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THE FUTURE OF LIFE

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In the two most recent plenary sessions of this Academy that I was able to attend, in 1996, when Pope John Paul II made his celebrated declaration: '*Evolution is more than a hypothesis*', and in 2002, when the present Pope, who was still Cardinal Ratzinger at the time, presented himself as a new member of the Academy, I have expressed some thoughts on the nature, origin, and evolution of life (de Duve, 1997, 2003). Today, in what is most likely my last participation in a meeting of the Academy, I will attempt to take a brief look into the future of life on Earth, as illuminated by our knowledge of its past and present. This topic is discussed in greater detail in a coming book (de Duve, 2009).

First, let me say a few words about the past. Life appeared on Earth at least 3.55 billion years ago, fairly soon after our newborn planet had become physically able to support it. Inaugurated by primitive cells of unknown origin, life remained unicellular for some 2.5 billion years, first in the form exclusively of prokaryotes (bacteria), to which, about 1.5 billion years later, were added the protists. These consist of much larger and more complex cells called eukaryotic and containing a nucleus, an elaborate membrane network, intricate cytoskeletal structures, and several cytoplasmic organelles, including lysosomes, peroxisomes, mitochondria, and, in photosynthetic organisms, chloroplasts. Many representatives of these microbes, both prokaryotic and eukaryotic, still abound in the world today.

Only about one billion years ago did eukaryotic protists first give rise to multicellular organisms. Plants led the way, soon followed by fungi and, 400 million years later, by the first animals. These started by blossoming into the rich world of invertebrates, of which one group eventually evolved into the first marine vertebrates, the fish, which, in turn, gave rise to the partly land-adapted amphibians, followed later by the fully land-adapted reptiles, from which arose birds, on one hand, and mammals, on the other.

Primates arose among the mammals some 70 million years ago, evolving to produce, in addition to a variety of apes and monkeys, a line, initiated some 6-7 million years ago, that led to the human species. Note the extreme lateness of this crucial event, which took place in the last 100th part of animal evolution, the last 600th part of the evolution of life.

The advent of humankind was signalled by several important acquisitions, including bipedalism, increased handiness, and, especially, a larger and more complex brain, which, in little more than two million years, almost quadrupled in size, from a volume of about 350 cm^3, the size of the brain of present-day chimpanzees, our closest relatives, to a volume of some 1,350 cm^3.

These acquisitions have allowed a fantastic evolutionary success, without equivalent in the entire history of life on Earth. Our early ancestors numbered about 3,000 when they separated from the Neanderthals, at a time estimated from recent DNA studies to lie between 800,000 and 500,000 years ago. There were about 10,000 of them 200,000 years ago, when 'mitochondrial Eve' and 'Y Adam' started *Homo sapiens sapiens* on its final evolutionary journey. They may have been on the order of 5-10 million, scattered over a good part of the world, when the first durable human settlements were created some 10,000 years ago. Since then, the human population has grown at an ever-increasing pace, reaching about half-a-billion in the time of Galileo, passing the one-billion at the start of the nineteenth century, and rising from less than 2 billion to more than 6.5 billion just in the last 100 years, coming to invade, occupy and exploit almost every habitable – or, even, uninhabitable – site on our planet. Ours is, by far, the most successful species – I leave out microbes – in the whole of biological evolution.

This success has a cost, briefly summarized in Table 1. We read or hear about it almost daily through the media. It is known to all of us and I need hardly elaborate. What I wish to do is extrapolate from the past and present to the future. If things continue in the same direction, there is little doubt that we are heading for disaster, soon to reach a point where we will be driven to extinction, together with a good part of the living world. If this happens, it will be nothing new in the history of life, including the recent history of humankind. These histories are landmarked by extinctions. But there will be a difference. Most likely, past extinctions were invariably associated with some kind of *failure* in the face of an external challenge (drought, glaciation, or other climate change, geological upheavals, meteorite impacts, epidemics, extermination by a more successful competitor, etc.). Our extinction, if it occurs, will be the consequence of inordinate evo-

TABLE 1.

The Cost of Success

1. Exhaustion of natural resources
2. Loss of biodiversity
3. Deforestation and desertification
4. Climate change
5. Energy crisis
6. Pollution
7. Overcrowded cities
8. Conflicts and wars

SUMMARY: IRRESPONSIBLE EXPANSION

lutionary *success*. We have developed to the point of endangering the ability of our planet to support us. If we go on following the same course, it can only lead to our doom.

Contemplating this ominous picture with the eyes of a biologist, I find a single culprit: *natural selection*. I use the word 'culprit' metaphorically – no guilt is involved – but, as will be seen later, the image is not entirely inappropriate. Natural selection is the process, now overwhelmingly established as a dominant evolutionary mechanism, whereby the forms of life that are most apt to survive and produce progeny under prevailing conditions obligatorily emerge from whatever set of organisms happen to compete for the same resources. All that is known about this process indicates that the variants on which it operates are accidentally generated, without intentionality or guidance, contrary to what is claimed by the defenders of intelligent design. Another key feature of natural selection, of special importance for our topic, is that it is governed entirely by *immediate* benefits. Natural selection has no foresight.

There is every reason to assume that humans are, biologically, products of natural selection, like all other forms of life. This implies that evolution has privileged in human genes traits that were immediately favorable to the survival and proliferation of our ancestors under the conditions that obtained there and then, regardless of later consequences. This is intrinsic to the process of natural selection. Note that I leave out traits that were

acquired by cultural evolution and transmitted by education. I shall turn to these later. Right now, I will deal only with genetically inscribed traits.

On an individual basis, human traits retained by natural selection included intelligence, inventiveness, dexterity, skillfulness, resourcefulness, and ability to communicate, all the qualities that have served to generate the fantastic scientific and technological achievements responsible for our evolutionary success. But the selected traits also included acquisitiveness, selfishness, greed, cunning, aggressivity, and any other property that ensured immediate personal gain, regardless of later cost to oneself or to others. The recent financial crisis has illustrated in a particularly dramatic fashion how such traits still flourish in the world today. On the other hand, genetic qualities whose benefits would become manifest only in the long run, such as far-sightedness, prudence, a sense of responsibility, and wisdom, were not singled out by natural selection. Their fruits would have appeared too late for that.

On a collective level, natural selection has favored traits, such as solidarity, helpfulness, cooperativity, tolerance, empathy, compassion, altruism, even personal sacrifice for the common good, that form the bases of human societies. But the selection of those traits has been mostly restricted to the members of given *groups*, united first by shared kinships and territories, and later by shared interests, a shared language and culture, shared beliefs, shared prejudices, even shared hatreds. The negative counterpart of those 'good' traits has been collective defensiveness, distrust, competitiveness, and hostility against members of other groups, the seeds of the conflicts and wars that have landmarked the whole of human history up to the present day.

In other words, the defects that endanger the future of our species and of much of the living world are *inborn*, written and sustained in our genes by natural selection. They were useful in the past, at a certain stage of our evolution but have become deleterious; they are a natural burden we assume at birth. I would like to suggest that awareness of these innate genetic defects inspired the notion of *original sin*. That is why calling natural selection the 'culprit', as I did earlier, is not entirely inappropriate, except, of course, that no culpability is involved. There is no Eve to blame, no serpent, only natural selection, which is mindless and without intention, devoid of foresight and responsibility.

Is there anything we can do? Fortunately, yes. Of all living beings on Earth, we humans are the only ones that are not slavishly subject to natural selection. Thanks to our superior brains, we have the ability to look into the future and to reason, decide, and act in the light of our predictions and

expectations, if need be against our immediate interest, for the benefit of a later good. We enjoy the unique faculty of being able to act *against natural selection*. The problem is that, in order to do this, we must actively oppose some of our key genetic traits, surmount our own nature.

It would be nice if we could correct our genetic defects by engineering, removing the bad genes and implanting good ones. We can do this to a limited extent with plants and animals; but we cannot possibly do the same with humans. We do not yet have a sufficiently reliable technology for human application. Even if we had it, we would not know what genes to modify in order to achieve a certain goal. Our knowledge of the genetic basis of psychological traits is still in its infancy. Even if we had this knowledge, there would be the problem of deciding who should benefit from the interventions. Finally, there are all the ethical objections such manipulations are likely to raise. So I won't waste time discussing this way out of our predicament. We are not ready, whether scientifically, technologically, or ethically, to create GMHs, genetically modified humans, for specified aims, as we do other organisms.

But there is another way out, provided by the fact that the structure of the human brain is genetically determined only in its general architecture. Its fine wiring takes place *epigenetically*, under the influence of the various stimuli to which the brain is subjected. Note that I use the word 'epigenetic' in its original meaning of 'added to the genetic', a meaning given to it by the developmental biologists who invented it and still used by neurobiologists; not in its new meaning of 'genetic, but not inscribed in DNA sequences', now accepted by many geneticists and molecular biologists.

It is known, from the work of Gerald Edelman, in the United States, and of Jean-Pierre Changeux, in France, that, in the developing brain, growing neurons continually send out extensions in various directions. Upon chance encounters between such extensions, the neurons form temporary connections, which are rapidly undone unless they happen to be repeatedly used, in which case they become stabilized as synapses. Thus, the stimuli to which the growing brain is subjected operate some kind of selection among the many interneuronal connections that are created by chance. The similarity with Darwinian selection has not escaped the authors. Edelman, for example, speaks of 'neural darwinism'.

Thus, the wiring of a human brain, which forms the underlying substrate of the thoughts, feelings and other mental processes the brain can experience, is largely determined by the impulses conveyed to it by the external stimuli to which the body is exposed. In a way, this has always

been known by all those who have had something to do with educating the young. Educators have always been aware of the importance of their work in the 'molding' of young brains. What is new is the realization that this process starts at birth, perhaps even before birth, and that parents, nannies, nurses, kindergarten personnel, elementary school teachers, baby sitters, that is, all those who deal with very young children, exert key influences on the wiring of the children's brains.

Thus, if we wish to create in young brains neuronal networks conducive to tolerance, sympathy, peacefulness, reasonableness, foresight, and wisdom, we must first do so with the parents and educators. Doing so in one shot is clearly impossible, but one can imagine initiating a self-enhancing movement that would progressively snowball into becoming worldwide. But for this to happen, the movement must be set in motion.

This brings me to my final message, of special significance within these walls. It concerns the role of *religions*. Historically, religions have always played a major role in the education of the young, even of adults. Even today, their influence in this domain remains tremendous. Religious leaders are, even more than the most powerful political leaders, uniquely placed to influence large crowds. When the Pope speaks, he reaches more than one billion individuals. Thus, he and the leaders of the other major religions are invested with an immense planetary responsibility. They are almost the only persons in the world who could play a decisive role in rescuing humanity from its suicidal course. They are particularly well placed to do this, in view of the millennia-old tradition of tolerance, love, and understanding that, originally, has been the main message propagated by the major religions.

Unfortunately, Churches have not escaped the genetic 'original sin' that plagues the whole of humanity. One cannot generalize, of course. There are important differences among the various religions. But each is, to a greater or lesser extent, tainted with authoritarianism, fundamentalism, doctrinal dogmatism, ethical rigidity, exclusiveness, extending, in some cases, to nationalism and strife, sometimes armed, even murderous.

The Catholic Church is not exempt from these defects. I hope that this statement, expressed within these venerable walls, will not be seen as disrespectful or unsuitable. This Academy was created to promote the free intercourse of ideas, within a framework of open-mindedness, intellectual honesty, and sincerity. With your permission and with apologies to those who disapprove, I will avail myself of this spirit, which corresponds to the true scientific attitude.

In my opinion, it is our duty, as members of this august body, to alert the higher Authorities to the extreme gravity of the menaces that weigh on the future of humanity and of planet Earth and to the urgent necessity of acting against those threats by all possible means. The facts (see Table 1) speak for themselves. They are evident and undeniable. We ignore them at our peril. The final outcome, if nothing is done to change the course of events, leaves little doubt. The Church, with its unique worldwide power and influence, bears an enormous responsibility in directing this course for better. If there is agreement on this point, this is a message our Academy, as advisor to the Holy See, could respectfully convey to the Magisterium.

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