Fundamentals of Biology

Introduction

This part of the Bio-Syllabus covers most of the fundamental concepts of biology. It is intended to serve as a guideline for the general knowledge presented in a course of biology for non-biologists, and teachers in various fields of science are encouraged to develop other alternatives to the methods presented here. It is assumed that the reader will avail him/herself of illustrative figures, pictures and graphs abundantly found in secondary literature, which have been omitted here.

In teaching the students the fundamentals of biology, special emphasis should be placed on the importance of all forms of life on Earth, with respect to the interdependence and the unity underlying all living things, including human beings. The survival of every species depends on the totality of living organisms, the bio-environment. Importantly, the bio-environment is something more than the simple sum total of all the animals, plants and microorganisms. Bio-environment can be envisaged as one integral, internally coherent system. Humanity is part of this global system and therefore should respect its laws, and not violate them.

In modern biopolitics, the term "bios" has been coined and refers to the whole ensemble of life on Earth. The concept of bios is in the core of biopolitics. Bios theory stresses that all living things are interdependent. Within the framework of biopolitics, special emphasis is placed on the creative inspiration we experience when contemplating living things: birds and fish, insects and microbes. As bios is considered one integral entity, the harm done to any living thing will inevitably tell on the functioning of the whole ensemble of bios including humankind.

Since modern technology has an increasingly negative impact on bio-diversity, it is imperative that people should come to understand and appreciate the value of bios. In order to put an end to human insensible behaviour toward bios, it is important for people to acquire sound knowledge of the basic properties, the structure and functioning of the living organisms. This minimum knowledge of biology is essential for the maintenance and promotion of bios by people, irrespective of their vocation, nation, race, age and sex. This basic knowledge will help a building engineer correctly design the plan of a building, so as to prevent serious damage to the bio-environment. It will enable a city-designer to harmonize the development of the city with that of bios, and expand the scope of the lawyer frequently involved in ecological debates.

Goals

- to clarify to people not directly involved with biology how important the preservation of the whole wealth of bios is; our planet is unique in being inhabited by living things; bios is an invaluable gift. The future of humanity and its very existence depend on the bio-environment;
- to help people avoid the risks associated with environmental deterioration, make them realize the complexity of bios activities and the fragile interdependence of all bios, including ourselves;
- to bring out the meaning of bios as a powerful factor reunifying people around the world, across geographical and national boundaries. The bios concept can also enable humanity to form a new alliance with the bio-environment, in order to exist and co-evolve in harmony;
- to reverse the current trend towards compartmentalizing knowledge, to promote its re-integration on biopolitical grounds, to develop a global vision of the bio-environment;
- to initiate the bio-assessment of technology, based on new values provided by a deeper understanding of the impact of technology on bios.

The Fundamentals of Biological Knowledge

Planet Earth is filled with life. Bios asserts itself everywhere: on the mountains and the fields, the cities and the rural areas, in hot geysers and deep oceanic waters. The adaptability of bios to different environments and the diversity of living organisms are amazing. A bacterium and a hippopotamus, a swallow and a pine tree, all demonstrate the enormous diversity and the intrinsic unity of the bio- environment.

Classification of Living Organisms

New insights into the course and the mechanisms of evolution have provided us with a new classification of living organisms. Instead of the traditional division of all forms of life into animals and plants, modern taxonomy suggests the following five kingdoms:

- prokaryotes: bacteria that lack a distinct membrane -coated nucleus (all other living cells have nuclei and are classified as eukaryotes);
- protista: eukaryotes lacking the features characteristic of plants, animals or fungi ö they are mostly unicellular organisms;
- fungi: eukaryotic organisms that are heterotrophic and develop from a spore that requires no fertilization for its germination;

- plants: eukaryotic organisms that possess chlorophyll and are therefore autotrophic. They develop from an embryo supported by a maternal tissue;
- animals: eukaryotic organisms that are heterotrophic, i.e. they depend on other living organisms for their nutrition. They develop from a sperm and egg.

The living organisms belonging to all the kingdoms are characterized by cellular structure, albeit of different kind. The viruses represent `a case apart': they lack the cellular structure and thus cannot be placed into any of the above kingdoms. Actually, they are little more than pieces of genetic information in form of DNA or RNA coated by a protective layer of proteins. All the viruses known are intracellular parasites. The life of all viruses depend on the cells they infect and eventually destroy. Careful studies of the viral life-cycles have revealed that the host cell infected by a virus is put under control of their genetic information. The cell is `enslaved', so that it supplies all the necessary `raw materials' for the viral reproduction and protein synthesis. The new viral particles produced are finally released from the disintegrated cell.

Moreover, in the early 1980s, a new type of cells was revealed, the archaeobacteria. These are primitive looking organisms that dwell under extraordinary conditions, e.g.. in geothermal waters at temperatures around 90oC, in concentrated brine and in complete absence of oxygen. Looking similar to bacteria in shape and size, they exhibit a number of unique biochemical features which provide justification for classifying them into a special kingdom.

Thus, recent data enhances our understanding of the great diversity of bios by adding a new microbiological dimension to it.

Chemicals

Bio-chemistry, the study of the chemicals that comprise all living organisms, is very important in the understanding of the fundamentals of biological knowledge. There are about 100 chemical elements on the crust of the earth and yet only 16 of them are essential for life. Of these sixteen, the four most common in living organisms are hydrogen, carbon, oxygen and nitrogen. These account for more than 99% of the mass of all living organisms.

All elements interact with each other to form molecules. Simple molecules associate to form larger molecules, macromolecules. There are three types of macromolecules: polysaccharides, proteins and nucleic acids.

- polysaccharides: they serve as food and energy stores and as structural materials. They are also known as sugars or carbohydrates and are made up of carbon, hydrogen and oxygen. Hydrogen and oxygen are in the same ratio that is found in a water molecule 2:1; thus the name carbohydrates. Some common polysaccharides are starch, cellulose, glycogen;
- proteins: they are complex organic compounds of versatile structure, comprised of smaller units called amino acids. There are twenty different amino acids, the sequence and number of which determines a specific protein. Proteins are very important organic compounds since they are involved in almost every function of the living organism. They constitute a `raw material' for most of the cell's organelles. Together with other compounds, the co-factors, they form the enzymes, which act as catalysts accelerating all the chemical reactions taking place in the organism. Proteins are essential in diet of animals and they display a wide range of metabolic and structural activities. Because of their key role in living organisms, an important part of this text will deal with the mechanisms of protein synthesis;
- nucleic acids: they constitute the genetic material of all living organisms. They therefore account for heredity, the transmission of characteristics from one generation to the next, mutations, the changes in these characteristics that lead to evolution, and protein synthesis.

Nucleic Acids and Genetic Information

There are two types of nucleic acids:

- DNA (deoxyribonucleic acid), a double stranded, helical molecule;
- RNA (ribonucleic acid), which consists of one strand and is plays a major role in protein synthesis.

Nucleic acids are composed of units called nucleotides. Each nucleotide consists of three parts:

- a sugar molecule (carbohydrate), deoxyribose for DNA, ribose for RNA;
- a phospate group attached to the sugar;
- a nitrogen base also attached to the sugar. A DNA nucleotide could have as its base one of the following: Adenine (A), Guanine (G), Cytosine (C), or Thymine (T). RNA nucleotides use the same bases with one exception: Thymine is replaced by Uracil (U). The two bases A and G are larger and are also called purines, whereas the other three, C, T, and U are smaller and called pyrimidines.

In a nucleic acid molecule, the nucleotides are arranged in a sequence attached to one another by chemical bonds. In the DNA molecule that is double stranded, the two strands are connected with weak chemical bonds, called hydrogen bonds. A hydrogen bond can form between:

- A and either T or U;
- G and C.

The bases between which hydrogen bonds can form are referred to as complementary bases.

The DNA molecule resembles a ladder: the sidepieces consist of a sugar and phosphate backbone and the rungs are formed by the bonding between complementary bases. The structure of the DNA molecule was discovered by Watson and Crick, who proposed that the `ladder' is wound up to form a helix. One complete turn of the helix contains ten nucleotides, ie. 10 base pairs.

Replication of the DNA

Synthesis of new DNA strands is called replication because the existing molecule serves as a template for the new molecule. The replication is said to be semiconservative, i.e. the new molecule consists of one strand that is completely new and one strand from the old molecule. The new strand is complementary to the one from the old molecule. DNA replication is a complicated process, involving many enzymes which catalyze reactions. In short, the process is the following:

- a `signal' for the initiation of the replication procedure is given through various enzymatic reactions;
- the helix is unwound and the two strands are separated;
- the enzyme DNA polymerase, along with many other enzymes, synthesize the complementary strands, using as `raw materials' all four deoxy- nucleotides and being in accordance with the rule of complementarity of bases;
- the new strands appear and another enzyme, DNA ligase, joins them and the molecule winds up again to resume its helical structure. The two new molecules are identical to the old molecule, unless there has been a `mistake' in the synthesizing of the new strands. These `mistakes' are called mutations and are necessary for evolution.

Genetic code

The remarkable property of the DNA is the fact that it carries the hereditary message: the information concerning all the inherited characters of a given organism. This information is expressed in the language of the nucleotides. A sequence of nucleotides codes for a specific sequence of amino acids, i.e. for a particular protein.

As we have already mentioned, aminoacids are the constituents of the proteins. It has been revealed that each amino acid of a protein synthesized in a cell corresponds to a sequence of three nucleotides. A sequence of three nucleotides is correspondingly termed a codon.

The genetic code has no `punctuation marks'. It is not overlapping, as each nucleotide forms part of only one codon. The DNA code is universal, in that nature uses the same language to describe the protein structure in a virus and a bacterium, a plant and a human being. The only important exception known is the DNA of the mitochondria where the code differs from that of the nuclear DNA and, moreover is species-specific: varies with the species of the living organism.

Role of the RNA in Protein Synthesis

In order to synthesize proteins according to the information contained in the DNA molecule, the participation of three distinct types of RNA is required:

- the messenger RNA which delivers the information on the amino acid sequence of the protein from the DNA located in the nucleus of a cell to the ribosomes, organelles in the cytoplasm of the cell where the protein is assembled from separate aminoacids;
- the ribosomal RNA which forms part of the the structure of the ribosome and is involved in protein synthesis regulation;
- the transfer RNA which recognizes and binds aminoacids, in order to deliver them to the ribosome and to add them to the growing amino acid sequence. One end of the molecule carries a sequence of three nucleotides complementary to a codon of the messenger RNA, this sequence is termed anticodon. The other end of the transfer RNA is distinguished by a specific nucleotide sequence, CCA. This sequence binds the amino acid coded for by the anticodon of the same transfer RNA.

Cells

Organisms are comprised of cells, which interact with each other and cooperate in order to ensure that the organism functions properly. There are organisms that are unicellular, ie. consist of only one cell, that is responsible for all the living functions of the organism. Most organisms though are multicellular, having a large number of cells dependent on one another and cooperating in structures called organs, responsible for all the functions of the organism. Interestingly enough, there is a third type of organisms, the colonial organisms, which are loose associations of cells, that are also capable of existing individually.

Structure of a Cell

Cells are separated from each other by their membranes. They always contain cytoplasm as well as genetic material in the form of DNA. In eukaryotic cells, the DNA is found in a special structure of the cell, the nucleus. The nucleus is the `data bank' of the cell, containing all information needed for its reproduction. Inside the nucleus, a round shaped structure can be distinguished, called the nucleolus. The nucleolus consists of proteins and RNA.

In the cytoplasm of the cell, a number of different organelles can be found, which can vary from cell to cell, depending on its function. These are the `industrial units' carrying out the different functions of the cell. The different organelles are:

- mitochondria which are surrounded by a double membrane. The inner membrane is folded to provide large surfaces where chemical reactions take place. The inside of the mitochondrion is rich in enzymes and also contains its own DNA molecule and some ribosomes. Mitochondria are the cell's energy factories;
- chloroplasts are characteristic cells of green plants only. They contain chlorophyll, which is a light sensitive pigment. Their main function is photosynthesis, the main procedure leading to the conversion of light energy to chemical energy, which is used by all other organisms to cover their energetic needs.
- Chloroplasts, like mitochondria, possess their own DNA and similar to mitochondria are believed to have evolved from primitive unicellular organisms;
- endoplasmic reticulum which is a vast network of membranous sacks. It is involved in protein synthesis and also promotes the transport of substances from one part of the cell to the other;
- microtubules and microfilaments, a vast network of tubes which comprise a `backbone' for the cell, the cytoskeleton and are also involved in the transport of substances within the cytoplasm;
- ribosomes are quite small organelles, consisting of two subunits. They are the sites of protein synthesis, and can be found either free in the cytoplasm or bound to the endoplasmic reticulum. Mitochondria and chloroplasts also contain ribosomes;
- lysosomes, spherical sacks containing digestive enzymes, which if released in the cytoplasm can destroy the cell itself;
- the Golgi apparatus, a membranous structure involved in the transport of cell materials, secretion, and formation of new lysosomes;
- vacuole, which is a characteristic organelle of plant and fungal cells, stores various substances, including waste products.

The membrane of a cell separates its contents from the surrounding environment and controls the exchange of substances between cells. They consist of lipids and proteins. The lipids form a bilayer, which membranes penetrate. Lipids comprise the hydrophobic part of the membrane, that most substances cannot penetrate. Therefore, the influx and exflux of molecules is controlled by the proteins present in the membrane.

Main Activities of Living Cells

The cells within an organism are specified to carry out specific tasks, depending on the part of the organism they are found. Thus, cells have different chemical compositions, different shapes and sizes. However, they all carry out some basic activities, necessary for their existence and of vital importance to the organism they are part of.

Nutrition

All living cells depend on nutrients, substances supplying the cell with energy and `building blocks' necessary to form new components of the cell. A cell can take up nutrients in a number of different ways:

- phagocytosis and pinocytosis, characteristic of some types of animal cells. The cell takes up material either in solid or liquid form by engulfing them with the cell membrane, forming a vesicle that includes the food substance. The vesicle is brought to the inside of the cell where it is digested. These mechanisms of taking up nutrients is used for substances with high molecular weight, that would not be able to cross the cell membrane;
- molecular transport, across the cell membrane. Small molecules are transferred either into or out of the cell via transmembranous protein channels. There are two such methods of transport: diffusion of substances according to the existing concentration gradient, which does not require energy and active transport, the movement of substances against a concentration gradient during which energy is expended by the cell. The phenomenon of osmosis is quite common among living cells and is essential to the maintenance of their shape and size. Osmosis is the diffusion of water across the cell membrane. The direction of the movement of water is from lower to higher concentration of chemicals on the inside and outside of the cell. In this way, an equilibrium of concentrations is achieved.

Digestion

Once the food particles are taken up by the cell, they will be broken down to components that the cell can use as building blocks or as sources of energy.

Digestion within a cell is quite different from the digestion of food that takes place in an animal, as an organism. Animals have an alimentary canal, which comprises a special system of organs that excrete liquids, take up nutrients, etc. The food passing the alimentary canal is chemically modified. With the help of specific enzymes, the useful for the organism substances are taken up by cells and processed accordingly, whereas the `extra materials' are excreted from the organism.

Respiration

Respiration is the process during which chemical energy of organic molecules is liberated and brought to a form that the cell can use for its functions. If it requires oxygen, it is called aerobic respiration; if the reaction takes place in the absence of oxygen, it is anaerobic respiration. Organic molecules are broken down by a series of reactions that are controlled by enzymes. Each releases a small amount of energy, most of which is stored by the cell in the form of a chemical nucleotide, Adenosine Tri-Phosphate ATP.

ATP is sometimes compared to be the `energy coinage' of the cell economy. After `exchanging' its small amount of energy, each ATP molecule looses its energetic `value' and reduces to an ADP (adenosinediphosphate) molecule. ATP and ADP are very important in maintaining the balance of the energy `parity' of the cell.

Cell respiration must not be confused with the exchange of oxygen and carbon dioxide with the environment. This is called external respiration, or gas exchange and is a totally different process, which involves specialized organs.

Respiration depends on specialized membranes within the cell that contain specific enzymes which catalyze the oxidation of substrates. Substrates for these reactions can be proteins, carbohydrates and fat molecules. The oxidation reactions take place in the mitochodrion which has the required membranous surfaces. Thus the mitochodrion is compared to be the energy factory of the cell.

On the inside membranes of the mitochondria, the enzymes are arranged in a sequence referred to as the electron-transfer chain. Electrons are very small particles, carrying electric charge. During respiration, charges are carried across the membrane; thus, one side of the membrane becomes positively charged and the other negatively charged. This difference in charge is efficiently used up by the cell and converted to energy in the form of ATP. Energy in the form of ATP can be used by the cell to meet all its needs.

Depending on whether oxygen is neededd, two kinds of respiration may be distinguished:

- aerobic respiration. If respiration takes place where sufficient oxygen is provided, then it is called aerobic respiration. It involves a series of chemical reactions whose end products are carbon dioxide, water and chemical energy in the form of ATP. The substrate that is usually the most common in respiratory reactions is carbohydrates. Polysaccharides are hydrolyzed converted with the addition of water molecules to monosaccharides. Fats are used when the cell "runs out" of carbohydrates. Proteins are a cell's last reserve when it comes to respiration and are only used if all carbohydrate and fat reserves have been used up. The oxidation of one sugar monosaccharide molecule yields 38 molecules of ATP. Therefore aerobic respiration yields a large amount of energy for the cell;
- anaerobic respiration. Anaerobic respiration is common among certain microorganisms and is also observed in certain cells of higher organisms in conditions where there is not sufficient oxygen. There are certain bacteria, called obligate anaerobes, that actually die if they are placed in an environment where there are substantial amounts of oxygen. Other organisms, such as yeasts, do not depend on the availability of oxygen. These are called facultative anaerobes. There are also some cells that can survive if they are temporarily deprived of oxygen. Such cells are muscle cells; when a person stresses himself too much while exercising, muscle cells respire anaerobically and produce lactic acid which brings about the feeling of fatigue. The phenomenon of anaerobic respiration is observed in everyday life. Yeast causes the dough to rise, grapejuice is converted to wine; these are examples of alcoholic fermentation. However, anaerobic respiration yields only 2 molecules of ATP per sugar molecule, which is 19 times less that the amount of energy that aerobic respiration produces.

Photosynthesis

All life on earth depends on photosynthesis, a process which:

- converts solar energy into useful chemical energy for the needs of the cell;
- makes carbon, the basic element of organic compounds available to living organisms;
- produces oxygen.

In higher plants, photosynthesis takes place in the chloroplasts, the organelles of the cells that contain chlorophyll.

Light is the ultimate source of energy for all forms of life on earth. This energy is captured by the chlorophyll molecules during photosynthesis. Carbon dioxide serves as the source of carbon for all the organic substances synthesized. Photosynthesis also needs water in order to take place.

In all likelihood the first photosynthetic organisms on earth were of the anaerobic type, working in the absence of oxygen, like the purple or green bacteria. The atmosphere of the primeval Earth was almost completely devoid of molecular oxygen. It is still a controversial point whether all the oxygen contained in Earth's atmosphere today is the product of photosynthesis or whether part of it is due to purely chemical processes in the crust of the earth. The drastic increase of oxygen concentration in the atmosphere led to the development of aerobic respiration, which is evolutionary speaking more advanced than fermentation. Aerobic respiration is more efficient than anaerobic, since the difference in energy yield is so great. Thus, the development of respiration, promoted the evolution of more advanced forms of life such as eukaryotes, multicellular organisms, vertebrates, mammals and finally humans.

The other highly important aspect of photosynthesis is that it undoubtedly accelerated the progressive development of bios with the efficient conversion of carbon dioxide to organic substances, on which all forms of life are dependent.

It is necessary to distinguish between two modes of life:

- autotrophic, characteristic of photosynthetic organisms, which include green plants and some bacteria, that can synthesize organic molecules from inorganic matter;
- heterotrophic, characteristic of animals, fungi and some bacteria, which are unable to use light energy and are therefore dependent of the biomass produced by the photosynthetic organisms.

Photosynthesis is a two stage process and can be divided into the light and the dark stages. These are so termed because the first requires light, while the second can take place independent of the availability of light. The importance of the light stage of photosynthesis is that solar energy is captured and converted to ATP and high-energy electrons. These two forms of energy are used in the following stage of photosynthesis, the dark reactions, which convert carbon dioxide to carbohydrates. Starting with carbohydrates and with the help of many enzymes, fats and proteins can be produced; thus, the importance of photosynthesis is appreciated.

Photosynthesis and respiration can be viewed as reverse processes. In photosynthesis, carbon dioxide and water react to form carbohydrates and oxygen; photosynthesis uses up energy. In respiration, carbohydrates are broken down, usually in the presence of oxygen, to carbon dioxide and water, releasing energy.

Today, it is especially urgent to understand the process of photosynthesis, which is very sensitive to pollution. Photosynthesis contributed greatly to the formation of the ozone layer, the existence of which allows us to live on earth. However, the destruction of the ozone layer is catastrophic for all forms of life on earth; the ozone is capable of absorbing a large amount of the dangerous solar radiation. Its depletion could be fatal to all terrestrial organisms.

Multicellular organism

The foregoing discussion focused on the cellular level of life. However, a great variety of plants, animals and fungi are composed of a great number of cells which are usually characterized by some degree of functional specialization and differentiation. This implies that each of the cell or tissue types performs a particular function of its own. This internal differentiation is especially spectacular in multicellular animals, where it comes to the formation of distinct organ systems, each specializing in a particular function. The following are the major functions multicellular organisms have to perform:

shape maintenance and protection of the interior of the body from harmful external influences; this is accomplished by an outer protective layer (skin, cuticle) and some sort of external or internal skeleton;

- digestion, mechanical and chemical breaking up of food molecules;
- respiration, involving organs responsible for oxygen uptake and carbon disoxide release this system includes gills or lungs in the vertebrates;
- mobility, involving organs necessary for motion, such as muscles in animals;
- internal transport, the function of the circulatory system, exemplified by the blood circulation system in the vertebrates;
- maintenance of the salt and water balance, which involves the release of metabolic waste products. This is the main function of the excretion system, which in most cases involves kidneys or their analogs;
- reproduction, depending on a specific system. In most animals reproduction is sexual, ie. it involves the formation and subsequent copulation of sperm and eggs. These sex cells develop in maturity organs called ovaries and testicles;
- regulation of the body functions. This can be considered on two levels: short term regulation, providing for coordinated responses to stimuli involving the nervous system and long term regulation which is responsible for maintaining proper balance among different activities of the body. This is the main function of the chemical agents, hormones, etc.

Ecology

Defining an Ecosystem

The term ecology comes from the greek words and ,namely `home' and `study'. It is the field of biology "dealing with living things as they are at home in their natural environments, interacting with on another and the non-living objects in Nature."

The basic concept of ecology is the ecosystem. An ecosystem comprises:

- a number of interacting species of living organisms (the biotic community);
- non-living matter termed the physical environment.

The characteristic property of an ecosystem is that its functioning is for the most part independent of the input from the outside, i.e. it is a materially closed or semi-closed system. Like a spaceship traveling across space, an ecosystem can make its own food from its waste products. It is thus an ideal example of waste-free recycled production, far surpassing what has been achieved so far by humans.

An ecosystem depends on a source of energy, because its dissipation in life-sustaining activities of the organisms is irreversible. With respect to the kind of energy they use, the ecosystems are divided into:

- photosynthetic (the overwhelming majority), depending on sunlight;
- chemosynthetic, depending on energy released by chemical reactions.

The biotic community of an ecosystem includes different kinds of organisms. Each of the species forms groups of its own which are known as populations. If close ties are established between several populations of different kinds of organism, these populations are said to form an association. The area occupied by an ecosystem is referred to as its habitat.

Abiotic Factors

These are dependent on physical environments and include the following:

- light, whose intensity varies from complete darkness in deep oceans to the strong illumination characteristic of the tropical regions of the Earth;
- temperature: bios can be sustained in Arctic frosts of -50oC as well as at tropical heats of +50^{o}C living organisms differ widely in their temperature adaptability;
- oxygen concentration: practically all animals, plants and fungi, as well as some bacteria need oxygen in order to survive; however, there are some microorganisms which require the absence of oxygen;
- availability of water: while water is vital to all forms of life, living organisms differ in their water requirements for sustaining life;
- concentrations of minerals in the environments (soil, water, etc.) For example, freshwater species typically tolerate low amounts of salts whereas inhabitants of the Dead Sea can survive in saturated solutions of sodium chloride;
- the acidity of the milieu: each organism adjusts to a definite range of acidity or alkalinity. Acidification of soils caused by intense agriculture and especially by the notorious acid rains has had a devastating effect on the natural ecosystems.

Biotic Factors

The biotic factors which involve interactions among living organisms belonging to the same or to different species:

- predation, the term used if one organism, the predator, feeds on another, the prey. In a well-balanced ecosystem, the predator does not cause the extinction of the prey, but merely keeps its number relatively constant;
- competition, direct or indirect struggle for the available food, refuge, potential mates, etc. It is competition for food resources that made the harmless European rabbit so dangerous for Australian ecosystems;
- symbiosis, "living together" which can be useful for both organisms involved (mutualism), useful for one and harmful for the other partner (parasitism) or, finally useful for one and neither useful nor harmful for the other organism (commensalism). A familiar example of mutualism is a lichen, a system composed of a fungus and an alga. The fungus gets nutrition as a result of photosynthesis carried out by the alga. The alga is provided by water and minerals absorbed by the fungus;
- the anthropogenic factors caused by man. Man has exerted a considerable influence on bios since the beginning of human civilization. Some forms of life were cultivated, others eliminated. Today, human activities jeopardize all bios so that its very existence is endangered. Suffice to mention the following results of human activity soil erosion, the loss of soil fertility, forest ecosystem destruction, deforestation, desertification or flooding caused by man, air pollution, water pollution, increasing hole in the ozone layer which may result in exposure of land bios to destructive ultraviolet radiation.

Physical and Chemical Cycles

As already mentioned, an ecosystem is capable of recycling substances. Cycles of substances can be physical if the substance involved undergoes no chemical changes; otherwise they are called chemical. Some ecosysem cycles are the following:

- the physical water cycle: water evaporates from the land and oceanic water surface. With subsequent precipitation of the water as rain or snow, it returns to the surface of the earth and it also penetrates through the soil where it saturates soil layers below the water table. Plants and animals participate in this global turnover, as plants absorb water from the soil, animals drink water, and water also transpires from both into the atmosphere;
- the chemical carbon-oxygen cycle: interconversion of oxygen and carbon dioxide. The green plants take up carbon dioxide and release oxygen during photosynthesis. Respiration in all types of organisms involves intake of oxygen and the release of carbon dioxide. The carbon cycle also involves the processes of decomposition and synthesis of organic compounds in animal organisms consuming plant biomass.

Except for these two cycles mentioned, there are several other mineral cycles, such as the nitrogen and sulfur cycles. Ecosystems carry out substances of transformation of other substances and rid of waste products. However, the overloading of ecosystems with human waste products often exceeds the capacity of such systems to recycle substances. It has been established, for instance, that carbon accumulation in a number of ecosystems in this century has already resulted in their oversaturation. These ecosystems become sources of secondary pollution as they do not recycle carbon but rather release it into the environment. Another substance that has accumulated in ecosystems as a result of man-produced chemicals is phosphorus. Accumulation of phosphorus in water results in excessive growth of algae; the decay of algae removes all the oxygen from the water, leading entire freshwater ecosystems to extermination.

Food Chains in an Ecosystem

The components of the biotic community in an ecosystem play different ecological roles:

- photo and chemosynthetic organisms are called food-producers because they are responsible for primary conversion of carbon dioxide to organic substances;
- animals, fungi and heterotrophic bacteria are referred to as food-consumers since they rely on the organic products manufactured by the food-producers;
- some bacteria, fungi and animals feed on dead organisms, excretions and debris. These are called scavengers;
- bacteria and fungi decompose organic substances so that they revert to the inorganic form accessible for food-producers. These decomposers complete the ecosystem turnover of matter.

Dynamics of the Biotic Community

The populations of organisms entering into an ecosystem develop in time. Whenever a new population is introduced into an ecosystem, its development undergoes the stages of:

- initial adaptation to the new environments;
- explosive population growth;
- retarded growth due to partial exhaustion of the natural resources, increased competition, and inhibitory effect of the waste products of metabolism;
- persistence at a relatively constant level in terms of numbers of the individuals or, if the resources available are limited, rapid extinction of the population.

Most populations encountered in nature have already reached the persistence stage. However, populations change in response to environmental changes. These can be aperiodic, having no definite rhythm (volcanic eruptions, forest fires) or periodic. Among the latter, daily, lunar (monthly) and seasonal changes can be discerned. For example, many organisms are active only in the daytime or only at night, they are, respectively, diurnal or nocturnal organisms. Some animals spend cold winters in the state of dormancy (hibernation), others are inactive during the hot tropical mid-summer (aestivation).

Ecosystems inhabiting a particular area on land or in the sea usually undergo a number of stages in their century-long life-history: several faunas and floras develop in succession. The final stage characterized by an indefinitely long persisting biotic community is referred to as the climax.

When humankind appeared on Earth, the human population was part of natural ecosystems. As civilization developed, many of the ties with natural ecosystems were severed. The resulting environmental crisis calls for urgent measures to be taken in order to achieve the reintegration of humanity into the great network of bios.

Evolution

Evolution is a gradual process through which life has come into being and developed up to the present moment. The concept of evolution has been substantiated by extensive evidence:

- remnants of fossil organisms have been studied and their age determined using precise methods. Apart from extinct animal and plant species, numerous microfossils have recently been discovered. They provide an insight into the earliest stages of biological evolution when the Earth was inhabited only by microorganisms. All these findings together with geological data have made it possible to establish the general time course of evolution and introduce a reliable geochronological scale;
- it has been demonstrated that the living organisms continue to evolve in the present era. In the periods of time which commensurate with human history new species can arise and pre-existing ones disappear;
- different species demonstrate similar features suggesting common ancestry. For example, all vertebrates have a great number of homologous organs, such as the heart, the central nervous system, the extremities. These must have descended from the same ancestral organs and have since differentiated in conformity with their functions;
- many organisms, including humans, exhibit vestigial traits, i.e. organs that have gradually lost their function but are still retained in reduced form; Such organs are the appendix, the third eyelid in the human eye, body hair, etc.;
- the embryos of different biological species demonstrate similar characters; the degree of similarity depends on the extent to which the organisms are related. In more distantly related organisms, only the earliest stages of embryonic development reveal similar structures. This recapitulation law, originally formulated by Mueller and Haeckel in application to vertebrates, has been recently shown to apply even to the microorganisms;
- the similarity of amino acid sequences of universally spread proteins such as ferredoxin and cytochrome c supports the concept of evolution and also expands our knowledge of evolutionary relationships among organisms;
- in terms of cell structures and functions all forms of life reveal a great number of universal patterns discussed in the preceding sections.

Biological evolution is considered as an established fact. But what are the driving forces of this process? Recent research has yielded important results concerning the mechanism of evolution:

- Darwin originally considered evolution as a slow, gradual process. Today, evidence is in favor of quick, jerky, punctuated evolution interspersed by long periods during which different forms of bios undergo almost no significant changes. the fact that no intermediary forms of life have been found to fill the gaps in evolutionary lineages previously explained by the incompleteness of the fossil record, is currently interpreted as consistent with the idea of evolutionary leaps (saltations) from one type or class to another;
- evolution was traditionally related to the struggle for survival in nature. Different organisms compete for limited food resources, territory, or for a limited number of mates. In this struggle only the fittest will survive to produce offspring. However, there are indications that the concept of natural selection may not be sufficient for rationalizing evolution. The following data was presented in the last few years. Some nucleotide substitutions produce mutations having no appreciable effect on the viability and fitness of the organism. These mutations are regarded as neutral in terms of the struggle for existence. The evolution dependent on these mutations is controlled by the pressure of natural selection;
- considerable attention is currently given to evolution through cooperation. This type of evolution eliminates or limits competition by forming a union between organisms. Cooperation, whose advanced forms are referred to as symbiosis, is abundant on Earth. As already mentioned, mitochondria and chloroplasts, essential organelles of the eukaryotic call, are the results of symbiosis.

Evolutionary changes in forms of life, though influenced by natural selection, are also influenced by the laws of symmetry and systemic theory. A number of biologists has suggested that evolution proceeds according to the laws of aesthetics.

Major Evolutionary Events

The Earth is estimated to be about 4.5 billion years old. The earliest fossil microorganisms found are well over 3 billion years old; some of the samples are as old as 3.8 billion years. Thus, life originated in a relatively short period of the Earth's history and the driving forces of the process are still unknown. It has been suggested that the chemical synthesis of organic substances preceded the development of the first life forms. This complies with Oparin's hypothesis on the abiogenic origin of life.

It is assumed that inorganic substances like carbon dioxide, water and ammonia reacted in the presence of other substances to produce organic molecules of increasing complexity. This abiogenic synthesis could have been driven by the energy of ultraviolet light and atmospheric electricity. It could also have been catalyzed by minerals contained in particles of dust or suspended in the oceanic waters. As it was shown experimentally, under such conditions the formation of amino acid sequences and nucleotide containing compounds is feasible. Lipids promote the formation of such structures by surrounding and concentrating amino acids, short peptides, nucleotides. These prebiological systems can grow, divide, accumulate substances from the environment and compete with each other. Certainly, they are far from being considered living organisms. Much subsequent development is needed for a living cell to arise.

Another piece of evidence involves RNA; short RNA molecules have been shown to assemble in the presence of inorganic catalysts such as clay particles. Clay itself may have formed structures capable of precisely reproducing themselves, the so-called inorganic genes. These may have been the first form of genetic information.

Events which took place after the emergence of primitive life on Earth are better documented. The structure of RNA and certain protein molecules have played the role of evolutionary markers. The differences noted in their structure relate directly to the distance between the organisms compared in terms of evolution.

The recent advances in the field of biological science have brought our understanding of bios beyond any past boundaries of imagination. However, one should not draw the impression that all of our problems have found a satisfactory answer. There still exist fundamental questions as for the origin, the mechanisms and driving forces of bios.

It is of utmost importance that humans realize the fact that we have only existed on Earth for an insignificant amount of time compared to the billions of years that different forms of bios have existed. We have no right to cause irreparable damage to all other forms of bios. It is an imperative to learn to respect all living organisms, including ourselves, and deepen our understanding and appreciation of nature and biological processes, so as to reestablish a harmonious coexistence with bios, a miraculous gift on our planet.

References

1. Allamong, B.D., Auffenberg, W., Glass, H.B., Heim, W.G., Moore, J.A., Morrill, K., and Wagner, J., (1980) Teacher's Guide Biological Science. A Molecular Approach, BSCS Blue Version, 4th Edition. D.C. Heath and Co. Lexington, Massachusetts. Toronto.
2. Campbell, N.A., (1987) Biology. The Benjamin/Cummings Publishing Company, California.
3. Friday, A., and Ingram, D.S., (1985) The Cambridge Encyclopedia of Life Sciences. Cambridge University Press, Cambridge, London, New York.
4. Griffin, R.D., (1962) Animal Structure and Function. Holt, Rinehart and Winston. New York, Chicago, San Francisco, Toronto, London.
5. Grzymek, B., (1976) Encyclopedia of Ecology. Van Nostrand Reinhold Co. N.Y., Cincinnati, Toronto, London, Melbourne.
6. Haynes, N.L., (1980) Resource Book of Test Items. Biological Science. An Ecological &127; &127;Approach, BSCS Green Version, 4th Edition. Rand McNally and Co.. Chicago, New York, San Francisco.
7. Hurlbut Jr., C.S., (1976) The Planet We Live On. Harry N. Abrams, Inc., New York.
8. Mader, S.S., (1985) Inquiry into Life. William C. Brown, Dubuque, Iowa.
9. Margulis, L., (1985) Symbiogenesis in Cell Evolution. New York.
10. Moore, J.A., Olsen, I.D., et al., (1973) Biological Science. An Inquire into Life, H.B. Jovanovich, Inc. New York, Chicago, San Francisco, Atlanta, Dallas.
11. Odum, E.O., (1985) Fundamentals of Ecology
12. Otto, J.H., and Towle, A., (1973) Modern Biology. Holt, Rinehart and Winston, Inc. New York, London, Toronto and Sydney.
13. Otto, J.H., Otto, W.D., Towle, A., and Weaver, R.A., (1969) Teacher's Guide Modern Biology. Holt, Rinehart and Winston, Inc. New York, Toronto, London and Sydney.
14. Perrott, E., Campbell, I.D., and Hughes-Evans, D., (1974) Biology: An Environmental Approach, Teachers' Guide, pp.161-206. J. Murray. London.
15. Sasson, A, (1987) Biotechnology: Challenges and Hopes
16. Skulachev, V.P., (1989) Membrane Bioenergetics. Plenum Press.
17. Villee, C.A., (1977) Biology. W.B. Saunders Co. Philadelphia, London and Toronto.
18. Vlavianos-Arvanitis, A., (1985). Biopolitics Dimensions of Biology. Biopolitics International Organization, Athens, Greece.