Basic knowledge in Biology

The following exposition includes an outline of the main topics related with basics of biology. It is not a complete description of these main topics. It contains some hints useful to carry out a more in-depth study. To get a comprehensive knowledge of the issues, two books are suggested:

Miller K.R. and Levine J.S. (2008) Prentice Hall Biology. Pearson Publisher.

Raven P., Johnson G.B., Mason K.A., Losos J.B., Singer S.S. Biology. McGraw Hill Education editions.

BIOLOGY OF THE CELL

All living organisms on Earth, from the unicellular bacteria to multicellular animals, are composed of the fundamental unit of life, the cell. Cells are the smallest unit of life that can replicate independently and hold the "equipment" necessary to keep an organism alive and successful on Earth. Let us look at some of the components of this basic organizer of living organisms. The cell membrane, or **plasma membrane**, surrounds the cytoplasm of a cell. It serves to separate and protect it from the surrounding environment and mostly consists in a bilayer of phospholipids that are amphipathic: One end of the molecule is hydrophobic (insoluble in water), the other is hydrophilic (soluble in water). A phospholipid is made of a molecule of glycerol with a phosphate added to one end, and two side chains of fatty acids attached at the other end. Within the cell membrane, there is the cytoplasm, composed of an aqueous solution, the cytosol, and a variety of structures called organelles that carry out specific functions. It contains ribosomes, the complex processing molecules that assemble proteins for the cell. It also contains the genome—the complete set of genes composed of **DNA (deoxyribonucleic acid)**. DNA contains the genetic information necessary for directing cellular activities. DNA and proteins are the major components of chromosomes.

Cells are too small to be seen without magnification. They range in size from 1 to 100 micrometres.

There are two primary types of cells: **eukaryotic cells** and **prokaryotic cells**. Eukaryotic cells have a true nucleus, separated by a membrane from other cellular structures, which houses DNA. In prokaryotic cells, the single bacterial DNA molecule is not separated from the rest of the cell. The majority of prokaryotic cells have a rigid cell wall that protects them. All prokaryotic organisms are unicellular, meaning that the entire organism is only one cell. Most prokaryotic organisms reproduce through a process called binary fission where the cell just splits in half after copying its DNA. Eukaryotic cells contain several types of organelles, while prokaryotic cells contain a few

organelles and none that are bound by a membrane. There are also differences within eukaryotic cell types. Plant cells for example, contain structures such as a cell wall and chloroplasts that are not found in animal cells. Typically, eukaryotic cells are more complex and much larger than prokaryotic cells. On average, prokaryotic cells are about 10 times smaller in diameter than eukaryotic cells. Most eukaryotic organisms are multicellular. This allows the eukaryotic cells to become specialized. Through a process called differentiation, the cells take on characteristics that can work with other types of cells to create an entire organism. Eukaryotes may use either asexual or sexual reproduction depending on the organism's complexity. Sexual reproduction allows more diversity in offspring by mixing the genes of the parents to form a new combination and hopefully a more favourable adaptation for the environment.

Organisms may be classified by the source of the energy and carbon they need for synthesizing the cellular material. **Autotrophs** (from the Greek autos, meaning "self," and trophos, meaning "feeder") are able to make their own energy-rich molecules out of simple inorganic materials. They obtain all needed carbon from CO_2. **Phototrophs** utilize solar energy, whereas chemotrophs obtain energy by the oxidation of a chemical fuel. For example, the lithotrophs oxidize inorganic fuels: HS^- to S^0 (elemental sulphur), S^0 to SO_4^{2-}, NO_2^- to NO_3^-, or Fe^{2+} to Fe^{3+}.

Heterotrophs (from the Greek heteros, meaning "other," and trophos, meaning "feeder") require organic nutrients. They are dependent on an outside source of organic molecules for their energy. However, nearly all living organisms derive their energy, directly or indirectly, from the radiant energy of sunlight. The light-driven splitting of water during **photosynthesis** releases its electrons for the reduction of CO_2 and the release of O_2 into the atmosphere:

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

(Light-driven reduction of CO_2)

Non-photosynthetic organisms obtain the energy they need by oxidizing the energy-rich products of photosynthesis, then passing the electrons thus acquired to atmospheric O_2 to form water, CO_2, and other products, which are recycled in the environment:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6\ CO_2 + 6H_2O$ + energy

(Energy-yielding oxidation of glucose)

The cells in complex multicellular organisms like plants are organized into **tissues**, groups of similar cells that work together on a specific task. **Organs** are structures made up of two or more tissues organized to carry out a particular function, and groups of organs with related functions make up the different **organ systems**. At each level of organization—cells, tissues, organs, and organ

systems—structure is closely related to function. For instance, the animal cells in the small intestine that absorb nutrients look very different from the muscle cells needed for body movement. The structure of the heart reflects its job of pumping blood throughout the body, while the structure of the lungs maximizes the efficiency with which they can take up oxygen and release carbon dioxide.

Prokaryotic organisms (or prokaryotes) include bacteria. Eukaryotic organisms (or eukaryotes) include algae, fungi, plants, animals.

SEXUAL REPRODUCTION, MEIOSIS AND MITOSIS

Haploid and **diploid** are terms referring to the number of sets of chromosomes in a cell. Diploid organisms are those with two sets. Human beings (except for their gametes), most animals and many plants are diploid. We abbreviate diploid as 2n. Haploid organisms/cells have only one set of chromosomes, abbreviated as n. Chromosomes that carry the same genes are termed homologous chromosomes. The alleles on homologous chromosomes may differ, as in the case of heterozygous individuals. Organisms (normally) receive one set of homologous chromosomes from each parent.

Meiosis is a special type of nuclear division which segregates one copy of each homologous chromosome into each new "gamete". **Mitosis** maintains the cell's original set of chromosomes (for example, one diploid 2n cell producing two diploid 2n cells; one haploid n cell producing two haploid n cells; etc.). Meiosis, on the other hand, reduces the number of sets of chromosomes by half, thus making it possible to maintain a constant number of chromosomes in a species. Cells that become gametes are referred to as germ line cells. Meiosis occurs in the production of gametes—the sperm of the males and the eggs of the females. When a sperm fertilizes an egg, a **zygote** is produced with the appropriate number of chromosomes for the species.

Most cells in the human body are produced by mitosis. These are the somatic (or vegetative) line cells.

<u>DIVERSITY OF LIFE ON EARTH</u>

BACTERIA

Bacteria have a prokaryotic cell and are basically unicellular with simple shapes: short rods or bacilli, spheres or cocci, or spiral, elongated cells, spirilla**.** The single cells often are linked together

into ribbon-like filaments, or bead-like chains of cells; some taxa form flat, sheet-like colonies, others produce stalked, branching ones.

All except the mycoplasmas have a cell wall composed of disaccharides and peptides (amino acids) together with a unique compound not found in eukaryotes: peptidoglycan**.**

Actinobacteria are a group of bacteria. They encompass a wide range of morphologies from coccoid or fragmenting hyphal forms (e.g. Nocardia) to branching filaments (e.g. Streptomyces) that resemble the mycelia of fungi. Most actinobacteria are found in the soil, and they include some of the most common soil life, playing important roles in decomposition and humus formation. In hypogea, Streptomyces are able to colonize the surfaces despite the unfavourable conditions.

Cyanobacteria are a group of bacteria that obtain their energy through photosynthesis. Therefore, they are autotrophs, i.e. organisms that produce complex organic compounds (such as carbohydrates, lipids, and proteins) from simple substances. Cyanobacteria can be found in almost every terrestrial and aquatic habitat—oceans, fresh water, damp soil, temporarily moistened rocks in deserts, bare rock and soil, and even Antarctic rocks. Cyanobacteria often occur in association with algae. They form biofilms on rock surfaces that are deep or bright green under humid conditions and deep black when dry. In addition to the cell wall, there is a gelatinous matrix that permits the adhesion to the substrate. It is the cement that holds together the cells and form biofilms on the substrates.

PROTISTS

Algae are included in the Kingdom Protista. They are **eukaryotic and autotrophic** organisms. Terrestrial micro-algae form powdery patinas and gelatinous layers different in colour (green, grey, black, brown, orange). Algae include unicellular species – one single cell covers all the vital functions – as well as multicellular species. Unicellular species live isolated or form colonies of different shapes and structures. Algae widely differ in dimensions. Unicellular species are microscopic (≤ 10 μm) while multicellular organisms are mostly macroscopic and may reach a length of several meters in the marine forms. Many algae have a haploid dominated life cycle. The dominant phase is haploid, while the diploid phase is only a few cells (often only the single celled zygote). Many algae reproduce by mitosis. They can also undergo sexual reproduction.

FUNGI

The fungi (singular, fungus) are **heterotrophic eukaryotic** organisms which are classified as a Kingdom, Fungi, which is separate from plants, animals, protists, and bacteria. One major difference is that fungal cells have **rigid cell walls** that contain **chitin,** unlike the cell walls of plants and some protists, which contain cellulose, and unlike the cell walls of bacteria. Chitin is the polysaccharide that gives hardness to the external skeletons of lobsters and insects. Fungi are heterotrophs, i.e. organisms that rely solely on carbon fixed by other organisms for metabolism. They have different structures ranging from unicellular organisms to filamentous ones. Most are formed by **tiny branched filaments called hyphae** which originate from the germination of the **fungal spore**. The hyphae are cylindrical, thread-like structures 2–10 µm in diameter and up to several centimetres in length. The growth of hyphae leads to the development of a **mycelium**, an interconnected network of hyphae.

The fungi reproduce by spores, both asexual and sexual, and the details and structures of the sexual process separate the kingdom into four phyla. The z**ygote** is the only diploid phase in the life cycle; meiosis occurs shortly after the zygote is formed—hence the life cycle is an instance of zygotic meiosis. Nonmotile sexual and asexual **spores**—microscopic in size—are the common means of reproduction and the primary agents of fungal dispersal. Although they can withstand desiccation, they are killed by heat. Sexual spores often require a period of dormancy after they are formed, but asexual spores usually germinate and produce new hyphae whenever and wherever moisture is available. Among fungi, there are no female and male individuals, and no eggs and sperm. Physiological differences among the hyphae do exist, however, and result in different mating types; only compatible strains fuse. Haploid (*n*) gametes are produced by mitotic division from haploid (*n*) parent nuclei in specialized hyphae called gametangia**.** The predominant phase in the life cycle of fungi is haploid, the zygote is the only diploid cell in the entire cycle. This is called a zygotic life cycle.

LICHENS

Lichens are organisms consisting of a **fungus (the mycobiont)** and a **photosynthetic partner (the photobiont or phycobiont)** growing together in a **symbiotic relationship**. The photobiont is usually either a green alga or a cyanobacterium. The morphology, physiology and biochemistry of lichens are very different from those of the isolated fungus and alga. They grow on tree barks, leaves and branches in rain forests, on bare rock, including walls and gravestones, and on exposed

soil surfaces. Lichens occur in some of the most extreme environments on Earth—arctic tundra, hot deserts, rocky coasts. The "plant body" of an individual lichen is called a **thallus**. Lichens are classified into three main growth forms. Crustose lichens form crusts that are tightly attached to the rocks, trees, or soils. Crustose lichens that grow immersed in rocks with only their fruiting bodies above the surface are called endolithic. Foliose lichens are somewhat leaf-like, composed of lobes. They are relatively loosely attached to their substrates, usually by means of rhizines. Their lobes have upper and lower sides and usually grow parallel to the substrate. Fruticose lichens are the most three-dimensional. They're usually round in cross section, and most are branched. They can be like little shrubs growing upward, or they can hang down in long strands. Nearly all lichens have an upper (or in the case of fruticose lichens an outer) cortex, which is a dense, protective skin of fungal tissue. Below that there is a photosynthetic layer (the photobiont). Then there is a layer of loose hyphae of the lichen fungus (the mycobiont), called the medulla. Some foliose lichens have a lower cortex. Crustose lichens never have a lower cortex, their medulla attaching firmly to the substrate.

The mycobiont produces the fruiting bodies, which are spore-producing structures. The most common kind of fruiting body is the apothecium (plural, apothecia), which is generally shaped like a disc, usually with a rim around the edge.

BRYOPHYTES

Bryophytes are non-vascular plants. Bryophytes are distinguished from tracheophytes by two important characters. First, in all bryophytes the ecologically persistent, photosynthetic phase of the life cycle is the haploid, gametophyte generation rather than the diploid sporophyte; bryophyte sporophytes are very short-lived, are attached to and nutritionally dependent on their gametophytes and consist of only an unbranched stalk, or seta, and a single, terminal sporangium. Second, **bryophytes never form xylem tissue**, the special lignin- containing, water-conducting tissue that is found in the sporophytes of all vascular plants. Modern studies of cell ultrastructure and molecular biology confirm that bryophytes comprise three separate evolutionary lineages, which are today recognized as mosses, liverworts and hornworts.

Of the three phyla of bryophytes, greatest species diversity is found in the mosses, with up to 15,000 species recognized.

Mosses are small, soft plants, typically 1–10 cm tall, that grow closely packed together in mats or cushions on rocks, soil, or as epiphytes on the trunks and leaves of forest trees. They have no

vascular tissue or wood to lend them structural support, nor do they have large leaves or showy cones or flowers. Their simple leaves cover the thin wiry stems. This does not mean that mosses are not important; in fact, mosses play important roles in reducing erosion along streams, water and nutrient cycling in tropical forests, and insulating the arctic permafrost. They commonly grow in damp or shady locations. They do not have proper roots but have threadlike rhizoids that anchor them to the substrate. Water and mineral nutrients required for the moss to grow are absorbed, not by the rhizoids, but rather by the thin leaves of the plant as rain water washes through the moss cushion.

Mosses reproduce through spores. A moss begins its life cycle when haploid spores, which are produced in the sporophyte capsule, land on a moist substrate and begin to germinate. From the one-celled spore, a highly-branched system of filaments, called the protonema, develops. Cell specialization occurs within the protonema to form a horizontal system of reddish-brown, anchoring filaments, called caulonemal filaments and upright, green filaments, called chloronemal filaments. Each protonema, which superficially resembles a filamentous alga, can spread over several centimetres to form a fuzzy green film over its substrate. As the protonema grows, some cells of the caulonemal filaments specialize to form leafy buds that will ultimately form the adult gametophyte shoots. Numerous shoots typically develop from each protonema so that, in fact, a single spore can give rise to a whole clump of moss plants. Each leafy shoot continues to grow apically, producing leaves in spiral arrangement on an elongating stem.

PLANTS

Vascular plants have vascular tissues which circulate substances through the organism. This feature allows them to evolve to a larger size than non-vascular plants, which lack these specialized conducting tissues and are therefore restricted to relatively small sizes. The vascular system is composed of two types of specialized tissue: **xylem** and **phloem**. Xylem conducts water and minerals upward from the roots of a plant, while phloem transports sugars and other nutrients from the leaves to the other parts of the plant. Both xylem and phloem are distributed throughout the plant. **Vascular plants produce either seeds or spores**. Plants like fir trees are **gymnosperms**; flowering plants are **angiosperms** and make up the largest segment of plants on earth today.

Plant life cycles have two sequential phases that are termed alternation of generations. The sporophyte phase is "diploid" and is that part of the life cycle in which meiosis occurs. The

gametophyte phase is "haploid" and is the part of the life cycle in which gametes are produced (by mitosis of haploid cells). In flowering plants (Angiosperms) the multicelled visible plant (leaf, stem, etc.) is sporophyte, while pollen and ovaries contain the male and female gametophytes, respectively.