COURSE CODE: **ANP 101**

COURSE TITLE: Introductory Animal Physiology

NUMBER OF UNITS: 2 Units

COURSE DURATION: Two hours per week

COURSE DETAILS:

Course Coordinator: **Dr. J.O. Daramola, B.Ed., M.Sc., PhD**
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COURSE CONTENT:

Characteristics of living things; Cellular basis of life: Cell organelles; Cell cycle, Cell division, Cell growth, Cell death; Classification of Animal Kingdom, Grades of Organisation, A brief introduction of the various Animal Phyla: Protozoa, Coelenterata, Porifera, Platyhelminthes, Nematoda, Annelida, Mollusca, Arthropoda, Echinodermata, and Chordata.

COURSE REQUIREMENTS:

This is a compulsory course for all B. Agriculture students in the University of Agriculture, Abeokuta, Nigeria. Students are expected to participate in all the course activities and have a minimum of 75% of attendance to be able to write final examination.

READING LIST:

1. **http://www.cliffsnotes.com/study_guide/Characteristics-of-Living-Things.topicArticleId-8741,articleId-8578.html**
2. **http://hyperphysics.phy-astr.gsu.edu/hbase/biology/life.html**
3. **http://lisacruz2.tripod.com/id30.html**
4. **http://www.saburchill.com/chapters/chap0001.html**
5. **Wikipedia**
6. **Encyclopædia Britannica 2010.**

7. **Microsoft ® Encarta ® 2009.**

LECTURE NOTE:

Characteristics of living things

Living things have a level of complexity and organization not found in lifeless objects. At its most fundamental level, a living thing is composed of one or more **cells.** These units, generally too small to be seen with the unaided eye, are organized into tissues. A *tissue* is a series of cells that accomplish a shared function. Tissues, in turn, form *organs,* such as the stomach and kidney. A number of organs working together compose an *organ system.* An organism is a complex series of various organ systems. A living organism must possess all the following characteristics:

Organization

Living things are highly organized. The smallest part of an organism is a cell. Some single-celled organisms are free-living and contain structures, called organelles, that allow them to be self-sufficient. More complex organisms are multicellular. In the case of a human, cells are organized into tissues. These have a common function like a muscle. Tissues are organized into organs like the heart. Organs are organized into organ systems, like the cardiovascular system. Organ systems functioning together make up a living organism.

A population is an organization of more than one individual. This is generally all of one species in a particular area. We could talk about the population of squirrels in our area or dogs or cats. Enlarging our view next comes a community. An example of a community is the town or place we live. A more accurate biological description would include all the living things in that area. A community is composed of many species, including plants and animals

An ecosystem not only considers the living things in an area, but also the physical environment and the interrelated flow of energy. You may live in a desert ecosystem, a forest ecosystem, or another kind of ecosystem. Most complex of all is the biosphere. In our case, this includes the all the areas of our planet where living things are found.

Metabolism

Most of us call this eating! Living things exhibit a rapid turnover of chemical materials, able to convert our food, a form of energy, to chemicals our cells can use through a process which is referred to as metabolism**.** It is the transformation of energy by converting chemicals and energy into cellular components (anabolism) and decomposing organic matter (catabolism). Living things require energy to maintain internal organization (homeostasis) and to produce the other phenomena associated with life. Metabolism involves exchanges of chemical matter with the external environment and extensive transformations of organic matter within the cells of a living organism. Some organisms like plants, algae, and some microorganisms are autotrophs. The autotrophs we are most familiar with are the green plants that use photosynthesis to make their own "food." Some bacteria use chemosynthesis for their energy source. Animals and fungi are heterotrophs and capture their food in a variety of ways.

The ability to acquire and use energy is extremely important. Without a constant input of usable energy, organisms would quickly become "disorganized" and die.

In order to survive, organisms must be able to achieve homeostasis. Each type of organism has a specialized way to stay in balance with its outside and inside environments. A *paramecium* has a contractile vacuole that pumps excess water out of its cell in order to survive in a fresh water environment. You and I have an internal "thermostat" that helps us maintain a body temperature of about 98.6 degrees Fahrenheit (37^oC) Nonliving things do not display metabolism.

Responsiveness

All living things are able to respond to stimuli in the external environment. This often results in movement of the individual toward safety. This helps to ensure survival of the organism. For example, living things respond to changes in light, heat, sound, and chemical and mechanical contact. To detect stimuli, organisms have means for receiving information, such as eyes, ears, and taste buds. As young children, for example, we learned to avoid hot stoves and busy streets

To respond effectively to changes in the environment, an organism must coordinate its responses. A system of nerves and a number of chemical regulators called **hormones** coordinate activities within an organism. The organism responds to the stimuli by means of a number of effectors, such as muscles and glands. Energy is generally used in the process.

Organisms change their behaviour in response to changes in the surrounding environment. For example, an organism may move in response to its environment. Responses such as this occur in definite patterns and make up the behaviour of an organism. The behaviour is active, not passive; an animal responding to a stimulus is different from a stone rolling down a hill. Plants also have some limited ability to move. They grow up toward the sun, and some have leaves able to turn to follow the sun (phototropism), allowing them to photosynthesize better. Their roots grow down to search for water and minerals. If a plant doesn't get enough sunlight, water or minerals it will die. Living things display responsiveness; nonliving things do not.

Growth

Growth requires an organism to take in material from the environment and organize the material into its own structures. It is the maintenance of a higher rate of anabolism than catabolism. A growing organism increases in size in all of its parts, rather than simply accumulating matter. To accomplish growth, an organism expends some of the energy it acquires during metabolism. An organism has a pattern for accomplishing the building of growth structures. During this period organisms also undergo a cycle of changes called development.

During growth, a living organism transforms material that is unlike itself into materials that are like it. A person, for example, digests a meal of meat and vegetables and transforms the chemical material into more of himself or herself. A nonliving organism does not display this characteristic.

Reproduction

A living thing has the ability to produce copies of itself by the process known as *reproduction*. These copies are made while the organism is still living. Among plants and simple animals, reproduction is often an extension of the growth process. For example, bacteria grow and quickly reach maturity, after which they split into two organisms by the process of *asexual reproduction*. Asexual reproduction involves only one parent, and the resulting cells are generally identical to the parent cell.

All living things, even the smallest bacteria, have a chromosome containing DNA. Prokaryotes like bacteria only have one circular chromosome, called a plasmid. Eukaryotes, multicellular organisms like plants and humans, have a species-specific number of chromosomes. As humans, we have 46 chromosomes, in 23 pairs. Genes on chromosomes contain the instructions for the organism's structure and function.

However, most organisms reproduce sexually. Some, like earthworms and snails are hermaphrodites. Most others have separate sexes, male and female, like marijuana plants, fish, birds, cattle and humans.

In order for two organisms to combine their genetic information without doubling the number of chromosomes given to offspring, Mother Nature came up with a way to reduce the number of chromosomes. Without it, each new generation would have double the number of its parents' chromosomes. This halving is done by meiosis in the sex organs. In the female, the ovary produces haploid eggs and in the male the testes produces haploid sperm. Each of these gametes contains only one chromosome from each of the pairs of chromosomes.

During fertilization, the sperm and egg unite to form a zygote, a diploid individual. This new individual is different from either parent, although it contains characteristics from both. This is what gives us the great diversity of life. In living things, we call this genetic biodiversity Nonliving things have no such ability or requirements.

Adaptation

Modifications enable an organism to survive in its environment. Natural selection allows individuals with better adaptations to survive better and reproduce more. Thus, their characteristics are passed into future generations and that makes the species stronger. However, it is important to note that individuals can only adapt to their environment, and species don’t adapt, they evolve. During evolution, changes occur in populations, and the organisms in the population become better able to metabolize, respond, and reproduce. They develop abilities to cope with their environment that their ancestors did not have.

Evolution also results in a greater variety of organisms than existed in previous eras. This proliferation of populations of organisms is unique to living things.

Death

Death is the permanent termination of all vital functions or life processes in an organism or cell. Death involves a complete change in the status of a living entity—the loss of its essential characteristics. After death, the remains of an organism become part of the biogeochemical cycle. Organisms may be consumed by a predator or a scavenger and leftover organic material may then be further decomposed by detritivores, organisms which recycle detritus, returning it to the environment for reuse in the food chain.

Definition of Biology

Biology is the science that is focussed on the study of living things. The major branches of biology are:

- Anatomy, which deals with gross structure
- Physiology, which is the study of gross function or how the organism works
- Histology, the study of tissues
- Cell biology, the study of cells
- Microbiology, concerned with the study of fungi (mycology), bacteria (bacteriology) and viruses (virology)
- Biochemistry and Molecular Biology, study of living systems at the molecular level
- Genetics, study of inheritance
- Zoology, study of animals
- Botany, study of plants

Definition of Physiology

- Characteristics of Living Things
    - Nutrition
    - Respiration
    - Irritability
    - Movement
    - Excretion
    - Reproduction
    - Growth
- Cellular Basis of Life
    - Cell Organelles
    - Cell Division
    - Cell Growth
    - Cell Death

- Physiological Systems in Mammals
    - Respiratory System
    - Digestive System
    - Reproductive System
    - Excretory System
    - Nervous System
    - Endocrine System
- Concepts of Homeostasis

What Is a Cell?

Cells are the structural and functional unit of all living organisms. Some organisms, such as bacteria, are **unicellular**, consisting of a single cell. Other organisms, such as humans, are **multicellular**, or have many cells—an estimated 100,000,000,000,000 cells! Each cell is an amazing world unto itself: it can take in nutrients, convert these nutrients into energy, carry out specialized functions, and reproduce as necessary. Even more amazing is that each cell stores its own set of instructions for carrying out each of these activities.

Cell Organization

Before we can discuss the various components of a cell, it is important to know what organism the cell comes from. There are two general categories of cells: **prokaryotes** and **eukaryotes**.

Prokaryotic Organisms

It appears that life arose on earth about 4 billion years ago. The simplest of cells, and the first types of cells to evolve, were **prokaryotic cells**—organisms that lack a **nuclear membrane**, the membrane that surrounds the nucleus of a cell. **Bacteria** are the best known and most studied form of prokaryotic organisms, although the recent discovery of a second group of prokaryotes, called **archaea**, has provided evidence of a third cellular domain of life and new insights into the origin of life itself.

Prokaryotes are unicellular organisms that do not develop or differentiate into multicellular forms. Some bacteria grow in filaments, or masses of cells, but each cell in the colony is identical and capable of independent existence. The cells may be adjacent to one another because they did not separate after cell division or because they remained enclosed in a common sheath or slime secreted by the cells. Typically though, there is no continuity or communication between the cells. Prokaryotes are capable of inhabiting almost every place on the earth, from the deep ocean, to the edges of hot springs, to just about every surface of our bodies.

Prokaryotes are distinguished from eukaryotes on the basis of nuclear organization, specifically their lack of a nuclear membrane. Prokaryotes also lack any of the intracellular organelles and structures that are characteristic of eukaryotic cells. Most of the functions of organelles, such as mitochondria, chloroplasts and the Golgi apparatus, are taken over by the prokaryotic plasma membrane. Prokaryotic cells have three architectural regions: appendages called **flagella** and **pili**—proteins attached to the cell surface; a **cell envelope** consisting of a capsule, a **cell wall**, and a **plasma membrane**; and a **cytoplasmic region** that contains the **cell genome** (DNA) and ribosomes and various sorts of inclusions.

Eukaryotic Organisms

Eukaryotes include fungi, animals, and plants as well as some unicellular organisms. Eukaryotic cells are about 10 times the size of a prokaryote and can be as much as 1000 times greater in volume. The major and extremely significant difference between prokaryotes and eukaryotes is that eukaryotic cells contain membrane-bounded compartments in which specific metabolic activities take place. Most important among these is the presence of a **nucleus**, a membrane-delineated compartment that houses the eukaryotic cell's DNA. It is this nucleus that gives the eukaryote—literally, true nucleus—its name.

Eukaryotic organisms also have other specialized structures, called **organelles**, which are small structures within cells that perform dedicated functions. As the name implies, you can think of organelles as small organs. There are a dozen different types of organelles commonly found in eukaryotic cells. In this primer, we will focus our attentions on only a handful of organelles and will examine these organelles with an eye to their role at a molecular level in the cell.

The origin of the eukaryotic cell was a milestone in the evolution of life. Although eukaryotes use the same genetic code and metabolic processes as prokaryotes, their **higher level of organizational complexity** has permitted the development of truly multicellular organisms. Without eukaryotes, the world would lack mammals, birds, fish, invertebrates, mushrooms, plants, and complex single-celled organisms.

This figure illustrates a typical human cell (*eukaryote*) and a typical bacterium (*prokaryote*). The drawing on the *left* highlights the internal structures of eukaryotic cells, including the nucleus (*light blue*), the nucleolus (*intermediate blue*), mitochondria (*orange*), and ribosomes (*dark blue*). The drawing on the *right* demonstrates how bacterial DNA is housed in a structure called the nucleoid (*very light blue*), as well as other structures normally found in a prokaryotic cell, including the cell membrane (*black*), the cell wall (*intermediate blue*), the capsule (*orange*), ribosomes (*dark blue*), and a flagellum (*also black*).

Cell Structures: The Basics

The Plasma Membrane—A Cell's Protective Coat

The outer lining of a eukaryotic cell is called the **plasma membrane**. This membrane serves to separate and protect a cell from its surrounding environment and is made mostly from a double layer of proteins and lipids, fat-like molecules. Embedded within this membrane are a variety of other molecules that act as channels and pumps, moving different molecules into and out of the cell. A form of plasma membrane is also found in prokaryotes, but in this organism it is usually referred to as the **cell membrane**.

The Cytoskeleton—A Cell's Scaffold

acts to organize and maintain the cell's shape; anchors organelles in place; helps during **endocytosis**, the uptake of external materials by a cell; and moves parts of the cell in processes of growth and motility. There are a great number of proteins associated with the cytoskeleton, each controlling a cell's structure by directing, bundling, and aligning filaments.

The Cytoplasm—A Cell's Inner Space

Inside the cell there is a large fluid-filled space called the **cytoplasm**, sometimes called the **cytosol**. In prokaryotes, this space is relatively free of compartments. In eukaryotes, the **cytosol** is the "soup" within which all of the cell's organelles reside. It is also the home of the cytoskeleton. The cytosol contains dissolved nutrients, helps break down waste products, and moves material around the cell through a process called **cytoplasmic streaming**. The nucleus often flows with the cytoplasm changing its shape as it moves. The cytoplasm also contains many salts and is an excellent conductor of electricity, creating the perfect environment for the mechanics of the cell. The function of the cytoplasm, and the organelles which reside in it, are critical for a cell's survival.

Genetic Material

Two different kinds of genetic material exist: **deoxyribonucleic acid** (DNA) and **ribonucleic acid** (RNA). Most organisms are made of DNA, but a few viruses have RNA as their genetic material. The biological information contained in an organism is encoded in its DNA or RNA sequence.

> Interestingly, as much as 98 percent of human DNA does not code for a specific product.

Prokaryotic genetic material is organized in a simple circular structure that rests in the cytoplasm. Eukaryotic genetic material is more complex and is divided into discrete units called **genes**. Human genetic material is made up of two distinct components: the **nuclear genome** and the **mitochondrial genome**. The nuclear genome is divided into 24 linear DNA molecules, each contained in a different **chromosome**. The **mitochondrial genome** is a circular DNA molecule separate from the nuclear DNA. Although the mitochondrial genome is very small, it codes for some very important proteins.

Organelles

The human body contains many different organs, such as the heart, lung, and kidney, with each organ performing a different function. Cells also have a set of "little organs", called **organelles**, that are adapted and/or specialized for carrying out one or more vital functions. Organelles are found only in eukaryotes and are always surrounded by a protective membrane. It is important to know some basic facts about the following organelles.

The Nucleus—A Cell's Center

The nucleus is the most conspicuous organelle found in a eukaryotic cell. It houses the cell's chromosomes and is the place where almost all DNA replication and RNA synthesis occurs. The nucleus is spheroid in shape and separated from the cytoplasm by a membrane called the **nuclear envelope**. The nuclear envelope isolates and protects a cell's DNA from various molecules that could accidentally damage its structure or interfere with its processing. During processing, DNA is **transcribed**, or synthesized, into a special RNA, called mRNA. This mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule. In prokaryotes, DNA processing takes place in the cytoplasm.

The Ribosome—The Protein Production Machine

Ribosomes are found in both prokaryotes and eukaryotes. The **ribosome** is a large complex composed of many molecules, including RNAs and proteins, and is responsible for processing the genetic instructions carried by a mRNA. The process of converting a mRNA's genetic code into the exact sequence of amino acids that make up a protein is called **translation**. Protein synthesis is extremely important to all cells, and therefore a large number of ribosomes—sometimes hundreds or even thousands—can be found throughout a cell.

Ribosomes float freely in the cytoplasm or sometimes bind to another organelle called the endoplasmic reticulum. Ribosomes are composed of one large and one small subunit, each having a different function during protein synthesis.

Mitochondria and Chloroplasts—The Power Generators

Mitochondria are self-replicating organelles that occur in various numbers, shapes, and sizes in the cytoplasm of all eukaryotic cells. As mentioned earlier, mitochondria contain their own genome that is separate and distinct from the nuclear genome of a cell. Mitochondria have two functionally distinct membrane systems separated by a space: the outer membrane, which surrounds the whole organelle; and the inner membrane, which is thrown into folds or shelves that project inward. These inward folds are called **cristae**. The number and shape of cristae in mitochondria differ depending on the tissue and organism in which they are found, and serve to increase the surface area of the membrane.

Mitochondria play a critical role in generating energy in the eukaryotic cell, and this process involves a number of complex pathways. Let's break down each of these steps so that you can better understand how food and nutrients are turned into energy packets and water. Some of the best energy-supplying foods that we eat contain complex sugars. These complex sugars can be broken down into a less chemically complex sugar molecule called **glucose**. Glucose can then enter the cell through special molecules found in the membrane, called **glucose transporters**. Once inside the cell, glucose is broken down to make adenosine triphosphate (**ATP**), a form of energy, via two different pathways.

The first pathway, **glycolysis**, requires no oxygen and is referred to as **anaerobic metabolism**. Glycolysis occurs in the cytoplasm outside the mitochondria. During glycolysis, glucose is broken down into a molecule called **pyruvate**. Each reaction is designed to produce some hydrogen ions that can then be used to make energy packets (**ATP**). However, only four ATP molecules can be made from one molecule of glucose in this pathway. In prokaryotes, glycolysis is the only method used for converting energy.

The second pathway, called the **Kreb's cycle**, or the **citric acid cycle**, occurs inside the mitochondria and is capable of generating enough ATP to run all the cell functions. Once again, the cycle begins with a glucose molecule, which during the process of glycolysis, is stripped of some of its' hydrogen atoms, transforming the glucose into two molecules of **pyruvic acid**. Next, pyruvic acid is altered by the removal of a carbon and two oxygen, which go on to form carbon dioxide. When the **carbon dioxide** is removed, energy is given off, and a molecule called **NAD+** is converted into the higher energy form **NADH**. Another molecule, **coenzyme A**, then attaches to the remaining acetyl unit, forming **acetyl CoA**.

Acetyl CoA enters the Kreb's cycle by joining to a four-carbon molecule called **oxaloacetate**. Once the two molecules are joined, they make a six-carbon molecule called **citric acid**. Citric acid is then broken down and modified in a stepwise fashion. As this happens, hydrogen ions and carbon molecules are released. The carbon molecules are used to make more carbon dioxide. The hydrogen ions are picked up by NAD and another molecule called **flavin-adenine dinucleotide** (**FAD**). Eventually, the process produces the four-carbon oxaloacetate again, ending up where it started off. All in all, the Kreb's cycle is capable of generating between 24 and 28 ATP molecules from one molecule of glucose converted to pyruvate. Therefore, it is easy to see how much more energy we can get from a molecule of glucose if our mitochondria are working properly and if we have oxygen.

Chloroplasts are similar to mitochondria but are found only in plants. Both organelles are surrounded by a double membrane with an intermembrane space; both have their own DNA and are involved in energy metabolism; and both have reticulations, or many foldings, filling their inner spaces. Chloroplasts convert light energy from the sun into ATP through a process called **photosynthesis**.

The Endoplasmic Reticulum and the Golgi Apparatus—Macromolecule Managers

The **endoplasmic reticulum (ER)** is the transport network for molecules targeted for certain modifications and specific destinations, as compared to molecules that will float freely in the cytoplasm. The ER has two forms: the **rough ER** and the **smooth ER**. The rough ER is labelled as such because it has ribosomes adhering to its outer surface, whereas the smooth ER does not. Translation of the mRNA for those proteins that will either stay in the ER or be **exported** (moved out of the cell) occurs at the ribosomes attached to the rough ER. The smooth ER serves as the recipient for those proteins synthesized in the rough ER. Proteins to be exported are passed to the Golgi apparatus, sometimes called a **Golgi body** or **Golgi complex**, for further processing, packaging, and transport to a variety of other cellular locations.

> The Golgi apparatus was first described in 1898 by an Italian anatomist named Camillo Golgi.

Lysosomes and Peroxisomes—The Cellular Digestive System

Lysosomes and **peroxisomes** are often referred to as the garbage disposal system of a cell. Both organelles are somewhat spherical, bound by a single membrane, and rich in digestive **enzymes**, naturally occurring proteins that speed up biochemical processes. For example, lysosomes can contain more than three dozen enzymes for degrading proteins, nucleic acids, and certain sugars called polysaccharides. All of these enzymes work best at a **low pH**, reducing the risk that these enzymes will digest their own cell should they somehow escape from the lysosome. Here we can see the importance behind compartmentalization of the eukaryotic cell. The cell could not house such destructive enzymes if they were not contained in a membrane-bound system.

What Is pH?
The term pH derives from a combination of "p" for the word power and "H" for the symbol of the element hydrogen. pH is the negative log of the activity of hydrogen ions and represents the "activity" of hydrogen ions in a solution at a given temperature. The term activity is used because pH reflects the amount of available hydrogen ions, not the concentration of hydrogen ions. The pH scale for aqueous solutions ranges from 0 to 14 pH units, with pH 7 being neutral. A pH of less than 7 means that the solution is acidic, whereas a pH of more than 7 means that the solution is basic.

One function of a lysosome is to digest foreign bacteria that invade a cell. Other functions include helping to recycle receptor proteins and other membrane components and degrading worn out organelles such as mitochondria. Lysosomes can even help repair damage to the plasma membrane by serving as a membrane patch, sealing the wound.

Peroxisomes function to rid the body of toxic substances, such as hydrogen peroxide, or other metabolites and contain enzymes concerned with oxygen utilization. High numbers of peroxisomes can be found in the liver, where toxic byproducts are known to accumulate. All of the enzymes found in a peroxisome are imported from the cytosol. Each enzyme transferred to a peroxisome has a special sequence at one end of the protein, called a PTS or **peroxisomal targeting signal**, that allows the protein to be taken into that organelle, where they then function to rid the cell of toxic substances.

Peroxisomes often resemble a lysosome. However, peroxisomes are self replicating, whereas lysosomes are formed in the Golgi complex. Peroxisomes also have membrane proteins that are critical for various functions, such as for importing proteins into their interiors and to proliferate and segregate into daughter cells.

Where Do Viruses Fit?

Viruses are not classified as cells and therefore are neither unicellular nor multicellular organisms. Most people do not even classify viruses as "living" because they lack a metabolic system and are dependent on the host cells that they infect to reproduce. Viruses have genomes that consist of either DNA or RNA, and there are examples of viruses that are either double-stranded or single-stranded. Importantly, their genomes code not only for the proteins needed to package its genetic material but for those proteins needed by the virus to reproduce during its infective cycle.

Making New Cells and Cell Types

For most unicellular organisms, reproduction is a simple matter of **cell duplication**, also known as **replication**. But for multicellular organisms, cell replication and reproduction are two separate processes. Multicellular organisms replace damaged or worn out cells through a replication process called **mitosis**, the division of a eukaryotic cell nucleus to produce two identical **daughter nuclei**. To reproduce, eukaryotes must first create special cells called **gametes**—eggs and sperm—that then fuse to form the beginning of a new organism. Gametes are but one of the many unique cell types that multicellular organisms require to function as a complete organism.

Making New Cells

Most unicellular organisms create their next generation by replicating all of their parts and then splitting into two cells - a type of **asexual reproduction** called **binary fission**. This process spawns not just two new cells, but also two new organisms. Multicellullar organisms replicate new cells in much the same way. For example, we produce new skin cells and liver cells by replicating the DNA found in that cell through mitosis. Yet, producing a whole new organism requires **sexual reproduction**, at least for most multicellular organisms. In the first step, specialized cells called **gametes**--eggs and sperm--are created through a process called meiosis. Meiosis serves to reduce the chromosome number for that particular organism by half. In the second step, the sperm and egg join to make a single cell, which restores the chromosome number. This joined cell then divides and differentiates into different cell types that eventually form an entire functioning organism.

Mitosis is the process by which the diploid nucleus (having two sets of homologous chromosomes) of a somatic cell divides to produce two daughter nuclei, both of which are still diploid. The left-hand side of the drawing demonstrates how the parent cell duplicates its chromosomes (one *red* and one *blue*), providing the daughter cells with a complete copy of genetic information. Next, the chromosomes align at the equatorial plate, and the centromeres divide. The sister chromatids then separate, becoming two diploid daughter cells, each with one *red* and one *blue* chromosome.

Mitosis

Every time a cell divides, it must ensure that its DNA is shared between the two daughter cells. Mitosis is the process of "divvying up" the genome between the daughter cells. To easier describe this process, let's imagine a cell with only one chromosome. Before a cell enters mitosis, we say the cell is in **interphase**, the state of a eukaryotic cell when not undergoing division. Every time a cell divides, it must first replicate all of its DNA. Because chromosomes are simply DNA wrapped around protein, the cell replicates its chromosomes also. These two chromosomes, positioned side by side, are called **sister chromatids** and are identical copies of one another. Before this cell can divide, it must separate these sister chromatids from one another. To do this, the chromosomes have to condense. This stage of mitosis is called **prophase**. Next, the nuclear envelope breaks down and a large protein network, called the **spindle**, attaches to each sister chromatid. The chromosomes are now aligned perpendicular to the spindle in a process called **metaphase**. Next, molecular motors pull the chromosomes away from the metaphase plate to the spindle poles of the cell. This is called **anaphase**. Once this process is completed, the cells divide, the nuclear envelope reforms, and the chromosomes relax and decondense during **telophase**. The cell can now replicate its DNA again during interphase and go through mitosis once more.

Cell Cycle Control and Cancer

As cells cycle through interphase and mitosis, a surveillance system monitors the cell for DNA damage and failure to perform critical processes. If this system senses a problem, a network of signalling molecules instructs the cell to stop dividing. These so called "checkpoints" let the cell know whether to repair the damage or initiate programmed cell death, a process called **apoptosis**. Programmed cell death ensures that the damaged cell is not further propagated. Scientists know that a certain protein, called p53, acts to accept signals provoked by DNA damage. It responds by stimulating the production of inhibitory proteins that then halt the DNA replication process. Without proper p53 function, DNA damage can accumulate unchecked. A direct consequence is that the damaged gene progresses into a cancerous state. Today, defects in p53 are associated with a variety of cancers, including some breast and colon cancers.

Meiosis, a type of nuclear division, occurs only in reproductive cells and results in a diploid cell (having two sets of chromosomes) giving rise to four haploid cells (having a single set of chromosomes). Each haploid cell can subsequently fuse with a gamete of the opposite sex during sexual reproduction. In this illustration, two pairs of homologous chromosomes enter *Meiosis I*, which results initially in two daughter nuclei, each with two copies of each chromosome. These two cells then enter *Meiosis II*, producing four daughter nuclei, each with a single copy of each chromosome.

Meiosis

Meiosis is a specialized type of cell division that occurs during the formation of gametes. Although meiosis may seem much more complicated than mitosis, it is really just two cell divisions in sequence. Each of these sequences maintains strong similarities to mitosis.

Meiosis I refers to the first of the two divisions and is often called the **reduction division**. This is because it is here that the chromosome complement is reduced from **diploid** (two copies) to **haploid** (one copy). Interphase in meiosis is identical to interphase in mitosis. At this stage, there is no way to determine what type of division the cell will undergo when it divides. Meiotic division will only occur in cells associated with male or female sex organs. **Prophase I** is virtually identical to prophase in mitosis, involving the appearance of the **chromosomes**, the development of the spindle apparatus, and the breakdown of the nuclear membrane. Metaphase I is where the critical difference occurs between meiosis and mitosis. In mitosis, all of the chromosomes line up on the metaphase plate in no particular order. In Metaphase I, the chromosome pairs are aligned on either side of the metaphase plate. It is during this alignment that the chromatid arms may overlap and temporarily fuse, resulting in what is called **crossovers**. During **Anaphase I**, the spindle fibers contract, pulling the homologous pairs away from each other and toward each pole of the cell. In **Telophase I**, a cleavage furrow typically forms, followed by **cytokinesis**, the changes that occur in the cytoplasm of a cell during nuclear division; but the nuclear membrane is usually not reformed, and the chromosomes do not disappear. At the end of Telophase I, each daughter cell has a single set of chromosomes, half the total number in the original cell, that is, while the original cell was diploid; the daughter cells are now haploid.

Meiosis II is quite simply a mitotic division of each of the haploid cells produced in Meiosis I. There is no Interphase between Meiosis I and Meiosis II, and the latter begins, with **Prophase II**. At this stage, a new set of spindle fibers forms and the chromosomes begin to move toward the equator of the cell. During **Metaphase II**, all of the chromosomes in the two cells align with the metaphase plate. In **Anaphase II**, the centromeres split, and the spindle fibers shorten, drawing the chromosomes toward each pole of the cell. In **Telophase II**, a cleavage furrow develops, followed by cytokinesis and the formation of the nuclear membrane. The chromosomes begin to fade and are replaced by the granular chromatin, a characteristic of interphase. When Meiosis II is complete, there will be a total of four daughter cells, each with half the total number of chromosomes as the original cell. In the case of **male structures**, all four cells will eventually develop into **sperm cells**. In the case of the **female life cycles** in higher organisms, three of the cells will typically abort, leaving a single cell to develop into an egg cell, which is much larger than a sperm cell.

Recombination—The Physical Exchange of DNA

All organisms suffer a certain number of small **mutations**, or random changes in a DNA sequence, during the process of DNA replication. These are called **spontaneous mutations** and occur at a rate characteristic for that organism. **Genetic recombination** refers more to a large-scale rearrangement of a DNA molecule. This process involves pairing between complementary strands of two parental duplex, or double-stranded DNAs, and results from a physical exchange of chromosome material.

The position at which a gene is located on a chromosome is called a **locus**. In a given individual, one might find two different versions of this gene at a particular locus. These alternate gene forms are called **alleles**. During Meiosis I, when the chromosomes line up along the metaphase plate, the two strands of a chromosome pair may physically cross over one another. This may cause the strands to break apart at the crossover point and reconnect to the other chromosome, resulting in the exchange of part of the chromosome.

Recombination results in a new arrangement of maternal and paternal alleles on the same chromosome. Although the same genes appear in the same order, the alleles are different. This process explains why offspring from the same parents can look so different. In this way, it is theoretically possible to have any combination of parental alleles in an offspring, and the fact that two alleles appear together in one offspring does not have any influence on the statistical probability that another offspring will have the same combination. This theory of "**independent assortment**" of alleles is fundamental to genetic inheritance. However, having said that, there is an exception that requires further discussion.

The frequency of recombination is actually not the same for all gene combinations. This is because recombination is greatly influenced by the proximity of one gene to another. If two genes are located close together on a chromosome, the likelihood that a recombination event will separate these two genes is less than if they were farther apart. **Linkage** describes the tendency of genes to be inherited together as a result of their location on the same chromosome. **Linkage disequilibrium** describes a situation in which some combinations of genes or genetic markers occur more or less frequently in a population than would be expected from their distance apart. Scientists apply this concept when searching for a gene that may cause a particular disease. They do this by comparing the occurrence of a specific DNA sequence with the appearance of a disease. When they find a high correlation between the two, they know they are getting closer to finding the appropriate gene sequence.

Binary Fission—How Bacteria Reproduce

Bacteria reproduce through a fairly simple process called **binary fission**, or the reproduction of a living cell by division into two equal, or near equal, parts. As just noted, this type of asexual reproduction theoretically results in two identical cells. However, bacterial DNA has a relatively high mutation rate. This rapid rate of genetic change is what makes bacteria capable of developing resistance to antibiotics and helps them exploit invasion into a wide range of environments.

Similar to more complex organisms, bacteria also have mechanisms for exchanging genetic material. Although not equivalent to sexual reproduction, the end result is that a bacterium contains a combination of traits from two different **parental** cells. Three different modes of exchange have thus far been identified in bacteria.

Conjunction involves the direct joining of two bacteria, which allows their circular DNAs to undergo recombination. Bacteria can also undergo **transformation** by absorbing remnants of DNA from dead bacteria and integrating these fragments into their own DNA. Lastly, bacteria can exchange genetic material through a process called **transduction**, in which genes are transported into and out of the cell by bacterial viruses, called **bacteriophages**, or by **plasmids**, an autonomous self-replicating extra chromosomal circular DNA.

Viral Reproduction

Because viruses are acellular and do not use ATP, they must utilize the machinery and metabolism of a host cell to reproduce. For this reason, viruses are called obligate intracellular parasites. Before a virus has entered a host cell, it is called a virion--a package of viral genetic material. **Virions**—infectious viral particles—can be passed from host to host either through direct contact or through a vector, or carrier. Inside the organism, the virus can enter a cell in various ways. **Bacteriophages**—bacterial viruses—attach to the cell wall surface in specific places. Once attached, enzymes make a small hole in the cell wall, and the virus injects its DNA into the cell. Other viruses (such as HIV) enter the host via endocytosis, the process whereby cells take in material from the external environment. After entering the cell, the virus's genetic material begins the destructive process of taking over the cell and forcing it to produce new viruses.

This illustration depicts three types of viruses: a bacterial virus, otherwise called a bacteriophage (*left center*); an animal virus (*top right*); and a retrovirus (*bottom right*). Viruses depend on the host cell that they infect to reproduce. When found outside of a host cell, viruses, in their simplest forms, consist only of genomic nucleic acid, either DNA or RNA (depicted as *blue*) surrounded by a protein coat, or capsid.

There are three different ways genetic information contained in a viral genome can be reproduced. The form of genetic material contained in the **viral capsid**, the protein coat that surrounds the nucleic acid, determines the exact replication process. Some viruses have DNA, which once inside the host cell is replicated by the host along with its own DNA. Then, there are two different replication processes for viruses containing RNA. In the first process, the viral RNA is directly copied using an enzyme called **RNA**

replicase. This enzyme then uses that RNA copy as a template to make hundreds of duplicates of the original RNA. A second group of RNA-containing viruses, called the **retroviruses**, uses the enzyme reverse transcriptase to synthesize a complementary strand of DNA so that the virus's genetic information is contained in a molecule of DNA rather than RNA. The viral DNA can then be further replicated using the host cell machinery.

Steps Associated with Viral Reproduction

1. **Attachment**, sometimes called **absorption**: The virus attaches to receptors on the host cell wall.
2. **Penetration**: The nucleic acid of the virus moves through the plasma membrane and into the cytoplasm of the host cell. The capsid of a **phage**, a bacterial virus, remains on the outside. In contrast, many viruses that infect animal cells enter the host cell intact.
3. **Replication**: The viral genome contains all the information necessary to produce new viruses. Once inside the host cell, the virus induces the host cell to synthesize the necessary components for its replication.
4. **Assembly**: The newly synthesized viral components are assembled into new viruses.
5. **Release**: Assembled viruses are released from the cell and can now infect other cells, and the process begins again.

When the virus has taken over the cell, it immediately directs the host to begin manufacturing the proteins necessary for virus reproduction. The host produces three kinds of proteins: **early proteins**, enzymes used in nucleic acid replication; **late proteins**; proteins used to construct the virus coat; and **lytic proteins**, enzymes used to break open the cell for viral exit. The final viral product is assembled spontaneously, that is, the parts are made separately by the host and are joined together by chance. This self-assembly is often aided by **molecular chaperones**, or proteins made by the host that help the capsid parts come together.

The new viruses then leave the cell either by exocytosis or by lysis. Envelope-bound animal viruses instruct the host's endoplasmic reticulum to make certain proteins, called **glycoproteins**, which then collect in clumps along the cell membrane. The virus is then discharged from the cell at these exit sites, referred to as exocytosis. On the other hand, bacteriophages must break open, or **lyse**, the cell to exit. To do this, the phages have a gene that codes for an enzyme called lysozyme. This enzyme breaks down the cell wall, causing the cell to swell and burst. The new viruses are released into the environment, killing the host cell in the process.

Why Study Viruses?

Viruses are important to the study of **molecular and cellular biology** because they provide simple systems that can be used to manipulate and investigate the functions of many cell types. We have just discussed how viral replication depends on the metabolism of the infected cell. Therefore, the study of viruses can provide fundamental information about aspects of cell biology and metabolism. The rapid growth and small genome size of bacteria make them excellent tools for experiments in biology. Bacterial viruses have also further simplified the study of bacterial genetics and have deepened our understanding of the basic mechanisms of molecular genetics. Because of the complexity of an animal cell genome, viruses have been even more important in studies of animal cells than in studies of bacteria. Numerous studies have demonstrated the utility of animal viruses as probes for investigating different activities of eukaryotic cells. Other examples in which animal viruses have provided important models for biological research of their host cells include studies of **DNA replication**, **transcription**, **RNA processing**, and **protein transport**.

One family of animal viruses, called the **retroviruses**, contains RNA genomes in their virus particles but synthesize a DNA copy of their genome in infected cells. Retroviruses provide an excellent example of how viruses can play an important role as models for biological research. Studies of these viruses are what first demonstrated the synthesis of DNA from RNA templates, a fundamental mode for transferring genetic material that occurs in both eukaryotes and prokaryotes.

Deriving New Cell Types

Look closely at the human body, and it is clear that not all cells are alike. For example, cells that make up our skin are certainly different from cells that make up our inner organs. Yet, all of the different cell types in our body are all **derived**, or arise, from a single, fertilized egg cell through **differentiation**. Differentiation is the process by which an unspecialized cell becomes specialized into one of the many cells that make up the body, such as a heart, liver, or muscle cell. During differentiation, certain genes are turned on, or become **activated**, while other genes are switched off, or **inactivated**. This process is intricately regulated. As a result, a differentiated cell will develop specific structures and perform certain functions.

Mammalian Cell Types

Three basic categories of cells make up the mammalian body: **germ cells**, **somatic cells**, and **stem cells**. Each of the approximately 100,000,000,000,000 cells in an adult human has its own copy, or copies, of the genome, with the only exception being certain cell types that lack nuclei in their fully differentiated state, such as red blood cells. The majority of these cells are diploid, or have two copies of each chromosome. These cells are called **somatic cells**. This category of cells includes most of the cells that make up our body, such as skin and muscle cells. **Germ line cells** are any line of cells that give rise to **gametes**—eggs and sperm—and are continuous through the generations. **Stem cells**, on the other hand, have the ability to divide for indefinite periods and to give rise to specialized cells. They are best described in the context of normal human development.

Human development begins when a sperm fertilizes an egg and creates a single cell that has the potential to form an entire organism. In the first hours after fertilization, this cell divides into identical cells. Approximately 4 days after fertilization and after several cycles of cell division, these cells begin to specialize, forming a hollow sphere of cells, called a blastocyst. The **blastocyst** has an outer layer of cells, and inside this hollow sphere, there is a cluster of cells called the inner **cell mass**. The inner cell mass cells will go on to form virtually all of the tissues of the human body. Although the inner cell mass cells can form virtually every type of cell found in the human body, they cannot form an organism. Therefore, these cells are referred to as **pluripotent**, that is, they can give rise to many types of cells but not a whole organism. Pluripotent stem cells undergo further specialization into stem cells that are committed to give rise to cells that have a particular function. Examples include blood stem cells that give rise to red blood cells, white blood cells and platelets and skin stem cells that give rise to the various types of skin cells. These more specialized stem cells are called **multipotent**—capable of giving rise to several kinds of cells, tissues, or structures.

Human development begins when a sperm fertilizes an egg and creates a single cell that has the potential to form an entire organism, called the zygote (*top panel, mauve*). In the first hours after fertilization, this cell divides into identical cells. These cells then begin to specialize, forming a hollow sphere of cells, called a blastocyst (*second panel, purple*). The blastocyst has an outer layer of cells (*yellow*), and inside this hollow sphere, there is a cluster of cells called the inner cell mass (*light blue*). The inner cell mass can give rise to the germ cells—eggs and sperm—as well as cells derived from all three germ layers (ectoderm, *light blue*; mesoderm, *light green*; and endoderm, *light yellow*), depicted in the *bottom panel*, including nerve cells, muscle cells, skin cells, blood cells, bone cells, and cartilage.

The Working Cell: DNA, RNA, and Protein Synthesis

DNA Replication

DNA replication, or the process of duplicating a cell's genome, is required every time a cell divides. Replication, like all cellular activities, requires specialized proteins for carrying out the job. In the first step of replication, a special protein, called a **helicase**, unwinds a portion of the parental DNA double helix. Next, a molecule of **DNA polymerase**—a common name for two categories of enzymes that influence the synthesis of DNA— binds to one strand of the DNA. DNA polymerase begins to move along the DNA strand in the 3' to 5' direction, using the single-stranded DNA as a template. This newly synthesized strand is called the **leading strand** and is necessary for forming new nucleotides and reforming a double helix. Because DNA synthesis can only occur in the 5' to 3' direction, a second DNA polymerase molecule is used to bind to the other template strand as the double helix opens. This molecule synthesizes discontinuous segments of polynucleotides, called **Okazaki fragments**. Another enzyme, called **DNA ligase**, is responsible for stitching these fragments together into what is called the **lagging strand**.

Before a cell can divide, it must first duplicate its DNA. This figure provides an overview of the DNA replication process. In the first step, a portion of the double helix (*blue*) is unwound by a helicase. Next, a molecule of DNA polymerase (*green*) binds to one strand of the DNA. It moves along the strand, using it as a template for assembling a leading strand (*red*) of nucleotides and reforming a double helix. Because DNA synthesis can only occur 5' to 3', a second DNA polymerase molecule (also *green*) is used to bind to the other template strand as the double helix opens. This molecule must synthesize discontinuous segments of polynucleotides (called *Okazaki Fragments*). Another enzyme, *DNA Ligase* (*yellow*), then stitches these together into the lagging strand.

The average human chromosome contains an enormous number of nucleotide pairs that are copied at about 50 base pairs per second. Yet, the entire replication process takes only about an hour. This is because there are many **replication origin sites** on a eukaryotic chromosome. Therefore, replication can begin at some origins earlier than at others. As replication nears completion, "bubbles" of newly replicated DNA meet and fuse, forming two new molecules.

With multiple replication origin sites, one might ask, how does the cell know which DNA has already been replicated and which still awaits replication? To date, two **replication control mechanisms** have been identified: one positive and one negative. For DNA to be replicated, each origin of replication site must be bound by a set of proteins called the **Origin Recognition Complex**. These remain attached to the DNA throughout the replication process. Specific accessory proteins, called **licensing factors**, must also be present for initiation of replication. Destruction of these proteins after initiation of replication prevents further replication cycles from occurring. This is because licensing factors are only produced when the nuclear membrane of a cell breaks down during mitosis.

DNA Transcription—Making mRNA

DNA transcription refers to the synthesis of RNA from a DNA template. This process is very similar to DNA replication. Of course, there are different proteins that direct transcription. The most important enzyme is **RNA polymerase**, an enzyme that influences the synthesis of RNA from a DNA template. For transcription to be initiated, RNA polymerase must be able to recognize the beginning sequence of a gene so that it knows where to start synthesizing an mRNA. It is directed to this initiation site by the ability of one of its subunits to recognize a specific DNA sequence found at the beginning of a gene, called the **promoter sequence**. The promoter sequence is a unidirectional sequence found on one strand of the DNA that instructs the RNA polymerase in both where to start synthesis and in which direction synthesis should continue. The RNA polymerase then unwinds the double helix at that point and begins synthesis of a RNA strand complementary to one of the strands of DNA. This strand is called the **antisense** or **template** strand, whereas the other strand is referred to as the **sense** or coding strand. Synthesis can then proceed in a unidirectional manner.

Although much is known about transcript processing, the signals and events that instruct RNA polymerase to stop transcribing and drop off the DNA template remain unclear. Experiments over the years have indicated that processed eukaryotic messages contain a **poly(A) addition signal** (AAUAAA) at their 3' end, followed by a string of adenines. This poly(A) addition, also called the **poly(A) site**, contributes not only to the addition of the poly(A) tail but also to transcription termination and the release of RNA polymerase from the DNA template. Yet, transcription does not stop here. Rather, it continues for another 200 to 2000 bases beyond this site before it is aborted. It is either before or during this termination process that the nascent transcript is **cleaved**, or cut, at the poly(A) site, leading to the creation of two RNA molecules. The upstream portion of the newly formed, or **nascent**, RNA then undergoes further modifications, called **post-transcriptional modification**, and becomes mRNA. The downstream RNA becomes unstable and is rapidly degraded.

Although the importance of the poly(A) addition signal has been established, the contribution of sequences further downstream remains uncertain. A recent study suggests that a defined region, called the **termination region**, is required for proper transcription termination. This study also illustrated that transcription termination takes place in two distinct steps. In the first step, the nascent RNA is cleaved at specific subsections of the termination region, possibly leading to its release from RNA polymerase. In a subsequent step, RNA polymerase disengages from the DNA. Hence, RNA polymerase continues to transcribe the DNA, at least for a short distance.

Protein Translation—How Do Messenger RNAs Direct Protein Synthesis?

The cellular machinery responsible for synthesizing proteins is the **ribosome**. The ribosome consists of structural RNA and about 80 different proteins. In its inactive state, it exists as two subunits: a **large subunit** and a **small subunit**. When the small subunit encounters a mRNA, the process of **translating** a mRNA to a protein begins. In the large subunit, there are two sites for amino acids to bind and thus be close enough to each other to form a bond. The "**A site**" accepts a new **transfer RNA**, or tRNA—the adaptor molecule that acts as a translator between mRNA and protein—bearing an amino acid. The "**P site**" binds the tRNA that becomes attached to the growing chain.

As we just discussed, the adaptor molecule that acts as a translator between mRNA and protein is a specific RNA molecule, the tRNA. Each tRNA has a specific **acceptor site** that binds a particular triplet of nucleotides, called a **codon**, -and an **anti-codon site** that binds a sequence of three unpaired nucleotides, the **anti-codon**, which can then bind to the codon. Each tRNA also has a specific **charger protein**, called an **aminoacyl tRNA synthetase**. This protein can only bind to that particular tRNA and attach the correct amino acid to the acceptor site.

The **start signal** for translation is the codon ATG, which codes for methionine. Not every protein necessarily starts with methionine, however. Oftentimes this first amino acid will be removed in later processing of the protein. A tRNA charged with methionine binds to the translation start signal. The large subunit binds to the mRNA and the small subunit, and so begins **elongation**, the formation of the polypeptide chain. After the first charged tRNA appears in the A site, the ribosome shifts so that the tRNA is now in the P site. New charged tRNAs, corresponding the codons of the mRNA, enter the A site, and a bond is formed between the two amino acids. The first tRNA is now released, and the ribosome shifts again so that a tRNA carrying two amino acids is now in the P site. A new charged tRNA then binds to the A site. This process of elongation continues until the ribosome reaches what is called a **stop codon**, a triplet of nucleotides that signal the termination of translation. When the ribosome reaches a stop codon, no aminoacyl tRNA binds to the empty A site. This is the ribosome signal to break apart into its large and small subunits, releasing the new protein and the mRNA. Yet, this isn't always the end of the story. A protein will often undergo further modification, called **post-translational modification**. For example, it might be cleaved by a protein-cutting enzyme, called a protease, at a specific place or have a few of its amino acids altered.

Figure 8. An overview of transcription and translation.

This drawing provides a graphic overview of the many steps involved in transcription and translation. Within the nucleus of the cell (*light blue*), genes (DNA, *dark blue*) are transcribed into RNA. This RNA molecule is then subject to post-transcriptional modification and control, resulting in a mature mRNA molecule (*red*) that is then transported out of the nucleus and into the cytoplasm (*peach*), where it undergoes translation into a protein. mRNA molecules are translated by ribosomes (*purple*) that match the three-base codons of the mRNA molecule to the three-base anti-codons of the appropriate tRNA molecules. These newly synthesized proteins (*black*) are often further modified, such as by binding to an effector molecule (*orange*), to become fully active.

DNA Repair Mechanisms

Maintenance of the accuracy of the DNA genetic code is critical for both the long- and short-term survival of cells and species. Sometimes, normal cellular activities, such as duplicating DNA and making new gametes, introduce changes or mutations in our DNA. Other changes are caused by exposure of DNA to chemicals, radiation, or other adverse environmental conditions. No matter the source, genetic mutations have the potential for both positive and negative effects on an individual as well as its species. A positive change results in a slightly different version of a gene that might eventually prove beneficial in the face of a new disease or changing environmental conditions. Such beneficial changes are the cornerstone of evolution. Other mutations are considered **deleterious**, or result in damage to a cell or an individual. For example, errors within a particular DNA sequence may end up either preventing a vital protein from being made or encoding a defective protein. It is often these types of errors that lead to various disease states.

The potential for DNA damage is counteracted by a vigorous surveillance and repair system. Within this system, there are a number of enzymes capable of repairing damage to DNA. Some of these enzymes are specific for a particular type of damage, whereas others can handle a range of mutation types. These systems also differ in the degree to which they are able to restore the normal, or **wild-type**, sequence.

Categories of DNA Repair Systems

- **Photoreactivation** is the process whereby genetic damage caused by ultraviolet radiation is reversed by subsequent illumination with visible or near-ultraviolet light.

- **Nucleotide excision repair** is used to fix DNA lesions, such as single-stranded breaks or damaged bases, and occurs in stages. The first stage involves recognition of the damaged region. In the second stage, two enzymatic reactions serve to remove, or excise, the damaged sequence. The third stage involves synthesis by DNA polymerase of the excised nucleotides using the second intact strand of DNA as a template. Lastly, DNA ligase joins the newly synthesized segment to the existing ends of the originally damaged DNA strand.
- **Recombination repair**, or **post-replication repair**, fixes DNA damage by a strand exchange from the other daughter chromosome. Because it involves homologous recombination, it is largely error free.
- **Base excision repair** allows for the identification and removal of wrong bases, typically attributable to **deamination**—the removal of an amino group (NH2)—of normal bases as well as from chemical modification.
- **Mismatch repair** is a multi-enzyme system that recognizes inappropriately matched bases in DNA and replaces one of the two bases with one that "matches" the other. The major problem here is recognizing which of the mismatched bases is incorrect and therefore should be removed and replaced.
- **Adaptive/inducible** repair describes several protein activities that recognize very specific modified bases. They then transfer this modifying group from the DNA to themselves, and, in doing so, destroy their own function. These proteins are referred to as **inducible** because they tend to regulate their own synthesis. For example, exposure to modifying agents induces, or turns on, more synthesis and therefore adaptation.
- **SOS repair** or **inducible error-prone repair** is a repair process that occurs in bacteria and is induced, or switched on, in the presence of potentially lethal stresses, such as UV irradiation or the inactivation of genes essential for replication. Some responses to this type of stress include mutagenesis—the production of mutations—or cell elongation without cell division. In this type of repair process, replication of the DNA template is extremely inaccurate. Obviously, such a repair system must be a desperate recourse for the cell, allowing replication past a region where the wild-type sequence has been lost.

From Cells to Genomes

Understanding what makes up a cell and how that cell works is fundamental to all of the biological sciences. Appreciating the similarities and differences between cell types is particularly important to the fields of cell and molecular biology. These fundamental similarities and differences provide a unifying theme, allowing the principles learned from studying one cell type to be extrapolated and generalized to other cell types.

Perhaps the most fundamental property of all living things is their ability to reproduce. All cells arise from pre-existing cells, that is, their genetic material must be replicated and passed from parent cell to progeny. Likewise, all multicellular organisms inherit their genetic information specifying structure and function from their parents.

Part B

Classification of Animal Kingdom,

Classification of Animal Kingdom, Grades of Organisation, A brief introduction of the various Animal Phyla: Protozoa, Coelenterata, Porifera, Platyhelminthes, Nematoda, Annelida, Mollusca, Arthropoda, Echinodermata, and Chordata.

Classification, identification, naming, and grouping of organisms into a formal system are based on **similarities** such as **internal and external anatomy, physiological functions, genetic makeup, or evolutionary history.**

With an estimated 10 million to 13 million species on Earth, the diversity of life is immense. In a related field known as **taxonomy**, scientists identify new organisms and determine how to place them into an existing classification scheme.

Since life first appeared on Earth 3.5 billion years ago, many new types of organisms have evolved. Many of these organisms have become **extinct**, while some have developed into the present **fauna** and **flora** of the world. Extinction and diversification continue nonstop, and scientists are frequently encountering fluctuations that may affect the way an organism is classified. In addition to ordering organisms, scientists give a new species a scientific name, typically a two-word name in **Latin**, to distinguish it from similar organisms.

This naming process creates a standard way for scientists around the world to communicate about the same organism. This standard minimizes confusion, particularly when common names are applied to organisms. For instance, the bird Europeans commonly call a robin is a different species of bird from the robin Americans recognize. The confusion ends when the birds are referred to by their scientific names: the European robin is *Erithacus rubecula,* while the American robin is *Turdus migratorius.*

When classifying organisms, scientists study a wide range of features, including those **visible to the naked eye**, those **detectable only under a microscope**, and those that can be **determined only by chemical tests**. Scientists compare the **external** shapes and **sizes** of organisms as well as the **anatomy** and **function of internal organs** and organ systems, such as the digestive or reproductive systems. Biochemists study and compare the **molecular interactions** within an organism that enable it to grow, make and store energy, and reproduce.

The early stages of an organism's development, or **embryology**, as well as an organism's behavior, or **ethology**, are also useful in grouping organisms. Even the role an organism plays in its **habitat** can help place it in a particular group. Scientists use the **fossil record** to learn how certain animals have changed and evolved through Earth's history, which may provide clues for classification.

More recently, scientists have employed the techniques of molecular biology to compare the units of **heredity, or genes,** among organisms. Scientists study the fundamental units of **deoxyribonucleic acid (DNA)**, the molecule that makes up genes, and organisms that share a similar DNA structure may be more closely related; called **molecular systematics,** this approach is a powerful analytical tool. Used in combination with the other features studied in classification, molecular systematics can provide valuable insight into classification problems. For many organisms, molecular systematics studies have supported traditional classification; however, in some cases, the evidence from genetics studies has indicated that organisms should be reclassified. Skunks, for example, traditionally have been classified with badgers, ferrets, and minks in the family Mustelidae. But recent studies of molecular traits indicate that skunks differ significantly from these animals and may warrant classification in their own family.

How species are grouped

Scientists classify organisms using a series of hierarchical categories called **taxa (taxon,** singular). This hierarchical system moves upward from a base containing a large number of organisms with very specific characteristics. This base taxon is part of a larger taxon, which in turn becomes part of an even larger taxon. Each successive taxon is distinguished by a broader set of characteristics. The base level in the taxonomic hierarchy is the **species**.

Broadly speaking, a **species is a group of closely related organisms** that are able to interbreed and produce fertile offspring. On the next tier of the hierarchy, **similar species are grouped** into a broader taxon called a **genus (genera**, plural). The remaining tiers within the hierarchy are formed by grouping genera into **families**, then families into **orders**, and orders into **classes**.

In the classification of animals, bacteria, protists (unicellular organisms, such as amoebas, with characteristics of both plants and animals), and fungi, classes are grouped into **phyla** (*see* Phylum), while plant classes are grouped into divisions. Both phyla and divisions are grouped into **kingdoms**. Some scientists go on to group kingdoms into **domains**.

Classification methods

Grouping organisms according to shared characteristics is not a simple task, and scientists often disagree about the best way to classify organisms. Some think that organisms should be grouped according to **differences or similarities** in the way they look or act. Other scientists argue that classification should be based on characteristics derived from a **shared evolution**. Conflicting philosophies about classification have resulted in a variety of classification methods, each with their own set of assumptions, techniques, and results.

The classification of insects, birds, and bats illustrates a **traditional classification** process. Insects, birds, and bats are all animals—that is, they are multicellular organisms that obtain energy from food. Scientists group these organisms into the **Kingdom Animalia.** Birds and bats both have spinal cords, causing scientists to classify both birds and bats in the **phylum Chordata.** Within the phylum Chordata, key features cause scientists to separate birds and bats. Birds are placed in the **class Aves,** which includes egg-laying animals, while bats are placed in the **class Mammalia,** which includes animals that give birth to live young and nurse their young from mammary glands. Insects, which lack spinal cords, are classified in the **phylum Arthropoda,** the taxon that includes animals with jointed legs and a skeleton on the outside of the body. Insects are further divided based on such broad physical features as the presence or absence of wings. Scientists using the classical approach must judge the relative importance of characteristics. They may decide, for example, that wing structure is more important than the presence of fingernails in certain cases of classification. Some critics argue that this interpretation and evaluation is too subjective.

To introduce more objectivity into classification, some scientists devised the **phenetics approach** to classification. In the phenetics approach, scientists rely on **quantitative methods** and consider only the **observable characteristics** of modern organisms.

Pheneticists identify a set of characteristics to measure and assign a certain numerical value to each characteristic. The tally is used to determine the extent of similarity between organisms. For example, pheneticists may find that, overall, birds and reptiles have a 77 percent similarity of body structure, or morphology, compared to a 55 percent morphological similarity between birds and mammals. From this measurement, pheneticists would suggest a classification that grouped birds and reptiles more closely than birds and mammals.

A third classification method is the **cladistic approach**, which strives to classify organisms by **natural evolutionary relationships**, known as **phylogeny**.

Cladists use the fossil record, molecular genetics, and other techniques to create an evolutionary tree called **a cladogram**. This branched diagram shows the relationship of a group of species based on the fewest number of shared changes that have occurred from generation to generation.

History of classification systems

Classification is one of the oldest sciences, but despite its age it is still a vigorous field full of new discoveries and methods. Much like other fields of science, great thinkers have shaped the course of classification. **One of the earliest classification schemes was established by Greek philosopher Aristotle, who lived in the 300s bc.** Aristotle believed that the complexity of life could be divided into a natural order based on dichotomies, or polar opposites. For example, Aristotle divided animals into **those with blood and those without blood,** a classification that roughly corresponds to the division between **vertebrates and invertebrates** used in contemporary classification schemes. Aristotle wrote extensively on both plants and animals, but his writings on plants were lost. Fortunately, his pupil Theophrastus applied Aristotle's taxonomic approach to the study of plants in his work *Inquiry into Plants* (trans. 1916). Theophrastus subdivided plants, based on shape, into such broad categories as trees, shrubs, and herbs.

A more pragmatic approach to classification was developed by Greek physician Dioscorides, who separated, for instance, medicinal herbs from those used in making perfumes. o unify the naming of organisms and to communicate more precisely about the increasing number of species being discovered, scholars in the Middle Ages (around the 5th century to the 15th century ad) translated the common names of organisms into Latin—at the time the language of educated persons. These names were often long and cumbersome, and included numerous descriptive terms. This complex naming process was simplified into a two words, or binomial, naming system in the mid-16th century to mid-17th century by a group of naturalists known as herbalists.

Sixteenth-century Italian botanist Andrea Cesalpino was the first scientist to classify plants primarily according to structural characteristics, such as their fruits and seeds. Cesalpino developed a method of character weighting in which he defined certain key characteristics that were important for recognizing plant groups. This method was adapted by Swiss botanist Caspar Bauhin, who catalogued an extensive list of plants.

More importantly, Bauhin was the first to organize plants into a crude system that resembles modern genera and species. Animal classification also advanced in the 16th century. French naturalist Pierre Belon extensively studied and catalogued birds. He was the first to use adaptation to habitat to divide birds into such groups as aquatic birds, wading birds, birds of prey, perching birds, and land birds, categories still used informally today. In the 17th century, English naturalist John Ray was the first to apply the character weighting method to structural features in animals. **He used key characteristics, such as the shape and size of the bird beak, to classify birds. In the mid-1700s, Swedish naturalist Carolus Linnaeus developed formal rules that provided consistency for a two-name system in common use called the binomial system of nomenclature. In this system, similar organisms are grouped into a genus, and each organism is given a two-word Latin name. The first word is the genus name, and the second word is usually an adjective describing the organism, its geographic location, or the person who discovered it.**

Using this system, the domestic dog is *Canis familiaris*. *Canis* is the genus name for the group of animals that includes dogs, wolves, coyotes, and jackals. The word ***familiaris*** acts as a descriptor to further differentiate the domestic dog from its wild cousins.

Prior to Linnaeus, biologists had established random categories of classification, such as the category of genus for a group of species. Linnaeus was the first to formalize the use of higher taxa in his book *Systema Naturae* (1735), establishing the standard hierarchy taxonomy still in use today. In addition, Linnaeus devised logical rules to classify species that continued to be used by scientists for over 200 years. Before the 19th century, Linnaeus and other taxonomists classified organisms in an arbitrary but logical way that made it easier to communicate scientific information.

But with the publication of *On the Origin of Species* in 1859 by British naturalist Charles Darwin, the purpose of classification took on new meaning. Darwin argued that classification systems should reflect the history of life—that is, species should be related based on their shared ancestry. He defined species as groups that have diverged from a shared ancestry in recent history, while organisms in higher taxa, such as genera, class, or order, diverged from a shared ancestor further back in history. Making evolutionary history compatible with the classification systems already established was no easy task, however.

Critics argued that classification should be consistent with phylogeny, but not based solely upon evolutionary history. They advocated using other factors, such as behavior or anatomy, along with phylogeny to better classify organisms. This controversy over the fundamental approach to classification continues today.

The development and **use of microscopes** in the late 16th century revealed a diverse array of single-celled organisms. These organisms presented new classification problems for the science community, which still relied on a two-kingdom classification system. At first, single-celled organisms that carried out photosynthesis were classified in **Kingdom Plantae**, and organisms that ingested food were placed in **Kingdom Animalia**. By the 19th century, scientists had identified a wide variety of microscopic organisms with diverse cell anatomies, specialized internal structures called organelles, and reproductive patterns that did not easily fit into the plant or animal classification system. This great diversity prompted German biologist Ernst Haeckel to propose placing these unicellular forms in a third kingdom, the **Protista**. Haeckel placed bacteria within the Kingdom Protista in a separate group that he called Monera, recognizing that these organisms differed from all other cells because they lacked nuclei.

As biologists learned more about bacteria, they became aware of the further differences between these organisms and all other life forms. In addition to lacking nuclei, bacteria differ from other types of cells in that they do not have membrane-bound organelles, such as mitochondria, the cell structures involved in energy metabolism. In the 1930s, these differences led French marine biologist Edouard Chatton to make a crucial distinction between prokaryotes, organisms such as bacteria that lack nuclei, and eukaryotes, more complex organisms that have nuclei. In 1938 American biologist Herbert Copeland argued that the distinctions between prokaryotes and eukaryotes were so fundamental that prokaryotes merited a fourth kingdom of their own called Kingdom Monera (now called Kingdom Prokaryotae).

Like all living things, animals show similarities and differences that enable them to be classified into groups. Birds, for example, are the only animals that have feathers, while mammals are the only ones that have fur. The scientific classification of animals began in the late 18th century. At this time, animals were classified almost entirely by external features, mainly because these are easy to observe. But external features can sometimes be misleading. For example, in the past, comparison of physical features led to whales being classified as fish and some snakes being classified as worms.

Presently, animals are classified according to a broader range of characteristics, including their internal anatomy, patterns of development, and genetic makeup. These features provide a much more reliable guide to an animal’s place in the living world. They also help to show how different species are linked through evolution. Scientists divide the animal kingdom into approximately 30 groups, each called a phylum (plural phyla).

- **Phylum Protozoa**
- **Phylum Cnidarata**
- **Phylum Porifera**
- **Phylum Platyhelminthes**
- **Phylum Nematoda**
- **Phylum Annelida**
- **Phylum Mollusca**
- **Phylum Arthropoda**
- **Phylum Echinodermata**
- **Phylum Chordata**

Phylum Protozoa

Protozoa, collective name for animal-like, **single-celled organisms**, some of which may form colonies. In the classification protozoa are placed in the kingdom Protista with other single-celled organisms that have membrane-enclosed nuclei. Protozoa have little or no differentiation into tissue systems. Several phyla are commonly recognized. They include flagellated Zoomastigina, many species of which live as parasites in plants and animals; the amoeboid Sarcodina, which includes the Foraminifera and Radiolaria both important components of the plankton; ciliated Ciliophora, many with specialized structures suggesting the mouth and anus of higher organisms; Cnidosporidia, parasites of invertebrates, fish, and a few reptiles and amphibians; and **Sporozoa, many species of which are parasites of animals (including humans).**

More than 20,000 species are known, including such familiar forms as paramecium and amoeba. Most species are found in such aquatic habitats as oceans, lakes, rivers, and ponds.

They vary in length from 2 to 70 micrometers. Protozoa obtain their food by ingesting bacteria, waste products of other organisms, algae, or other protozoa. Most species are motile, either by whiplike structures called flagella, hairlike structures called cilia, or amoeboid motion, a streaming type of movement involving the formation of pseudopods (footlike extensions).

Ciliated Protozoan

Ciliated protozoans are single-celled organisms that are propelled by minute, hairlike projections called cilia. In addition to locomotion, cilia also create currents that help sweep food particles into a small depression in the body surface through which food is ingested.

Ciliated protozoans can be found in water or soil and in parasitic or symbiotic relationships with other organisms. In soils, ciliated protozoans function as decomposing organisms, breaking down organic matter into substances that can be used by other organisms.

Dinoflagellate

The dinoflagellates are the second most important group of phytoplankton, responsible for producing energy in the ocean food chain. They have a whiplike structure called a flagellum that acts as an organ of locomotion, and the organisms demonstrate both plant and animal traits. Dinoflagellates can reproduce rapidly, or bloom, and certain species bloom in toxic red tides that kill fish and contaminate shellfish. **Reproduction** of protozoans occurs by means of **binary fission** or mitosis. ***Amoeba*** is one of the most common protozoans and moves by means of pseudopodia.

One of the most agriculturally important species of Protozoans is **Babesia**. This protozoan causes **Red-water fever**, a disease that affects 100,000 cattle a year.

Amoeba is one of the most common protozoans moves by means of pseudopodia.

Most agriculturally important species of Protozoans are: Babesia, Trypanosome, and Coccidia. Babesia causes Red-water fever, a disease that affects 100,000 cattle a year.

Phylum Cnidarata

Cnidarians, also known as **coelenterates**, diverse group of aquatic, invertebrate animals armed with microscopic stinging structures. Cnidarians make up the phylum Cnidaria, which encompasses more than 9,000 species, **including corals, hydras, jellyfish**, Portuguese man-of-war, and sea anemones. **Cnidarians live in all oceans, and a few species inhabit fresh water.** Although they have various physical characteristics, all cnidarians exhibit radial symmetry—that is, similar body parts radiate from a central mouth. Six to ten tentacles surround a cnidarian's mouth to aid in the capture and ingestion of the animals they feed on. Cnidarians have a saclike body with a single mouth opening. The body wall is composed of two sheets of cells—an inner layer (the endoderm) and an outer layer (the ectoderm). A gelatinous mesoglea layer holds these two cell layers together. **Cnidarians are invertebrates (animals that lack a backbone), but the ectoderm of some cnidarians, including hard corals and some hydrozoans, may form a skeleton-like structure externally**. The ectoderm of other cnidarians, such as some soft corals, forms an internal skeleton-like structure. **The ectoderm and endoderm layers contain contractile fibers that enable the animal to move about**. Invertebrate zoologists believe these fibers are primitive versions of the muscle cells found in more complex animals.

Cnidarians lack internal organs and they do not have digestive, circulatory, or respiratory systems. Secretions from endoderm cells digest food within the central body cavity and endoderm cells also distribute nutrients and dissolved oxygen to all parts of the body. Lacking an anus, cnidarians discharge waste matter through the mouth opening.

Types of cnidarians

Scientists divide cnidarians into four classes: Hydrozoa, Scyphozoa, Cubozoa, and Anthozoa. They base this division partly on whether the polyp or medusa is more conspicuous during an animal's life cycle.

Reproduction

Reproduction in cnidarians varies among the different species. They may reproduce by means of asexual reproduction, sexual reproduction, or both. Polyps generally perform asexual reproduction by budding, in which an outgrowth from the body wall separates to form a new polyp or medusa. Medusae primarily reproduce sexually—they produce gametes (sex cells), and a gamete (sperm) from a male medusa fuses with a gamete (egg) from a female medusa to form a zygote. The zygote develops into a larva, which in turn develops into a polyp or medusa. The medusae of some cnidarians may also form polyps by budding.

The reproductive life cycle of a typical jellyfish illustrates both asexual and sexual reproduction. Males release sperm and females release eggs into the water. When an egg and sperm fuse during sexual reproduction, a larva develops that attaches to a rock or other object and develops into a polyp. In a type of asexual reproduction, the polyp divides to form a colony of polyps that resembles a stack of saucers. Each saucer in the stack develops tentacles and swims away from the colony as a new medusa, and the reproductive cycle repeats.

In the reproductive life cycle of a typical jellyfish, males release sperm and females release eggs into the water. When an egg and sperm fuse to form a fertilized egg during sexual reproduction, a larva develops that attaches to a rock or other object and develops into a polyp. In a type of asexual reproduction, the polyp transforms into a colony of polyps that resembles a stack of saucers. Each saucer in the stack detaches itself from the colony as a new medusa, and the reproductive cycle repeats.

A

Exhibit radial symmetry

1. definition: body parts arranged symmetrically around central asxis

2. polyp and medusa forms:

a. polyp- sessile, hydrozoans, anemones, and corals have polyps as the prodominant body form

b. medusa- free-swimming; dispersal stage for many cnidarians

c. some cnidarians alternate between an asexual polyp and asexual madusa

B

Cells of cnidarians- tissues levels of organization

1. diploblastic: organized into two tissue layers

a. epidermis derived from ectoderm

b. gastrodermis derived from endoderm

c. mesoglea in between (‘jelly-like substance which give jellyfish their common name

2. cnidocytes-specialized stingy cells which give the phylum its name

a. contain harpoon-like structures called nematocysts

b. venom which paralyzes prey

c. some varieties are toxic to man –Portuguese Man-O-War

C

Food processing

1. tentacles with cnidocytes

2. gastrovascular cavity- incomplete (one opening)

3. digestion by cells—cells engulf food fragments through phagocytosis

D.

Nervous system

1. nerve network in polyps

2. rings of nerve cells in medusas

E.

Typical life

Cnidarian cycle

1. characterized by a planula larva stage

2. some alternate between an asexually reproducing polyp and asexually reproducing medusa (true jellyfish)

3. external fertilization

Phylum Porifera (Sponges)

exclusively aquatic and, with a few exceptions, a filter-feeding group of animals.

Adult sponges can be asymmetrical or radially symmetrical (divided into two identical halves)

They come in a variety of sizes, colours and shapes. They including:

- **arboresecent (tree-like)**
- **Flabellate (fan-shaped)**
- **Caliculate (cup shaped)**
- **Tubular (tube shaped)**
- **Globular (ball shaped)**
- **Amorphous (shapeless)**

Habitats:Freshwater, marine mangroves, sea grass ecosystems.

A single outer layer of cells (pinacoderm) separates the inner cellular region (mesohyl) from the external environment. The pinacoderm lines the internal canals and is eventually replaced by the choanoderm, a layer of characteristic flagellated collar cells (choanocytes) grouped in chambers.

Choanocytes make up the principle 'pump' and' filter', driving water through the sponge, trapping, phagocytizing suspended bacteria and other particulate food, then digested nutrients distributed among the cells of the mesohyl that facilitate the functions of feeding, respiration, reproduction.

The flow of water inside a sponge is unidirectional: the water is drawn in through tiny pores (ostia) in the pinacoderm and exits through one or more larger openings (osculae). The aquiferous system of a sponge is supported by a combination of two types of skeletal elements:

- Mineral spicules (either calcareous or siliceous) and
- Special protein fibers (spongin)
- Although either one or both of these elements can be absent.

Sponges are monophyletic group (common ancestor). Sponge body is unique among animals because it continuously remolds itself to fine-tune its filter-feeding system. Constant rearrangement of the body is accomplished by the amoeboid movements Although often considered immobile, Sponges also display several behavioural patterns resulting from coordinated movements of cells, including crawling, production of filamentous body extensions ***and body contractions.***

Sponges lack many characteristics associated with other animals, including a mouth, sensory organs, organized tissues, neurons and muscle cells. They are the only animals with Skeletons made of microscopic mineral spikes.The only ones that feed by pumping water through hollow pores. Some of their cells are remarkably like free-living protozoans called collar flagellates. To evolutionary biologists, this resemblance strongly suggests that sponges and other invertebrates arose from protozoan-like ancestors

Phylum Platyhelminthes

The phylum literally means “flat worms” and all the members of this phylum are flat worms! The phylum is classified into three main groups or classes:

*Class **Turbellaria*** (Free living)

*Class **Trematoda*** (Parasitic Flukes)

*Class **Cestoda*** (Parasitic Tapeworms)

A.
Exhibit bilateral symmetry

1. Efficient locomotion

2. Dorsal and ventral surfaces

3. Anterior and posterior ends

4. Cephalization-head region with sensory organs:

a. sensory cells at anterior end;

b. ganglia as forerunner of brain

B
Triploblastic

1. Mesoderm between ectoderm and endoderm

2. Give rise to specialized adult tissues

3. Solid body with no internal body cavity- acoelomate

C

Free-living flatworms-planaria

1. Food processing-incomplete digestive tract

2. Muscular pharynx

3. Sensory system-eyespots ‘ocelli’

4. Musculature-muscle cells

5. Excretory structure-flame cells

6. Reproductive organs-hermaphroditic

D

Parasitic flukes and tapeworms

1. Organism which causes schistosomiasis- disease in which the fluke live in the intestinaltract, liver, or bladder causing injury to the organs; 1 in 20 people in tropical Africa, Asia, South America and the Middle East are afflicted with schistosomiasis.

2. Tapeworms- important parasite of livestock and pets

All platyhelminths are **hermaphrodites** (are both male and female) and can, if required, can fertilize themselves. The most important agricultural species of platyhelminths is the **Liver Fluke or *Fasciola hepatica.*** The life cycle of the liver fluke is very important in finding ways of controlling the disease. The Life cycle is complicated and the fluke must lay huge amounts of eggs to survive. **The lifecycle takes place in the cow, on grass and in a secondary host (the mud snail).**

The Lifecycle of the Liver Fluke

The Liver fluke lives in the ducts of the liver. The fluke lays eggs in the bile ducts (20,000 or so a day) The eggs pass in the faeces and hatch two weeks later in water and form a ciliated **Miracidium.** The Miracidium enters the foot of the mud snail and changes into a **Sporocyst**. Still inside the snail, the Sporocyst changes into a **Redia.** The Redia then produce very small tadpole shaped **Cercaria.** For every Miracidium that enters the snail, 10,000 Cercaria can be produced. The Cercaria then leaves the snail and goes onto grass. There it becomes encysted (forms a shell) and waits to be eaten by a sheep or cow. If eaten, the stomach acids dissolve the cyst and the liver fluke moves to the liver and restarts the cycle.

Understanding the lifecycle of the liver fluke allows us control the spread in the following ways:

Dosing any animals to kill the adult fluke

Spraying molluscicides to kill the snail.

Draining land (the snail only lives in water)

Fencing flooded areas

Don’t graze wet lands after August

Phylum Nematoda

Nematodes are also known as roundworms or eelworms. There are huge numbers of species in this phylum. All these worms reproduce by laying thousands of eggs, which become encysted in the grass and wait to be ingested. The most important species are:

Lungworms (causes hoose)

Hairworms (worms in school children)

Potato eelworm

Stomach worms

Largest group of invertebrates in terms of sheer numbers

Unsegmented round worms

Characteristics:

1. triploblastic

2. first group to have a complete digestive tract

3. pseudo-coelomates- fluid-filled cavity located between msoderm and endoderm:

a. inncreases the effectiveness of muscles

b. functions as a hydrostatic skeleton

4. dioecous

Important parasites of man, livestock, pets and economically important crop plants

1. Trichinella- contracted from eating poorly cooked pork

2. Heart worms in dogs

3. Elephantiasis

4. Thick cuticle which prevents digestive enzymes of the host organism from damaging the round worm

Phylum Annelida

These are the **segmented** worms and include the earthworm – *Lumbricus terrestris* and leeches. On each segment, earthworms have four bristles or **Chaetae**, which they use to move. Earthworms are important to the farmer because they improve the soil in the following ways:

They eat their way through the soil and mix the ingested material with mucus in their guts. This helps to improve soil crumb structure.

Depositing soil in different places and mixing horizons.

Improve drainage of heavy clay soils

Introduces more air into the soil.

When they die the further increase the amount of organic matter.

A

Body divided into segments

1. Segments are advantagous– allow for specialized movement

2. Internal structures—nerves, nephridia, blood vessels, and reproductive organs are repeated in several segments– damage to one segment is less harmful to the functioning of a segmented organism

A

Evolutionary link with mollusks

1. Trochophore larva

2. Coelomate

3. Triploblastic

4. Protostome development

C
Characteristics

1. segmented muscles and coelomic compactments:

a. Longitudinal and circular muscles

b. Bristle (setae) assist in burrowing

2. Complete digestive tract and closed circulatory system

3. Paired nephridia in each segment for excretory system

4. Chainlike nervous system

5. Hermaphroditic

6. Dorsal blood vessel and ventral nerve cord

D
Leeches:

Substances in the salivary gland which is an anticoagulant– hirudin (first commercially available blood thinner); still used in the treatment of burns and the reattachment of body parts

<u>Phylum Mollusca</u>

The molluscs include slugs, snails, squid, mussels, clams and octopus.

These animals generally have a foot, which excretes a slimy mucus. They also have a rasping tongue.

The most agriculturally important mollusc is the mud snail (*Lymnaea truncatula)*

Achachatina marginata

Generalized Anatomy of a Mollusk

There are around 50,000 species of mollusks, ranging from tiny snails less than 1 cm (0.25 in) in length to giant squids, which reach a length of 18 m (60 ft). Despite this great variation in size, most mollusks have the same basic body structure. Most mollusks have a glandular body covering, called the mantle. In some mollusks, such as clams and snails, the mantle secretes a hard shell. Most mollusks have a large muscular organ, called the foot, which is used for burrowing or for moving over the ground or sea bottom.Many mollusks feed by means of the radula, a flexible organ that bears many sharp teeth. Mollusks use gills to absorb nutrients from water and release waste products from cells.

Mollusks make up the second largest group of invertebrates. Even by invertebrate standards mollusks are extremely varied. Mollusks include snails, clams, octopuses, and squid, as well as some lesser-known animals, such as chitons and monoplacophorans. Some mollusks, such as bivalves, are sedentary animals, while others such as squid are jet-propelled predators that are the swiftest swimmers in the invertebrate world. Most sedentary mollusks are filter-feeders—that is, they feed on tiny organisms that they strain from water.

Other mollusks, including snails and other gastropods, scrape up their food using a *radula*—a ribbonlike mouthpart that is unique to mollusks and covered with rows of microscopic teeth

Major Groups of Mollusks

The mollusks represent a diverse group of marine, freshwater, and terrestrial invertebrates, including such varied forms as snails, chitons, limpets, clams, mussels, oysters, octopuses, squid, cuttlefish, tusk shells, slugs, nudibranchs, and several highly modified deep-sea forms.

They all have one anatomical feature in common, the presence of a shell at some stage in the life cycle. Although most mollusks have a shell as adults, the octopus, squid, and deep-sea forms do not. They do however have a small, shell-like structure, called a shell gland, present for a short time during embryonic development.

Have a mantle: tissue that secretes or form a shell

A. **Shells**

1. one piece shells: snail

2. two piece shell: clams

3. eight piece shells: chitons

B. Mantle forms a mantle cavity which may house:

1. gills

2. lungs

3. reproductive systems

2
Muscular ‘foot’:

A. **Foot**

1. flat sole (snails)

2. compressed (clams)

3. arms or tentacles (squid)

Types of mollusks

1. Gastropod

2. Bivalve

3. Gephalapode

All mollusks bivalve have radula which is used to scrape food

Mollusks have both an open and a closed circulatory system (cephalopoda)

Classes of mollusks

1. Gastropoda- coiled shell; including snails and slugs

2. Peleypoda (bivalves)- hinged shells: clams and oysters

3. Cephalopoda- head with tentacles: squid, octopus

- ***Kingdom: animalia;***
- ***Phylum : mollusca;***
- ***Class: gastropoda;***
- ***Order: pulmonata;***
- ***Family: achatinidae;***
- ***Genera: achatina and achachatina;***
- ***Species: achatina fulica, achatina achatina, achachatina marginata***

Phylum Arthropoda

This is the largest phylum containing nearly a million species. Therefore it is necessary to sub classify the phylum into classes. All Arthropods have jointed legs and an exoskeleton (outer skeleton). Members of the phylum include scorpions, insects, spiders, shellfish (crustaceans), woodlice, centipedes and millipedes.

The most important classes of Arthropods are the spiders and insects.

Class Insecta (Insects)

They have three main body parts: Head, thorax and abdomen They include aphids, lice, fleas, crane-flies and butterflies. The life cycle of all insects follows this path:

Egg -Larvae -Pupa -Adult

Arthropods live in every habitat on Earth from mountaintops to hydrothermal vents, springs of hot water located on the deep ocean floor. Surrounded by protective exoskeletons, arthropods have tubular legs that bend at flexible joints. This unique characteristic sets them apart from all other invertebrates, and it enables them to hop, walk, and run.

Insects dominate the arthropod phylum.

Making up 90 percent of all arthropods, insects have a strong claim to be the most successful animals in the world. On land, they live in almost every habitat, aided by their small size and, for many, their ability to fly. They also live in fresh water, but remarkably, they have failed to colonize the sea. Some zoologists believe this is because crustaceans have already exploited this habitat to its fullest.

a. Marine, fresh water, and terrestrial

b. Segmentation: segmented bodies

c. External skeleton: exoskeleton

d. Ventral nerve cord

e. Open circulatory system: gills, tracheae (insect)

Main groups

1. Class Crustacea

2 pair of antennae

Respire by gills

Examples: lobster, crayfish,shrimp, and barnacles

2. Class Arachnida

Examples: spiders, horseshoe crabs, mites, and ticks

No antennae

Reduced segmentation

4 pair of legs

No jaws

3. Class Insecta

There are more organisms in this class than any other

Have a head, thorax, and abdomen

1 pair of antennae

Usually 2 pair of wings

3 pair of legs

Characteristics of Arachnids

Poison gland-

a. immobilize their prey,

b. Digest contents of their prey in the sucking stomach

c.They are scary to some; who might consider themselves arachnophobics

Lobster:

Their claws are modified legs, and they really taste good, cooked properly, especially in New Orleans, Preying Mantis. The female, who is bigger, bites off the head of the male, and then copulates with the headless male. Then the female eats the male's body. Thus, reproducing and finding its food at the same time

Metamorphosis

This is the process where an organism starts as a small larvae and develops into adult. The larvae collects organic material and then molts into a pupa stage. After a certain time the pupa molts to form the mature larger adult.

Fleas:

Wingless go through complete metamorphosis and can carry disease

<u>Class Arachnida (Spiders)</u>

The spider has two main body segments, the cephalothorax and the abdomen. Some of the diseases spiders cause on the farm are mange (scabies) and flea (mites). Ticks are blood sucking spiders that can attack sheep and spread disease (red water fever)

A lot of the members of phylum Arthropoda are **Parasites.**

Parasites are animals that live at the expense of other animals.

Phylum Echinodermata (Spiny skin)

Members of the phylum Echinodermata, commonly called echinoderms, or spiny-skinned animals, are so named because of their spiny outer body coverings.

Echinoderms differ from other animals in that they have a water vascular system that uses seawater to accomplish respiration, locomotion, and reproduction.

The echinoderms include marine groups such as the sea stars (top, left), sea cucumbers (bottom, left), brittle or serpent stars (top, center), sand dollars (bottom, center), sea lilies (right), sea urchins, basket stars, heart urchins, and feather stars.

Generalized Anatomy of an Echinoderm

The starfish exhibits the internal hydraulic system particular to echinoderms.

A central ring connects canals that run the length of each arm and branch into rows of tube feet. The hollow network, a modified body cavity, fills with water, creating a "skeleton" firm enough to walk on. By forcing water out through the tube feet, the starfish can extend and attach its suckers to a surface; by contracting the muscles at the base of the tube feet, it can move itself forward. To defend against predators, other invertebrates have evolved exoskeletons, hard outer coverings such as the shells found in clams and mussels and the body cases that surround adult insects. As well as protecting the animal, these exoskeletons also provide anchorage for muscles. On land, a body case is also useful because it prevents the water that bathes internal structures from evaporating. As a result the animal does not dry up and die. Arthropods, animals with a hard, outer skeleton and a jointed body and limbs, make up the single largest group of invertebrates. Arthropods include insects, crustaceans, and arachnids, such as spiders and ticks.

Among the major phyla, the echinoderms are the most distinctive and unusually shaped. They include starfish, sea urchins, and sea cucumbers and are the only animals with a five-pointed design. They live in the sea and move with the help of tiny fluid-filled feet—another feature found nowhere else in the animal world.

Characteristics

1. Echinoderms and chordates most likely have a common ancestor based on embryonic developmemt

2. Familiar examples includes starfish, sea urcins, sand dollars, and sea cucumbers

3. Characterized by:

a. bilateral symmetrical larvae and radial symmetrical adult

b. radial 15 part body plan

c. a vascular water system that is used for locomotion

d. rings of nervous tissue but no centralized brain

4. Starfish:

They attach to attach to clams and oyster and avert their stomach into the shell and suck up the clams or oysters

Regenerates

Have tube feet

Hydraulic pressure: locomotion

<u>Phylum Chordata</u>

All animals in the phylum **<u>Chordata</u>** have **<u>backbones and are vertebrates</u>**. Examples include fish, birds, amphibians, reptiles and mammals. The two main agricultural classes are Class Aves (Birds) and Class Mammalia (Mammals). Only these two classes are said to be **homoeothermic –** warm blooded – and can regulate their body temperature.

Class Aves

All members of this class have feathers, no teeth but a beak, lightened bones and no bladder.

Class Mammalia

All mammals have the following traits:

Hair

A Placenta

Mammary glands to produce milk

Again they are further classified into sub classes. Some of the common sub classes are:

Carnivores (Dogs and cats)

Ungulates (Hooved animals)

Odd toed - horse

Even toed – sheep, cattle

Marsupials – kangaroos

Primates – monkeys and humans

They are characterized by:

a. a single, dorsal, hollow nerve cord

b. a notochord

c. 5 pharyngeal gill slits

Human embryo gill slits become the bones of the inner ear, but we have them at early stagesof development.

Divided into acraniate (no head, e.g: tunicates) and cranata (has a head e.g us, the vertebrates)

Larva tunicates exhibite chordate features, but adults do not

Vertebrates are characterized by a vertebral column that surrounds the dorsal nerve cord

3
Subphylum

1. Tunicata

2. Cephalochordata

3. Vertebrata

Fish: 3 classes of fish:

1. Aganatha

2. Chondrichtyes

3. Osteichthyes

Four classes of tetrapods:

1. Amphibia

2. Reptilia

3. Aves

4. Mammals

Animal, multicellular organism that obtains energy by eating food. With over 2 million known species, and many more awaiting identification, animals are the most diverse forms of life on earth. They range in size from 30-m (100-ft) long whales to microscopic organisms only 0.05 mm (0.002 in) long. They live in a vast range of habitats, from deserts and Arctic tundra to the deep-sea floor. Animals are the only living things that have evolved nervous systems and sense organs that monitor their surroundings. They are also the only forms of life that show flexible patterns of behavior that can be shaped by past experience.

The study of animals is known as **zoology**. Animals are multicellular organisms, a characteristic they share with plants and many fungi. But they differ from plants and fungi in several important ways. Foremost among these is the way they obtain energy. Plants obtain energy directly from sunlight through the process of photosynthesis, and they use this energy to build up organic matter from simple raw materials. Animals, on the other hand, eat other living things or their dead remains. They then digest this food to release the energy that it contains. Fungi also take in food, but instead of digesting it internally as animals do, they digest it before they absorb it. Most animals start life as a single fertilized cell, which divides many times to produce the thousands or millions of cells needed to form a functioning body.

During this process, groups of cells develop different characteristics and arrange themselves in tissues that carry out specialized functions. Epithelial tissue covers the body's inner and outer surfaces, while connective tissue binds it together and provides support. Nervous tissue conducts the signals that coordinate the body (*see* Nervous System), and muscle tissue–which makes up over two-thirds of the body mass of some animals–contracts to make the body move.

This mobility, coupled with rapid responses to opportunities and hazards, is one feature that distinguishes animals from other forms of life. Some kinds of animal movement, such as the slow progress of a limpet as it creeps across rocks, are so slow that they are almost imperceptible. Others, such as the attacking dive of a peregrine falcon or the leap of a flea, are so fast that they are difficult or even impossible to follow. Many single-celled organisms can move, but in absolute terms, animals are by far the fastest-moving living things on earth.

Animal life spans vary from less than 3 weeks in some insects to over a century in giant tortoises. Some animals, such as sponges, mollusks, fish, and snakes, show indeterminate growth, which means that they continue to grow throughout life. Most, however, reach a pre-defined size at maturity, at which point their physical growth stops.

One phylum of animals, the chordates, has been more intensively studied than has any other, because it comprises nearly all the world’s largest and most familiar animals as well as humans. This phylum includes mammals, birds, reptiles, amphibians, and fish together with a collection of lesser-known organisms, such as sea squirts and their relatives (*see* Tunicates).

The feature uniting these animals is that at some stage in their lives, all have a flexible supporting rod, called a notochord, running the length of their bodies. In the great majority of chordates, the notochord is replaced by a series of interlocking bones called vertebrae during early development. These bones form the backbone, and they give these animals their name—the vertebrates. Vertebrates total about 40,000 species. Thanks to their highly developed nervous systems and internal skeletons, they have become very successful on land, sea, and air. Yet vertebrates account for only about 2 percent of animal species. The remaining 98 percent, collectively called invertebrates, are far more numerous and diverse and include an immense variety of animals from sponges, worms, and jellyfish to mollusks and insects. The only feature these diverse creatures share in common is the lack of a backbone.