HISTORIA Y FILOSOFÍA
DE LAS TEORÍAS EVOLUCIONISTAS
HISTORY AND PHILOSOPHY
OF EVOLUTIONIST THEORIES

ON PROGRESSIVE ANIMAL EVOLUTION AND THE PLACE OF HUMANS IN NATURE

FRANCIS DOV POR

> The influence of man, as the most successful species in the competitive struggle, seems to have been to accelerate the circulation of matter through the life cycles, both by 'enlarging the wheel' and by causing it to 'spin faster'.
>
> Lotka, 1922.

INTRODUCTION

Modern biology is lacking a theory of zoology that can explain the evolutionary sequence from unicellular to multi-cellular animal organisms, followed by the appearance of animals with complicated behavior and lately by the emergence of the human species. The reigning view, almost a dogma, ascribes everything to a sequence of aleatory non-directional modifications, the results of which are reshuffled again and again by sudden mass-extinction events, primarily of extra-terrestrial origin. This doctrine of contingency, claiming Darwinian orthodoxy, is chiefly proclaimed and masterly popularized in the many writings of S. J. Gould.

Nowadays, when the relationship between humans and the rest of the biosphere is of central interest and acuity, it is of primary importance to decide whether humanity is an ephemeral, accidental and even deleterious side-product of evolution, or an irreversible, logical and natural product of it.

An alternative theory of animal evolution, which has been published *in extenso* (Por, 1994) is presented below as a historical sequence of theses.

The Alexander Silverman Institute of Life Sciences. Hebrew University of Jerusalem. 91904 Jerusalem, Israel. / dovpor@netvision.net.il

As against the dominant view of evolutionary contingency and neo-catastrophism, an hypothesis is exposed according to which animal evolution is a predictable patterned process and irreversibly channeled.

EVOLUTIONARY IRREVERSIBILITY

In accordance with the thermodynamic theory of the open dissipative structures, the biosphere operates with an external energy source, the solar energy, and an open thermal sink, the surrounding abiotic cosmic medium. Like other dissipative non-equilibrium systems and within the given constraints, the biosphere evolved farther and farther away from the original high entropy level of structural disorder and simplicity. Progressive animal evolution is a further stage in a process which led to the organization of living matter and in sequence to the appearance of the eukaryotic cell. With each step, more energy rich and more energy expanding structures evolved; in other words, the level of information in each new system increased.

Natural selection acted on this evolutionary process, already at the biochemical level. The left-handed amino acids were selected and so where the four nucleotide bases of the genetic code. About one billion year ago the dominant photosynthetic enzyme of the green plants became selected. It has not been surpassed since, although it is fairly inefficient. The “universal” energy storing and transferring capacity of the phosphonucleotide molecules (ATP, NADH) is also a plateau reached about the same time in the past. This twosome of the selected energy-fixing and energy-storing biochemical pathways represent the basic constraints of biological evolution .

These are some basic examples that demonstrate how evolution proceeds, both on the molecular and the cellular and organismic levels. The first step is that of *experimentation* with different ways of problem solving. Then follows the natural *selection* of the best available solution. The selected solution is *irreversible* and *canalizes* further evolution into a restricted direction. The first half of this sequence is known to biologists as the Dollo’s law of irreversibility.

One of the basic problems with this “universal” biological pathway is the fact that the selection is made vis-a-vis environmental conditions that reigned at the time the evolutionary experimentation occurred. Since the global environment, both physical and biological is evolving, we have here as a result another constraint. Many irreversibly selected solutions might be already anachronistic, and functioning in an environment which is different from that in which they were originally selected. Organisms with such anachronistic features must survive in environmental refugia, where conditions still remind the old ones, or become extinct.

TWO WAYS OF THERMAL BUFFERING

The most important environmental change, to which the biosphere was submitted during its existence, was the gradual increase in the amount of solar irradiation. As our central star advanced in its stellar evolution, as much as 30 per cent of increase has occurred. If the biosphere had not been able to adapt accordingly and to buffer this increase, the result would have been a thermal death in an overheated atmosphere similar to that of our sister-planet Venus. Till the end of the Proterozoic, there has been an important source of heating originating from the radioactive decay of Earth. The last paroxysm of volcanic activity happened probably around 700 million years ago during the rapid termination of the so-called global "snowball" conditions, when atmospheric CO_2 reached 350 times the present concentration. Afterwards the dominant way was to decrease the greenhouse effect of the atmosphere, first by limiting methane emission and, afterwards, by gradually extracting the atmospheric CO_2, the most important greenhouse gases. During the lifetime of the biosphere, there has been an increasing "ice house" effect as the levels of atmospheric CO_2 decreased by two orders of magnitude, counteracting the increase in solar radiation. The result was that for at least the last 700 – 1 000 million years, the global temperature did not significantly change and has always remained in a range which allowed the existence of multi-cellular organisms. This is the core of the Gaia principle (Lovelock, 1988).

How could this be achieved? With its basic energy capture and energy exchange biochemical mechanisms irreversibly fixed, the biosphere had only two dimensions of liberty left.

First, through the massive increase in the biologically fixed carbon which led to an equally massive extraction of carbon dioxide from the atmosphere. Since an increase in the carbon-capturing efficiency of the plant organisms could not be achieved anymore, the answer was the expansion of the vegetation to the whole global surface. This expansion resulted in the establishment of a huge vegetal biomass of reduced carbon, such as the biomass of oceanic phytoplankton, the submarine mountains of the coral reefs, and the mass of the terrestrial forests. The build-up of fossil biomass (coal, oil, etc.) over the ages represent organic accumulations which were not recycled..

Second, through the acceleration and increse of dynamic pace of biological processes. This function of conveyors of energy within the biosphere was to be the main function of the animal organisms, relative latecomers on the biospheric scene. Exclusively consumers of biomass of reduced carbon, the animal's incentivate growth and supply the minerals needed for renewed production. They increase the ejection of respiratory carbon dioxide back into the atmosphere, and are in a sense a guarantee that the carbon extraction by the plants will not turn into a runaway process.

Since here we are treading for the first time on "zoological soil", the subject of this essay, this line of thought will now be further developed.

THE AGE OF ANIMALS

Among the kingdoms of the living organisms, the animals contain by far the largest number of species. At first sight, this seems to be paradoxical. The biosphere existed at least for the first two billion years in the so-called Precambrian times without the presence of animals. The photosynthetic organisms, bluegreen algae and other primitive unicells, produced organic matter (the *producers*). For their activity, besides light and water, they needed inorganic nutritive minerals; the bacteria then decomposed the organic matter produced (the *decomposers)*, down to the inorganic elements needed for renewed production by the synthesizers. This simple cycle functioned exclusively, as mentioned above, for most of the history of the biosphere. When the animal organisms appeared, in the last billion years or so, they added a complication to the cycle: different levels of *consumers* and various links in a food chain or steps in the food pyramid. The newcomer animal consumers transformed the simple linear connections between producers and decomposers into complicated food webs.

Apparently, the exuberant flowering of the animal species is an unnecessary excrescence on the body of the laborious producers and decomposers. However, reprocessing the organic products through a complicated food web is much more rapid and effective than in the linear producer-decomposer cycle.

We can see today in some marginal environments, like the hypersaline pools, in which animals cannot live, how the primitive Precambrian biosphere worked. Crusts of photosynthesizing bluegreens algae are alternating in time and space with layers of decomposing bacteria. There is an often long-lasting separation between the sites where nutrient-starved algal growth collapses and rots away, and the sites where the bacteria accumulated plenty of mineral nutrients. The distances that separate the sites are often minimal, since both producers and decomposers are barely moving microorganisms. By modern standards, the Precambrian ecosystems were sluggish slow-supplying and slow-producing systems. Furthermore, they were probably limited to the shallow well-lit coastal lagoons, where dissolved nutrient salts can be redistributed by waves and by tidal action.

Enter the animals and the Phanerozoic eon starts, the second eon of biological history, the age of the diversifying animal life. Unlike bacteria and fungi, which mainly feed by decomposing dead organisms, the animals are killing, engulfing and digesting their food organisms without delay. Moreover, the animals are in general highly mobile organisms, which detect and approach their prey, spanning distances unheard of by their vegetal and bacterial partners. The complicated food webs passing through many levels of animal links ensure that little of the organic production is lost. The big diversity of animal organisms represents as many channels of recycling specific food items, everywhere in space and during all the time. Feeding on live prey includes all the food objects from bacteria to plants and, of course, other animals. In ecological terminology, we speak of grazers, scrapers, engulfers of cells, filtrators of suspended small food, herbivores, outright predators, parasites, and so on.

HARPACTIC ACTIVITY

I am proposing a more generalized name of "harpactic activity" (from the Greek *arpagos*, a greedy predator) for all the aspects of animal activity. This notion does not cover only the feeding activity of the animals in its multifarious manifestations, but also their activity as stimulators of growth and re-distributors of nutrients.

Darwinian fight for survival and natural selection gained a richer and more dramatic content with the rise of the animals and the ensuing *harpactic pressure*. Till then, unicells and their colonies died of food exhaustion, of adverse physical environmental conditions and competed among themselves by overgrowing or by chemical antibiosis. Like growth itself, death and exclusion were a slow matter. Harpactic pressure needed more efficient and quicker means of survival and competition. Death at the hand of the animals was quick and merciless. A colony of unicells could not allow itself to become senescent; it had to maintain logarithmic growth in order to replace predatory losses. Suddenly, the biological world became replete with physical and chemical defense systems, rapidly improving in response to the enhanced performance of the predatory animals. Rapid growth, in order to replace the losses and increased body mass of the prey organisms, became widespread means of defense. A seemingly endless positive feedback process resulted, aptly called by Vermeij (1987) "escalation". Over time, action and reaction become more and more rapid and complex; the dynamism of adaptation and selection processes increased and reached the present breathtaking speeds. Gradually, the behavioral component of this arms race became more important.

Happily, irreversible evolutionary channeling made the huge majority of the animals unable to digest cellulose and lignin; they have to use the borrowed enzymes of the bacteria and the fungi. Much of the way the present biosphere looks depends on this basic shortcoming of the animal organisms. Perhaps this has been one way which prevented uncontrolled over-consumption of the vegetal biomass of the globe.

Animals should not be seen only as one-sided recyclers of vegetal biomass; their role as promoters of bacterial decomposition cannot be estimated enough. It is not only in their guts where they harbor and consume colonies of cellulose decomposing bacteria. Also in the free, they are promoting decomposition, for instance by bulldozing the dead, mainly vegetal organic matter, in the marine sediments. In the old biosphere, devoid of animal activity, enormous amounts of dead organic matter ended up buried within the anoxic marine sediments and were lost to the carbon cycle. The burrowing animals re-expose this organic matter to oxygen and to bacterial decomposition and of course benefit by scraping-off the nutritive bacterial films. This so called bioturbation of the marine sediments, returns to the atmosphere large amounts of carbon dioxide, balancing the carbon dioxide fixation by the vegetal world. A runaway depletion of carbon in the atmosphere is therefore probably avoided.

THE INCENTIVE FOR EXPANSION AND OPTIMIZATION

One of the most frequent ways of avoiding predatory pressure was and is colonization of novel and more extreme environments that are out of reach to the predators. Temporary escape from predators compensate for the extra metabolic effort required by an unfamiliar environment. In big history, as in instances of recent re-colonization, it is always the plant producers that are first to arrive; but the animal consumers always follow after some delay, and the same cycle of predation and defense starts again. After the first herbivores arrive, the first predators come next and then the predators of the predators. This succession repeated itself again and again; when land was colonized, when the oceanic expanses sprung to life, or when a newly born island emerges from the sea. One can suspect that without the incentive of escaping predation there would not have been any expansion of the biosphere, from the marginal coastal shallow waters to the almost complete global covering.

Moving into more and more unfriendly environments and leaving the bosom of the shallows required a host of new adaptations. Land life, for example, required mechanical adaptation to a less dense aerial environment, to a patchy nutrient supply, to low salinity waters, to drought or flooding, to extremely fluctuating and unpredictable temperatures, to a more hazardous reproduction and dispersal, etc. All the morphological, physiological and behavioral mechanisms used to maintain a homeostatic equilibrium, to free the organisms from the whims of the unpredictability of the new physical environments, are extremely energy dissipating. Homeosmotic, homeohydric and homeothermic devices consume tens of times more energy than the one needed before. To compensate, terrestrial vegetal biomass is abundant and oxygen is always present to fuel the needs of active metabolism.

More complex individual organization and more efficient ecosystem functioning paid for the expansion of the biosphere. Lotka (1922) stated many years ago: "Evolution proceeds in such direction as to make the total energy flux through the system a maximum compatible with the constraints."

Animals are the energy-traders of the biosphere: they replaced the clumsy energy bartering between the primitive plants and the bacteria into an efficient global network which satisfies the countless local energy demands. It is the animals that turned the modern biosphere into an interwoven global system. The higher the animal consumer is in the food web, the more mobile, the more sensorial alert it is, the more space it covers in search of prey. Within its body, with its mineral excreta, he links between the production of distant ecosystems. It is not only the Englishman of the story who every weekend crosses the Channel to feast in Calais. There are the myriads of planktonic animals that every day perform two-way vertical migrations of hundreds of meters; the countless animal larvae of the shallow waters that swarm out into the open oceans; the marine fishes which migrate into the estuaries and rivers and return to the sea; the billions of winged mosquitoes and other insects that emerge from the waters; the immense flocks of migratory birds that cross the globe twice every year, the moving herds of thousands of African herbivores, and so forth. A bird, which is gorging itself with the midges of the tundra in the Arctic summer, leaves its carcass a season later, to be decomposed and recycled in the welds of South Africa. An eel which was born in the Atlantic, and grew-up on oceanic plankton, ends up in a shallow ditch hundreds of kilometers from the nearest sea. Stories like these are legion.

THE UNEASE WITH PROGRESSIVISM

Although a gradual evolution of complexity and performance of the animal organisms during the last 500 million years is evident, few animal biologists will openly agree that there has been a progressive evolution here. The discussion of the roots and the reasons for the academic denial of such a blatantly obvious fact would make the substance of a separate text. Here we can only shortly define three main causes and identify a few arguments of this denial.

The *first cause* is the widespread view of a one-dimensional evolution. Natural selection acts everywhere and it results in individual survival. The means of adaptive survival are extremely varied and in this sense, both an ameba and a horse have been equally successful in the game of survival. That each of them has achieved success by different means is not relevant. There is no other objective yardstick, besides selective survival. The evolutionary panorama of this dominant opinion is a waste flat evolutionary plain with countless branching trails, leading nowhere. Much before political correctness became widespread, zoologists were already censured when speaking of a “superior” versus and “inferior” animal. Deep Green revulsion against; ″Speciesism″ is only the newest form of this attitude.

Second. There exists now a prevalent profound distrust in social progress and improvement (Nisbet, 1980). Since the times of Plinius till the recent Dawson, we seek to reflect us in the animal world and than bounce back with new sociological theories. A directional, progressive evolution can be accepted for the heavenly bodies, the structure of the molecules, the origin of life and even for the plants, but not for our animal paragons. Son of another generation, Darwin did believe in a trend of evolutionary improvement; our generation is deeply pessimistic about human progress, even while our more technical minded colleagues are busily improving life everywhere. If our species is the product of a progressive animal evolution then, logically, the same “arrow of time” should extrapolate also to human history. This would result in an optimistic way of thinking, and belittle in a “panglossian” way population explosion, global famine, atomic threats, environmental poisoning, meteoritic hits, ozone holes, global warming, and so forth. Humans are considered to be a small but virulent evolutionary accident, hopefully soon to disappear, like other species did before. Animal evolution will retake its course with a sigh.

Third. Lacking a palatable materialistic explanation, progressive evolution was attributed often to an “*elan vital*” such as Bergson’s, or to an idealistic teleology, like that of Teilhard de Chardin. Diversely, progressive evolution was presented as if it would mean a linear process, an orthogenesis, fueled by unknown forces. This is one more reason to distrust progressive animal evolution. By defining the attributes of animality and accepting the overall ecosystemic role of the animal world, we can have an objective yardstick for zoological progress. Following Lotka and placing animals into the central role of maximisers of the energy flow through biological systems, we have the thermodynamic mechanism behind animal progress.

THE ESSENCE OF ANIMALITY

If we can define the essence of animal function in the biosphere, as we did above, we can also objectively discern superior from inferior functioning. The essence of *animality*, in biospheric context is: aggressive consumption of live organisms; sensory capacity to detect the food resources; mechanical means to approach and subdue the prey; liberty to move among different physical environments in search for food. Improvement in all these attributes leads to more and more energy-hungry organisms and speeds-up and refines recycling within the biosphere.

The trend to progressively improve *animality* is not universal in the animal kingdom, it is not a broad front in which each animal type participates. Universality of progress is often assumed by the critics of progressivism for the pleasure of knocking it down. Nor is progress in the animal kingdom a linear process, a relay race in which each phylum hands the torch to another; a modern replay of the classical Aristotelian "scale of life" as the critics allege. To use again the athletic example, progress in the animal kingdom resembles a marathon race in which a whole crowd starts and then, as most of the participants remain behind or are desisting, the leaders run in a single thin file.

Who are the runners and what are the rules of the race?

PHYLETIC SELECTION

The runners are the large, basic taxonomic entities of the living world, the phyla. There are some 35 recognized phyla, probably the same number as at the dawn of the Cambrian period, 570 million year ago. At the outset, each of the phyla counted only a few species, all living in the primordial environment of the shallow sea. As life branched out into the other environments of the globe and evolutionary history proceeded, most of the phyla stayed behind in the sea, while only a few settled the harsher environments. Many of the phyla confined to the oceans are represented today only by a small number of species following repeated crises, the "extinction events" of the modern catastrophists. Only a few phyla remained predominant. Today there are many more animal species than ever, probably some 15-30 million in all. Almost all are members of three leading phyla: the Mollllusca, Arthropoda and Vertebrata, while three more, the so-called Protozoa, the Platyhelminthes (flatworms) and the Nematoda (roundworms) flourished as hitchhikers on the three leading phyla. The majority of the species is found today on land, an initially inhospitable environment.

Natural selection acted also at the level of the phyla. Each species bears the functional marks of the phylum to which it belongs. In its young developmental stages, long before being able to react to the selective environment according to its specific capabilities, each animal species is already marked by its belonging to a certain animal type. Natural selection does not play its hand with jolly jokers or wildcat cards, but only with cards which belong each to a certain suite and color.

As mentioned at the outset, evolution is canalized by the existence of irreversible functional and morphological properties. Each of the animal phyla is characterized by a set of such specific irreversible traits. We know of no transitions between the phyla, these basic morpho-physiological types of the animal kingdom; the space between the phyla is empty. We don't know yet when did this fateful separation of animal life in different basic structures occurred, We are using the term "Cambrian revolution" for the event of the seemingly sudden and more or less concomitant appearance of these structural types in the fossil documentation. It is already evident that the beginnings were at least another 500 million years back in time.

Since the Cambrian, each animal phylum had its future evolutionary performance limited or even defined. For example, the sea stars and their allies (phylum Echinodermata) developed a five-branched symmetry during a sedentary phase in their history, different from the two-sided symmetry of other phyla. They never could get rid of their fundamental pentamery and their capability of efficient oriented movement remained impaired. The flatworms (phylum Platyhelminthes) could not develop a skeleton of any type. They can glide over the substrates and insert themselves into the interstices, but no flatworm can force its way into it by burrowing. The roundworms (phylum Nematoda) are structurally obliged to move only on a substrate covered with a film of water; no roundworm was ever found living free in the plankton or on dry soil. Four phyla are definitively condemned to sedentary and colonial life; another number of phyla are totally committed to parasitism.

THE OSMOTIC HURDLE

Without going too much into zoology, we have now to mention also some irreversible physiological capacities, or rather shortcomings. There are few phyla of the initial marine stock which were able to control and regulate the osmotic pressure of their body fluids and therefore able to live in waters with different salinities, brackish and even fresh waters. The amount of energy necessary to perform osmotic regulation of a certain volume of body liquid has been compared with that needed to lift the same volume to several meters. Many phyla and classes are characteristically unable to osmoregulate: such are the corals, the above-mentioned Echinodermata, the lamp shells (Brachiopoda), the Cephalopoda (squids, and octopuses), the sea squirts (Urochordata) and a dozen of smaller phyla and many more classes. All these remained confined to the ocean waters, which are as a rule poor in food (oligotrophic). The osmoregulators: annelid worms, crustaceans, the ancestors of the scorpions, the shells, snails, were able to colonize the estuarine and fresh waters; so did most classes of fish. They can regulate and maintain the stable osmotic pressure of their body liquids in spite of the unpredictably changing salinities of the new surrounding media. Food is in abundance in these waters, which have a high biological productivity, and thus largely compensates for the energy spent in osmoregulation. The rich biomass of the newly colonized changing-salinity waters gained an influx of hungry consumers and energy traders.

The capacity to osmoregulate was a long-term asset also in the marine environments. Seawater has a relatively stable salinity and a buffered temperature on a short time scale. But during critical periods of the tectonic history of the globe, these parameters could fluctuate sharply and even dissolved oxygen could be at times in short supply. Some 250 million years ago, during the Permian crisis, nearly 90 per cent of the marine biota were wiped-out, when the oceans underwent an environmental collapse. The mollusks, the crustaceans and the fish turned out to be successful survivors of these crisis times, whereas those unable to osmoregulate were extinguished or barely survived and recovered only after a considerable lapse of time.

LANDFALL

On to the land and out of the water was the next step. Around 400 million years ago lush terrestrial wetland vegetation was already established there. Understandably, only osmoregulating animals could colonize land. At the onset worms and a variety of minute arthropods settled the wet soils, surviving in humid environments. As the plants grew taller and expanded to upland environments, their animal following had to cope with winds and drought.

The problem of opposing gravity without the friendly flotation of the ancestral watery environment and to withstand the blowing winds could be managed only by skeleton bearing animals. The skeleton was needed not only as a support, but also as a necessary system of pulls and levers for efficient movement in the aerial environment. Only two phyla among the whole osmoregulating aquatic ancestry had such a skeleton, namely the Arthropoda, which have an external skeleton of chitin, and the Vertebrata, which have an internal skeleton of calcium phosphate. The Mollusca also have a shell-like external skeleton of calcium carbonate, but the shellfish were irreversibly committed to feed by straining their food from the water. The snails, committed to slow gliding, flatworm-like movement on wet soils, could use their shells only as a protection but not as a lever. Besides, many continental areas are notoriously poor in the calcium carbonate needed for their shells. But even under these limitations, the snails are the only mollusk class which could leave the waters; their role on land is fairly marginal.

ARTHROPOD LIMITS

Arthropods are with their unaccountable numbers of species of insects, mites and spiders, the most frequent terrestrial animals. But as strange as it may appear, the arthropods suffer also of some critical and irreversible evolutionary limitations. Their armor-like external skeleton is not shock-proof and has to be shed from time to time in order to allow growth. During the soft-skinned inter-molt episode, the arthropods are very vulnerable and need to hide. Therefore perhaps, already in the seas, the crustaceans rarely reach very large sizes. This molting crisis is an especially dangerous time on land, when the "naked" insect or spider body is also exposed to severe loss of liquids. Also the tracheal system for air-breathing which the insects have evolved, is not a centralized respiratory system like that of the vertebrates, but functions through a multitude of breathing openings; there is a certain critical body mass which cannot be supplied with oxygen anymore through these tracheae. For reasons like these and others, the insects remained limited in size; for them, small is beautiful. In the crucial competition with the other successful terrestrial phylum, the vertebrates, the insects evolved more in the direction of smallness. The ancestors of the terrestrial insects were often bigger than the recent ones and the most advanced, ants, moths, midges, tripses, excel in miniaturization. In the vertebrates the evolutionary tendencies were often opposite: small ancestors generated impressive-sized evolutionary descendants, dinosaurs, whales, pachyderms and giant cave bears.

Insect smallness results naturally in a nervous system of few neurons. A small and rigid behavioral menu happens, compensated only by the stupendous organization of the termite, ant and bee societies.

VERTEBRA TE SUCCESS

This leaves us with the vertebrates in the marathon course of progressive animal evolution. What exactly singled-out the vertebrates from among the tens of other animal types? Nobody could have foretold this when *Pikaia*, the first vertebrate ancestor appeared in the Cambrian Sea, wrote Stephen Gould (1989). But unknown to him by that time, chordate precursors of the vertebrates like the Conodonta and some Amphioxus-like animals, were already frequent. Older kin's of *Pikaia* were recently unearthed in China. Conway Morris (1998) considers on the contrary, that all the future success of the vertebrates was already recognizable in *Pikaia.*

The success of the vertebrates probably resides in the fact that they represent a morpho-physiological type which shows the relatively minimum set of constraints, which has the most efficient available devices and which is in the broadest possible way adaptable to the requirements of the abiotic and biotic media. This is today solidly supported by the structure of their morphogenetic gene complexes, the HOX group of genes. Not many millions of years after *Pikaia*, the fish-like vertebrates were already the top predators of the seas. Today, the most advance fish class, the Teleostei, the bony fishes, are, together with several other vertebrates of secondary marine life, the uncontested masters of the seas.

SUBSERVIENCE IN ANIMAL EVOLUTION

It is being often and rightly asked why the vertebrates are singled-out and thrown into the center of the discussion, when there are so many more species in the other phyla, most notably, among the arthropods. An answer is not simple, but can be still sketched-out. If one checks the large numbers in the species-rich phyla it often turns-out that most of the species exist due to the presence of the vertebrates and of course also of the modern vegetation of flowering plants. Among the protozoans, the flatworms and the roundworms, there are many more parasitic than free-living species. They make their living on and in the bodies of the vertebrates, partaking in their food and exploiting their physiological stability. As a rule, one species of a vertebrates is used by many tens of species of host-specific parasites. No less than 60 species of nematode worms are specific parasites of the human species alone. The vertebrate body, offering the safety of a homeostatic haven, represents a whole new environment, a small continent for a host of small parasites. An enormous diversity of ticks lives on the terrestrial vertebrates. The insects have first of all diversified following the flowering plants. Some 300 insect species can depend on a single species of trees. But among the insects there are also whole orders and many families which are vertebrate clients: ectoparasites, blood suckers, feather and hair eaters, nest parasites, dung eaters and even tear-lickers. In the insects the rule is monophagy: one species for one feed. Among the vertebrates there is a tendency towards omnivorous feeding.

We are used to the classical food pyramid where at the base we have many food organisms and at the uppermost one top-predator. There exists also an inverted pyramid where each vertebrate top species serves as provider and host for a multitude of client species, parasites and parasites of the parasites. A very large segment of the global biodiversity is composed of *subservient species*. It is right that today there are many more bacteria and primitive species than before. But far from being an argument against progressive evolution (Gould, 1996), this situation is the direct result of the opportunities opened up for them by a very small and very advanced segment of the animal world. Singled-out as this segment are the vertebrates.

HOT BLOOD

The terrestrial vertebrates have mastered the problem of water saving, by developing an impermeable keratin skin cover and by producing water-tight eggs. These has been first the achievement of the reptiles that could now freely roam the uplands, far from the original wetland habitats of their amphibian ancestors and follow the upland vegetation, which developed there in advance. In the full sunshine of the dry Mesozoic continental environments, the reptiles could solve also another important problem of homeostasis: keeping an optimal high body temperature.

All the biochemical processes are speeded-up at higher temperatures. With decreasing temperatures, everything slows-down to a stop. For an active animal high temperature is an important bonus to look for. Several of the most advanced types of fishes among the tunas and the sharks already found the means to preserve some of the heat produced by their muscular activity. However, the high thermal capacity of the surrounding watery medium proves to be an efficient cooler. It is much easier to warm up in the air. The high body temperature limit is slightly above 40^0 C, as the protein molecules start disintegrating. The solution therefore was a *thermal brinkmanship* of how to generate and preserve heat obtained from muscular activity, keep it as near as possible to the upper limit, yet avoiding overheating. Some of the most advanced insects, notably the bumblebees, also experiment with muscle-generated high body temperatures. But this is a momentary achievement; their insect-sized bodies cool down as quickly as they heat up.

The reptiles could use huge, dinosaurian body sizes. A great body mass, without thermal insulation and with sufficient muscle activity, can heat up during the sunny day hours and still preserve enough inertial heat during the night. If there are no real cold seasons, a dinosaur could maintain a reasonable activity the year around. Global climate, in particular during the apex of the dinosaurs in the Cretaceous period, was especially friendly for this dinosaurian *inertial thermal strategy*. The danger for them was overheating. Many morphological adaptations served as cooling devices. Like today's elephant, many of the giants probably used to take cool dips.

High and fairly constant temperatures in the guts of the large reptiles promoted the establishment of large colonies of cellulose-splitting bacteria. This symbiotic relationship enabled the reptiles for the first time to consume large quantities of vegetal cellulose, indigestible before. The stage was set for large-scale terrestrial herbivory. The joint processing of terrestrial vegetal biomass by the symbiotic couple vertebrates plus bacteria opened for the first time an unlimited energy market for the more and more energy-expensive vertebrate organisms.

Towards the beginning of the modern Cenozoic era, the long-lasting climatic episode of the sunny and dry Mesozoic climates came to an end. The dinosaurs were already well on their way out when a big asteroid wrought additional havoc. In the dark of the dense rain forests of the Paleocene and with the general downward trend of the world climates, which started in the Eocene, the dinosaurian thermal strategy became anachronistic. Only small "cold-blooded" reptiles survived, leading a life of alternative activity and torpor.

The turn of the active thermoregulators, homeothermic birds and mammals, came. They rely only on the heat produced by the body functions, its conservation by an insulating plumage or pelt and, if needed, controlled active means to avoid overheating. Active heat production requires massive feed; endothermic vertebrates use about 90 per cent of their food intake to produce heat. They are without doubt the most complex and most dissipative organic structures. Under the new global post-Cretaceous conditions, birds and mammals would have prevailed even without the help of the killer asteroid.

THE BEHAVIORAL ATTRIBUTE

We did not speak till now of *behavior*. This is a typical animal attribute; this combination of sensorial, muscular and neurological functions is unique to them. As a rule, the patterns behavior are innate, genetically transmitted functions of the nervous system. In the insects, for example, each species corresponds to one behavioral stereotype; this is also a reason for the insect multitude. Movement in search of a prey exposes the animal organism to a variety of physical and biological environments and this requires homeostasis, a capacity to buffer the impact of changing environments. At the same time, behavior became also a means to avoid unfriendly surroundings; fish seasonally migrate to waters with suitable temperature, reptiles and insects bask in the sun but hide against overheating, migrating birds avoid the winter, and so forth. Complicated acts of nest building and of brooding vouchsafe the thermoregulation of the unprotected chicks. In this case, learning, memory and transmission of information are already superposed on rigid behavioral design. In mammals lactation does not only provide the much needed food for the youngsters, but also provides ample possibilities of horizontal transmission of acquired immunological properties and active experience transmission by the parents. In this important segment of the animal world, aspects of Lamarckism are vindicated.

With some exceptions, like in the bee colonies, learning and memorizing appeared only twice during animal evolution, and strangely in two totally separate branches of evolution: in the cephalopod mollusks and in the homeothermic birds and mammals. The cephalopods have very voluminous brains, an extremely discerning vision, and a capacity to learn and to memorize complex behavioral patterns. Considered the apex of invertebrate evolution, they surpass even the mental performances of some mammals. One cannot have thought of a better proof that an evolution towards advanced behavior is innate to the animal kingdom and not an entirely accidental "adaptation" of some higher vertebrates. Unfortunately for them, the cephalopods have some very restrictive evolutionary limitations. They cannot osmoregulate and are therefore confined to the nutrient poor oceanic environment. To maintain their impressive body complexity, all cephalopods are aggressive predators. However, their oxygen-carrying blood pigment is the copper-containing hemocyanin, which, unlike our widespread hemoglobin, cannot get bound to blood cells and remains always in solution. The blood of the cephalopods is concentrated to the maximum viscosity; their circulatory system perfected to the maximum efficiency has an unequaled arterial pressure. All this to no avail; it seems that the over-stretched cephalopod organism winds down very rapidly. The biggest and "wisest" octopus rarely exceeds two years of life and reproduces only once in this short lifetime. They can learn nothing from this unique experience; nor can their offspring.

BIRD VERSUS MAMMAL BRAINS

Homeothermy was certainly the major factor which made possible the advanced functions of the bird and the mammal brains; actually, the brain itself is one of the important thermogenic organs. An internal medium of stable and optimal temperature enables the brain cells to accumulate memorized personal experience, and learned behavioral patterns. Even if taken with a grain of salt, the relative increase of the brain mass is a good general measure for progressive vertebrate evolution.

Memory build-up and exchange of experience within the group, became a new type of information transmission, additional to the genetic one. The small cold-blooded reptiles, as it is suggestively expressed, forget during the stupor of the cool nights what they have learned during the day, not to speak of the long season of hibernation. Perhaps the dinosaurs were wiser.

The fact that birds and mammals have achieved active thermoregulation in somewhat different ways, as well as the different anatomy of their brain development, speak against the claim that this progressive evolutionary view is a linear, orthogenetic one. Quite on the contrary, it proves that the circumstantial drive towards progress acts independently and often convergently in different lineages.

Active thermoregulation, a process that requires ten times more food than the one required by a non-thermoregulating reptile, opens up, as a fair compensation, the possibility to feed actively the day around and in all seasons of the year. In fact, large African herbivores practically don't stop eating and ruminating.

We are reaching now the end of our argumentation. Birds have many shortcoming which are related to their extreme adaptation to flight: their size limitation, the related need for selected light-weight energy-rich food, the lack to manipulate fore-limbs, the imperfect homeothermy, and the nest hatching. The different way in which their brain mass increases inward, instead of expanding in an outer and circumvoluted cortex, represents also a limitation. As shown by Allman (1999), birds have only one stereotypic visual map and have a limited possibility to change stereotyped behavior. For all this, birds are at an evolutionary dead end, even if a glorious one.

PRIMATE PRIMACY

From among the mammals, the primates, probably an old Cretaceous lineage, had many preconditions to produce the first rational animal: they have prehensile hands and feet, they rely primarily on vision, they have color vision, they are omnivorous, and they live in various types of group organization. Gould believes that if it were to start again, animal evolution would result in completely unforeseen products. We believe that a replay, like in Anatole France's *L'ille des Pinguins*, would, under similar environmental circumstances, most probably produce again a thinking endothermic terrestrial animal, eventually even a primate-looking vertebrate.

The human species embodies in the most extreme form the evolutionary tendencies of the animal world or even of life as such. There is nothing wrong about it. The human cooking pot hydrolyzes cellulose and prepared for consumption the most refractory or poisonous vegetal materials. Humanity has tapped for its needs the fire, the fossil carbon products and directed the wind, the streams, the solar and the atomic energy. The total of the soon 10 billion human specimens represents the biggest, most complex and energy consuming biomass ever produced.

To achieve this, the human species from its early stages has hunted down without mercy the larger-sized mammals, its most obvious prey and competitors for food. Soon enough, it subjectively classified and selected all the diversity of the species either as useful species or as vermin. Through domestication, the humans selected a few tens of animal—and a few hundred plant—species and turned them into their subservient allies. These are new biological entities, *cultigens,* that survive only with human help; together with them, and the inevitable camp followers, we consume already nearly 50 per cent of the bioproduction of the globe.

With every progress in the economy, legions of species, from bacteria to mammals turned into weeds, camp-followers, inquilines, pests, pets and outright parasites. Today, there are tens of thousands of subservient profiteering species living at the expense of the human biomass; others are simply tolerated by the grace of the victor or benevolently cared for. Thousands of species took profit of the human carrier and invaded environments and continents, which were utterly beyond their natural possibility of expansion.

THE HUMAN PHASE OF EVOLUTION

True to their animal ascendancy, humans have integrated the totality of the biosphere into a common bio-energy market. There are no secluded continents or islands anymore and even the deep sea suffers indirectly from human interference. The whole evolutionary process has been diverted and constrained by the human agency and this is possibly an irreversible fact. What is called wildlife survives today only due to the more or less good-will of humans. Although the list of the species endangered by man is still long, it is encouraging that there has been no notable extinction in the last half of this century. Much of the surrounding animal world, if not outright profiteering, will have to become habituated to the human presence; furthermore, humanity produces new cultivated biological entities, artificial products of pre-existing wild ancestors, for instance, the countless beautiful races of horses and dogs, of tulips and roses. Nowadays, genetic engineering creates even more exotic organisms. The future *humanized biosphere* will be inhabited not only by rats and cockroaches and by half-domesticated animal species in protected environments, but also by nice manipulated *pseudo-species* (Por, 1996).

Obtaining unlimited energy from "clean" atomic fusion or from hydrogen plants is a distinct possibility. The day is not far when in our laboratories we will overcome the basic limitations of biological energy transformation and increase the photosynthetic efficiency of the chlorophyll molecule. A biosphere of super-efficient man-made plants will be an entirely different story.

The human species is often considered to be only a small twig on the tree of evolution; it's easy to draw a tree which shows this. But in real time the little twig grew to dimensions that overshadow the entire tree of life. With the humans, life became for the first time intelligent and this is, without doubt, a new and irreversible step in the evolution of matter on the globe. The marathon race of progressive evolution has been won by the human species. And one day, many millions of years ahead, when our sun will turn into a red giant engulfing our planet, human colonies might already be flourishing elsewhere.

BIBLIOGRAPHY

Allman, A. (1999). *Evolving Brains*. New York: Scientific American Library.
Conway Morris, S. 1998. *The Crucible of Creation. The Burgess Shale and the Rise of Animals.* Oxford: Oxford University Press.
Gould, S. J. (1989). *Wonderful Life. The Burgess Shale and the Nature of History.* NY: Norton
Gould, S. J. (1996). *Full House. The Spread of Excellency from Plato to Darwin.* NY: Harmony Books.
Lotka, A. J. (1922). "Contribution to the energetics of evolution." *Proceedings National Academy of Sciences* 8:147-152.
Nisbet, R. A. (1980). *History of the Idea of Progress.* NY: Basic Books.
Por, F. D. (1994). *Animal Achievement. A Unifying Theory of Zoology*. Balaban Publishers, Rehovot.
Por, F. D. (1996). "Diversity, subservience and the future of evolution". *Israel Journal of Zoology* 24(2):455-463.
Vermeij, G. J. (1987). *Evolution, Escalation. An Ecological History of Life.* New Jersey: Princeton University Press.

ABSTRACT

In disagreement with the reigning view that animal evolution is only the result of contingency and of catastrophic events, this article presents a view which considers animal evolution as a cumulative process of information buildup, channeled by irreversible constraints. The roots of the prevalent anti-progressivist views are briefly reviewed.

The role of the animals in biospheric evolution is analyzed on the background of the general entropy increase in the solar system. Animals act as energy traders and stimulators of the expansion and efficiency of the biosphere. The basic functions of animality are defined, and their improvement is seen as a yardstick of progress. Progressive evolution in the animal kingdom is followed along its winding and narrow path, as their respective structural and physiological burdens successively bind the different phyla. Natural selection at the phyletic level is seen as acting, rather than the extraterrestrial catastrophes. Increasing segments of the animal world are induced into establishing subservient relationships with the dominant phyla. Terrestrial animal life, with its high demands for homeostasis compensated for by an ample vegetal biomass and rich oxygen supply, had the uniquely capacity to give rise to the most complex animal forms. Among the homeothermic vertebrates, mammals are singled-out by natural selection to produce the most intelligent and energetically active animal beings. The rise of the humans is not an accident, but the present crowning of a long 'post-hoc' foreseeable process. It is a new and, again, irreversible stage in organic evolution, with long-lasting and profound effects.

RESUMEN

SOBRE LA EVOLUCIÓN PROGRESIVA DE LOS ANIMALES Y EL PAPEL DEL SER HUMANO EN LA NATURALEZA

En desacuerdo con la postura predominante que sostiene que la evolución animal es el resultado de la casualidad y de acontecimientos catastróficos, este artículo plantea una visión que considera la evolución animal como un proceso acumulativo de concentración de información, encauzado por limitantes irreversibles. Se analizan brevemente las bases de los puntos de vista antiprogresivistas prevalecientes.

El papel de los animales en la evolución de la biosfera se analiza sobre la base del aumento general de la entropía en el sistema solar. Los animales actúan como vehículos de energía y como estimulantes de la expansión y la eficiencia de la biosfera. Se definen las funciones básicas de la animalidad, considerando sus mejoras como una medida del progreso. Se sigue la evolución progresiva del reino animal a lo largo de su sendero sinuoso y cada vez más estrecho, conforme los diferentes phila se van concatenando sucesivamente debido a sus respectivas cargas estructurales y fisiológicas. En lugar de catástrofes extraterrestres, se considera como un actor a la selección natural a nivel de phila. Segmentos cada vez mayores del mundo animal son inducidos a establecer relaciones de sometimiento con los phila dominantes. La vida animal terrestre, satisfechas sus enormes demandas homeostásicas gracias a una generosa biomasa y a un ambiente rico en oxígeno, tuvo la singular capacidad de dar origen a las formas animales más complejas. Entre los vertebrados homeotermos, la selección natural lleva a los mamíferos a dar origen a los seres animales más inteligentes y más activos en términos energéticos. La aparición de los humanos no es accidental, sino la culminación de un largo proceso "post-hoc" previsible. Es una fase nueva y, una vez más, irreversible en la evolución orgánica, con sus efectos profundos y perdurables.