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MAMMALS VERSUS DINOSAURS: THE SUCCESS OF A CONSPIRACY

If a meteorite had not fallen on the earth sixty-five million years ago, we would not be where we are now; or more exactly we would not be here at all. If icebergs had not covered a third of the globe's surface three hundred million years ago, this collision some two hundred and thirty-five million years later would have been of no benefit to us. If drought had not swept over the Eurasian continent some ten million years ago, we would still be in the trees, and nothing would encourage us to come down from them.

Evolution, and more generally history, is not only a glorious march toward progress; it is also a series of coincidences, of sudden turns and unforeseen detours. There are some things on earth which are as they are because they could not be otherwise, said Pangloss. But there are also other things which owe their present existence to several distant events, long since forgotten, and with no apparent connection to what happened before or afterward. Each time that memory intervenes, in other words each time that an event occurs which brings into play past events and which in turn modifies future events, explanation of the phenomenon escapes an analysis, no matter how minute it may be, of the immed-

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iate internal and external conditions of this phenomenon. The past also counts. Man does not have five fingers on each hand to count to ten more easily. Nor can this particular characteristic be explained by purely mechanical reasons. Man has ten fingers because the first crossopterygian fish to crawl out of the water onto dry *terra firma*, three hundred and fifty million years ago, had ten fingers. And such examples are numerous.

Those who have seen in museums reconstructions of ichthyosaurs, those swimming reptiles from Mesozoic oceans and seas, could not help but be struck by their resemblance to dolphins. But the two groups manifest an equally remarkable, and not easily explicable, anatomical difference: where the caudal fin in all species of ichthyosaurs is invariably vertical, that of dolphins is always horizontal. In fact this difference is even more generally widespread; it extends to all marine reptiles from the Mesozoic Era: plesiosaurs, pliosaurs, mososaurs, etc., all of which have a vertical caudal fin, while in all marine mammals (whales, sirenians, etc.) it is horizontal as with dolphins. For what reasons? The physical properties of water are the same today as in the Mesozoic Era, and so that explanation can be discarded. The mechanical properties of the caudal fin itself are not in question; it paddles as well in one direction as in another. Then why is there this morphological difference between the two groups? To explain it we must go back to the distant *terrestrial* ancestors of ichthyosaurs and dolphins–for both descend from animals who lived on land. The ancestor of the ichthyosaur was a primitive reptile whose anterior and posterior members projected laterally and it could only move itself by contorting its body and its tail. These motions, genetically fixed and perpetuated in the history of its marine descendents, can be found again after its arrival in an aquatic milieu, which provides the source for the vertical caudal fin which still performs the same lateral movements inherited from the past.

The history of marine mammals began quite differently. Their terrestrial ancestors were primitive quadrupeds whose feet supported the body vertically. When they moved into an aquatic milieu, their feet rotated, but still in the vertical plane, bringing them to a horizontal position, like in seals. When this occurred, the locomotive movement, which originally had been from front to back along the dorsal fin, rotated by 90° from top to bottom. It is this

movement performed by feet, which in the meantime became attached two by two by a membrane, genetically fixed and retained throughout all subsequent history, that is found today in dolphins whose fin, we can note in passing, no longer has much relation to the feet of its ancestor since it has lost its internal bone structure and now forms simply a thick muscular paddle in the form of an appendage. Only the *movement* has been retained.

To attempt to explain the morphological differences between ichthyosaurs and dolphins by an adaptation to immediate conditions would thus be a serious error. It is not the environments which differ but the historical antecedents.

Let us consider another, no less eloquent example. The large Australian apterous birds, cassowaries and emus, are capable of such speed in running that they can escape from even the most rapacious predators. Obviously this speed is a response to the rapidity of the attack. However, at present in Australia there is no indigenous species of predator capable of constituting a threat for these racing birds. The wild dog, the dingo, is too recent an import to be considered responsible for such an adaptation, also found in kangaroos.

The answer can be found in paleontology. Fossils have been found of a whole group of marsupial predators—similar to the famous Tasmanian marsupial wolf mercilessly pursued by sheep growers and finally eliminated from the island in the early 1960's—which, toward the end of the Tertiary Era, proliferated over the entire Australian continent until the arrival of the humans and their fearful companion, the dog. But the racing birds survived and are still running from an adversary which disappeared millennia ago. They are fleeing from the memory of their persecutor, unable to forget their own history, like the Japanese veteran who emerged from the jungle so many years after the end of the war and who in his unawareness wanted to continue fighting for his country which had no further need of him.

This soldier shipwrecked on the shores of time reminds me of another example, this time dealing with plants. There exists in South America a tree well known for its fruit which is called an avocado tree. Avocados are apparently meant to be eaten by animals who thereby contribute to the perpetuation of the plant. However, these fruits have such a thick and hard skin that no known frugivorous mammal or bird can succeed in doing so. What,

then, is the source of such an apparently unfavorable development? Daniel Janzen, specialist in tropical flora and fauna, has explained that avocados are truly meant to be eaten, but by animals which no longer exist. South America recently lost (recently on a geological scale, I mean) a whole range of large herbivorous mammals, including some who were frugivorous, whose size exceeded by a great deal the average size of present mammals: mastodons, megatheria, glyptodons and many other giants have today disappeared. Only the plants and fruits which nourished them have survived, adapted to now anachronistic ecological conditions. Such is the avocado.

History is present among us sometimes without our realizing it. And it is not simply a matter of biological oddities, like the examples cited above. Sometimes it is the entire vision of our destiny which is at stake, all the philosophy of our existence. I said that the presence of man on earth resulted no doubt from a collision with some giant asteroid which occurred about sixty-five million years ago. I am going to try to explain why, and how, this accident is of great importance in my opinion.

The Mesozoic Era is often called the Age of Reptiles, and it is easy to understand why. The land was then populated by dinosaurs, the air by pterosaurs and the seas by ichthyosaurs and plesiosaurs. This Age of Reptiles gave way to an era in which amphibians dominated, who then in turn relinquished the stage to an era in which mammals held sway; this age has now lasted sixty-five million years. This much is clear, and this offers us the familiar image of a progressive ascent toward increasingly evolved types in which man represents the perfect conclusion. However, this image is false and would never have gained sway except for our disturbing tendency to seek to impose on Nature philosophical and political convictions which can only be harmonized with it with difficulty when examined more closely.

For although it is true, for example, that mammals supplanted dinosaurs toward the end of the Mesozoic Era, it is no less well proven that mammals can hardly be given credit for this; they had only to wait for the dinosaurs to clear out and then to take possession of the ecological void just created. There was no rivalry, no direct confrontation between them, no struggle, and hence no victors or vanquished. Moreover, how could it have been otherwise

if we consider the physical and biological characteristics of the species involved in this substitution? On the one hand were gigantic monsters, whose weight was measured in tons, the dinosaurs of that era. On the other were minuscule beings weighing only a few dozen grams and who led a nocturnal life so that they were active during the times that dinosaurs were sleeping and *vice versa*. No, there was no struggle there along the lines of a David and Goliath, with the little protagonist defeating the large one because of his greater ingenuity, like the ogre was defeated by Tom Thumb. The smaller being had only to wait until the giant was overcome by a felicitous confluence of circumstances.

To understand this history, we have to turn back the clock of time more than two million centuries to the middle of the Permian Era. Curiously, mammals, or rather their direct ancestors, therapsids (in whom some already see evolved mammals) were already present, everywhere, on every exposed land surface which at that time formed a single continental block called Pangaea. Moreover, they were present in large numbers, making up more than 80% of tetrapod species. Often they were large in size, sometimes gigantic, and perfectly adapted to daytime life. But dinosaurs had not yet been born in this era. Their history did not begin until several tens of millions of years later. This raises a serious problem for the linear evolution of vertebrates, for we find mammals *before* and *after* dinosaurs, and it makes us think more of a closed circuit than a straight line.

Therapsids, those ancestors of mammals with so many points in common with them that the two are sometimes confused, made their first appearance toward the end of a great Permo-Carboniferous glaciation which covered nearly a third of the planet, particularly the south of Pangaea. It is precisely in these cold and inhospitable lands, barely emerged from the ice, that the first therapsids appear. Their adaptation to the cold is a unique characteristic which they seem to be the first to have cultivated; no other large scale true reptile, neither then nor now, would have been capable of this.

As time want on, the climate changed. The earth began to warm up. Therapsids, who were more at ease with cold and humid weather, were forced to change their habits, something which is not always easy. It was then that the thecodonts, ancestors of the

dinosaurs, made their first appearance on earth. More mobile and better adapted to a warm, dry climate, they multiplied and diversified, gradually increasing their size as the therapsids diminished. Thus their evolution went in the opposite direction; by becoming smaller they were able to expel their excess internal heat more rapidly, a capital problem for animals accustomed to the cold and who must adapt themselves to a warmer climate. And they converted to a nocturnal way of life which allowed them to avoid the more torrid daytime hours. This is why at the end of the Triassic period, some two hundred million years ago, the only large vertebrates on the earth were already the thecodonts and the first dinosaurs; therapsids—small, nocturnal mammals—were a barely visible element of the biosphere. The Age of Reptiles had begun.

There is a tendency to see in this progressive miniaturization of therapsids and their move to a nocturnal life the result of an ardent struggle between the two groups, a competition whose outcome would demonstrate the superiority of the victor over the vanquished. However, if the model outlined above is correct (and it has an increasingly large number of adherents in the evolutionist camp), it would seem that the eclipse of the therapsids did not at all result from the presence of their rivals. In fact there was no intermixing at all between the two groups. They simply paid no attention to one another. Competition played no role whatever in the defeat of the therapsids who were above all victims of their past.

However, it is precisely vital concurrence which was to dominate the subsequent history of mammals and their evolution. Independently of all ideas of intermixing or of rivalry between the two groups, of any interfering of the one in the affairs of the other which could bring on or hasten its decline, it should be acknowledged that once the fate of mammals had been settled by their miniaturization, only the presence of thecodonts and dinosaurs in their territory barred all hope of the dominated group to regain its lost position. Living beings have a power of adaptation which can function within certain limits, and the ecological milieu itself is capable of modifying itself in accordance with the degree of tolerance of the organism. This plasticity is what makes evolution possible. Populations singled out by natural selection change from generation to generation. In the case of the evolution of two

parallel lines—of therapsids and thecodonts—each stage accomplished certainly had a stabilizing effect on the ecological equilibrium between the two groups. Each time that a population—or a species of therapsids—left its habitat or abandoned a site, another neighboring population, in the geographical and ecological sense of the word, took possession, thereby provoking the modifications necessary to its own survival. Nature abhors a vacuum, as is said, and each niche left vacant found a new occupant sooner or later. Thecodonts proved themselves to be quick to seize their opportunity. While therapsids were miniaturizing themselves and looking for a refuge in nocturnal living, thecodonts were taking over their abandoned lair. And by doing this automatically blocked any hope on the part of therapsids of returning to their former territory. A new "power relationship" was established. For there is an enormous difference between occupation without a struggle of a deserted habitat and the expulsion of the legitimate occupant by an intruding group, even if the latter is able to lay claim to a right of asylum. This second operation is much more difficult, for its success requires not only a power of adaptation to new vital conditions but the mobilization of means for entering into open struggle with a rival species.

A French-speaking immigrant to an island inhabited by English-speakers would be automatically eliminated unless he began speaking English, even though the French language is by nature superior, as Richard Dawkins says in his book *Le gène égoiste* from which I borrow this flattering comparison. In the case of the history of therapsids and thecodonts—and of their mammal and dinosaur descendents—the application is particularly clear. Mammals, who were reduced to ridiculous dimensions and forced to lead a nocturnal life, remained discreet as long as dinosaurs ruled over the earth—and 140 million years is a long time! Not that this miserable existence was especially suitable for them. For when dinosaurs disappeared at the end of the Cretacean period, mammals regained the foreground and immediately occupied their former territories, thereby demonstrating that they had always been ready to do so and that their condition had been inflicted on them rather than chosen. Under these conditions, how can we say objectively that one group was superior to another simply because it was able for a longer time to keep it at bay and to deprive it of the exercise of

its powers of creation? Only a coincidence of circumstances can allow one group, over a period of tens of millions of years, to impose its law on another, and this at a time when the master-slave dialectic was already perhaps no longer valid. Nothing prevents us from believing that mammals in the Mesozoic Era, left free to do as they wished, would have also been able to grow and develop in daylight, just like dinosaurs, and with intelligence as an added factor. Some even go so far as to say that man could have conquered space and walked on the moon in the Cretacean period if dinosaurs had not tipped the balance in their favor during the Triassic period, although opportunities were basically the same for both groups. There is a bit of exaggeration in such an assertion, but there is also a basis of truth.

Pure speculation, you will say, of course! And it does indeed seem scarcely probable that in Mesozoic conditions, too "easy" to allow a rapid creative evolution, mammals were really much more "brilliant" than dinosaurs. But the problem is not there, at least with regard to what interests us here. The problem is that mammals were prevented from exercising all their creative powers and that their fate was controlled by the dominating presence of dinosaurs. This situation also recalls an experiment called the "ecological cage," frequently repeated in laboratories all over the world. The principle of the experiment is simple. It consists in cutting the bridges between predators and their prey so there can be no intermixing between the two, and then seeing what is the role exercised by the domination of the former over the latter. In other words, how does an ecological group control or inhibit the development of another group, and what would the latter be capable of if it were left to itself.

In practice the experiment consists in introducing a sort of filter between the two populations allowing passage of all that is necessary to the subsistence of herbivorous animals, but forbidding access to their territory by carnivorous animals or various parasites. Technically this can be done by constructing an actual cage over an area of prairie land which protects worms and insects from the birds which feed on them, or of stretching a net along a part of a shore to allow mollusks to live in peace, protected from the starfish whose favorite dish they are. The conditions of existence of mammals in the Mesozoic Era greatly recall the situation of insects and

mollusks before the installation of the cage or the net, a cage which would have allowed them to develop protected from dinosaurs. Let us note, however, that this situation, while it recalls the carnivorous/herbivorous situation described above, also manifested original and quite exceptional features. First of all, the dominated/dominating dichotomy is quite different from the predator/prey dichotomy; the former is asymmetrical and the second circular. For in the first case, only the dominating element influences the dominated, and the total elimination of the latter would probably have no effect on the former. The sudden extinction of all Mesozoic mammals would have no doubt gone unnoticed in the eyes of the dinosaurs. In the second case, asymmetry creates a loop within which predators and prey are mutually independent. Indeed we can conceive of the ecological cage in two manners: either that access to the territory of herbivorous species is forbidden to carnivorous species, or that the latter are deprived of their favorite nourishment.

The second difference touches on the scale of the experiment. What is possible over a few square meters becomes inconceivable if the cage must cover the entire surface of the earth. Particularly since in such a case there would have been no experimenter to construct the cage or to stretch the net.

There were two possibilities remaining for mammals: either to colonize a territory, an ecological zone forbidden to dinosaurs, in one way or another, and there to pursue their vital experiences; or else await the total disappearance of dinosaurs and seize the opportunity to "experiment" on a planetary scale. It seems that both solutions were tried. The second, certainly: the extinction of the huge Sauria dates back sixty-five million years. The first, probably, within the Arctic Circle. Why there rather than elsewhere? Because dinosaurs, due to their size, their rhythm of daytime life and their relative lack of thermal insulation, were probably limited to wandering in warm and highly sunny lands, conditions which were not too difficult to fulfill since they prevailed over a large part of the globe, with just one exception—the polar regions.

And there, in this region which is subject to the rigor of long polar nights, with sparse vegetation and extreme temperatures (even if the climate was certainly more clement in the Mesozoic Era than in our times), mammals found the ideal refuge for hatching their conspiracy. There, protected from the cold and

darkness and free to attain their full development (which seems a rule in polar regions) they were able to feel themselves in full safety. Some American paleontologists, like Van Valen and Sloan, believe that the plot was highly successful and that mammals worked from this base, more precisely from the North Pole, to threaten dinosaurs once the earth's climatic conditions had changed in their favor, leading to the return of a new glacial era. According to another hypothesis, much in favor in recent years but which does not exclude the first one, the end of the dinosaurs was caused not by a progressive cooling down which led to an offensive return of large mammals, but by a brutal catastrophe, like the collision of the earth with an asteroid of gigantic proportions. This collision in turn would have caused the formation of enormous clouds of dust and assorted debris which, once dissipated in the atmosphere, would have covered the entire earth with an opaque layer, filtering out most solar rays and causing a long period of cold and darkness. A long night would have then covered the planet and would have remained as long as the dust was in suspension in the atmosphere.

Such an event would have had repercussions on all living organisms. But it was not felt in the same way by all groups nor by all individuals of the same species. Who would have suffered most from this?

First of all, all organisms whose vital activities depended entirely on sunlight, namely plants. Secondly, all animals who nourished themselves exclusively on these plants. And third, carnivores who depended on animals in the second category. In short, everyone. But if we look at the situation more in detail, the picture becomes more complicated. Let us come back to our dichotomy of dominating/dominated, or, the same thing in other words, of dinosaurs /mammals. It seems clear that the former, accustomed for millions of years to stable conditions and clement temperatures, not equipped with a protective layer and requiring huge quantities of grass for nourishment, would have been particularly vulnerable. On the other hand, the smaller mammals, accustomed to cold and darkness, protected by their fur and content with more frugal fare, were certainly better equipped to survive the crisis. In any case they did survive, assisted by the darkness which covered the earth. Later, after these dusky years, when light and warmth had once more returned, they found themselves all alone to recolonize the

earth and take over the areas left to them by dinosaurs. The ecological cage was set up. Now they needed only demonstrate their know-how.

The rest of the story is well known. There was an extraordinarily rapid expansion in every direction; progressive adaptation to every possible area of colonization, including the air, the seas and the trees of the forest; incredible diversification; and, to crown it all, the appearance of the "noosphere," in other words the domain of knowledge and development of the mind. The path to the moon was laid out. The earth belonged to the humble, to the dominated beings of the Mesozoic Era. The dominators of long ago, those who had been so capable of repulsing the aspirations of mammals, are no longer among us, devoured by their success. The dominated were able to hold out and to resist, even when such was not easy. Moreover, their trials were perhaps in part the explanation for their success. Without pushing things too far, let us note that the development of the brain and the sense organs in Mesozoic mammals (except for vision which could hardly have been expected of nocturnal species) are part and parcel of an adaptation to nocturnal life. Mammals acquired a particularly heightened sense of smell and hearing along with all the neurological mechanisms for analysis and integration needed to compensate for weakness of vision, which had as consequence an expansion of the neocortex. This adaptation survived in mammals who became secondarily diurnal and contributed as by-product to the development of intelligence.

But this is not all. It is also possible that the formation experienced by mammals for millions of years while living in the shadow of dinosaurs had as effect to immunize them, or at least to desensitize them to cataclysms, whether analogous or not to the one which led to the extinction of dinosaurs. Nothing is less sure, but there are good reasons to believe that another collision of the earth with a giant asteroid took place thirty million years after the end of the Cretacean period with the same effects: massive destruction of life on earth, prolonged darkness, a change in climate. Mammals, although seriously tried during this ordeal, survived the catastrophe and even experienced an accelerated evolutionary progress afterward. It is not to be completely excluded that the distant memory of a nocturnal life helped mammals to survive the last Ice Age without too much damage, a period which witnessed the appear-

ance of the most extraordinary creature in the world: the species *Homo sapiens*.

And so a dramatic event, forgotten for sixty-five million years and which concluded a long "conspiracy" between mammals, still works its influence on us without its real and symbolic topicality being diminished in any way. It was not the only one of its kind in the long history of life on earth. Nor have such events been absent from the history of man.

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