the Pontifical Academy of Sciences

Contemplation on the Relations Between Science and Faith

Paper offered by Prof. Werner Arber (University of Basel, Switzerland – President of the Pontifical Academy of Sciences) to the Holy Father, and to the members of the Synod of Bishops on 12 October 2012 on "The New Evangelization for the Transmission of the Christian Faith".

Introduction

Curiosity is a basic property of the human mind. On the one hand, it is the driving force of scientific investigations seeking to identify natural laws. On the other, curiosity is also at the basis of every human being's interest in knowing the fundamental laws of nature as an essential contribution to his own search for meaning and truth. Whereas the sciences are far from being able to give appropriate responses to all the questions raised, especially the ones transcending the natural sphere, various beliefs (including the ones that have their source in religion) also play an important role in answering the question about meaning. They are essential parts of the orientational knowledge that serves to guide our human activities. In this context we would like to raise the question of the mutual relations and compatibilities between scientific knowledge and the essential contents of faith.

Context and impact of orientational knowledge

Orientational knowledge is built up and updated in the human mind during our entire lifespan. It contains elements already acquired during embryonic development and early childhood. It is then enriched by education and by one's personal search for the truth. Established scientific knowledge is thereby placed side by side with various kinds of beliefs, including religious faith. Incidentally, we may consider that agnostics also have a specific belief, namely in the non-existence of God. In many of our daily activities, and particularly in making important decisions, we are guided consciously, or often also subconsciously, by our orientational knowledge. We can consider orientational knowledge as a socializing element in our lives. It helps make our activities compatible with our life in community and with a sustainable use of our habitats and of the available resources.

Cosmic evolution and biologic evolution as facts that reveal important laws of nature

The Pontifical Academy of Sciences repeatedly deals with the steadily increasing scientific insights into both the evolution of the Universe and the evolution of life. These are largely based on observing the ongoing evolution. At least some of these notions can allow us to draw conclusions on past evolutionary processes. But so far the sciences still have no detailed knowledge of either the origin of cosmic evolution (e.g. how did the fundamental particles, the building elements of matter, come about?) or the roots of life (how did all the elements required for life activities come together?). In other words, as yet we have no firm scientific evidence for a so-called creation ex nihilo, which remains for philosophy to deal with. On the other hand, the ongoing processes of evolution of the Universe and of life are now well-established scientific facts that serve as essential elements of permanent creation.

In recent centuries, and increasingly in recent decades, scientific investigations have revealed through highly efficient research strategies that our Universe is tremendously large in size and also contains, besides a very large number of solar systems, the still mysterious so-called dark matter and dark energy. And this entire complex, of which our planet Earth is just a minute component, is known to be in a slowly progressing, steady evolution. Any attentive observer may notice the physical evolution happening on our planet in relatively small steps, such as landslides.

We currently assume that life may also exist on some extraterrestrial planets, but scientific evidence for this assumption is still pending. On the other hand, the life sciences have acquired extensive in-depth knowledge about the complexity of life processes, both in terms of the processes in individual organisms and of ongoing biological evolution at the level of populations.

Spontaneously occurring genetic variation as the driving force of biological evolution

For roughly 60 years we have known that life processes are dependent on the genetic information that is encoded in very long stands of the nucleic acid DNA. The specific linear sequences of only four different building blocs (nucleotides) encode for all life processes and control their expression at the required times and sites within the organism. If we compare the sequences of nucleotides with the sequences of letters in our texts, the genetic information of a single-celled bacterium corresponds to the content of a book. For example, the widely studied E. coli bacterium corresponds to the information content of the Bible. By contrast, the genetic information of multicellular plants and animals often corresponds to an encyclopedia of 100 up to 1000 volumes of the size of the Bible. The human genome corresponds to about 700 such volumes.

Genetic information is passed from generation to generation. Occasionally an alteration of the parental nucleotide sequences occurs in this process. Some of these alterations cause a change in a phenotypic trait of the concerned organism. Such alterations are more often known to affect life activities negatively rather than provide a functional advantage to the concerned organism. Moreover, a considerable part of spontaneously occurring sequence alterations has no immediate effect on life functions.

According to the theory of biological evolution based on Charles Darwin's postulate of natural selection acting on phenotypic variants, the spontaneous generation of genetic variants is the driving force behind biological evolution. Scientific research in recent decades has made it clear that a multitude of different specific mechanisms can contribute to the generation of novel genetic variants. These so far known molecular mechanisms can be assigned to contribute to one – and in some cases to two – general mutagenic strategies found in living organisms. One of these natural strategies of genetic variation implies a local nucleotide sequence change, such as a nucleotide substitution, the deletion of one or a few adjacent nucleotides, the insertion of one or a few additional nucleotides, or finally a scrambling of a few adjacent nucleotides. This can happen by means of the replication of DNA molecules or the impact of a mutagen. A second natural strategy of genetic variation produces a segmental rearrangement of the available genetic information of an organism. This can result in a duplication, in a translocation or in a deletion, normally of a small part of the genetic information of the concerned organism. The third natural strategy of genetic variation consists in the acquisition of a relatively small segment of genetic information from another kind of organism by so-called horizontal gene transfer.

It is natural selection that will sort out and maintain those rare variants that provide a functional advantage to the organism. We can further note that each of the three natural strategies of genetic variation contributes with a different quality to biological evolution. Local DNA sequence changes can contribute to a stepwise improvement of a particular function. DNA rearrangements of segments of available genetic information can lead to novel fusions of functional domains or the fusion of an existing gene with an alternative element for the control of gene expression. Finally, the strategy of DNA acquisition is seen as a participation in the functional success of different kind of living organism.

The natural potential to evolve and its impact on biodiversity

Particular gene products and some non-genetic elements are both generally involved in the natural generation of genetic variants. The products of so-called evolution genes thereby act as variation generators and/or as modulators of the rates of genetic variation. Non-genetic elements may be caused by chemical or physical mutagens, random encounter and structural flexibilities such as isomeric forms of biological molecules. One can assume that in the long-term past evolution, evolution genes had become fine-tuned to exert their evolutionary functions consisting in the occasional generation of novel genetic variants. These processes are largely contingent as regards the site of the DNA sequence alteration and also with regard to the time of mutagenesis. The rates of any kind of genetic variation are naturally kept quite low. This ensures sufficient stability of the genetic information of living organisms, which is a prerequisite for sustainable living in populations. In conclusion, the living world actively takes care of biological evolution thanks to its natural potential to undergo biological evolution. In other words, biological evolution is a steadily ongoing natural process of permanent, step-by-step creativity

We are aware that the natural potential to evolve is the source of biodiversity and that ongoing biological evolution also guarantees a steady, although very slowly progressing, replenishment of biodiversity. However, in view of the largely contingent generation of genetic variants, one cannot expect lost biodiversity to be restored precisely in the future process of evolution. Replenished biodiversity can rather be expected to represent mainly novel kinds of mutant organisms.

Cultural values of scientific knowledge

Scientific insights into the laws and constants of nature are cultural values from the following two points of view: on the one hand, established scientific knowledge enriches our worldview and thus contributes to our orientational knowledge. On the other, scientific knowledge can also open novel approaches to technological applications and innovations for the benefit of our lives and our environment. Since such innovations will often contribute to shaping the future, ideally we should postulate that any respective decision should depend on careful technological assessment and, on the other hand, that the civil society and the Church are ready to take co-responsibility – with the scientists and with the economy – in reshaping the future with prospective benefits for mankind and for its environment. Such measures can help ensure the sustainability of the process and thus the long-term future development on our planet.

The role of rules of conduct for Humanity

We are aware that our life in society requires some binding rules of conduct that should become an integral part of our orientational knowledge. In modern societies, politically established legislation ensures that recommended rules of conduct are widely followed. Acceptance of such rules can be facilitated if their principles are also anchored in a religious faith. In the Christian society, important rules of conduct were propagated by Jesus Christ throughout his life and have been widely followed by Christians ever since. Nevertheless, it is an important task of today's societies to update the established set of rules, paying particular attention to our acquired scientific knowledge. In this context, I assume that if Jesus Christ were still alive among us today, he would be in favor of the application of solid scientific knowledge for the long-term benefit of humans and of their natural environment, as long as such applications, which lead to shaping the future, could ensure that the relevant laws of nature were fully respected.

Let us briefly illustrate this postulate by a particular example. Thanks to the recent advances in genomics, proteomics and metabolomics, it has become possible to direct biological evolution in order to better fulfill our needs for healthy nutrition as a contribution to medically relevant improvements. The Pontifical Academy of Sciences devoted a study week in May 2009 to this issue with particular emphasis on transgenic plants for food security in the context of development. Our Academy concluded that recently established methods of preparing transgenic organisms follow natural laws of biological evolution and that there are no risks anchored in the methodology of genetic engineering. Indeed, these methods involve local sequence changes, a rearrangement of segments of the genetic information available in the concerned organism, and/or the horizontal transfer of a relatively small segment of genetic information from one organism to a different kind of organism. As explained above, these are the three natural strategies for the spontaneous generation of genetic variants in biological evolution. The beneficial prospects for improving widely used nutritional crops can be expected to alleviate malnutrition and hunger still existing in the human population of the developing world.

The compatibility of scientific knowledge and religious faith

For a long time curious human beings have acquired scientific knowledge primarily by observing with their senses and aided by mental reflections including logical reasoning. The chapter of the Genesis in the Old Testament is for me a testimony of an early scientific worldview already existing several thousand years ago. This chapter also reflects a wide consistency between religious faith and available scientific knowledge. It proposes a logical sequence of events in which the creation of our planet Earth may have been followed by the establishment of the conditions for life. Plants were then introduced and subsequently provided food for animals before human beings were finally introduced. Leaving aside the question of Revelation, this is clearly a logical narration of the possible evolutionary origin of things by imaginary events that led to the nature that the ancient populations could observe. From the genealogy outlined in the Old Testament I can also conclude that its authors were aware of phenotypical (i.e. genetic) variants. The people described have their own personal characteristics and are not genetically identical clones of Adam and Eve. In these stories we find a good consistency between early religious faith and scientific knowledge about evolutionary developments. It is our duty today to preserve (and where necessary restore) this consistency on the basis of the improved scientific knowledge now available. I am convinced that scientific knowledge and faith are complementary elements in our orientational knowledge and should remain so.

Conclusions

Placing particular emphasis on the evolution of life and of its environmental habitats, we have outlined here how scientific knowledge, together with other elements of our orientational knowledge, can influence human activities, including the application of scientific knowledge for the benefit of human well-being and of an intact environment for the long-term sustainable development of our planet Earth and its inhabitants. The examples given here can be extended to any other course of action based on available scientific knowledge that may serve for a sustainable cultural development. In this respect, the Pontifical Academy of Sciences tries to fulfill its mission of critically following the development of scientific investigations and the application projects of acquired knowledge. It periodically issues its publications – both in book form and digitally on its website www.pas.va – to inform the scientific world, the Church hierarchy, and all Christians and people of good will of its work, and also makes relevant recommendations in favor of a safe, responsible and sustainable development.