

Review

Spherophylon, the concept of life at a level higher than that of the individual

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Abstract: A new term, spherophylon, indicates a unit of life higher than the individual level. To define this term, critical notes are given on the meaning of age in terms of life, the interrelationships among the elements of biodiversity, and an analogy of development between the multicellular body of an individual and the spherophylon. Life is compared at various levels; at the level of the cell, the individual as a multicellular organism, and the spherophylon. The biology of the spherophylon is discussed in the context of integrative biology.

Key words: Age of life; cell; individual; integrative biology; multicellular organism; spherophylon.

Introduction – Spherophylon, a newly coined term. Spherophylon combines the ‘sphere’ from ‘biosphere’ and ‘phylon’. It signifies life composed of the more than the 10 (or even 100!) million estimated extant species on earth (=biosphere) with an evolutionary background of nearly 4 billion years (=phylon) (cf. Fig. 3 on p.274). During those past 4 billion years, various evolutionary events have affected earth’s organisms: Eukaryotes evolved from prokaryotes some 2 billion years ago, multicellular organisms evolved from unicellular organisms some 1.5 billion years ago, after which animals, plants and fungi were differentiated from the protista. Organisms usually are recognized at the level of the cell and/or individual, although they do not complete their performance as living things at either level, i.e. their lives as cells or individuals. Organisms actually also live on earth at the spherophylon level. Recognizing this third level, the spherophylon, we can analyze the life of organisms much better and, at the same time, understand the true reason why we need to maintain a harmonious co-existence between nature and mankind. Spherophylon is a term that explains a unit of life in the sphere of biodiversity at a level higher than that of individual, and we, organ-

isms on earth, all exist as important spherophylon elements at the same time as we live at the level of individual human beings, *Homo sapiens*.

This newly coined word in English, spherophylon, first was introduced at a symposium organized by the Royal Swedish Academy of Science in September, 1998,¹⁾ when I read a short paper entitled ‘Plant Systematics for the 21st Century’. In this paper, I referred briefly to this new concept of biodiversity by the term ‘spherophylon’.

This concept has been more deeply discussed in my book in Japanese under titled “Seimeikei – a new concept of biodiversity”, published in 1999.²⁾ Biodiversity was discussed in this book, both in purely biological terms and from a standpoint of applied biology. The book is entirely in Japanese, and — although it was warmly accepted in Japan — those who do not understand the language will have no chance to read it.

Since then, I have had no opportunity to publish a detailed paper on this topic, although I have had time to reconsider and develop the concept. Since the book’s publication in Japanese, I have given several lectures on the topics of biodiversity and the spherophylon, and I have been happy to speak to biologists as well as to the general public. I have read some English-language papers at international conferences that have referred to the idea of the spherophylon.

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phylon, and this particular English term has appeared in some proceedings of scientific meetings.³⁾ In this paper I will attempt to define the term spherophylon more accurately and will discuss the effectiveness of using such a concept for the sustainable use of biodiversity, as proposed at the Biodiversity Convention that was adopted at the 1992 Environmental Summit in Rio de Janeiro. For a full understanding of spherophylon life, we have to discuss the components of the word from a more or less biological standpoint.

Phylon – a life concept and its historical background. Phylon is a term that denotes the historical background of the organisms concerned. The general public often is unaware that the earth has been populated by living organisms for nearly 4 billion years, although in each species, multicellular bodies die after completing their individual lives (about 90 years for human beings). Here, I will take up the length of life in three phases and compare them.

1) *Life span of individual organisms*

When we ask someone their age, he or she usually gives it counted by the length of one's individual life, or the time since birth from the mother's womb. Human beings in general have a life span of 60~80 years, and the limit of life is said to be some 90~100 years on average, although it may be expected to lengthen to some 200 years if we succeed in transplanting most of the important internal organs. The life span of an individual animal species is known to be fixed by its neuron cells and the length of its chromosomes' telomere. The life span of individual plant species, however, differs because the organization of the plant body differs completely from that of animals. Anyway, the life span of any individual animals in general is less than a century.

Counting age by the duration of time since birth can be called one's 'social age'. We recognize our age in this sense, by written records at local government offices that note the date of birth, but age also is recognized socially beyond our own memories. Usually we say that human beings can expect to live an average of 90 years if they do not die an unnatural death. Still, we know that we will die after completing our lives according to natural processes, the longest life expectancy being about 120 or 130 years.

Using biological knowledge, age usually is counted in the sense of 'social age'. Usually we say that humans should die after their expected natu-

ral life-span duration, even if they can stay alive if there is no unnatural death, such as by sickness or accidents, but, if we consider it biologically, we understand that one's life may continue forever.

More accurately, one must say that the individuality of each multicellular organism began when a fertilized egg started its particular career, in the case of human beings in the mother's womb, and the age of an individual correctly should be counted from a biological point of view, as its social age + some ten months. It is often said that an unborn baby in its mother's womb can not live by itself. Even when it is born, however, it can not do anything by itself; its life depends on its parents or a caretaker. Each person grows up and gains social individuality when he or she is recognized as an adult. In the case of Japan, people gain the right to vote at age 20, but most are dependent even at this age on their parents in economic terms, their social life, and various other ways.

2) *A time span of the life of organisms in general*

Even when we ask someone how long they have lived, most people count their age as the length of their individuality. If a person considers the question more seriously, he or she will easily recognize that one's life not only is inherited from one's parents, but also from grandparents, and so on, the continuation of life going back, beyond the origin of humans, to the origin of life itself, to the time when the first ancestral organisms appeared on earth, some 4 billion years ago.

Actually, every individual organism carries a life that has existed since the origin of life on earth. Life itself is not material, but organisms composed of materials carry life. We can say that DNA is the macromolecule that carries the information to have life, thus we call it a genetic substance. Carrying genetic information on their DNA, all organisms live their lives, although individual organisms die after some time, or at the appointed age for the organisms concerned. DNA yields a particular variation ratio when replication of a particular molecule takes place and, after many years, evolution occurs which introduces biodiversity of organisms.

By such an evolutionary process, life on earth has had a continued existence for nearly 4 billion years, and all organisms, including human beings, have long life. We, and all other organisms on earth share lives, such that we can say that the age of our lives is nearly 4 billion years.

The phylon is defined as the lineage of successive generations of different individuals belonging to the same taxon. There are phylons of a particular species as well as of a particular taxon. The same life that goes through a phylon may diverge into two branches, or daughter taxa, through the process of evolution. We, individual human beings, are all part of the phylon *Homo sapiens* which, in turn, is a part of the phylon of the primates.

3) *Life span of the matter forming the bodies of organisms*

Along the same line, the question may be asked, how old is your body? All organisms are comprised of a combination of the atoms of particular elements that make up matter. In most cases oxygen, carbon, nitrogen, and hydrogen compose much of the body. This question concerns how long each atom remains in the body of a particular organism. Some may think that all the matter in his or her body has been maintained since birth. In fact, everyone rids themselves of portions of it repeatedly, and often rather rapidly. People cut their hair and trim their nails, and they shed epidermal cells when they shower. It is true that cells of human beings are replaced rather quickly, except for some particular cases as neuron cells which live very long as their hosts. Actually, the raw materials that constitute organisms are under dynamic equilibrium and do not remain long in an organism. By some estimates, nearly one-third of the atoms that compose a human's body are changed with different atoms of the same element, so that most atoms are renewed within one year.

Furthermore, we know that life first appeared on earth in the form of a single organism; that is, life originated monophyletically. Biodiversity has been formed through the evolutionary process of some 4 billion years. This means that all species on earth are related to each other as networked in a phylogentic tree (Fig. 1).

All organisms live within their bodies, but the matter of those bodies changes quickly. The body carries life that already has been lived for nearly 4 billion years, but the body carrying that life changes very quickly. I will not go further into this topic, but species of organisms evolve rather quickly in a time span of millions of years. In the case of sexually reproducing species, the time frame of life has existed for nearly 4 billion years.

As noted briefly, organisms have maintained life for nearly 4 billion years since life first appeared on

earth. The bodies of organisms, or the matter which makes up their lives, changes rapidly at the level of the atom, the same atom staying only a short time in a particular body. All individuals, whether uni- or multicellular, die within a period of a century or so. The succession of life from one generation to the next is one of the particular characteristics of living things. Organisms carry the life of nearly 4 billion years in bodies whose elements are quickly changing, even within the short duration of an individual's life span. Organisms are classed as species, and generally species survive for only tens of millions of years, even those produced sexually. A living thing thus has existence that perpetuates life forever through matter that changes fairly rapidly at various levels, the atom, cell, individual, and/or species. Finally, it must be noted that all organisms living on earth share in the original life form which originated 4 billion years ago. The phylogeny of organisms is given in simple form in Fig. 1 which shows that all organisms share one and the same life. We human beings would be another species if our DNA underwent a different type of variation in the course of its history.

Individuals of multicellular species and biodiversity: an analogy between ontogeny and phylogeny.

1) *The origin of biodiversity and phylogeny:* When the original form of an organism appeared on earth nearly 4 billion years ago, it was in a single form; there was only one species. We call this the monophyletic origin of organisms, which was proven sometime ago. As soon as organisms appeared on earth, their first activities were to diversify; that is to begin the evolutionary process, in order to sustain life. At least ten million species but probably more are estimated to exist on earth at present, following the nearly 4 billion years of evolutionary history. The mechanism of evolution is a biological fact, that will not be described here in detail. One example is the role of DNA in evolution. DNA is a macromolecule which carries the genetic information of organisms. Principally, it is copied precisely with regular variation in very small ratio; commonly once every million copies. This genetic variation produces the diversity of organisms; one of the most crucial principles of life.

2) *Origin of the individual and ontogeny:* The adult body of a human being is said to comprise some 60 trillion cells. The multicellular organism, however, is unicellular at the start of growth in the form of a fertilized egg. This single cell develops into

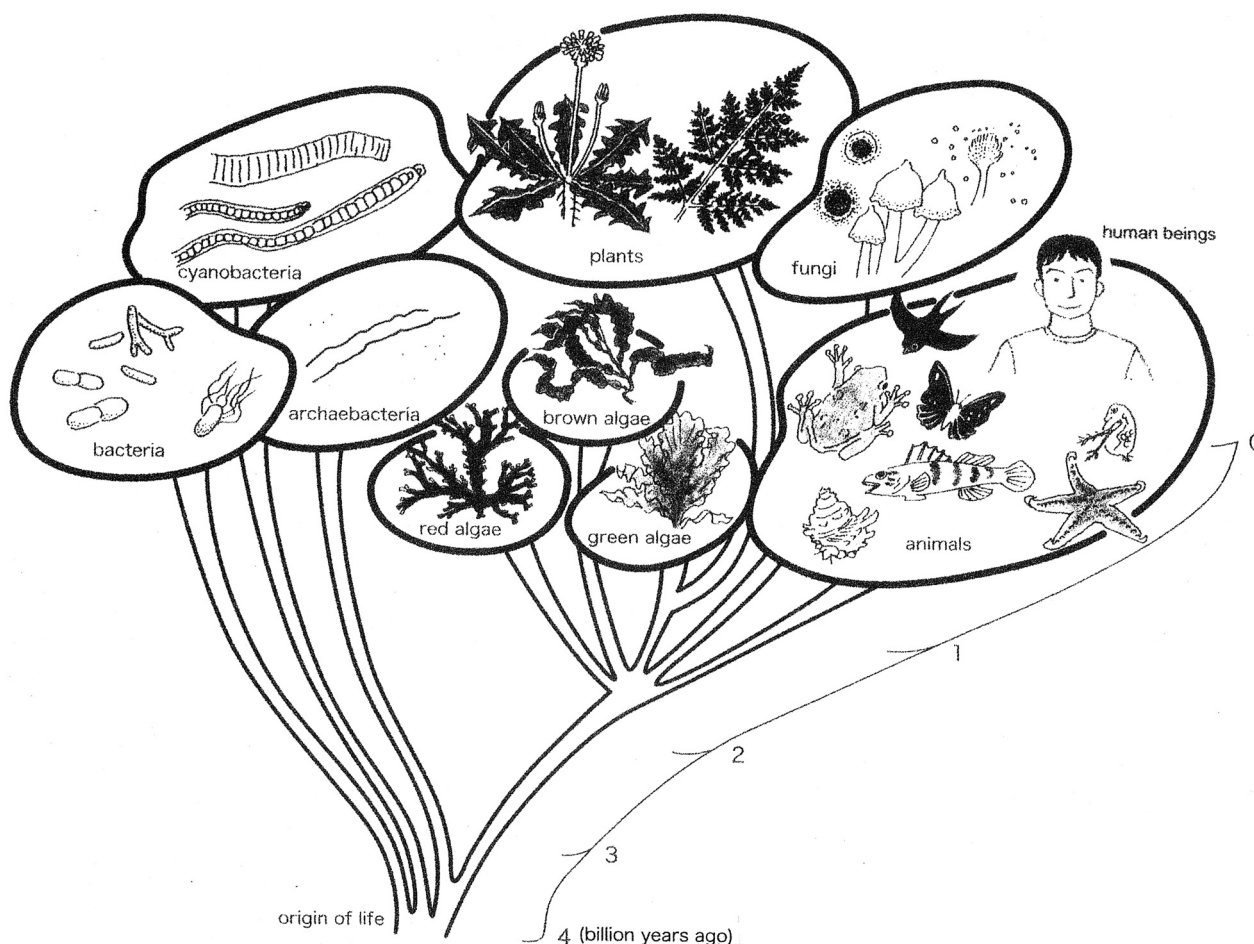


Fig. 1. Phylogeny. We are now human beings, but we might have been another species if we had received another form of DNA in the history of life on earth over nearly 4 billion years (drawn by N. Abe).

two, four, eight, and so on, until it becomes a single body of matter, with 60 trillion cells in the case of humans, in a regular course of development.

It is amazing that one's body consists of such a vast number of cells. Do the skin cells of your foot exert any particular action with your chin muscle cells? The human chin consists of a goodly number of muscle cells, and also there are many foot skin cells, but I am sure the skin cells of the foot and the chin muscle cells are completely independent throughout your life. They never are in direct collaboration during a long human life of some 90 years.

The same patterns of structure and function are seen in the diversity of organisms which have developed in the course of organic evolution. Each individual human being has some 60 trillion cells that developed from a single fertilized cell when one's life as an individual started. In the same way, all organisms

presently living on earth have evolved from a single form of organism born on earth, which evolved into the more than 100 million diversified species that form our current biodiversity.

Biosphere: concept of life in its expansion in space. The biology of the biosphere is one of the most active subjects of analysis today in the natural science. It has been repeatedly stressed that no one individual can survive by itself wholly independently and that all organisms earthly are dependent upon each other in varying degrees, directly or indirectly. Some 1.5 million species are recognized by science at present, but 10 million, or even more than 100 million, species are estimated to be living on earth. The enormous number of species are dependent on each other and form a variety of ecosystems.

An ecosystem usually is defined as a unit of organisms together with their environment in a partic-

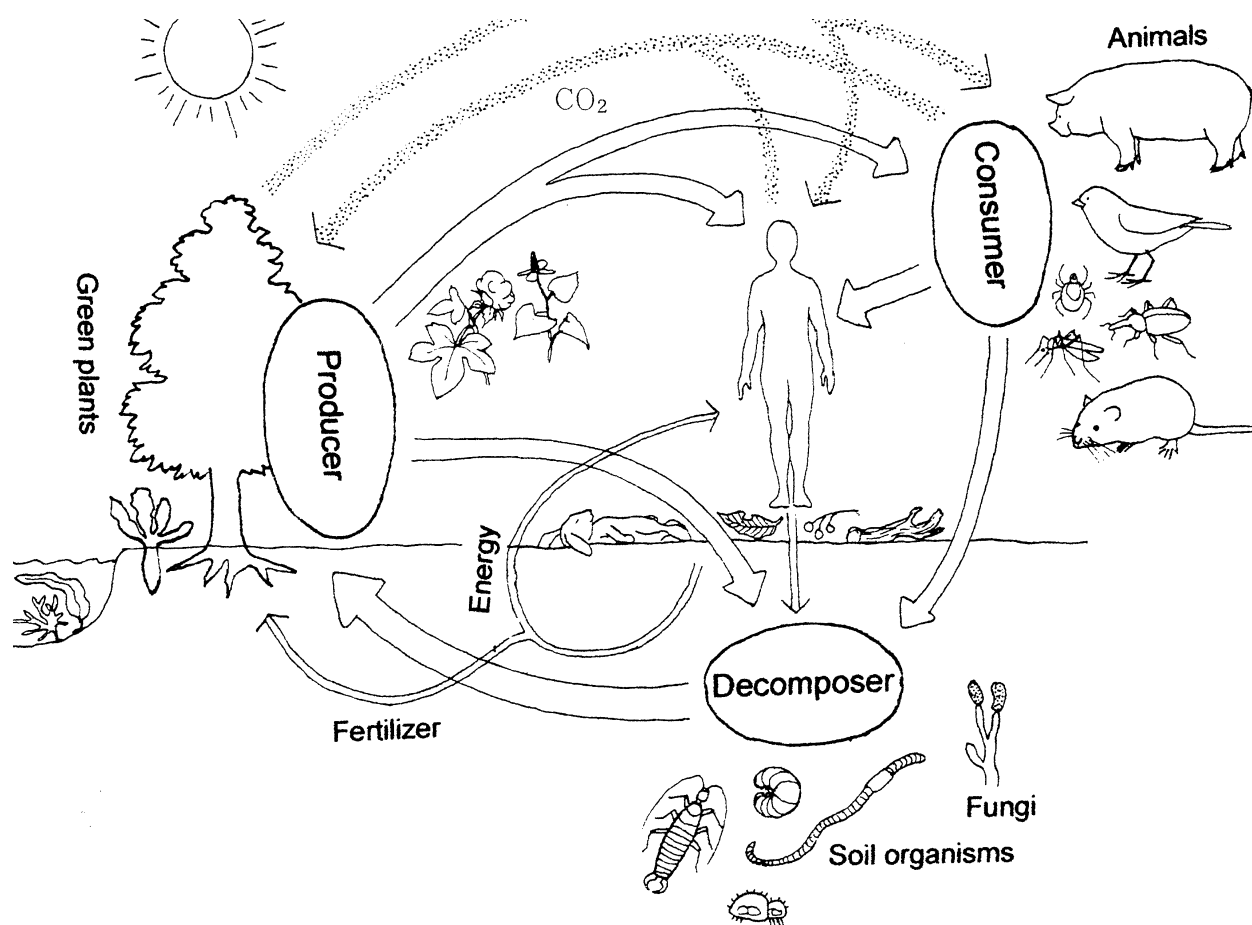


Fig. 2. Ecosystem of the earth's biosphere. All organisms on earth are directly or indirectly related.

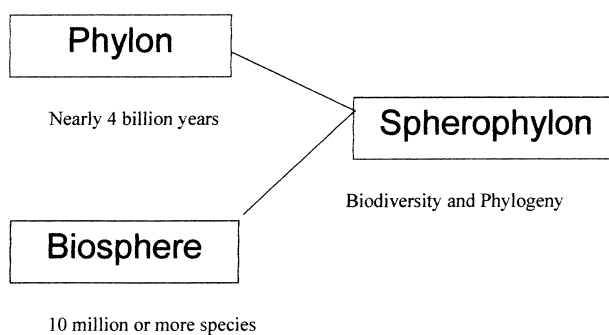


Fig. 3. Spherophylon. The level of life of organisms beyond that of the individual, which has existed for nearly 4 billion years, spreading over the entire surface of the earth.

ular area; whereas, organisms living far apart often are considered to live independently throughout their lives.

Diversified organisms sustain themselves by

close ties to each other. We can say therefore that all organisms on earth attempt to be in harmonious co-existence. This can be seen globally, if we consider every direct and indirect interrelationship among existing species.

All animals eat food to supply energy for their daily activities. These foods mostly are composed of other earth's organisms. Humans also depend on other organisms for clothing, shelter, and other needs. Oxygen is constantly taken in, but the supply of molecular oxygen does not diminish even though animals and fungi constantly absorb it. Even primary school children know that we depend on the oxygen given off by plants, which provide molecular oxygen through the process of photosynthesis. We know further that *Escherichia coli*, a species of probionta, has a symbiotic function in human beings, although we usually consider humans to be the most advanced animal and bacteria the most primitive.

This example shows that even the most advanced human beings can not live without the help of the most primitive organisms. There are many examples of the interrelationships among organisms.

We also can explain these interrelationships among extant organisms through the following stories:

Example 1) Consider having tuna salad in your lunch today in Tokyo. That tuna has been caught in the South Pacific and brought to Tokyo. It became fat by eating small fish and even plankton in the South Pacific where the tide usually moves from east to west. Plankton eaten by small fish or by the tuna itself often come from the east and again nutrients from birds' excretions. The birds may come from the Andes where they feed on the fruits of forest trees. Forest trees may, moreover, have symbiotic fungi in their roots which help them to achieve their full growth potential. Well, a person who orders tuna from the South Pacific for lunch in a Tokyo restaurant and functions variously depending on the energy gained from that tuna usually does not consider the fact that he or she also obtains energy from closely related organisms such as the unknown fungi in this example that live in a forest on the opposite side of the earth.

Example 2) No one would consider that a species of insect on Japan's Mt Fuji has any relation to a soil fungus along the Amazon River in Brazil. This needs a bit of explanation: That insect may be eaten by a bird who then flies to Southeast Asia where it constructs its nest. An alga there may be used for the nest, and the alga grew from a spore brought by a tidal current from Polynesia. The mother stock of this alga may have been brought there by a fish swimming from the coast of South America, where the molecular oxygen is from a growing plant. The seed of that plant may have come from Brazil where the tree in question had a close relationship with a soil fungus. I know that this is rather a far-fetched story, but it illustrates that all organisms on earth have direct or indirect relationships to each other in a very broad sense.

These stories, more or less exaggerated, have been told with a sense of humor to make my point. The interrelationships among extant organisms are always such that each is linked to others in a web of direct and indirect ties. Such relationships extend to all species, the 1.5 million recognized as existing, as well as the several million as yet estimated as un-

known.

Spherophylon: the existence of life at a level higher than that of the individual. A cell exists as a unit to sustain the minimum, principle form of life. This is generally and widely understood, since we have seen a sheep named Dolly who was produced by the process of cloning. All multicellular organisms have a unicellular stage in their life cycle, as in reproductive cells. For plants, reproduction from totipotent cells has been recognized for a long time.

The organisms usually recognized are mostly multicellular, and the life of organisms usually is considered to be that of the multicellular individuals around us. In this sense, according to popular belief organisms are multicellular, living until they complete their individual lives when body cells have died, in spite of the fact that their reproductive cells have already produced the next generation. Therefore, we usually measure the length of human life by the age of a multicellular individual, the duration after leaving the mother's womb, and never consider that our individuality was established when the original form of our body, a fertilized egg, was produced.

Every multicellular individual grows from a single fertilized egg, and the adult body develops through a species-specific process called ontogeny. In the same way, a single organism borne on earth nearly 4 billion years ago has evolved and diversified forming the biodiversity we see today. Throughout this evolutionary process, organisms have maintained direct or indirect interrelationships among themselves. Even now, when organisms have diversified to more than ten, or even a hundred, million estimated species, all species, or all the individuals existing on earth, maintain direct or indirect interrelationships. In this sense, all earthly organisms have the unique experience of living together, just as all the 60 trillion cells that make up human bodies live together, even though most of those cells have no direct relationship to each other. Most human beings, however, are ignorant of the fact that they themselves form just one element of the spherophylon; life at a level higher than that of multicellular individuals.

Sustainable use of biodiversity has become a common concept throughout the world. If we are to manage this, the life of the spherophylon should naturally be live and maintained forever, and artificial or non-natural death of the spherophylon should

not be the result of the activities of human beings.

Biology of the spherophylon: towards an integrative research of life. Towards an integrative biology – In the 20th century, especially in the latter half, biology achieved great developments by promoting research under the keyword ‘DNA’. Modern biology began in the 20th century with the re-discovery of Mendel’s law of genetics, and it is very symbolic to consider its historical development. In the 19th century, biology rested mostly on the observation of facts and less on analytical works, including successful experiments. In answering the question, “What is life?”, analytical studies in the biological sciences have elucidated much in analyzing principles and universal facts about organisms.

At the starting line of the 21st century, some biologists are interested in the concept of development of integrative biology.⁴⁾ When establishment of the International Cosmos Prize was discussed, the main research to be rewarded was that which integrated various fields of science. It is difficult to show the true meaning of the integration in science in a few words, but research on the spherophylon should be promoted under an integrative concept.

It is natural that the biological sciences will be promoted by results of analytical studies based on physico-chemical analyses of the workings of organisms. Reductionism was at the center of science in the 20th century, and we can expect more information about life through such kinds of analyses in the biology of the 21st century.

Some people insist that natural science can not answer the question “What is life”, because science is principally under the influence of reductionism and life is much more complicated. My impression, without scientific evidence, is that the question of what is life can be answered by natural science, but it will take more than ten or even twenty centuries to do so. The natural science of that time will completely differ from that of the present. Not only the biology, but every field of science, including physics and chemistry, will be much modified over the next ten or even twenty centuries. Saying that it will take ten, or even twenty, centuries, means that I can not

expect to see the answer to this question from natural science while I live, as my age, at most, will be a century.

To understand the true nature of life, we require integrative studies based on the results of analytical research from the various disciplines of the biological sciences. We still do not know how we can make an integrative analysis of the question, “What is life?” At the moment we can say only that we should conduct our research on the life of the spherophylon just as we do research on cells and individuals, by which research on biodiversity based on biological concepts and techniques can be expected to develop. In this sense, integrative biology should be promoted at both the individual and spherophylon levels.

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Profile

Kunio Iwatsuki was born in 1934 in Hyogo Prefecture. After graduating from Kyoto University in 1957, he started his research career as a botanist, and studied plant taxonomy, especially on the pteridophytes. At that time, it was rather difficult to have field works, and he made his first trip to southern Ryukyu in 1962 with particular certificate like a passport, as Okinawa Prefecture was under governance of the US at that time. His actual botanical trip abroad was in 1965 when he made field research in Thailand for about 4 months. Since then, he has made a variety of works in the fields in various countries in addition to researches in the herbaria and laboratories. He succeeded in systematic works in some particular groups of pteridophytes and in floristic studies in East and Southeast Asia. After a career in Kyoto University for 30 years from an undergraduate student to a full professor, he moved to the University of Tokyo in 1983 and served as the Director, Botanical Gardens. He succeeded in forming a wonderful research group there, and was the President, International Association of Botanic Gardens. In addition to his success in systematic botany, his research area extends to conservation biology, and served in editing Red Data Lists and so on. He made contributions in various governmental and non-governmental organizations, either national or international. He was awarded the Duke of Edinburgh Prize in 1994. After retiring from the University of Tokyo in 1995, he served in Rikkyo University and the University of the Air, and is the Director, Museum of Nature and Human Activities, Hyogo.

