property of matter, as known to science (and also to our pre-scientific experience) is its changeability. Physics can be defined as the study of the interactions of matter at all levels, as they are qualitatively and quantitatively specified by different “forces” whose activity can be concisely expressed in mathematical formulations. There is no “inert matter” in the full sense of the word, even if we continue to use the expression to refer to inanimate as opposed to living structures.

All physical activity takes place within a framework of space and time, and only in a succession of moments can we perceive change and thus the effects of one object upon another. While defining time in the strict philosophical sense is impossible, the Minkowsky diagram establishes for the physicist the possibility of causal interactions, that always follow “the arrow of time” from past to future, thus using that possibility as the reason to consider an event previous to another. There is no acceptable way to introduce causality towards the past in any strict description of physical phenomena. The present and the future are influenced by the past, but not the other way around.

Other “arrows of time” have been proposed as means to distinguish between past and future states. The Second Law of Thermodynamics with its statement regarding the increase in total entropy in every process (even if it might diminish in a part of the system considered), the decay of some atomic particles (the K meson), and the fact of human memory are also clear indications that there is a one-way street for the development of the world that we are able to study.

There is also an undeniable increase in the richness of structure from the Big Bang to the present. From the primitive basic particles, through atoms and molecules, we reach the stage where the first stars were formed. Atoms of higher and higher atomic number were synthesized in those stars, while the more massive chunks of the primordial cloud gave rise to globular clusters, small galaxies, and then -by gravitational attraction and mergers- large galaxies and their clusters and superclusters. This is the panorama we

observe at present across billions of light years of space, and after over 13 billion years of time.

All this activity is explained by science in terms of four “forces” or interactions with different strengths, ranges and objects affected by each. The operational definition of matter relies upon those forces, so that the term “matter” simply includes *all and only* the observable reality that can be affected at least by one of the forces. Thus we will use the word to cover particles (with or without mass), energy, the physical vacuum and even space and time (in so far as these basic constituents of our experience can be checked by measurements of length or motion-change.)

The regularity that we observe in nature and that by induction is attributed to matter itself and to its objective properties, is the basis for the enunciation of “laws of nature”, valid in specified circumstances without dependence upon cultural conditionings or personal preferences. In the case of inanimate matter no allowance is made for any kind of choice or spontaneity: we expect that in the same circumstances, given an initial state, we will be able again and again to predict the outcome of a process, with certainty only limited by the margin of error of the initial parameters inserted in our equations. No room is left for “chance” in a self-contained system: Hydrogen and Oxygen will combine in a definite way when isolated in a suitable enclosure and brought to a given temperature. In this sense, there is no possibility of disorder in nature, even in the most complex physical system. There are no magic forces to change the outcome, and things do not occur because of some arbitrary “chance” that would be equivalent to a childish “just because”.

We do correctly introduce the concept of *chance* to refer to the coincidence in time and place of events that are physically independent, each following a certain causal development, but without mutual influence until their common occurrence at some point in space-time. In this sense, most of our daily experiences can be described as due to chance: meeting an old friend in the subway, having the winning number in a lottery, being caught in a traffic jam due to an accident, having rain spoil a lawn party. In every case mentioned –and in an unlimited number of events in the workings of nature– chance simply expresses the absence of laws that would permit the prediction of the coincidence that we are considering. But we should stress the fact that we do not attribute activity to any “force” that we would identify as chance, and thus chance can never be the sufficient reason to explain anything: it is rather used to indicate that there is no reason.

When dealing with the real world, especially at the microphysical level, we are limited by experimental constraints and the laws of Quantum Mechanics when we want to exactly specify the initial conditions of a system. Consequently, the certain prediction of a definite outcome for a particular experiment becomes impossible. We can then speak of “chaos” (especially in the macroscopic world) or “indeterminacy” at the atomic level, and we are forced to use probability calculations that are only applicable to large numbers of measurements, but we cannot predict the outcome of a single one.

It is worth noting that Schrödinger’s equation is *deterministic* in the calculation of those probabilities, even if we can never predict the value that will be obtained the next time a measurement is performed. But the regularity described by the probabilities needs to have a reason, and it cannot be attributed also to chance.

The possible role of chance is to be carefully discussed especially when we deal with the evolution of living structures. Their amazing complexity (a single cell is considerably more difficult to understand and describe than a galaxy) and the myriad forms that have

developed on Earth through the eons, seem to be due to chance events at the molecular level, causing mutations in the genetic material of the reproductive cells. This process, coupled with the effects of mutations in making the living structure more or less apt to survive in a given environment, form the explanatory framework for evolution from the first cell to Man, according to a Darwinian outline described in the most general terms.

II - THE DENIAL OF THE COSMIC TIME SCALE: BIBLICAL CREATIONISM

There is a current of literal interpretation of the Bible -especially the book of Genesis and its description of the six days of Creation, the ages of the patriarchs, and the Flood- that presents a compressed tale of history incompatible with the long eons of the scientific evolutionary view. If the Genesis account is the basis for world chronology, the Universe can only be a few thousand years old, and each object -both in the inanimate astronomical world and in the multiple life forms- came into existence independently of all others, due to separate creative acts of the Omnipotent and only universal Cause.

This biblical view has to overcome the objections of many fields of science – Astronomy, Physics, Geology, Biology, Anthropology- that require long time periods, according to well-known laws, to explain the present state of the Universe, as shown by multiple experiments. It would require a rather long discussion to examine in detail each piece of data to show that the creationist position appears time and again to defy scientific certainties. This has been done by various authors and it can be checked in the bibliography found at the end of this essay. Here it might suffice to give some examples:

- Nuclear reactions are the only suitable source to explain energy production in the Sun and in stars in general. They determine the luminosity and age of each star, according to its mass and central temperature. Spectroscopic measurements of those parameters, and of element abundance as stars evolve, are quite consistent across the sky, and they show that many stars, including the Sun, have to be billions of years old.

- The same nuclear forces cause radioactive decay of elements present in Earth rocks from the time the planet was formed, incorporating heavy nuclei that can only be the product of stellar evolution during eons previous to the origin of the solar system. By the accurate measurement of isotope ratios and decay products, in Earth rocks, Moon rocks, and meteorites, we can date the formation of the Sun and planets to about 4.5 billion years ago.

- Plate tectonics, driven by the internal heat of the Earth's core, result in continental drift at speeds of a few centimeters per year. The studies of rock similarities on opposite sides of an ocean, and of magnetization patterns frozen in the solidified magma, permit us to reconstruct the map of the continents through hundreds of millions of years. To explain such changes in the biblical time scale, the continents would have to move at rates of kilometres per day.

- When dealing with life, fossils can be dated also by the age of the rocks where they are found, be it by radioactive decay, by the rate of deposition of sedimentary rocks in lakes and seas, or by the evidence of glacial periods. We consistently find that more recent strata contain higher life forms, beginning with only single-cells about 3.5 billion years ago. Macroscopic life starts about 600 million years ago and develops first in the sea, with animals without a skeleton, followed by external shells and then the internal backbone of the vertebrates: fishes, amphibians, reptiles, birds, and mammals.

- All life on Earth –including Man- shares the same basic constituents at the macromolecular level. Catastrophic events punctuated its evolution, especially in five great episodes of extinction due to either astronomical impacts or geological causes. To say that only one planet-wide flood explains the fossil record is really to ask too much from our rational way of seeing nature.

All of this points to the philosophical and theological weakness of Creationism, more important than its scientific incongruity. On the basis of assuming that the Bible (written when nobody could even imagine the simplest data of modern science) is not only a theological text, but also a scientific encyclopedia, we are presented with claims that almost imply a plan to induce us into error. This problem is not solved by asserting that our present determinations of radioactive decay and other physical processes do not apply to previous times: there is no reason why that would be the case. Matter is what it is, at the level of atomic particles and forces and in the macroscopic world, and it is only a prejudice to claim otherwise for times past, when the only reason to do so is the mistaken idea that the word of God –meant to guide us to Him- is also a treatise of Astronomy, Geology or Biology.

Our approach to God must be consistent with our rationality. This means that, even to know that the Bible is God's word, we need proofs which cannot be found by a private reading of a written text, interpreted in different forms by each reader. Only within a historical tradition that includes the promise of divine assistance for those entrusted with the task of teaching God's plan to the nations, can one find the true meaning of the written word. And this meaning will never be in contradiction with scientific truths in any field. God is the author of nature and of Revelation, two complementary sources of knowledge that should lead to a fuller comprehension of Creation and of our relationship to the Creator, each with its own methodology, independent but never in conflict.

III – EVOLUTIONARY STEPS PREPARING FOR LIFE - ASTRONOMY

In Cosmology and Astrophysics, we should distinguish facts that are no longer in doubt and detailed problems that might require further data and better theories to be satisfactorily explained. The initial state of high temperature and density at the “beginning” of the Universe (in the sense that science cannot speak of anything previous) is as well established as one can reasonably require. In simple words, we know that there was a fire in the past, because we have found the ashes and the persistent glow of that fire, both as predicted by detailed calculations already presented by G. Gamow in 1948.

More explicitly: Nuclear reactions during the first half-hour, when the temperature was in excess of 10 million K, should have produced He and Deuterium, the first with a mass contribution of close to 25% (the rest being Hydrogen.) Deuterium, or “heavy Hydrogen”, should exist in the minimal ratio of one atom for every 100,000 of ordinary H. Spectroscopic analysis of stellar light shows precisely those values, both for primitive and for recently formed stars, a clear indication that those elements are not mainly the result of stellar evolution (they should increase with each stellar generation if that were the case.) Even clouds of intergalactic gas, where no star formation appears to have taken place, show the same proportion of those products of previous nuclear reactions.

The glow of the Big Bang, filling all space, should have cooled to an apparent temperature of about 3 K after 13 billion years of cosmic expansion. Microwave and infrared radiation should appear as a consequence, with a spectral distribution proper of a

“black body” radiator at that temperature. It is well known that the *predicted* (by Gamow) radiation was detected in 1965 by Penzias and Wilson, who shared a Nobel Prize for their discovery. All efforts to attribute that background of radiation to the combined output of stars during eons of evolution have met with failure. This has forced even the most fervent proponent of a Steady State Universe (Fred Hoyle) to admit that the *observable* Universe harboured the intense fire of the Big Bang eons ago, even if he still insisted that in the largest and *unobservable* scale, the entire cosmos might be unchanging. This is, obviously, a rather unsatisfactory way out, since science can only be based upon data from observable phenomena.

Remaining problems concern the earliest times of the Big Bang, limited to the first second of the existence of matter in any form, and the steps from the first half-hour to the formation of and galaxies. Slight irregularities in the Cosmic Background radiation seem to indicate regions of higher density that could give rise to clusters of galaxies, while the overall homogeneity is described as a mystery if only the standard Big Bang is considered: distant regions in a fast expanding space volume would not have the chance to interact (with any physical action limited by the speed of light.) Current thinking favors an “inflationary” period when a supposed unified super-force would have split into the present 4 forces with a release of energy that would have caused the Universe to increase its size by as much as 10^{50} .

We do not need to go into a detailed discussion of this view, which still waits for a clear formulation of the unified theory and experimental proof of the inflation itself. What is to be stressed is that all the efforts to describe evolution are based upon properties of elementary particles and laws that are deterministic in their control of physical processes at all scales and times. There is no room for arbitrary happenings, even if the “seeds” of galaxies and clusters are to be found in “quantum fluctuations” of the most primitive matter (perhaps just space endowed with the highest density of pure energy.)

Only in unscientific proposals of multiple universes (neither observable nor required by theory) appearing spontaneously from the primeval space can one find a claim of “chance” being sufficient to explain why the observable Universe has the properties it shows in fact. The only justification offered for those supposed universes is the fallacy of equating the possibility of existence with its actual realization, using probability calculations to assert that anything that has some non-zero probability *must* happen somewhere. This is totally unwarranted in any philosophy or science, including Quantum Mechanics. Our mathematical formalism does not determine what happens: at best, it describes what actually happens or *might* happen without conflicting with the known laws of matter behaviour.

“Chance” in the large scale evolution of cosmic structures is only mentioned to state that the coincidence of particular galaxies to merge into a larger one, or the coalescence of clouds to produce large stars or clusters of smaller ones, cannot be predicted from our limited knowledge of previous conditions. But those processes are due to gravitational forces acting necessarily, then as now. There are no extra “degrees of freedom” to make the outcome other than that imposed by the parameters of matter.

This is still true when coming down from clusters of galaxies to the level of individual stars and planets. Even if we speak of chaos and unpredictable collisions taking place in the process of planetary development, both in our system and around other suns, we are always turning our attention to the way masses, orbits, temperatures

and compositions, will interact in fixed ways to produce the observed effects. There is no true objective “chance”, even if the coincidence of events we single out for study appears as unexpected and even surprising.

An example of such “chance” coincidences that have a bearing upon the development and evolution of life on Earth is found in the fact that our planet orbits a star with billions of years of practically constant luminosity (energy output.) And the orbit is placed squarely in the center of the “habitable zone”, where temperatures are suitable for the long term existence of liquid water in large oceans. At the same time, the mass of the Earth is such that it can retain a sufficient atmosphere to keep the water from evaporating into space, and to act as a protective screen against harmful UV radiation from the Sun. The large iron core gives the Earth a magnetic shield against cosmic rays, and its high heat content drives plate tectonics that produce mountains and renew the atmosphere and the crust where life can develop to the full. The Moon, most probably due to a totally unexpected early impact with a full-size planet, acts as a brake for the initial fast rotation of the planet and keeps the inclination of its axis practically constant through eons, thus guaranteeing a fairly steady distribution of heat over the surface with the regular cycle of the seasons.

No other planet in the solar system partakes in any significant way of all those properties, without which we would not exist today. It would be totally impossible to predict from physical laws that a planet would enjoy all those coincidences, but they happen by physical necessity from the detailed initial conditions of the pre-planetary nebula. We might try to calculate the probability of something equivalent occurring more or less frequently in the Milky Way or across the entire cosmos, but those calculations –which are mostly guesswork- do not change the fact that the Earth seems to be the privileged home of mankind by sheer “chance” if we reason only within the limits of scientific data and laws.

IV – ORIGIN AND EVOLUTION OF LIFE FORMS ON EARTH

At an early time after the Earth was formed and it cooled down sufficiently to have oceans, life appeared in the liquid environment, where UV from the Sun was screened by a layer of water and where sources of energy could be found, perhaps in volcanic vents of the ocean floor. We still do not know when or how the first living cell appeared, but we can confidently state that its structure was dependent upon the macromolecules of Carbon chemistry, and we know that natural processes (found in interstellar space and reproduced in the laboratory by Urey and Miller in Chicago, 50 years ago) can and do lead to the pre-biotic synthesis of carbon-based lipids, sugars and amino-acids, the building blocks from which living cells could, in principle, be assembled.

We can accept, therefore, that biology is an extension of physics and chemistry, at least in so far as it appears to be based upon the properties of specific atoms (especially Carbon, Hydrogen, Oxygen, Nitrogen) and the electromagnetic force that drives chemical reactions. It is evident, nevertheless, that there is a *qualitative* difference of the most important kind between a simple mixture of those elements and molecules and a functioning, living cell. A difference that can be compared to that existing between a box of assorted electronic components –even if assembled into quite complex circuits- and a computer with an operating system and a variety of programs. Only if the hardware is endowed with software of the proper kind will we have a computer, capable

of specific functions. Or, in a less technologically advanced field, there is a world of difference between thousands of printed letters of an alphabet, even if assembled into words of a dictionary, and a literary work where information and meaning can be conveyed.

This is the issue that science, at present, cannot satisfactorily deal with. The cell –the unit of life- has programming that regulates functions of seeking and processing sources of energy (food), the elimination of waste products, its eventual reproduction and even death. No source of such programs can be found in physics or chemistry considered by themselves: their activity might lead to beautiful structures like crystals, but they are dead ends. Whatever the definition of life might be, it implies a self-contained structure with proper activities that tend to keep its integrity and lead to its survival and propagation.

Early philosophers reasoned, with apparent logic, to the need for a “vital principle” of an unspecified nature to endow matter with those drives that we have compared to the program in a computer. But this solution immediately clashes with the obvious fact that examining living things at the most intimate level we can only find atoms, molecules, attractions and repulsions. Of course, if we examine under a microscope the pages of a book or the electronic chips in a computer we will only find atoms and molecules devoid of meaning. And in a TV set, where electrons and their motions are the only observable entities for the physicist, we cannot find through physics the information and emotional or artistic content of a show.

Still, if we were to observe the process by which the first cell formed, it is natural to suppose that we would only see “chance” collisions of atoms to form some large molecules, with further “chance” groupings assembling what we now call RNA or DNA, and other molecules enclosing a small volume in a semi-permeable membrane where some chemical activity would seem to take place simply by the physical necessity of affinity and energy exchange. At some point, interactions within the cell would lead to a splitting into two similar units, and the two cells would continue similar processes independently. We would never witness anything extraordinary in any way: life uses the normal behaviour of matter based upon its properties and laws. Such behaviour is necessary and determined by the components of the cell, while the presence of the components in the right place at the right time can be described as a chance happening.

We seem, therefore, to be in a position to attribute life to the same play of necessity and chance that produces a galaxy or a crystal. And this is right as far as it goes. But, does it go far enough? Would we be satisfied with the same kind of explanation for the programming of a computer or for the development of a TV show? To ask the question is enough to answer it negatively. Where is the difference, if we want to accept the answer for the cell and for living things in general? If there is a guiding principle by which life develops organs and activities that can only be described in terms of purpose (self preservation, nutrition, reproduction), where is the “programmer” found and how does it act?

It should be noted that the functions we are describing cannot be attributed to a physico-chemical need within the cell, or to its interaction with the environment *independently* of the “program” (we call it *instinct*) for survival of the individual and of the species. This is more and more evident when we observe the extremely complex and sophisticated ways by which higher life forms actually survive and propagate, with patterns of building traps and nests, methods of food acquisition, storage and sharing,

care for the immature progeny, migration routes, and so on. All those activities require an extremely complex program that must be genetically transmitted and that can include a mimicking ability to learn from others by simple imitation. We are certainly very far from obvious predetermined chemical reactions or chance coincidences.

Going back to the primitive life of single cells (without a nucleus and unable to use oxygen directly) we have a sufficient record of its permanence with multiple variations through approximately 3 billion years. During this extended period, comprising most of the time life has existed on Earth, three important developments can be mentioned. The first is the evolution of some cells to have a nucleus, where most of the genetic material is tightly packaged and then doubled and split to produce a new cell by simple division. The second is the mutation that gave some cells the ability to use sunlight, acting upon chlorophyll, to combine water and carbon dioxide into carbohydrates, thus becoming able to produce their own food, while exhaling Oxygen into the environment. The third, another mutation that enabled cells surrounded by an Oxygen-rich atmosphere to overcome their previous incompatibility with Oxygen to start using it as a most efficient source of energy, thus opening the way for multi-celled organisms, first in the oceans and then in practically every environment on the Earth's surface.

It seems that none of those steps would be predictable from the mere consideration of physical and chemical forces. In that sense, they can be attributed to "chance", and one might say that if life were to start a thousand times on the planet Earth or in a similar one, their happening again even singly, would be most unlikely. Their combined appearance, along a constant track of ever higher complexity, certainly impresses us with the feeling that it was preordained. But feelings are not proofs, and one can remain at the level of factual data, where nothing but material necessity and chance coincidences can be actually checked.

The mechanism for developing new life forms, as presented by evolutionary schemes of current science, is composed of two elements which again combine chance and necessity: genetic variations and the struggle for survival. The plans for the organs of each life form, the instructions for their development, and the patterns of instinctive behaviour, are found in the genetic code. This is written with the 4 "letters" of the DNA double helix, and it produces its effects in a necessary and predictable way, even if we are still far from deciphering all the information encoded in the DNA of even simple organisms. Chemical agents, temperature variations, cosmic ray impacts, radioactive decay in the environment, can cause breaks and changes in the DNA molecule, always happening in unpredictable ways and thus attributed simply to "chance". The simple replication of DNA is frequently subject to slight errors. The result of all those factors, individually and in their totality in each member of a given species, must produce changes of programming that affect the suitability of some organs for their proper functions, and –consequently- make the living entity more or less apt to survive in a given environment. In the case of sexual reproduction, characters inherited from both parents might be so incompatible that life is imperilled or impossible. Or they might make the new life more suitable for its survival.

This is what happens as the result of human efforts to produce cattle or other domestic animals with the traits that are deemed most desirable, either economically or even aesthetically. Darwin remarked, quite logically, that artificially induced evolution by the selection of traits in those cases is a daily proof of the possibility of changing genetic programming, thus opening the way to admit similar effects taking place by

natural causes. Directed evolution might be able to achieve noticeable bodily changes in a few generations, but in nature it should require longer times due to the random nature of the process. We could compare the two cases to the radiation of energy from the center of the Sun into space: a straight path from the hot core to the surface would require only a bit over 2 seconds for light to escape, but the “random walk” nature of the zig-zag emission and absorption changes that estimate to close to one million years.

While the general framework just described is quite logical and undeniable as far as establishing a mechanism for change and requiring long periods of time -well evidenced in the fossil record- its detailed application to specific organs and to changes from one species to another is quite a bit more questionable and even perplexing. The *single* genetic modifications produced independently by any of the proposed natural agents cannot cause a significant change in organic structure or instinctive behaviour: thus evolution is assumed to proceed by minute steps, each one barely noticeable and hard to establish as a significant factor for survival.

Acquired physical or behavioural improvements –for instance, physical strength due to exercise- cannot be encoded into the DNA of the individual so endowed. We seem to encounter the need to accept many unimportant genetic mutations that finally reach a critical level where their combined effect truly makes a difference with regard to survival and to species evolution. This is the view proposed under the title of “punctuated equilibrium”, where long time periods of apparent stability are followed by sudden significant change when the total effect of many mutations reaches the critical level. And there might be many genetic changes that are neither helpful nor harmful when acquired, but can become important in a new environment: we know that in any large population of microbes exposed to an antibiotic agent, there are always some individuals that show a resistance to its effects without previous reason to have developed that immunity.

But his view is not free of difficulties when applied to the real world. It seems extremely unlikely that many unrelated genetic mutations will coincide in the same individual to suddenly release their combined potency for a truly significant improvement of the biological system of the species. Add to this the need for many individuals (thousands) to simultaneously possess the improved organ or instinct in order to have a real probability of perpetuating it in their descendants, and the difficulty appears truly unsolvable.

The fossil record shows that in a relatively short period of time (perhaps no more than 5 million years) the body plans of all phyla in the animal world seem to spring suddenly and simultaneously in full detail (the “Cambrian Explosion”, about 600 million years ago, proved by the Ediacara and Burgess Shale fossils.) In the words of Michael J. Denton: “The tree of life underwent a great and never-to-be-repeated burst of creative growth, sprouting all its main branches that were subsequently to grow more sedately down through the geological eras to the present day” (*Nature’s Destiny*, 1998, p.268.) Why this sudden “burst of creative growth”? We really have no answer except to say that at that point the Oxygen content of the atmosphere, closely resembling the present abundance, made multi-cellular life possible after 3 billion years of single-cell protozoa. Even so, this possibility does not explain the simultaneous genetic changes that would produce so many basic and different body plans.

We also know that in five different occasions most life forms disappeared in sudden extinctions due to either astronomical or geological factors. Perhaps as many as 90% of

all the species that ever existed have disappeared. The detailed reasons why this happened are not known, and both failure to evolve and a too rapid evolution have been invoked as the cause for specific instances. Whatever the answer, we cannot ignore the fact that many life forms have persisted practically unchanged for hundreds of millions of years, while the same agents of genetic change were responsible for significant mutations in other species, even in the same environment. The history of life gives us proofs of evolution, but it does not clearly indicate a common and satisfactory way to achieve it.

Even Darwin recognized his frustration when confronted with the marvellous structure of the eye, where optical laws produce an image that is then relayed by nerve impulses to the brain to be assembled and interpreted in the visual cortex. To explain such marvellous achievement as the result of innumerable small changes, that should simultaneously improve all the steps of vision to render it more conducive to survival, seems to strain logical credibility if we only invoke necessity and chance as the ultimate reason. And wholesale body restructuring, the kind that took place when a donkey-sized mammal ventured into deeper and deeper water to become a whale, seems totally unbelievable as the result of chance mutations. During that time, in the same aquatic environment, the coelacanth remained practically unchanged until our age.

Once more we must stress that the *fact* of evolution should not be questioned in the biological world, any more than it can be doubted in the astronomical realm. But while in Astronomy we can feel satisfied with the interplay of the four forces of matter to produce stars and planets, in the case of living things *there seems to be an internal drive to diversify* and expand life forms to their full possibilities consistent with the laws of nature. The range in size, mass, sources of energy, ways of locomotion, reproductive and nutrition techniques, adaptations to temperature, radiation, pressure, chemical changes, actually found in life, exceeds the most daring flights of human imagination. It has been said (by Victor Weisskopf) that a theoretical physicist, knowing modern Atomic and Quantum theory, should have been able to predict the existence of atoms, macromolecules and crystals, but nobody would guess that liquids were possible, still less life. With better reasons we could venture that nobody, knowing how a cell lives, could have thought that something as different as an ant and an elephant would ever be found in nature.

The final step in biological evolution requires the discussion of Man's origin and the specialized activity that we call "rational knowledge", with its consequences of abstract thought, self-consciousness and free will. While part of the panoply of life on Earth and clearly related to other life forms in body structure, metabolism and interaction with the environment, the human animal appears as set apart by new functions that are different not only in degree, but qualitatively, from those found in the rest of the animal kingdom. Why is it so?.

V - MAN'S NATURE AND ORIGIN

In the words of Descartes, "*I think!. Therefore, I am!*". We might practice the most extreme form of scepticism in Philosophy or in any other field, but even when universal doubt is consciously embraced, we *cannot deny that we are doubting*, and thus thinking. This deep certainty is stronger than any argument or external evidence, and it forces us to

consider ourselves as subjects of a new activity *of a different kind* from anything else that we might do as living entities similar to other life forms.

We perceive ourselves as subjects, as *persons*, intelligent and free. We are aware of our thirst for knowledge, even of the most abstract and “useless” kind. We seek understanding and order, we appreciate beauty regardless of any value it might have for survival or any other benefit. We can love abstract entities –culture, liberty, social and political structures- and we can even go directly against our survival instincts and give our life for religious or ethical convictions.

Again, in Weisskopf’s words, “There cannot be a scientific definition of ethical right and wrong, of good and evil, of dignity and humiliation, or of concepts like the quality of life or happiness, While it is certainly possible to analyze the nervous and psychological reactions that occur during the process of experiencing such ideas, there remains an important part of the experience that is not touched by this analysis” (The Frontiers and Limits of Science, *American Scientist*, July-August 1977, p.410.)

The most obvious activity by which the human species develops through time is the transmission of *culture*, of acquired knowledge and values, something that cannot be encoded in the DNA given to succeeding generations. We might remember the imposition in the Soviet regime of the Lamarckian view of hereditary transmission of acquired characters, pushed to the absurd limit of postulating that new generations would be born with the instinctive acceptance of communism and its denials of human dignity and freedom. No biologist would accept for a moment that political viewpoints would be transmitted by DNA mutations. And the same can be said of anything that is scientific or humanistic knowledge. Even technical developments that truly help our survival must be shared by a lengthy learning process, without any automatic biological channel. No animal aside from Man has any “culture” to share with succeeding generations to bring about a higher level of development, even in the quest for food, protection against the weather, increased mobility, or health care.

When in the study of nature we seek sufficient reasons for an observed pattern of activity, we come to accept properties of matter that might not be obvious to our daily sense experience, but that seem required by a logical inference from the known facts. We talk about “mass” as something that determines how something reacts to our efforts to move it, and we come eventually to find that the concept can be also used in connection with the behaviour of falling bodies and astronomical motions, thus expressing a general interaction under the name of “gravitation”. When other phenomena of attraction or repulsion seem independent of mass, we accept something else, “electric charge”, as the reason for the new behaviour with its own laws under the heading of “electromagnetism”. Once more, when those “forces” seem inadequate to describe what happens in the atom and in the realm of elementary particles, we are forced logically to admit two more interactions, the strong and weak nuclear. Nothing in the study of matter forces us, at present, to admit new forces, even in the chemistry and activity of non-human life. We can then say that, from the methodological viewpoint of science, where operational definitions are used, the four forces define our concept of matter in its full range, as previously indicated.

The logical extension of this methodology would require attributing all of human behaviour to those forces *if Man is to be explained in material terms*, differing only in *degree* from other life forms. Many efforts have been made to reach that explanation, and many books have been published claiming that this has been successfully done.

Comparisons of the human mind with so-called “artificial Intelligence” or with the learning abilities of trained animals are presented as proofs of the simple difference in degree, that is attributed to our larger brain capacity and the extremely complex structure of the cerebral cortex with its billions of neurons and trillions of interconnections. But those comparisons are extremely deceptive and faulty.

As previously indicated, the “hardware” of the brain can be considered similar to the electronic chips of a computer, and clearly there is a technical progress that makes it reasonable to say that in the capacity to store information, the computer exceeds or will surpass any human mind. But there are two basic differences:

First, the computer does not “know” that it has stored beautiful poetry or deep mathematical developments, junk mail or pornography. And it doesn’t care! It has *no consciousness of itself thinking*, nor any desire to know or satisfaction in doing it, nor initiative to produce any literary work or even a simple computation.

Second, the computer does not produce its own programs, from the operating system to the way to recognize the most obvious use of words. It is totally inert unless a human operator introduces coded instructions that the computer cannot *understand*, but that through selected electrical impulses oblige currents to follow predetermined paths until a result is obtained that still remains meaningless for the machine, but that can have a meaning for the human user. The most primitive calculating machines, with gears and levers, achieved something equivalent –even to the point of solving equations or deciphering military codes- without any “magical” brain power attributed to the fast activity of electrical systems.

No matter how many elements are interconnected by electrical or chemical stimuli, the net result is still *only another electrical or chemical state*. The step to consciousness and free will remains totally absent from the scientific description, because science does not include consciousness or freedom in its roster of material parameters. And it is totally gratuitous to assert –without the slightest experimental support- that if we put together a sufficient number of particles with electrical charges in a very complex arrangement, intelligence and freedom will “emerge” spontaneously.

Materialistic reductionism is an *a priory* philosophical position that requires closing our eyes to the most obvious experience of human life. A position that is -in practice- in clear contradiction with the behaviour of those who claim to accept it: they want recognition for their intellectual achievements, they require respect and honesty from others, they claim to be responsible for their acts, they do not want to be considered in the same level as non-human animals, no matter how evolved and appreciated they might be. Neither culture nor human society can be explained in terms of blind forces between atoms, no matter how complex the system where they are found.

We are forced, by the clear inability of Physics and Chemistry to rise above the deterministic description of material interactions, to postulate in Man something else, just as science has done when faced with the need for new sufficient reasons in the case of the four interactions. But if those four forces *define* matter and leave no other opening, the new element to explain consciousness and culture and freedom must be *non-material*. Any name we might want to use to refer to it will be a matter of conventional use, but its different nature will necessarily imply a discontinuity in the evolutionary process, so that a qualitative change has to be accepted between the previous developments of biological evolution and the emergence of Man. Matter, according to its laws, can only produce other forms of matter, restricted to act according to the four forces that define it.

VI – THE DRIVING FORCE IN THE EVOLUTION OF LIFE

Scientists and philosophers, in more or less explicit statements, try to explain the facts of evolution in terms of one of three “sufficient reasons”, that appear to be mutually exclusive: necessity, chance or intelligent design. But the proposed mechanisms are not limited to a unique viewpoint, thus leading to inadequate formulations of choice. It will be necessary to develop each one by itself and then to see if they are truly incompatible when properly understood.

- The first proposal sees in nature only the interplay of necessary, deterministic, laws of physics, leading to the astronomical structures in the cosmos, to chemistry and biology on Earth and also in any other suitable environment (which is commonly supposed to be found in many other places across the immensity of the Universe.) Just as there is no alternative to the formation of the elements in the stars when the proper raw materials and temperatures are present, one has to assert that chemical combinations are predetermined by the properties of each element and the energy available in each particular place. Since biology is due to chemistry and physics, so that macromolecules should also necessarily come into being in a suitable “primordial soup”, the appearance of life is seen as the certain and inevitable consequence of blind forces as soon as the Earth had cooled sufficiently to have abundant liquid water and the basic carbon compounds. The same would be true in uncountable Earth-like planets in the cosmos, with many of them being ready for the crucial step earlier than the Earth and others coming to have the necessary conditions now or in the future.

Once the first living structure appears, the same necessary forces would leave no choice for evolution. Thus it is expected that life forms –anywhere and at any time– would follow a similar path to the track found here on Earth. This is the common way that alien life is presented in most science fiction novels or movies: extraterrestrials might be green or have larger eyes or antennae, but they are different from humans only in details that allow us to recognize their foreign origin, but do not imply drastic changes in body plans or biological functions. It is said that there is a cosmic imperative for life to develop: it is written in the very nature of matter from the beginning.

The deeper question, about the reason why matter exists and why it exists with the concrete properties it has, is not addressed in most cases. This limits the logical usefulness of the solution since, in principle, matter could be conceived as having innumerable sets of properties different from the ones we observe. Multiple Universes are sometimes offered as the way out of the problem, with almost all of them being sterile, while the one we observe, by definition, has observers because life can exist in it. Attributing the multiplicity to the indeterminacy of Quantum Mechanics –which implies the lack of determination - seems almost contradictory. And the existence of each Universe remains unexplained: “Why is there something instead of nothing?” “Just because”...

The philosophical viewpoint underlying the exclusively deterministic solution is the denial of the possible existence of anything non-material. But the fact that matter evolves –the crucial tenet in the whole discussion- forces us to seek a reason why matter is the way it is, when in each case it could have been different. This is the argument that logically obliges to accept a non-material agent, unchanging and free from space and time constraints, with the infinite power to make matter exist without a previous raw

material. And if the Creator is non-material, it would be totally arbitrary to deny the *possible* existence of finite realities that are non-material as well.

Only if we could *prove* that nothing but matter can exist, would it be logical to require that whatever happens should be explained only in terms of matter and its interactions. We typically find that the very concept of matter is left undefined, and only some general statements are made to try to explain intelligence, and free will and culture, as due to the necessary outcome of extremely complex structures in the human brain. Without endowing even elementary particles with a minimum of intelligence and freedom, there is no reasonable expectation to find those properties fully developed in Man. But the requirement is totally gratuitous and no scientific status is granted to that supposition in any theory supported by experimental data.

- The second answer introduces the concept of “chance” as a way to expect variety and development not constrained by the deterministic forces of matter. Once more, Quantum Mechanics is invoked to justify fluctuations of the primeval energetic state of the Big Bang, reaching the point of playing with words to make a “nothingness” out of the first physical vacuum endowed with almost infinite energy and subjected to the laws of Quantum theory, thus asserting that the Universe appears from “nothing” because “nothing” is unstable. This is “the ultimate free lunch” of Alan Guth and the Inflationary theory.

Chance is particularly sought as the main reason for the unpredictability of biological evolution, so that innumerable changes might then be selected by the interaction with a given environment in terms of suitability for survival. Since chance defies prediction and regularity, it is assumed that the course of life on Earth would never be duplicated if it were to start anew under identical conditions in our planet, and similarly, no other planet, -no matter how Earth-like it might be- could be expected to follow a similar path even if life did start on it.. In fact, the case of life developing at all might be so rare that even in the immensity of cosmic structures, we might be the only instance, since probability calculations seem to imply the extreme rarity of all the necessary factors happening by chance anywhere else.

Since microscopic, single-cell life is incredibly flexible in adapting itself to extreme conditions (as evidenced by “extremophile” bacteria thriving in hot undersea vents and even in nuclear reactors) it might be accepted that life limited to that level could be quite common in the Universe, but macroscopic life –even at the level of a mouse- would be almost impossible to find anywhere but on Earth. This is the viewpoint presented in the book *Rare Earth*, whose authors (Peter Ward and Donald Brownlee) made news by their indirect detection of several extra-solar planets with physical parameters incompatible with life. This, at present, remains as a theoretical proposal: laboratory experiments do show that earth microbes can survive a Mars-like environment, but we have no data about the existence of microbes on that planet in the distant past when liquid water was available (the bacteria-like structures seen in the Martian meteorite found in Antarctica are so small that a simple cell wall would leave zero volume for the internal constituents of the cell).

Whatever the extent of life might be, the core question remains: is “Chance” a sufficient reason for structure and biological programming? Strictly speaking, there is no physical content to that word, and no experiment can detect or measure a property that might be identified as “chance” in any elementary particle or in any form of matter. As previously explained, the only acceptable reference to chance implies the unpredictable

coincidence of unrelated events or objects, where independent causal chains are considered as affecting an outcome due to the fact that they happen at the same point in space and time. The result of that coincidence is still due to the known forces of nature acting in a necessary way. The simple coincidence of events is never the reason for order or structure, even at the level of a simple crystal: the atoms that form a specific geometric arrangement *might be there by chance*, but it is their mutual attraction and the energy levels of their electrons that produce molecules and determine the suitable 3-dimensional positioning of the atoms.

The well-known physicist Paul Davies pointed out in an article (Life Force, *New Scientist* 163, Sept. 18, 1999) that the main problem with explaining life lies, not in the chemical structure (the hardware), but in the information processing system, the software of the living cell. Biological information *is not encoded in the laws of chemistry and physics, and it cannot arise spontaneously from nothing*. If this is true, no matter how we might try to combine necessity and chance, for a simple cell, it is more evident still when we deal with the specifically human aspects of life, not only because of the incredible complexity of the brain, but because it gives rise to thought that cannot be expressed in terms of physical parameters, that is not reducible to matter arrangements.

Introducing natural selection to streamline and optimize the results of chance mutations does not solve the original problem. One might write a self-correcting program for a computer to try possible alternatives and choose the one that most efficiently leads to a predetermined end, but this is only if the program is written by some intelligence, that also specifies the end to be achieved. This is the way a computer “plays” chess, and thanks to its rapid calculation of possible outcomes, it can win against a slower human opponent by concentrating upon moves and positions specified as “advantageous” by the programmer. This is a parody of intelligence, since the machine only performs blindly the prescribed algorithms, without knowledge of any meaning of their effects. In biology, we can expect natural selection to weed out those individuals that are defective in some way and to lead to the survival of the best endowed ones, but still the program to develop organs and ways of acting has to aim for specific ends, and it has to be explained before natural selection can play a role.

- The third way to propose a sufficient reason for the drive towards complexity, and variety in life forms, seeks an explanation by applying to the problem the way of thinking that we find necessary in our daily experience, and that includes the idea of purpose and design. Just as a piece of human technology cannot be understood except by reference to a given end, consciously sought, and that determines the adequate means to obtain it, so in the living organism we consider that an organ cannot be understood except by specifying a function, for which the organ is uniquely suited. We speak of the eye as meant to produce an image that guides the activities of animals living under sunlight; the heart is only suited to pump blood in large animals, the reproductive organs are clearly meant for the propagation of the species, and so on. Many such organs are impossible to understand as chance results of innumerable small changes: they exhibit “irreducible complexity”, in the words of Michael J. Behe, (see *Darwin’s Black Box*, The Free Press, N.Y. 1996) because unless they are fully developed, they can have no useful function to lead to their conservation as an aid for survival.

This view could be dismissed as mere anthropomorphizing: since in human activities we seek an end, thanks to our intelligence and free will, we tend to impose on other living things a kind of planning that at the same time we have to deny when we state that

only Man is endowed with reason and liberty. This objection would be valid and final if we were to look for design and purpose produced by the animals, and it could be still underlined by pointing out that no matter what the planning might be, without adequate technology (which we are just beginning to develop) no genetic changes can be introduced in the reproductive stage to make one generation more perfect than the previous one.

The proponents of Intelligent Design are not blind to the objections just stated, but their view of biological planning does not impose the burden of design upon the members of any living species. Rather, after seeking a sufficient reason for the existence of the Universe and its evolution at the physical level, and finding that only a non-material Creator, Intelligent and all-Powerful, can bridge the infinite gap between nothingness and cosmic reality, the Creator is also seen as the ultimate cause of order at all levels. A non-material Being capable of creating the Universe has to be unchanging and free of space-time constraints, so that in an everlasting “now” the entire history of creation, in full detail, is always present to the divine mind. Only thus it can be understood that, in the first moment of the Universe, matter is endowed with properties and laws that are foreseen as leading to the outcomes sought by the Creator.

Matter acts according to its laws applied to the initial conditions. For the Creator, there will never be a coincidence or development due to chance, and thus unforeseen. An infinite time-less intelligence cannot be surprised by anything that happens even to the most minute particle: the entire evolution of matter is clearly present to that all-knowing Mind, and events that occur any time and anywhere, either by the necessary interactions of inanimate structures or by the activities of living entities, intelligent or not, are known in all their implications and consequences. To say otherwise, setting limits to that knowledge, implies a contradictory view of the true Infinite that we have described, that necessarily has to be unchanging and thus cannot acquire new information nor be limited by the behaviour of mere creatures.

We can, then, logically expect that the Creator will have an all-encompassing design, a plan to bring about, as a necessary outcome of initial conditions, the full development of nature, including life and its evolution up to Man. This is not to imply that the Creator has to intervene anew upon created things to add something to the original plan. Matter itself is endowed with potentialities to be realized when the moment arrives when its activities will produce the intended effect, and the effect is certainly due to those potentialities as long as it does not exceed the level of matter, even living structures.

It might be sobering to remember that Scholastic philosophers, in Medieval Europe, accepted without a qualm the idea of “spontaneous generation”, later rejected as a scientific hypothesis. In their view, the Creator did give matter the ability to form living things when the suitable environmental conditions were present; their only error was to think that an ordinary corner in a present-day home or piece of land would be adequate. But their acceptance of the possibility of a natural step from non-living to living structures would make it also conceivable that under the correct laboratory controls a living cell might form out of a mixture of the non-living necessary elements. The only limit always seen as impassable for mere matter was the step to Man, endowed with a spiritual soul, the only new element that could explain intelligence and free will.

Intelligent Design is not meant to deny the potentialities of the material world, nor as a refuge in the so-called “God of the gaps”. Just the opposite: it underlines the marvellous beauty and power of the creative act, which is not a blind evolution of an

impersonal “nature” or a way for the Creator to reach a new level of perfection. Created beings –at all levels- partake of the dignity of truly acting according to their nature to bring to completion the whole plan set in motion at the first moment of the Big Bang. And the plan includes Man as the apex of Creation, capable of knowing the Creator even by studying the works of nature, and of giving thanks for the great gift of existence. Still more, Man is the steward that should maintain the order of nature in his surroundings for the benefit of all, now and through succeeding generations.

The Anthropic Principle stresses the tight connection between our existence and all the parameters of matter, as well as the properties of the planet Earth, the jewel of the Solar System. Time and again the description of our home mentions the unpredictability and possible uniqueness of all the events that make it the ideal place for life: if -with our full knowledge of the requirements- we were to plan for it, we would not be able to do better.

The existence of Man, with the acceptance of a non-material element in an amazing unity with biological structures similar to those of other life forms, gives also a suitable answer when asking if the Universe, destined to decay into emptiness, darkness and cold, is finally absurd. This is the depressing view of mere scientific extrapolations regarding material evolution: In the words of Steven Weinberg, *“It is very hard to realize that this all –the habitable Earth- is just a tiny part of an overwhelmingly hostile universe. It is even harder to realize that the present universe has evolved from an unspeakably unfamiliar early condition, and faces a future extinction of endless cold or intolerable heat. The more the universe seems comprehensible, the more it also seems pointless”* (The First Three Minutes, Basic Books, 1977, last page.)

Accepting a Design that includes human existence and a non-material element in human life, the way appears open to a less negative outcome. Whatever is not matter, is not constrained by the evolution of matter to cease to exist. Science can say nothing about this assertion, but as we have repeatedly seen, science can only give a partial view of the human reality, ignoring precisely the higher levels of activity that include the development of science itself.

VII - THE ROLE OF CHANCE AND DESIGN AS SCIENTIFIC ALTERNATIVES

If we accept what the actual work of scientists implies, namely, that science can deal only with the interactions of matter that can be checked by experiments and expressed in quantitative data, then we have to deny scientific status to both hypothesis, the existence of Chance only and the hypothesis of Design as the explanation for the evolution of living structures. No experiment can prove or disprove that Design is present, even in the case of the most obvious products of human technology. It is only in the realm of Meta-physics where finality, purpose, design, or their absence can be inferred, not by any measurement, but by considering the suitability of a structure for a particular function, without which it would be impossible to justify or understand its existence and its properties.

It seems logical, therefore, to leave outside the biology classroom what biology cannot treat according to its proper methodology. There is much work to be done to reach a complete understanding of genetic encoding and variability, to find the data about the evolution of species on Earth, perhaps even to reach further in the effort to duplicate the environment where life sprang and –possibly- to observe its happening again in the

laboratory. We have almost complete ignorance of the interaction of mind and brain. In all those fields science is expected to progress and bring about techniques that will benefit our life in many respects. We should do everything we can to improve our life and to give every person on Earth the true opportunity to fully develop all the potentialities that our nature implies, so that all of us enjoy our unique dignity and share the bounty of existence to the full.

In the field of the Philosophy of Science, it will be proper to discuss the meaning and explanatory power of the views that appear as contradictory in many popular accounts. Chance is the only thing that science can propose as an alternative to rigid *determinism*, which is hard to give as an answer when asking about genetic mutations due to impacts of cosmic rays from far reaches of the cosmos. Chance is the simple denial of that determinism, if we seek it in the immediate environment and physical laws. But it does not go farther than that level.

Intelligent Design accepts that *experimentally* only chance events seem to be at work when mutations occur. But by raising sights to the Creator, it points out that what for the scientist is only chance, is quite the opposite for the Infinite Mind that sees how created nature fulfils the original plan. At this level chance has no role, and the purpose of the Creator is achieved through the activities due to the parameters of matter as created in some specific initial conditions.

Time and again it is said that the Big Bang has to be explained without introducing “arbitrary” initial conditions in order to obtain the present state of the universe through its evolution according to physical laws. This is asking for the impossible: *any* initial conditions can and should be described as arbitrary when there is no previous state from which to derive them. To begin with a given amount of mass or another, with some strength of each interaction rather than a different value, with quantum properties in a vacuum or in a soup of quarks, all that might seem something to be chosen on the basis of “elegance” or mathematical simplicity, but it does not impose on the Creator how the universe should be if there is true *nothingness* from which it will develop. This means that the creative act is totally free and it incorporates all and only those parameters that will eventually lead to the entire cosmic panorama intended by the Creator. We will see “chance events”, that can also appear as “arbitrary” to our limited understanding, but chance is meaningless for the intellect that knows the totality of existence. In the famous words of Einstein, “God does not play dice”.

There is no true opposition between Science and Theology, as long as it is recognized that each human effort to know the totality of our world is limited by its methodology and the restricted experience we have of our environment. This requires that many independent views be considered as partial answers to the total question of where we are, how did we come to be, where is the universe headed and what the future means for us. Complementing each other, Science in all its richness, Philosophy and Theology, contribute to the understanding of the masterpiece of nature, the Thinking Animal.

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