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EVOLUTION OF THE BIOSPHERE AND ECOLOGICAL FORECASTING

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Man's interrelation with Nature which has generated in him the relationship between the biosphere and the sphere of reason and labour, the noosphere, is one of the most important and involved issues facing mankind. The conflicts that are arising on this ground are sometimes interpreted as a global ecological crisis and are numerous and diverse. On closer examination, however, they do in most cases stem from a common root, which comes down basically to the conflicting interaction of two systems capable of self-regulation, the biosphere and human society.

The ecological crisis is not so much the outcome of man's thoughtless activities which cause destruction of biological resources, as it is a consequence of the fact that the capacity of natural complexes for self-regulation is undermined or that the self-regulation begins to "work" against man and mankind. The emergence of a socialist society creates objective preconditions for a new harmonious union. These preconditions will not be used to advantage unless the laws of the biosphere's evolution are known. The guidelines of this approach have been laid down by V.I. Vernadsky and V.N. Sukachev.

For a very long time evolution was regarded as nothing more than the development of organisms, as the flow of phylogeneses. But it has now become clear that the evolution of organisms and that of the biosphere are two interrelated processes. The biosphere's structure and functions do not remain invariable, but are changing together with the changing morphophysiological properties of organisms. Nevertheless the basic properties of living matter and of the biosphere as a whole have been virtually immutable for more than 3,000 million years. Classical examples of this are the common hereditary code of all the organisms inhabiting the earth and the universal principle of the transformation of energy. The basic structure of elementary communities capable of self-regulation and development also emerges, with all its distinctive features, at the very dawn of life.

Photosynthetic plants - producers creating primary organic substance; animals - consumers feeding on plants and on other animals; and bacteria - reducers and destroyers. It is a commonly known scheme. It is also generally known that the activity of bacteria reducing organic substance to a form in which it can be assimilated by plants is as indispensable a part of the earth's natural cycle as the process of photosynthesis. Obviously, the processes of creation, accumulation and decay of organic substance even at the dawn of life must have been coordinated in some way to secure the continuous cycle of matter and energy. A major feature of the biosphere's activity was the considerable pre-eminence it gave to processes of production over those of destruction, to creation over decay. As a result, oxygen appeared in the atmosphere and combustible minerals in the bowels of the earth. This phenomenon must have been fully manifest at the very early stage of life's evolution, since by the time multicellular organisms emerged (680 million years) the oxygen content of the atmosphere already amounted to 10 per cent of its present level. In this way an ozone screen was formed which protected the live systems from the damaging effects of UV-radiation, which, in turn, intensified the oxygen inflow into the atmosphere. The primal precondition for an unlimited morphophysiological progress had been brought about by unicellular organisms in the course of their evolution. Subsequently, the atmospheric homeostasis - the maintenance by life of optimum physico-chemical conditions for its own development - became a law of the biosphere's evolution. The present-day concentration of oxygen in the atmosphere and the strict balance between the oxygen cycle and the carbon cycle date from a time about 50 million years ago. This meant a dynamic stabilization of the biosphere at the highest level of integration of living matter. It was an emphatically important event. It is important indeed for us to know the sort of biosphere that mankind had found itself in when it attained the planetary frontier of evolution. The biosphere had maintained optimum proportions of the vital elements in the atmosphere for hundreds of millions of years. Several decades of the industrial revolution have been enough to disrupt this equilibrium. This mere fact impresses on me the urgency of "Man and Biosphere" problem more than a thousand local ecological confrontations can do.

The producers - consumers - reducers triad underlies any plant-animal association, any biogeocoenosis. But depending on the specific ecological and morphophysiological features of the member species of the triad, the workings of the biocoenosis may be different. Compare, for example, three groups of herbivorous animals - primary consumers - insects, small rodents, and ungulates.

Large herbivorous mammals consume from 30 to 60 per cent of the primary production of the biogeocoenosis, while insects and rodents rarely account for more than 10 per cent. But rodents assimilate more than 80 per cent of the energy they consume, whereas large herbivores, not more than 6 per cent, and insects, 30 per cent. But then insects use up to 30 per cent to build up their body's biomass of the energy assimilated, whereas mammals usually expend not more than 2 per cent on it. Therefore, insects' productivity can be superior to the maximum productivity of mammals by an order. However, even insects cannot transform into their own biomass more than 5 per cent of that of plants (with mammals it is just 0.7 per cent). Naturally, such differences in the ecological physiology of different groups at one trophic level predetermine the overall workings of the biogeocoenosis. It becomes evident that the emergence, in the course of the evolution, of organisms characterized by some basically new relationship to the environment (fish, insects, reptiles, herbs,etc.) resulted in the change in the biosphere's structure and function. At this point it is very tempting to take a closer look at the global consequences of the appearance of new organism groups signalling the formation of essentially important aromorphoses. Understandably, this is out of the question, so let us confine ourselves to the global results of the appearance of homothermal (warm-blooded) animals. Their appearance in the history of the biosphere was comparable in importance to the origin of man . An animal's ability to keep its body temperature constant in extremely varied environmental conditions was a precondition for unlimited morphophysiological progress, which with the inevitability of a law led to the emergence of thinking beings - the humans (from an ecologist's point of view, reason is the highest faculty of purposeful response to changing external conditions).

The need for keeping the metabolic processes at a constant high level meant that most of the energy was expended on maintaining an optimum physiological condition rather than on building body tissues. A lion weighing 200 kg consumes six to seven times as much feed as a crocodile of the same weight. Small mammals and birds expend more than 95 per cent of their energy to keep their body temperature constant. These, seemingly special, physiological features of mammals and birds have brought about a general revolution in the biosphere's structure.

While the rate of energy transformation in communities had increased many times over, the ecological efficiency of the biocoenoses dropped sharply. In ancient coenoses, the plant biomass was just four to five times that of animals, and not less than 15 per cent of the production of the lower levels of food chains was converted into that of the upper levels. In the new communities, the plant biomass is tens and hundreds (and sometimes thousands) of times that of the animals, while the community's efficiency is not more than two or three per cent; meanwhile the rapidity of the transformation of matter and energy has increased dozens times over. On the other hand, the coming of the homothermal animals promoted the creation of direct biological channels linking the biogeocoenoses of various regions of the earth, fusing the biosphere into one integral whole.

Examples can be cited which show that ecological events in the Arctic do to a great extent determine the course of major biocoenotic processes in the tropics.

Mammals acted as powerful catalysts of biocoenotic processes. By converting enormous amounts of raw plant mass into substances easily assimilable by plants, the higher vertebrates provided conditions for the formation of highly fertile soils. At the same time vigorous growth of higher insects - the pollinators of flowering plants began. This led to an intensified biochemical evolution of plants and the creation of forms with a high content of proteins and lipids. In this way soil fertility was enhanced even more. It is remarkable that the co-evolution of higher vertebrates, higher insects and the most progressive plant groups created on the earth the steppes and the prairies and the most fertile soils.

Each step that life made in its evolution gave it a foothold for further advancement. Progressive animal and plant groups paved the way for the appearance of man and for the development of mankind. The views on life as the motive force of the planet's development advanced by V.I. Vernadsky and V.I. Sukachev are at present being elaborated in all their aspects.

Man entered the arena of life at a juncture in evolution when the biosphere had become a single system of a higher level of biological integration, capable of the highest biological productivity and stability. What has become of the biosphere today?

The annual production of living substance is estimated at 380,000 million tons. In the process more than 300,000 million tons of CO_2 is extracted from the air; and from the soil, some 5,000 million tons of nitrogen and 10,000 to 15,000 million tons of other elements of plants' mineral nutrition. The tissues of living organisms contain about five times the amount of water carried by all the rivers on Earth. These and similar figures indicating the scope of the work done by the biosphere are generally known today, so there is no need to add to the list of examples, but I should just like to make them a bit more vivid.

An age-old oak-tree or a hornbeam has some 500,000 leaves with a total area of about 1,000 sq m. The photosynthesizing inner surface of these leaves processes some 2,000 g of CO_2 per hour and, using up about 5,000 calories of solar energy, produces 1,200 to 1,300 g of glucose. To visualize these figures let us compare them with man's oxygen and food requirements. It has been calculated exactly that mankind's yearly consumption is not greater than 1 per cent of the biosphere's net production (not counting the combustible minerals accumulated by the biosphere throughout the past ages), and it has been calculated no less exactly that 25 sq m of photosynthesizing leaf surface produce enough O_2 on a sunny day to last man for twenty-four hours. But the atmosphere's pollution with industrial gases cuts down the photosynthesis energy by an order.

It is quite clear that ecological confrontations do occur, not as a result of mankind's tremendous requirements, but because these requirements are being met without any account being taken of the structure and function of the biosphere. We know that the elementary units of the biosphere's structure are trophic levels providing for the transformation of matter and energy. And we knpw also that each level consists of hundreds of thousands of biologically unique species. It is appropriate on this occasion of our Academy's jubilee to recall a major theoretical conclusion advanced by Academician A.A. Ukhtomsky: "The environment, which is physically uniform, is physiologically different for the animal species inhabiting it, differing primarily in the mode of reception therein". It is the fact that thousands of biologically unique species - in turn, comprising millions and myriads of biologically specific individuals - are performing a similar ecological function which creates that miraculous resistance which enables the biosphere to maintain optimal environmental conditions for its evolution over millions upon millions of years, in spite of radical climatic and orographic changes, including the formation of mountains and the movement of continents.

This, too, deserves to be made more visual and palpable. The total number of insects on the earth is 10^{18}, and that of birds, 10^9. There are not less than 200 million gnats and flies alone, belonging to thousands of species, per one human being. Even nowadays some locust flights weighing tens of thousand tons occur. Birds play a part in global economics of nature which is only two or three times less in importance than that of mankind. Analogous figures for mammals and some invertebrates are astronomical. All this makes it clear that the biosphere's front line of defence against possible disruptions in its development is what biologists describe as organized diversity.

The second line of defence, no less important, is based on the hierarchic character of the structural levels of life. The theory of these levels is now so popular which that we would not need to dwell on it any longer, were it not for the fact that by viewing the matter in energy terms we can arrive at a new line of approach to this issue.

Proceeding from various published data as well as our own laboratory findings, we have tried to draw a tentative outline of the efficiency of energy utilization at different levels of the integration of life (in per cent):

Elementary physiological functions	up to 70-80
Complex physiological functions and the functioning of an organism as a whole	15-50
Utilization of organisms' energy for growth, reproduction, development	1.5-15
Utilization of the energy of populations of organisms for growth, reproduction, development	0.5-7
Utilization of energy by a community of photosynthetic organisms	0.1-2
Utilization of solar radiation energy by higher trophic units	0.01-1
Utilization of solar energy for the production of new animal tissues	0.0002-0.05

In drawing up this scheme we had to base ourselves on very inexact data. Moreover, organisms referred to one trophic level sometimes substantially differ in energy terms. Yet a major tendency is clearly traceable in this energy scheme of living systems: with the increase in the level of biological integration, the efficiency of energy utilization lessens.

These figures deserve an allround analysis, but I shall confine myself to just one question, which I shall take the license of stating in a slightly different form than is usual in a scientific report. Why has Nature, which has proved itself capable of creating such a super-perfect tool as the human brain, why has she been satisfied with creating communities working at such low efficiency? The answer is self-evident. The ratios of the energy utilization efficiencies at different life integration levels warrant the maintenance of life's primal principle - the capacity to reproduce organisms. Whatever happens on the nature's top storeys, whatever cataclysms shatter the biosphere and its component biogeocoenoses, energy utilized most efficiently at the level of cells and tissues secures life for organisms which are sure to restore the structure of life at all storeys and in a form which will be best conform to the new environmental conditions.

It must still be emphasized that the feasibility and inevitability of both the morphophysiological progress and of improvement of the biosphere's stabilizing mechanisms are inherent in the very principle of life's development. This is an extremely interesting issue, which I can shed just a little light on.

The intimate connection of animals with the environment is a most general law of their development. The more sensitive is the animal to the changes in the environment, the greater is its chance of survival. Thus results in the inevitable improvement of the central organ of communication with the environment, the brain, whose minimal size is determined by the minimal number of molecules and atoms necessary for maintaining intra-cerebral contacts (hundreds of millions at a most conservative estimation). A larger brain is a really useful adaptation. But to increase the size of the brain, the organs feeding it must be also increased. This resulted in the larger size of the body and in the morphophysiological progress that ultimately gave birth to man.

But the morphophysiological progress and increased body size lead, with an implacability of a law, to a reduction in the number of organisms and to simplification of their populations. The simplification of populations inevitably leads to the greater biological vulnerability of organisms. This is why it was not only higher animals and plants that came out of the struggle for life victorious, but also numerous groups of lower organisms characterized by enormous populations and by a complex structure of populations. The fact that organisms using basically different principles of mastering the environment are united in one biogeocoenosis, is a pledge of the stability of ecological systems and of the biosphere as a whole.

Endless charges are brought against the "technologically armed barbarians" (to mention present-day technology in fairly mild terms). Industry is polluting the atmosphere, soil and water with substances that are harmful to all living things, disrupting the thermal balance existing at individual points in the life arena, increasing the CO_2 content in the atmosphere, jeopardizing the ozone screen, taking ever larger territories out of the biological cycle (several thousands hectares a day at least), altering the reflecting ability of the earth's surface and enabling an arid climate to develop, and so on and so forth. As a matter of fact, modern industrial society does cause and cannot help causing all these disruptions in the biosphere. Mankind's progress implies industrial development, and the technophobian attitude imbuing many an article on the protection of nature (as if it were nature and not we, people, who really needed protection) too often smacks of indifference to man's lot. But indeed, if from our list of charges (or a similar more detailed and longer one) we cancelled the violations that are not connected with the technological strategy of modern society, but just with errors in technological policy and practice, the list would be much shorter and more to the point.

The processes of production prevailed over destruction in wild nature; ecological systems became more and more involved and thus grew in productivity and stability; the degree of heterogeneity within individual biogeocoenoses and the heterogeneity of the biogeocoenotic cover of the earth grew continually (it should be recalled once again that the biosphere is an organized heterogeneity).

This state of affairs has been changing essentially in urbanized milieu.

Ecological systems are being simplified and becoming "younger." Most of the energy and oxygen is spent on the restoration of disrupted biogeocoenoses, but the processes of the destruction of poorly dispersible substances, the exchange of matter and energy are slowed down. The efficiency of atmospheric homeostasis is lowered. The floristic and faunistic differences between the biogeographical regions are being erased, the endemic species are ousted more and more by cosmopolitan ones, new endemic species inhabiting technogenic terrains are emerging, the number of species with a heightened resistance to toxicants, drugs, etc. is continually increasing, etc. The biological "communication channels" between continents and biogeographical regions are being supplemented by technogenic ones. All this may be regarded as a kind of a statement verifying an ecological forecast, since the traceable tendency in nature's charging structure is bound to gain in scope and intensity, whether we like it or not. A preposterous and dangerous but very common blunder is that of taking an ecological forecast to be a presage of the growing influence of man upon nature while the question of the probable response of the biosphere to our actions is left out of sight and simply forgotten. It is wrong to consider violations of the natural balance that had been maintained by the biosphere for millions of years to be a kind of a breakage of a complex mechanism. Such simplification of a highly involved natural phenomenon is tantamount to distorting it completely. An intelligent onlooker who lived in the Cretaceous at the very turn of the period, when the realm of reptiles was changed by the realm of mammals and birds, would certainly have registered a drop in the ecological efficiency of the planet's biogeocoenoses and could have interpreted this fact as a degradation, an impoverishment of the biosphere. He would have been wrong of course. Likewise, it is wrong to describe the changes in the biosphere that we are witnessing now as its degradation. Of course, poisoning a river or putting toxicants into the soil is detrimental to nature. But these and similar actions, whatever their scope, must not be regarded as expressing the strategy of industrialized mankind vis-à-vis nature, but rather as a deviation from an optimal technological policy. There is every reason for considering above-mentioned regular changes in nature as life's reaction to changed environmental conditions.

Simplification of biogeocoenoses, their "rejuvenation", has altered pattern of individual links in the food chains, the increased importance of animals as destructors of primary organic matter - all this is not just degradation of the biosphere, but its evolution under new conditions. It is not sensible to regard all these changes as undesirable a priori. They do lead to increased biological stability, and create premises for utilization of the high CO_2 concentration in the atmosphere. Moreover,although lacking that amazing internal harmony so typical of ancient communities, the new, rejuvenated biocoenoses are less "closed" and to a greater extent "work" in the best interests of the biosphere as a whole. This is a highly involved and virtually unexplored issue and likely to lead one astray. There is one pitfall that should most certainly be avoided. We should not look upon the biosphere as the passive object of our actions capable of no other response to an unusual environment than degradation.

Each of the changes in the biosphere's structure and function that have been mentioned deserves discussion. We shall pick out one. What is meant by simplification of a biocoenosis?

Most of the geochemical work and the work of biomass accumulation is performed in each biocoenosis by a small number of dominant species which constitute its core while a large number of satellite species help to maintain its working efficiency. The stability of the community is guaranteed by the above-mentioned "organized heterogeneity". The number of dominant species sharply declines in the biocoenoses subject to anthropogenic action. Figuratively speaking, the job of maintaining natural equilibrium has to be shouldered by just a few, sometimes one or two species. But, one can say that nature has managed to find a way out. The stability of the community is maintained by the biological plasticity and intraspecific variety of the population of the dominant species. Here is a concrete example.

A survey of the small lakes in the Trans-Urals forest-steppe zone has established the fact that fresh water molluscs played an important part in the cycle of matter. But the majority of species were extremely small in numbers while just one species (Lymnea stagnalis) was really abundant. Just a few years ago this would have been all there was to say about it. But progress in biology, the new biology, lies not only with a greater penetration into the micro world of living matter, but in the fact that it is now possible to comprehend the events of the biological macro world in exact quantitative terms. It has been established, notably, that the number of dominant mollusc species is several million per square kilometre and that during the summer season it accumulates a biomass amounting to tens of tons (up to 300) per square kilometre, processing not less than 10,000 tons of phytomass in that period. It is noteworthy that the structures of the different micropopulations of Lymnea stagnalis turned out to be different.

This modest observation suggests, however, that a species of this sort can indeed cope with the work of maintaining the biological equilibrium of an entire community. It shows that the population mechanisms for maintaining the biological balance have a more important role to play in the present-day biosphere than in "virgin" nature. I cannot go into technical details here, but suffice it to say that knowledge of the principles underlying the maintenance of the biosphere's balance provides the bases for i plementing an optimal behavioural strategy of man in nature. It can be formulated as concisely as this: man ought to incorporate his production processes in the normal cycling of matter and energy in the biosphere, or, to be more exact, in "the new biosphere". One gets the impression that this is just a good wish and no consideration has been given to ways of accomplishing it. I believe these doubts can be answered quite definitively: man must not usurp the biosphere's function, but just help it in its work. I even dare to suggest that man's relations with nature must be based on trust.

I believe this is a very important principle, which I shall illustrate by a concrete example.

The water protective and climatic function of forests has long since been appreciated. Even the fiercest technocrats are fully aware of the disastrous consequences of wood felling. The shallowing of rivers will put the centres of world culture and industry in jeopardy. Indeed, a little less than 70 per cent of the major cities are situated in river estuaries. Already the water supplies in Rome carry half of the amount of water that flowed through the famous aqueducts of the immortal city in the days of the Emperor Augustus. But.... people still do fell trees and will continue to do so in the future. There is a way out - afforestation. The benefits of afforestation are unquestionable: the atmospheric and hydrological regimes are stabilized over vast areas, and even modest gardens and parks cut down the dust content in the atmosphere by 40 per cent. The advantages are obvious, and amount of work needed is tremendous. The total area under protective afforestation (including the green belts of cities) is roughly equal to that covered by the forests of West Siberia. Add to this the fact that almost everywhere urbanization means that natural vegetation is turned into park-like forests, and it will be evident that man-made woods are becoming comparable in area to natural ones. In area, but not in their biological function. They lack a basic property of natural silvan biogeocoenoses - their capacity for self-development and self-protection. What is more, for the most part they are incapable of self-reproduction.

The entire endeavour of developing artificial forests epitomizes the strength and weaknesses of technological thinking which arrogantly places itself above nature. You say woods are indispensable; okay, we'll do the job ourselves and solve this biological problem by technological means. The upshot is thousands of millions spent on afforestation and the upkeep of plantations. This despite the fact that the alternative way exists of helping nature to create specialized sylvan biogeocoenosis in a human-altered environment. The stable plant associations which have emerged in the process of evolution, unfolding before our very eyes on soils drastically enriched in lead and very poor in phosphorus show how realistic this approach is. Specialized communities are emerging in an urbanized environment before our very eyes and often against man's will and to his displeasure. If man combines his efforts with those of nature, the process of creating productive and stable biogeocoenoses in a modified environment will be stepped up.

For this task to be accomplished, we must elaborate the principles of biological engineering which will enable us to streamline the course of the biosphere's evolution in the direction we want it to take.

Here, too, it is better to comply with nature's laws rather than go against them. The following considerations are especially important.

Studies on animals, plants and microorganisms show that all major processes at the level of populations and communities are basically determined by the chemical background created by these very organisms in the course of their vital activities. By changing the chemical background we are already able to modify the rates of growth and development of animals in laboratory conditions and to bring about drastic changes in their physiology, modify the genetic composition of natural populations and thereby predetermine the outcome of the competition of rival species. Knowing the "chemical code" of the population development of the major species, we shall be able to use perfectly safe and biologically adequate methods to channel the evolution of individual species and communities towards a desirable end.

The deciphering of the chemical code of the individual development of organisms has been a greatest scientific discovery of modern times. There is every ground for believing that mastering the code governing the life of populations (and, hence, of biocoenoses) will be no less important as a scientific event whose practical implications are hard to overestimate. The dangerous "poison chemistry" will give place to a "life chemistry" and die off not as a result of propaganda campaigns, but simply because it will lose its raison d'être.

The issue has a tremendous general scientific significance. The chemical composition of our blood largely reflects the ocean's chemistry. The conditions of the birth of life are recalled in our very organism. But we know that even in the early stages of life's evolution biological progress must have been based on a union of population and biocoenotic processes. The chemical background whose features were largely determined by the vital activities of organisms themselves was the main factor in maintaining this union. This is brilliantly borne out in experiments on bacteria populations. The chemical principle of maintaining the unity of the vital activities of single-celled animals and plants was inherited by multicellular organisms as one of the main principle maintaining organisms' integration and regulating the epigenetic processes. But chemical signalization as a medium of population and biocoenotic unity retained its importance for higher animals and plants, too. At the new turn of the spiralling evolution, the chemistry of organisms' internal and external media secured the harmonious development of organic systems at all levels of biological integration -

from a cell up to a biogeocoenosis. Not just the unity of life as a special form of existence of matter, but the unity of animate and inanimate nature as a whole is conspicuous. It is symptomatic that elaboration of these ideas, which lie at the interface of biology and philosophy, leads to practical conclusions. Experimental research and computer simulations show that by modifying the population structure, the distribution of animals over the territory, their age composition, etc., we can achieve substantial evolutionary changes of even slowly reproducing animals in a just a few years.

Finally, application of up-to-date techniques to studies of biological macro systems, as well as at the micro level of life, can produce fast and objective estimates of the efficiency of the work done by individual communities. For example, with the optico-acoustic infra-red gas analyser in a matter of minutes one can measure the summary photosynthetic energy of whole phytocoenoses, as well as of individual plants.

It becomes obvious that present-day biology has enough theoretical knowledge to cooperate with nature reasonably well and that it has enough technical means to objectively gauge what we can expect to get from nature and what is definitely beyond our reach.

However, before fresh opportunities can be taken into account in the struggle for a prosperous biotechnosphere, the citizens of the industrial society must become ecologically minded. We are too much in the habit of solving biological problems by technological means in conformity with our easily understandable and historically determined tradition. I have no time to dwell on this point, so I'll just exemplify it. The amount of energy required to irrigate one hectare of developed land with desalted seawater is equivalent to 120 tons of petroleum. And yet the engineers and designers are not deterred by this spending. The costs of an ecological analysis of urban and industrial development plans amount to less than 0.01 per cent of the total construction costs, but I cannot cite a single production branch in any country of the world in which ecological expert analysis has become an obligatory procedure.

One can hope that the decisions adopted by top-level government agencies in the USSR with regard to the conservation of the natural environment will form the basis of completely new relationships between man and nature. These new relationships should proceed from a view of the biosphere as an integral whole and a differentiated approach to work with different biomes.

Compare, for instance, tropical woods and the modest northern taiga in the USSR. The average productivity of tropical woods is immense. A hectare of tropical forest produces 28 tons of oxygen annually, which is double the average figures. The diversity of the trees is ten times greater than in temperate zones. Tropical woods are the most ancient biocoenotic units, and they have been almost canonized as "the triumph of the organization of interadapted species". But there is a seamy side to this triumph. The basic stock of nutrients is not in the soil, but in the plants; the cycle of matter is closed and nearly all the oxygen is consumed by the destructors inside the system. So any disruption leads to the forest being replaced by bushes and then it takes centuries for it to be restored. The energy expended on this is hundreds of times greater than that taken to maintain the balance. If the secondary forest happens to be disrupted again, it is impossible re-afforest the exhausted soil. A few decades of intensive exploitation will suffice to wipe out all the tropical forests on our planet once and for all, so tropical ecologists tell us.

The northern taiga is a biocoenotic unit formed in fluctuating climatic conditions, regular massive proliferation of pests and frequent forest fires. There are grounds for supposing that the radical changes in the environment that we are inclined to consider disasters are in fact a vital factor in maintaining the natural equilibrium of the typical biocoenoses of the northern biomes. The taiga's "resistance" is incomparably higher than that of tropical woods; moreover, each stage in the succession is particularly valuable for man and for the biosphere.

There is no need to say that for each of the biomes to retain its specific function in the biosphere's life we must approach it in an individual manner.

The regions whose biological production is extremely frugal- near -polar areas, deserts, highlands - deserve special attention. So far whatever interest, apart from a purely theoretical one, has been taken in these regions, was determined by the possibilities of extracting "utilities". The notion that the biosphere is one integral entity means that these areas which make up about 40 per cent of the earth's dry land,are an immense reserve of biological productivity. This again calls for a psychological switchover on the part of man equipped with up-to-date technology. It is possible to obtain useful products immediately from these territories but this is not always - and perhaps never will be - economically efficient. But an overall increase in biological productivity compensating for the general drop in this productivity in heavily urbanized areas and the resultant regularizing effect on the planet's atmosphere and hydrosphere are quite attainable, even with the present-day level of technological development. The attendant technological and economic difficulties cannot be discussed here. At any rate, the experience that has been gained up till now shows them to be far smaller than those involved in the construction of large electric power stations and similar projects.

An analysis of the main trends in the biosphere's evolution and in man's attitude to biosphere problems makes it possible to compile a very general ecological forecast for the next few decades. Dropping all particulars, this forecast can be epitomized in a few words.

A substantial change is needed in the structure of the earth's biogeocoenoses. Population processes with have to play a greater role in maintaining the biocoenotic equilibrium. Emergence of self-reproducible and self-regulatable specific biogeocoenoses of anthropogenic terrains, characterized by a heightened stability and a greater capacity for biological cleaning. On territories admitting but limited anthropogenic development, the evolvement of biogeocoenoses will be marked by an increased biological productivity. The overall biosphere's balance will have to be maintained at a level securing the optimum development of human society.

For these goals to be achieved, ecological expertise must be incorporated into industrial and agricultural production and industrial culture must be inculcated in the practices of the exploitation of nature. Instead of passive "nature conservation", there will be active attempts to create an optimal natural environment, to create biogeocoenoses capable of self-regulation in an environment altered by man.

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