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Life Sciences and Conservation and Sustainable Use of Biodiversity

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Life Sciences and Conservation and Sustainable Use of Biodiversity

by Tewolde Berhan Gebre Egziabher*

1. Introduction

Biodiversity is at last officially important. Departments of systematics in the developed world had been closing down for some decades now because it had been felt that the gene is now the unit of life, the organism being a mere packaging (Dawkins, 1986). There is now talk of infusing new life into systematics (e.g. Janzen, 1993).

This came about from two different type of influence. On the one hand, pollution, soil degradation and population pressure combined to cause such large numbers of extinctions of species that some people started to become frightened. Predictably, these were not scientists. On the other hand, scientists with all attention on genes finally managed to combine, or at least to feel that, through biotechnology they could combine, genes across all taxa, no matter how different the taxa are from one another. Suddenly, therefore, all peculiar genes became rare commodities and biotechnology firms mushroomed (RAFI, 1989). Where would one find genes? Packaged in species, of course. Those packages must be saved for the genes they contain. The two almost opposite starting points, the one which saw life as intrinsically worth sustaining, and the other which saw it as normally a disposable package but now, awaiting a more secure permanent gene storage system, worthy of temporary protection, for once converged. As a result, the Convention on Biological Diversity was negotiated to minimize extinction of taxa for some, and to maximize availability of genes for others. Other international agreements were also reached which had important implications for the conservation and sustainable use of biodiversity including Agenda 21, the Convention on Climate Change, the Basle Convention on hazardous substances, and the Vienna Convention and its protocols on the ozone layer.

Is biodiversity, therefore, now secure? Not really. So long as the dominant biological view continues to be that all that there is to life is only genes, it is a matter of time, and not very long at that, before the well known human arrogance feels that all genes have now been stored in deep freezers and taxa can disappear. Therefore, it is necessary to look at biology and relate genes to the rest of biodiversity. If we develop a balanced view of the whole of life, the chances of sustaining it will improve.

2. The Structure of Life

Biology is usually defined as the science of life. A less cryptic but concise definition would state that biology is the study of the structure and processes of life the functions of its parts, and its interactions with its environment. Other definitions are also possible, but this will do for us now.

For the purpose of discussing the conservation and use of biodiversity, we do not need to look at the processes of life *per se*. Even the functions of life's environment do not require our full attention though we will need to look at some of their elements. Our main focus will be the structural parts of life.

If we arranged materials according to their degree of complexity, at one end we would have elementary particles and at the other end the biosphere, with all other non-living and living materials being spread out in between.

If we arranged them hierarchically according to levels of organization, we would

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find the same order. This is not surprising since, as the level of organization increases, so must complexity. The reverse, however, need not necessarily be true and thus complexity can increase without creating an upper step in the hierarchy.

The simplest situation would be when there are only 2 units at each level of hierarchy, and when the magnitude of the complexity of each unit is the same. We would then have a perfectly symmetrical dendrogram dichotomously branching to successive lower levels. If we standardized both the index of organization and the index of complexity to lie between 0 and 1, and represented the hierarchical units on a graph with $\log_2$ of the index of organization on the Y-axis and $\log_2$ of the index of complexity on the X-axis, we would have all the units of hierarchy on a straight line of 45° slope starting at the origin with elementary particles and ending with the biosphere at the top right hand corner.

In practice, the number of sub-units aggregating to form a higher unit will be many more than 2, and would be millions or even billions at the lowest levels. However, the aggregation of identical components does not increase complexity. For increase in complexity we look at the heterogeneity among the component parts, and the number of differing categories of units is always a small number, especially at the lower levels of the hierarchy, e.g. types of elementary particle, though it rises at the higher levels, e.g. in an ecosystem, where there could be hundreds or possibly even thousands of populations, with each species bringing in additional heterogeneity at aggregation into a community. Even the additional heterogeneities need not be very large as often many of the species are related at the subgeneric, generic, family, etc. levels. This would mean that the index of complexity will not necessarily increase linearly with the index of organization or, in other words, some of the points on our graph could lie to the right of the line of 45° slope and our curve would thus not be a perfectly straight line. However, what interests us besides the order of the hierarchy is what happens to the left and to the right of each of the points of the units of the hierarchy. We would, therefore, not loose much information if we assumed that the line joining the points on the graph is straight and at 45° to the axes as in Fig. 1.

As we can see in this figure, in theory, any level of complexity would be possible for a given hierarchy, and any number of hierarchies could be made out of a single level of complexity. For example, we talk of a human being as a "corps" "body", "individual", "spirit" or "soul". When we talk of a "corps", we focus at the level of the constituent material devoid of any functionality, or, in other words, at the bimolecular level. When we talk of "body", we think of organs combining together to form a unit. When we talk of an individual, we think of the body with all life processes functioning.

If we draw a horizontal line through "individual", we would find that its intersection with the Y-axis gives us the elementary particles in that individual. This is not a very useful unit and therefore, we have no name for it. But it can be precisely defined. When we extend the curve to the right of the line, i.e. when only complexity increases, we have units that interest us very much, but elude precise definition. We can talk of an individual as being "spiritual", and there seems to be an agreement that there is such a thing as "spirituality". But not many people would agree about its circumscription. As for the "soul", even its existence has to be left to individual belief. All the units to the right of the curve are emergent from that level of organization, and those to the left are constituents. It is one of the inherent problems of science: What can be precisely studied is the composition up to any specified level of organization;

what is interesting but elusive is the creativity and creation at that level. It is this ease of studying left of the curve, and its difficulty right of the curve that predisposes scientists to stay left of the curve and be accused of being reductionist (e.g. Shiva, 1991; Mayr, 1982; Lewontin, 1993; Weston, 1993, pp. 22-37).

At what point on our curve does life begin? This causes some debate. For example, biomolecules are made only by living things. Are they then living? Could we consider them as members of "biodiversity"? As a minimum, for a level of organization to be considered living, it must respire, grow and reproduce, as any elementary biology text book can tell us. Biomolecules do not do these. So they are not living. DNA on its own, and even genes on their own cannot satisfy the criteria for being living. It is at the level of the cell that these criteria are fully satisfied. This view would consider viruses non-living since they are merely genes. This uncertainty only shows that, as in most good systems of classification, there are boundary problems, and genes share some properties with the living but not enough to make them alive. Since the justification for classification is its functionality, we can consider these as living in those contexts in which their behaviour as living is the issue, and otherwise as non-living. Genes can, therefore, be considered a component of biodiversity by the biotechnologist who will introduce them into cells, but as non-living by the physiologist who tests them for life processes and finds them inert. But the definition of biological diversity given in the Convention on Biological Diversity includes the range from "genetic material" to "ecosystems". This is because biotechnology figures in the Convention and thus the context of "genetic material" makes it living.

In the history of the life sciences the various components of biodiversity have, at differing times, dominated as objects of study. The earliest to attract attention must have been the individual, the population, the organ and some tissues. Cells and organelles had to await the invention of the microscope. Communities, ecosystems and the biosphere, though they must have been appreciated as vague entities, became clearly defined only in the last century. The levels from biomolecules down to the elementary particles had also to await the development of physical and chemical knowledge and techniques in the 19th and 20th centuries to be given attention, even though atoms as theoretical entities go back to the time of the Greeks. The most recent focus has been at the levels of the gene and the biomolecule. Since these levels cannot be found outside the individual, however, their consideration cannot be made in isolation. To give what is seen as due emphasis to genes and biomolecules, therefore, the individual had to be downgraded to being considered merely a convenient substratum to support the gene (Dawkins, 1986).

Of the entities to the right of the curve, the "species" was probably the earliest to be recognized, and it is central to the story of Noah and the Flood. However, even now it eludes a precise definition. The others are even more elusive and the newest, the Gaia, is, next to the "soul", perhaps the most controversial.

With the help of Fig. 1, we can now circumscribe biodiversity as consisting of the hierarchical organization starting from the biosphere and going down to the level of the cell; and in some contexts, down to the level of the biomolecule called DNA.

However, depending on developments in equipment and methodology, research at a given time is likely to focus on one level of hierarchy of biodiversity or another, but the temptation to be reductionist and consider that the level one is studying is all there is to biodiversity has to be resisted. The possibility for this failing increases as the level being focused upon is lowered. This is because it then becomes easy to consider the higher levels to consist of simple successive additions of that level of focus.

Mayr (1982) calls the belief that the material composition of organisms is the same as that of the inorganic world "Constitutional Reductionism". The reductionism that we have just considered can, therefore, be seen as constitutional, but not going down to the lowest level possible as would have been expected, and it is thus not consistent even within its own premise of studying the most basic constituents to know the whole.

For a balanced view of biodiversity, therefore, one would accept that the properties of a given hierarchical unit would be determined by influences from lower levels and from higher levels, the magnitude of the influence varying depending on the degree to which the influencing unit is internally organized and functionally integrated with the unit in question. There is no doubt, for example, that organs have a great share of determinism on the properties of an individual of which they are parts, as can be seen in the differences between a person who has lost his/her eyes and another one with normally functioning eyes. It is equally clear that the hive, of which the individual bee is a component, has a major share in determining the properties of that individual bee. Besides these influences from above and from below, there also are emergent properties that cannot be attributed to sources higher up or lower down. For example, a lot has been written about consciousness. What seems obvious is that no amount of attention to the lower levels such as studying the individual neurons constituting the brain can explain it away; and there is no way that society, from its upper but organically unlinked level, can introduce consciousness into the individual though it can very much influence the use he/she makes out of it. Finally, it should be remembered that one's environment can modify one's properties, which even Dawkins (1976, p.37) accepts. This balanced view should, therefore, be based on an equal attention being given to those organizational levels whose emergent properties go into determining the properties of the unit (level) in question.

The theory of complex adaptive systems (Kauffman, 1993, pp. 173-281; Huberman, 1992) looks both at the component parts of a system and also at it as a whole, and would thus be appropriate for developing an integrated view of biodiversity. It sees the component parts of biodiversity in a balanced perspective with connections making it possible for the whole system to evolve towards a state at which adaptability is maximized through coevolution. If the components of a system coevolve, then there is no need to attribute all responsibility for adaptation to one or even a few of the components only. It would be possible to identify the role of each contributing level and develop a systems-wide understanding.

3. The Focus of Conservation of Life - Biodiversity or Genes?

Neo-Darwinian evolutionary theory is now dominant in biology. If we were to be guided completely by it, all we would need for life to continue would be genes. As constituents of genes, obviously all the hierarchical levels below the gene in Fig. 1 would also be required. All levels above the gene can be re-created through the correct combination of genes. In fact, since we can now, at least in theory, produce all imaginable combinations of genes, it is in our control to create totally new forms of life. It is also in our control to create totally new and uniform environments as we have done in the green revolution and produce any new life support system that we fancy.

This view has a disquietingly disruptive implication on the conservation of life as we now know it. In a discussion by a panel of scientists established to evaluate the conservation of crop germplasm held by the Consultative Group on International Agricultural Research, the worry emerged that perhaps the world's best gene banks are not safe and that a very high proportion of their holdings had degenerated beyond any possibility of rejuvenation (Fowler and Mooney, 1990). In spite of this realization, an eminent geneticist, knighted for his achievements, circulated a proposed addition to our report to the effect that genetic finger-printing be used to identify the genes in the collections and, to avoid redundant storage, the collections that do not contain any unique gene be destroyed.

A view that the whole range of structure of biodiversity forms a complex system that adapts as a whole would have recognized the suggestion to have been ridiculously reductionist. If we want biodiversity to be perpetuated, we cannot focus at one of its components alone to the detriment of the others. Such an isolationist focus at any particular level is fraught with danger.

If we focused at the species level only, we could continue believing that all is well while infraspecific variation down to the level of the gene is very seriously eroded. For example, though Scandinavia is perhaps one of the most forested parts of the world, its biodiversity has been greatly reduced (Salo, 1993) because of the focus on only a few tree species.

A focus at infraspecific levels only is equally fraught with the danger of assuming that the properties of that taxon are the only valid properties and that individuals which deviate from that are not valid. This is the basis for the modern crop variety with its very narrow genetic base, and, therefore, its vulnerability. It is this vulnerability that is employing most of the breeders of the world in shadow boxing with diseases and pests (Shiva, 1991). The most odious manifestation of this restricted focus is perhaps racism.

As we have already seen, in this era of biotechnology, a focus at the gene level only will produce the ridiculous reductionism that the organism is irrelevant, that it is only the gene that matters. In this view, all genes can be admixed, the whole of life is one super organism, and biodiversity is merely a product of an arbitrary packaging of genes. Even the environment is irrelevant since the inclusion of the appropriate gene(s) can beat any constraint that it imposes, or a new uniform environment can be created to suit the new genetic combination. It should be pointed out, however, that a body of opinion that puts the gene in its appropriate perspective in the species as a complex adaptive system is growing. The gene is being seen as a mechanism for changing parameters drastically enough for the whole system of the individual to jump from one position maintained by a stabilizing attractor to another position stabilized by another attractor (Goodwin, 1989; Hubbard and Wald, 1993, pp. 58-71).

Focusing at levels above the species have produced less problems. It should be noted, however, that a rigid view of the community as a super-organism (sometimes referred to as quasi-organism) has given rise to dogmatism on succession and climax vegetation which have had to be refuted by experiments, and to the disregard of lower levels of biodiversity (Sagoff, 1993).

There is one common failing to focusing at any of the levels without relating it, and equally focusing on, the other levels: it becomes easy to feel that all that needs to be known pertains only to that level which is being focused upon. This will lead to decisions based only on partial information. And if that decision is to affect biodiversity, its consequences could be serious and irreversible. In this context, it is encouraging that one of the tenets agreed upon in the Rio Declaration is the Precautionary Principle which states: "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". It is to be hoped that not only administrative and political decision makers, but also scientists will heed this principle.

4. Conservation of Biodiversity

If we begin by examining the purpose of biodiversity conservation, it would help us evaluate the efforts being made to that end.

4.1 The Purpose of Biodiversity Conservation

The desire to conserve biodiversity arises from the feeling that human intervention is eroding it and even causing the extinction of some of its components. "Conservation" in this context, therefore, must mean the enabling of the biodiversity components in question to continue into the future. Obviously, in order to do this, we must know what maintains that particularly component of biodiversity.

The variables involved in maintaining it are of three distinct categories. One category is the external environment. The "fitness landscape" described by Kaufman (1993, pp. 37-172) is a good model for visualizing this category of variables. In this model, the directions of variation in the environment which are towards conditions of increasing adversity to the organism in question are visualized as ascending sloped, the directions of decreasing adversity as descending slopes, and the least adverse parts as valleys. Obviously adaption on this model means moving into the valleys.

A second category of variables is the internal environment of the biodiversity component which can also be viewed as a fitness landscape. This environment settles down to a given state, or specific components of it to given specific states, even if the internal environment were moderately perturbed. A given perturbation may push the organism some way up a slope in the fitness landscape, but when that perturbation stops, the state of the organism slips back to the valley. The stable states of the internal environment corresponding to valleys of the fitness landscape are called attractors. In other words, provided that the variations in the internal environment do not go beyond the catchment of the corresponding valley in the fitness landscape, these variations always settle down to the levels of these attractors.

But this stable situation would at times need to change since the external environment does not necessarily remain unchanged. The organism would then be on a slope or a ridge and thus loose its fitness. The internal environment will then need to keep changing until it finds an attractor which corresponds with a valley in the fitness landscape. Therefore, it needs some mechanism to jerk it out of the catchment are of the now maladaptive attractor. Genes are able to change the internal environment to do just that.

Obviously, when we think of "conserving biodiversity" in term of the three categories of variables we have just noted, we mean that we want the external and internal environments to remain unchanged since a change in the external environment will necessarily force a change in the internal environment, or else an extinction of the taxon in question.

4.2 Types of Conservation Used and Their Suitabilities

Efforts at conserving biodiversity have been classified into *ex-situ* and *In-situ* activities. The Convention on Biological Diversity considers *In-situ* as the appropriate type to aim for, with *ex-situ* being used only to supplement it. The assumption here is that *in-situ* conservation leaves the external environment unchanged and thus the internal environment is protected from perturbations which would move the taxon out of its valley of fitness. Even if there were genetic changes affecting the attractors that keep the taxon stable, the stable external environment would eliminate them.

This assumption will be valid so long as the "*in-situ* condition" continues really unchanged. Perpetuating conditions unchanged is not as easy as it might at first appear. This is because when we "conserve", we usually change environmental management and thus, unwittingly, also the external variables.

The usual prescription for *In-situ* conservation is the enclosing of the area so that humans and domestic animals are excluded. This would be the right action to take if one could assume that the '*in-situ*' situation we want to perpetuate had previously also excluded humans and domestic animals. In practice, such untouchedness is very hard to find and like the continent of Antarctica, usually these areas do not possess much biodiversity. Much of *in-situ* conservation is, therefore, flawed.

In a 24-year study in a grassland in Breckland, UK, Watt (1960a, 1960b, 1962) excluded grazing by rabbits and found that the number of species was the highest when under grazing and that it gradually reduced to a few species at the end of the study. Under that assumption that we are conserving biodiversity by excluding interference, we may be actually hastening its erosion.

Theoretically, the solution to the problem is simple! Just allow the human and domestic animal pressures to continue. The trouble with this approach is that, though we may be certain that humans and domestic animals have been part of the external environment, we have no quantitative data to enable us to maintain that pressure unchanged. *In-situ* conservation would best be initiated, therefore, after a reliable quantification of the initial conditions. But this is usually not easy.

This problem is, however, serious in "natural" ecosystems, but much less so in the *In-situ* conservation of crop germplasm on farmers' fields since the management regime of such "artificial" ecosystems can be quantified relatively precisely and thus maintained more or less unchanged.

In practice, most conservation activities have been *ex-situ*, and they have focused on cultivated crops. Carried away by the momentum of what they have so far been doing, germplasm conservators see the relationship between *In-situ* and *ex-situ* in reverse of the view of the Convention on Biological Diversity. In discussions at the International Plant Genetic Resources Institute in Rome in 1994, I was amazed to hear them raising "scientific" queries and even objections about *in-situ* conservation of crop germplasm and insisting that, until more is known about it, it has only to be taken as a supplement to *ex-situ* conservation.

There has been a good evaluation of the effectiveness of *ex-situ* conservation in gene banks (Fowler and Mooney, 1990), which has shown that unacceptably high proportions of the seeds stored in the gene banks of even the richest and technologically most advanced countries have now lost their ability to germinate. The basis for the objections to *ex-situ* conservation can be summarized as in Fig. 2 (Tewolde, 1993). This portrays the reductionist freezing of time at the point when the sample was dropped into the deep freeze, and the equally reductionist squeezing of space into a tiny volume in the gene bank. And yet the system the sample is supposed to represent is the complex not only of genes, which would, at least theoretically, be maintained unchanged until rejuvenation, but also of the environmental conditions which bear no relationship with that ambient in the deep freeze, and of the physiological internal environment, with its essential attractors, which bears little relationship with that ambient in the frozen state. Yet, the freezing of time only slows down loss of viability; it does not stop it. Therefore, *ex-situ* conservation is supported, or is supposed to be supported by rejuvenation at regular intervals. This subjects the sample to an external environment and, therefore, to a fitness landscape, that usually is very different from what it was when the sample was originally collected, increasing the likelihood of artificially beneficial responses to new attractors causing unwanted adaptations, or rather undesirable deviations from the original genotype.

Non-domesticated plants, especially trees, are kept *ex-situ* growing in botanical gardens and parks. Since the external environment is usually very different from that where the tree came from and the sample is now constantly interacting with it, the likelihood of undesirable genotypic deviations from the original occurring is obviously much greater than is the case with the less frequent rejuvenation of gene bank accessions.

5. The Sustainable Use of Biodiversity

For the use of biodiversity to be sustainable, the range of variations in the living things with which we interact must continue more or less unchanged. Change cannot be totally excluded as this would imply the cessation of the process of evolution. And yet, change cannot be allowed to continue unchecked because then it would mean that sustainability was unattainable. It would also not be practicable to aim at starting with adequate baseline data so as to monitor shifts in the rate and direction of genetic change.

An even more daunting problem is that in the areas under crop cultivation or animal rearing, the need to maximize the required biomass often means the elimination from those areas of all biodiversity other than one, or at best a few, selected taxa. Even the single taxa have been getting genetically more and more homogenous as efforts to intensify production have continued to emphasize only specific traits.

In order to sustain approximately the whole range of extant biodiversity, therefore, we have to resort to *in-situ* conservation in selected area adequately representative of both the areas under cultivation as well as those with "natural" vegetation. The areas under *in-situ* conservation for crops could be increased substantially if the participation of rural communities were solicited and secured. Besides the conservation areas that governments set aside and pay for the management of, each community could also set aside areas from both agricultural and non-agricultural land for *in-situ* conservation of the flora and fauna, domestic and wild, in their area of jurisdiction. Since biodiversity now has at least a potential monetary value, communities could willingly create and look after their own *in-situ* conservation areas if they were assured that is for their own use and empowered to make decisions including the use of the benefits accruing from any such action.

Even agricultural ecosystems could be made to include a lot more diversity in species and in infraspecific taxa. Genetically narrowly-based monocultures have been shown to be vulnerable (Shriva, 1991). Such an increase in heterogeneity would make modern agricultural ecosystems as ecologically robust as their traditional counterparts and they would require decreased quantities of agro-chemicals (herbicides, fungicides, pesticides, etc.) and thus enable the many beneficial organisms in the system to flourish.

But to make this possible, two types of structural change are required.

On the one hand, industries that use biomass should be designed so as to accept heterogeneous agricultural products. Given present-day technological capacity, this is theoretically possible, but it will be a hard fight to convince economists, managers, etc. o such industries.

On the other hand, research should discover those species and/or infraspecific taxa that can be planted in mixtures that minimize competitive wastage of resources and go into a synergy which maximizes yields. There are many traditional agricultural systems that practise mixed planting. Since they have been doing this for centuries or even millennia, much empirical knowledge could be obtained from them which could help identify fruitful avenues for standardized scientific research to enquire into and make results available to modern farming systems.

For evaluating such empirical data and for scientific investigations to find new and better yielding viable mixes, it would be useful to develop a quantifiable model which related taxa to fitness landscapes. In the simplest model, there would be two taxa in the mix. The fitness landscapes of the two taxa should be such that what is a ridge for one is the adaptive valley for the other, thus maximizing niche specialization and minimizing competition. When we mix more than two taxa, the valleys for the second, third, etc. could be along the slopes in the fitness landscape, keeping as much distance as possible between them. It remains to be seen as to whether methodologies for locating the required valleys, slopes and ridges using quantified indices can be developed, or whether this will require alternative models. The research need, however, is clear.

One possible way would use the spatial dimensions of the soil to do this by mixing deep-rooted and shallow-rooted plants. Another would be the planting of a taxon that requires direct sunshine with lower growing ones that are light sensitive and/or shade tolerant. The species need not be in pairs. For example, one could think of deep-rooted, medium-rooted, and shallow-rooted taxa planted in a mixture of three.

6. Conclusion

Agriculture is based on a strategy of replacing all the total biomass of all the biodiversity that used to grow in a given area by the biomass of one or a selected small number of taxa. As such, agriculture is not compatible with biodiversity.

On the other hand, the types of environment created by traditional agriculture, unstable over a long (sometimes very short) time frame but recurrent and relatively narrowly defined, has produced many new species and varieties of crop and domestic animal, as well as ruderals, and pests and diseases, which would otherwise not have existed. As such, traditional agriculture has fostered an increase in biodiversity.

The modernization of agriculture has, however, reduced biodiversity by eroding the infraspecific variables that existed in traditional crops and domestic animals, as well as eliminating ruderals and many important soil organisms in its attempt to eliminate a few pests and diseases.

Though probably only to a limited extent, agriculture could be made to cultivate a mixture of types of biodiversity, thereby not only contributing to conservation but also reducing crop diseases and pests. This would reduce the use of agro-chemicals and spare other beneficial organisms, particularly those in the soil, which would otherwise be killed off unintentionally, eventually rendering the soil sterile.

Natural biodiversity is everywhere giving place to agricultural monocultures. Conscious *in-situ* conservation programmes run by governments and local communities could help conserve it. It should be noted, however, that the maintaining of "natural conditions", if to be achieved by excluding humans and domestic animals is not easy, and may well not be completely desirable. *Ex-situ* techniques are even less satisfactory and requires much more research into the maintenance and management of such collections if they are at all to be part of the biodiversity conservation paradigm. The conservation and sustainable use of biological diversity in the agricultural cultures is full of difficulties which will not go away by ignoring them. A political, social and economic shift, and a greater awareness among all citizens are required to improve the situation. Anticipating the requisite public awareness, research and development work should focus on methodologies for maximizing the use of biodiversity in agricultural production. With the world population increasing very rapidly, the problems posed by agriculture on biodiversity conservation is going to be exacerbated.

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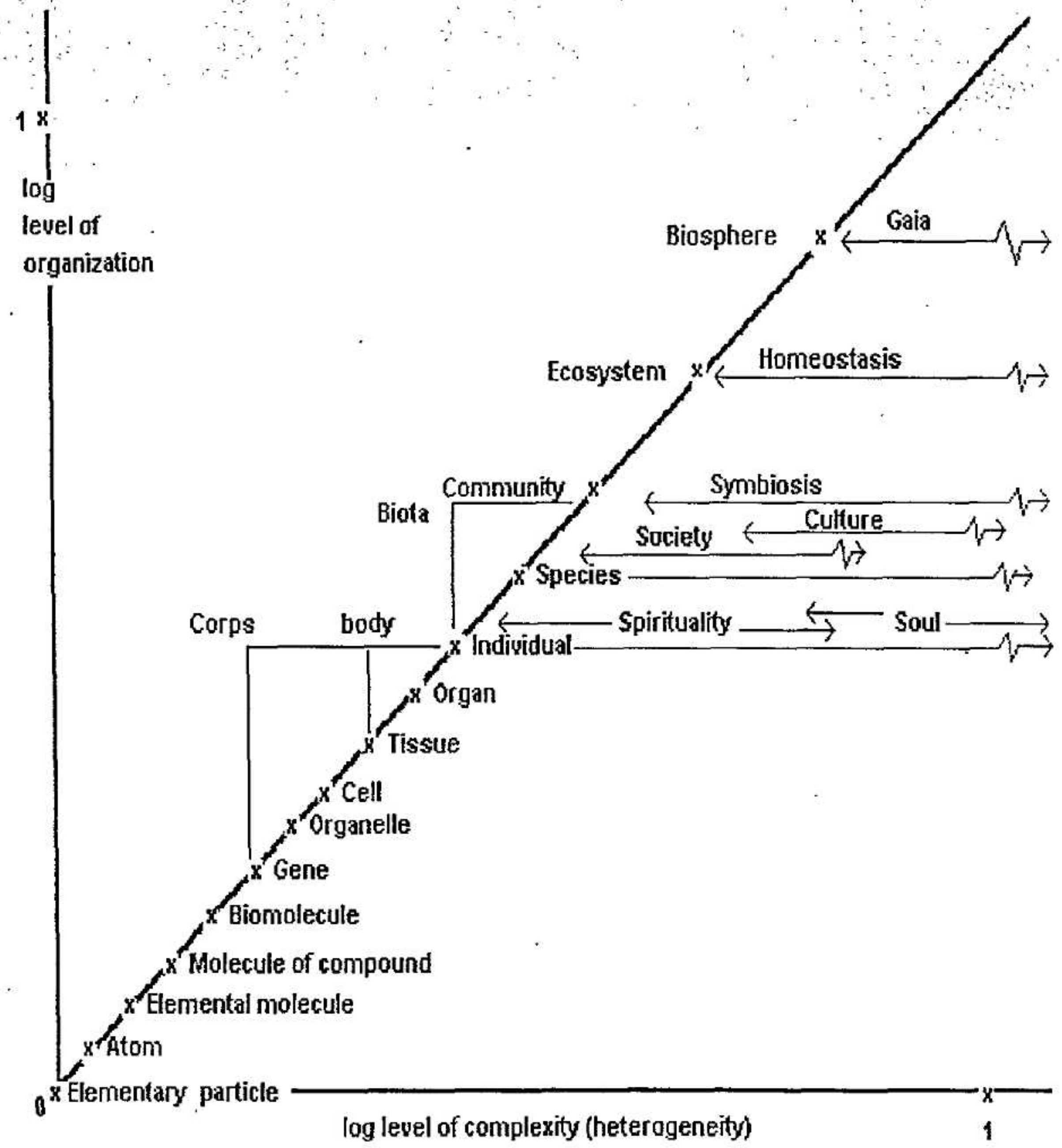

Fig. 1 Components of Biodiversity

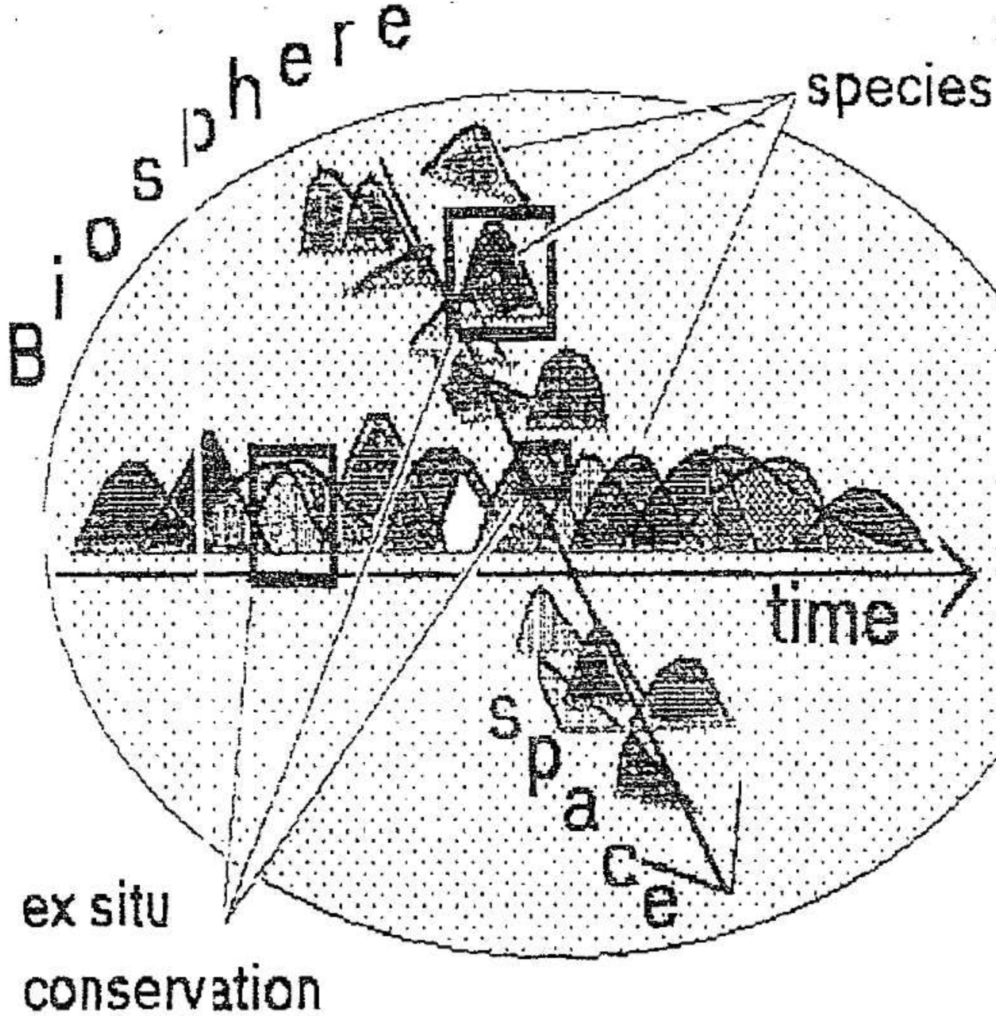

Fig. ' A representation of species in time and space, and the relationship of _ex-situ_ conservation to the dynamics in the two dimensions (Tewolde, 1993).