Towards a Sustainable Use of Natural Resources by Respecting the Laws of Nature

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Introduction

On our planet Earth a remarkable diversity of living organisms exists which make use of a great number of diverse habitats. This represents a highly complex global system of mutual interdependencies, both between different forms of life and of living organisms with their used habitats (1). Although this global setup reflects a relatively comfortable stability, both the living world and its habitats undergo a slowly progressing but steady evolution (2).

Most kinds of living organisms are forced to use a number of natural resources such as available nutrition, potable water, sources of energy and other life-supporting elements. Thanks to its remarkable intelligence the human species has been quite successful in doing so. It is in particular in recent centuries that our impressive acquisition and progression of scientific knowledge together with its beneficial applications has provided various kinds of benefits and facilities to human life. This raises the question of responsibility to ensure a long-lasting sustainable development on our planet. Answers to this question will be sought in the following sections.

Appreciation and cultural values of scientific knowledge

In the course of recent times, ever more powerful methodology has allowed the scientific community to acquire in fundamental research a remarkable treasure of scientific knowledge. This basic knowledge includes deep insights into the fundamental laws of nature and represents cultural values for our civilization (3). On the one hand, scientific knowledge enriches our worldview, which forms part of man's orientational knowledge influencing his decisions, including those which impact on sustainable development. On the other hand, it is often novel scientific knowledge together with appropriate methodology that can lead to practical applications to the benefit of human life, as well as of the wider environment. Good examples for this general outline can be found in many disciplines of scientific investigations. In the life sciences, striking developments currently occur in genomics and its applications (4).

Insights into cosmic/terrestrial evolution

Astrophysical investigations indicate that the Universe in which we live must have steadily but slowly evolved since about 14,000 million years ago. At the microlevel, fundamental particles contributed to form atoms, chemical elements, composing matter. At the macrolevel, numerous galaxies appeared in the course of time. Their stars are solar systems with extremely long but limited life times. Our solar system with its planets must have an approximate age of 4,500 million years. Our sun can be expected to continue to provide energy to the Earth still for a few thousand million years.

Insight into biological evolution

Life on our planet is postulated to have its origin some 3,500 million years ago and it must have slowly evolved ever since that time to reach by today a remarkable diversity of forms of life. These have in common to be able to replicate and to have the potency to undergo evolution at the level of their populations.

Molecular genetic research has revealed that diverse specific molecular mechanisms contribute stepwise to the evolution process by occasionally forming a genetic variation in an individual organism. The so far closely studied specific molecular mechanisms can be assigned to three qualitatively different groups that we call natural strategies of genetic variation (5).

A first strategy brings about a local change in the nucleotide sequence of the genome. Such local changes can be a nucleotide substitution, a deletion or an additional insertion of one or a few nucleotides, or a scrambling of a few adjacent nucleotides. Local genetic variants can have their origin upon DNA replication or by the impact of a mutagen. Local mutations occur quite rarely thanks to the preventive action by repair enzymes that modulate the rate of local genetic variation. Only occasionally a local mutagenesis brings about an improvement of a biological function. This then provides the organism in question with a selective advantage in comparison with its parent. More frequently, a new genetic variation results in a selective disadvantage by an impaired or lost function.

A second natural strategy of genetic variation consists in an intragenomic rearrangement of DNA segments. Recombination enzymes are thereby usually involved. Such rearrangements can bring about the duplication, the deletion, the transposition or the inversion of a DNA segment. This can lead to the loss of function or the novel fusion of previously independent functional domains. In the latter case, the DNA rearrangement may, by chance, result in an improved or even in a novel function providing a selective advantage. Segment-wise DNA duplication provides means for sub-

sequent further mutagenesis in one of the copies while the second one may maintain its inherited essential function.

A third strategy of genetic variation consists in the acquisition by horizontal DNA transfer of a segment of genetic information from another kind of living organism. The DNA acquisition strategy can provide an elsewhere developed, useful biological function to the receiving organism in only one step. This strategy is a sharing in the evolutionary success of others. The universality of the genetic code, i.e. of the genetic language used, favors the success of this strategy (6).

These three natural strategies have in common to affect in each step of genetic variation only a tiny fraction of the whole genomic information. This ameliorates the chance of spontaneous mutagenesis to bring about a functional improvement (rather than a functional disharmony) to the organism in question. But we have to be aware that spontaneous mutagenesis events are largely conjectural (7). As a matter of fact, this makes sense, if we look at the global system of evolving life in evolving environments. Living beings can, of course, not predict which different kinds of environmental living conditions they are going to encounter. Adaptation goes stepwise by the impact of natural selection on populations of different genetic variants and their parents. Natural selection reflects the capacity of a living being to deal with its environment, i.e. with the physico–chemical composition of the environment and with other forms of life in the given ecosystem.

Self-organization or intelligent design?

A critical evaluation of the scientific knowledge on biological and on cosmic evolution indicates that these processes reflect nature's self-organization. This points to intrinsic potencies to undergo steps of alterations: genetic variation as the driving force for biological evolution and steps of various kinds of structural and compositional transformations in cosmic/terrestrial evolution. We, human observers, can be particularly impressed by the logical nature of these processes. This raises the question of a possible direction of evolution by "intelligent design". So far, we have no scientific argument that would point to this concept of a designer, a planning authority for the macro system of evolving life in an evolving environment. Nevertheless, the encountered situation representing permanent creation can appear wonderful and miraculous to the human observer. This requires and justifies a deep respect for the natural processes of evolution and a particular care not to interfere drastically with the evolutionary processes on our planets.

Additional facts to be considered

We have become aware that living beings do not only depend on their own genetic information; rather, they may profit, or sometimes suffer, from impacts by their environment. Many epigenetic effects are responses to environmental contacts and can influence various life performances. On the other hand, living organisms often show genetically anchored possibilities to live in various kinds of environment. Think, for example, of bacteria able to grow on different alternative sources of energy. Genetic expression can thereby respond to the encountered environment. Another situation largely neglected until recently is the cohabitation of various living organisms. Symbiosis between microorganisms and higher forms of life (humans, animals, plants) greatly facilitates life of the cohabiting partners. Only rarely microorganisms can thereby become pathogenic, either by novel mutations or by environmental impacts. These few indications can remind us of the long-neglected complexities of sustaining life in evolving environments.

Fundamental laws of nature can provide guidance for a sustainable development

Fundamental laws of nature are known to influence and regulate capacities and processes intrinsic to the living world and/or the inanimate world. We have here already referred to the situation in biological and in cosmic/terrestrial evolution. Another example can be the laws controlling chemical and physical stabilities of atoms and molecules including tautomery and atomic decay. Generally speaking, it is a good precautionary principle to respect the laws of nature in the inventive application of acquired scientific knowledge to the benefit of the human population and its environment; together with other measures this can insure sustainability of the development. Other measures can involve, for example, the prediction of possible impacts by a scientifically based technology assessment before an envisaged innovation becomes introduced. Similarly, it is advisable to carry out scientifically based policy assessment before political measures to either favor or hinder the introduction of possible innovations become activated.

Genetically modified food plants

As an illustration to these suggestions, let us turn our attention to genetic engineering applied to essential food plants. Genetic engineering was inspired by, and it generally follows, the three natural strategies of genetic variation: i.e. local DNA sequence changes, intragenomic rearrangement

of DNA segments and insertion of a DNA segment from another kind of living organism. These manipulations are not done randomly but with good knowledge of the specific biological functions involved. These experimental approaches are most successful if only small amounts of genetic information are involved, as it is also the case in spontaneous genetic variation. In addition, we have to note that any engineered genome will reveal its activities and viability under the pressure of natural selection, as it is the case in spontaneous genetic variation. We can conclude that directed evolution by genetic engineering follows fundamental laws of nature and should thus not be expected to be associated with method–specific unforeseeable dangers (8). This holds at least as long as horizontally transferred genes are actually taken from a living organism.

As a suggestion for a sustainable contribution to provide accessible and healthy nutrition to all human beings, we have discussed a road map to enrich nutritional values as well as the plant's health of a number of widely used food crops (9). It should be possible to reach this goal by genetic engineering based on our increasing knowledge in genomics and metabolomics accompanied with careful experimental testing for the envisaged results. If successful, this approach may, in fact, lead to a largely vegetarian diet. This might, at a longer term, free large surfaces of agricultural land from growing animal feed and render it available for growth of food plants for human nutrition.

Limited carrier capacity of our planet

As we have seen, we find on our planet Earth a very rich diversity of forms of life using a remarkable diversity of habitats. But the space available on our planet must have remained constant during many million years of past evolution. We have good reasons to expect and to hope that this remarkable richness will continue to evolve on the basis of the present diversity. Thus, our civilization should avoid drastically disturbing the natural process of this slow but steady evolution of forms of life and of potential habitats for a rich biodiversity. This strongly requires humanity to abstain from claiming more and more fertile soil to exclusively produce food crops by agricultural practice with monocultures. These requested limits to overuse the available carrier capacity of our planet mainly for human beings requires the human population to reach an equilibrium that may allow for a largely undisturbed, further biological evolution of many different forms of life in a rich diversity of habitats. Let us remember that our sun can be expected to send energy to Earth still for many million years. Sustainable development should avoid strongly interfering with the ongoing process of biological evolution in the context of terrestrial evolution.

Tasks of education

It will be an important educational task of the scientific community and the political leadership to spread and to validate the fundamental principles discussed here. This can enrich our worldview as part of our orientational knowledge, the basis for our behavior and activity. A well-informed population can be expected to contribute to a long-term sustainable development of life on Earth.

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