Lecture 1: INTRODUCTION IN MEDICAL BIOLOGY. CELL STRUCTURE

1. Biology: The Science of Our Lives
2. Theories Contributing to Modern Biology: Cell Theory
3. Forms and Diversity of Life
4. Levels of Organization
5. Cell Structure

Biology (from Greek βιος - life and λογος - *word, judgement)* – is a branch of the natural sciences, and is the study of living organisms and their interactions with environment.

The term was specially proposed by French naturalist *Jean-Baptiste Pierre Antoine de Monet, Chevalier de Lamarck* in 1802

Biology deals with every aspect of life in a living organism. Biology examines the structure, function, growth, origin, evolution, and distribution of living things.

Modern biology is complex of sciences. Most biological sciences are specialized disciplines: Botany, Zoology, Protozoology, Microbiology, Virology, Molecular biology, Genetics, Embryology, Evolution theory, Ecology and so on.

The history of biology traces the study of the living world from ancient to modern times. Although the concept of *biology* as a single coherent field arose in the 19th century, the biological sciences emerged from traditions of medicine and natural history reaching back to ancient Egyptian medicine and the works of Aristotle and Galen in the ancient Greco-Roman world, which were then further developed in the Middle Ages by Muslim physicians and scholars such as al-Jahiz, Avicenna, Avenzoar, Ibn al-Baitar and Ibn al-Nafis. Ancient Greek philosopher, Aristotle developed his *Scala Naturae*, or *Ladder of Life*, to explain his concept of the advancement of living things from inanimate matter to plants, then animals and finally man. This concept of man as the "crown of creation" still plagues modern evolutionary biologists

Medical Biology is a science about foundations of human vital functions, studying the mechanisms of

- heredity,
- variability,
- individual development, and
- morpho-physiological adaptation to environment

which all are associated with the biosocial essence of human and influence of some factors upon population health Medical Biology – theoretical basis of medicine, foundation of grounding of future doctors. It is associated with other sciences: Anatomy, Human physiology, Biochemistry, Genetics, Medical parasitology, Ecology. Task of Medical Biology is analysis of molecular-genetic, cellular, ontogenetic, ecological and population factors, influencing on health of people.

Modern biology is based on several great ideas, or theories:

1. The Cell Theory
2. The Theory of Evolution
3. Gene Theory
4. Homeostasis

Cell Theory is the study of everything that involves cells. Cell theory states that all living things are composed of one or more cells, or the secreted products of those cells, for example, shell, bone and skin.
Therefore **a cell is the fundamental unit of life**. However there are specific, non-cellular, forms of life

Forms of Life

- Non-cellular: viruses & prions
- Cellular: prokaryotes & eukaryotes

Viruses (from the Latin *virus* meaning "*toxin*" or "*poison*"), are not quite living organisms, but when inside a living host cell they show some features of a living organism. Viruses are too small: the characteristic size is about 0.05-0.1 micron. Viruses were discovered by Russian biologist *Dmitry Ivanovsky* in 1892.

> *D.Ivanovsky studied in the University of St Petersburg (Russia) in 1887, when he was sent to investigate a disease affecting tobacco and referred to as "wildfire". Three years later, they asked him to look into another disease of tobacco plants, this time raging in the Crimea (Russia). He discovered that both diseases were caused by an infinitely minuscule agent, the tobacco mosaic virus, capable of permeating porcelain filters, something which bacteria could never do. He described his findings in an article (1892) and a dissertation (1902).*

Viruses infect all cellular life forms and are grouped into animal, plant and bacterial types, according to the type of host infected.
Each viral particle, or *virion*, consists of genetic material (either DNA or RNA), within a protective protein coat called a capsid. The capsid shape varies from simple helical and icosahedral (polyhedral or near-spherical) forms, to more complex structures with tails or an envelope.

Viruses

DNA genome	***RNA genome***
Herpes simplex virus	HIV
Hepatitis B	Hepatitis C virus
Smallpox (has affected humans for centuries).	Influenza viruses (types A, B, C)
Adenoviruses (infections ranging from *respiratory diseases* and *conjunctivitis, to gastroenteritis* (*stomach flu*), and *encephalitis*.	Poliovirus causing poliomyelitis, often called polio or infantile paralysis
Parvovirus B19, causing *erythema infectiosum* (meaning *infectious redness),* is also referred to *fifth disease, slapped cheek syndrome, slapcheek, slap face* or *slapped face.*	Rabies virus causing rabies (or *lyssa, hydrophobia*)
Some oncoviruses (e.g., human papillomavirus)	Some oncoviruses (e.g., human T-cell leukemia virus-1)
	Viscerophilus tropicus causing Yellow fever (also called *yellow jack*, *black vomit* or *American Plague*)
	Virus of tick-borne [vernal] encephalitis
	Paramyxovirus, causing measles
	Rubella virus, causing rubella disease, common known as *German measles*

Prions

A **prion** (after combination of the first two syllables of the words ***pr****oteinaceous* and ***in****fectious* (**-on** by analogy to viri**on**) ï is a infectious agent that is composed entirely of proteins (no nucleic acid ï DNA or RNA).

The protein that prions are made of is found throughout the body, even in healthy people and animals. However, the prion protein found in infectious material has a different folding pattern (packing).

Prions are proteins that are unique in their ability to reproduce on their own and become infectious. They can occur in two forms normal and abnormal (infectious*), e.g.,* PrP-C (normal) and PrP-Sc (abnormal). Both normal protein and prion has identical primary structure (amino acid sequence) whereas prion protein has abnormal spatial

Prions cause a number of brain diseases in a variety of mammals. These diseases

- are transmissible ð from host to host of a single species and, sometimes, even from one species to another (such as a laboratory animal)
- destroy brain tissue giving it a spongy appearance

I. Inherited Prion Diseases

Creutzfeldt-Jakob Disease (CJD)

10ï 15% of the cases of CJD are inherited; that is, the patient comes from a family in which the disease has appeared before. The disease is inherited as an autosomal **dominant**.

Loss of brain function resembles Alzheimer's disease, but is very rapid in progression. Complete dementia usually occurs by the sixth month, death follows quickly. There is no known cure.

Gerstmann-Sträussler-Scheinker disease (GSS)

Fatal Familial Insomnia (FFI)

Scrapie ï this disease of sheep (and goats) was the first prion disease to be studied. It seems to be transmitted from animal to animal in feed contaminated with nerve tissue. It can also be transmitted by injection of brain tissue.

II. Infectious Prion Diseases

Kuru. It was once found among the Fore tribe in Papua New Guinea whose rituals included eating the brain tissue of their recently deceased members of the tribe. Since this practice was halted, the disease has disappeared. Before then, the disease was studied by transmitting it to chimpanzees using injections of autopsied brain tissue from human victims.

Scrapie (see above)

Bovine Spongiform Encephalopathy (BSE) or "Mad Cow Disease"

An epidemic of this disease began in Great Britain in 1985 and before it was controlled, some 800,000 cattle were sickened by it. Its origin appears to have been cattle feed that

- contained brain tissue from sheep infected with scrapie and
- had been treated in a new way that no longer destroyed the infectiousness of the scrapie prions.

The use of such food was banned in 1988 and after peaking in 1992, the epidemic declined quickly.

Creutzfeldt-Jakob Disease (CJD)

Variant Creutzfeldt-Jakob Disease (vCJD)

Miscellaneous Infectious Prion Diseases

Cell forms of Life. Kingdoms of living organisms

All cells fall into one of the two major classifications of prokaryotes (pro=before, karyo=nucleus) and eukaryotes. The **prokaryotes** (pronounced /proʊ̯˜kærioʊ̯ts/; singular **prokaryote** /proʊ̯˜kæriɒt/) are a group of organisms that lack a cell nucleus (= karyon), or any other membrane-bound organelles. They differ from the eukaryotes, which have a cell nucleus. Prokaryotes were here first and for billions of years were the only form of life. Bacteria and blue-green bacteria are prokaryotic cells. **Eukaryotes** - cells that contain a nucleus and organelles surrounded by a membrane. The cells of protozoa, algae, fungi, plants, and animals are eukaryotic cells.

Kingdom Monera, the most primitive kingdom, contain living organisms remarkably similar to ancient fossils. Organisms in this group lack membrane-bound organelles associated with higher forms of life. Such organisms are known as ***prokaryotes***.

Bacteria (technically the Eubacteria) and blue-green bacteria (sometimes called *blue-green algae*, or *cyanobacteria*) are the major forms of life in this kingdom.

The most primitive group, the archaebacteria, are today restricted to marginal habitats such as hot springs or areas of low oxygen concentration.

Kingdom Protista was the first of the eukaryotic kingdom, these organisms and all others have membrane-bound organelles, which allow for compartmentalization and dedication of specific areas for specific functions.

The chief importance of Protista is their role as a stem group for the remaining Kingdoms: *Plants*, *Animals*, and *Fungi*.

Major groups within the Protista include the algae, euglenoids, ciliates, protozoa, and flagellates

Kingdom Fungi are almost entirely *multicellular* (with yeast, *Saccharomyces cerviseae*, being a prominent unicellular fungus), *heterotrophic* (deriving their energy from another organism, whether alive or dead), and usually having some cells with two nuclei (*multinucleate*, as opposed to the more common one, or uninucleate) per cell.

Ecologically this kingdom is important (along with certain bacteria) as *decomposers* and *recyclers of nutrients*.

Economically, the Fungi provide us with *food* (mushrooms; Bleu cheese / Roquefort cheese; baking and brewing), *antibiotics* (the first of the wonder drugs, Penicillin, was isolated from a fungus *Penicillium*), and *crop parasites* (doing several billion dollars per year of damage).

Kingdom Plantae include multicellular organisms that are all ***autotrophic*** (capable of making their own food by the process of photosynthesis, the conversion of sunlight energy into chemical energy).

Ecologically, this kingdom is generally (along with photosynthetic organisms in Monera and Protista) termed the *producers*, and rest at the base of all food webs. A food web is an ecological concept to trace energy flow through an ecosystem.

Economically, this kingdom is unparalleled, with agriculture providing billions of dollars to the economy (as well as the foundation of "civilization"). *Food, building materials, paper, drugs* (both legal and illegal), and *roses*, are plants or plant-derived products.

Kingdom Animalia consists entirely of *multicelluar heterotrophs* that are all capable (at some point during their life history) of mobility.

Ecologically, this kingdom occupies the level of *consumers*, which can be subdivided into *herbivore* (eaters of plants) and *carnivores* (eaters of other animals). Humans, along with some other organisms, are *omnivores* (capable of functioning as herbivores or carnivores).

Economically, animals provide meat, hides, beasts of burden, pleasure (pets), transportation, and scents (as used in some perfumes).

Levels of organization

Molecule Ÿ Organelle Ÿ Cell Ÿ Tissue Ÿ Organ Ÿ Organ System Ÿ Individual Ÿ Population Ÿ Community Ÿ Ecosystem Ÿ Biosphere

Molecular level

Carbohydrates include simple sugars and polysaccharides. Polysaccharides serve as storage forms of sugars, structural components of cells, and markers for cell recognition processes.

Lipids are the principal components of cell membranes, and they serve as energy storage and signaling molecules.

Nucleic Acids (DNA and RNA) are the principal informational molecules of the cell. They are polymers of purine and pyrimidine nucleotides.

Proteins are polymers of 20 different amino acids, each of which has a distinct side chain with specific chemical properties. Each protein has a unique amino acid sequence, which determines its 3D-structure.

Organelle level
Within cells there is an intricate network of organelles. Literally ï ñlittle organsò
These organelles allow the cell to function properly.
Each organelle has a distinct organization and is specialized for a specific function
Organelles are suspended in cytosol
Organelles are grouped into two broad classes:

- enclosed in a lipid membrane that isolates organelle from cytosol (ER, Golgi apparatus, vesicles and mitochondria)
- lack an outer membrane and are directly exposed to the cytosol (ribosomes, centrioles, cytoskeleton, cilia and flagella)

Cell level & Cell Theory

In 1839, cells were finally acknowledged as the universal units of life by ***Matthias Schleiden*** and ***Theodor Schwann***, two German biologists

Formulation of the Cell Theory: historical facts

In 1838, Theodor Schwann and Matthias Schleiden were enjoying after-dinner coffee and talking about their studies on cells. It has been suggested that when Schwann heard Schleiden describe plant cells with nuclei, he was struck by the similarity of these plant cells to cells he had observed in animal tissues. The two scientists went immediately to Schwann's lab to look at his slides.

The first strong statement that ñall living organisms consist of cellò was made by Theodor Schwann in 1839. Schwann published his book on animal and plant cells the next year, a treatise devoid of acknowledgments of anyone else's contribution, including that of Schleiden (1838).

In 1858 ***Rudolf Virchow*** concluded "*Omnis cellula e cellula*"... that is ñall cells come from pre-existing cellsò

Classical Cell Theory

1. All organisms are made up of one or more cells.
2. Cells are the fundamental and structural unit of life.
3. All cells come from pre-existing cells.

Cell level: prokaryotic cell

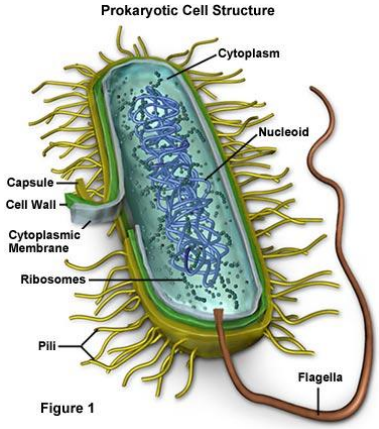

Figure 1

Nucleoid region - coiled DNA
Cell wall - outside plasma membrane
Capsule - only in some, outside cell wall, sticky coating
Pili - short projections, help attach cell to surface
Flagella - propel cell through liquid environment
Ribosomes - protein production
Cytoplasm - inter membrane fluid

Cell level: eukaryotic cell

An eukaryotic cell has a *nucleus*, which is separated from the rest of the cell by a membrane. The nucleus contains chromosomes, which are the carrier of the genetic material. Most cells, both animal and plant, range in size between 1 and 100 micrometers and are thus visible only with the aid of a microscope.

There are internal membrane enclosed compartments within eukaryotic cells, called organelles, which are specialised for particular biological processes.

The area of the cell outside the nucleus and the organelles is called the cytoplasm. Membranes are complex structures and they are an effective barrier to the environment, and regulate the flow of food, energy and information in and out of the cell.

There is a theory that mitochondria are prokaryotes living within eukaryotic cells.

Example: The neuron is the functional unit of the nervous system. Humans have about 1012 neurons and 1013 glial cells in their nervous system! While variable in size and shape, all neurons have three parts.
Dendrites receive information from another cell and transmit the message to the cell body. The *cell body* contains the nucleus, mitochondria and other organelles typical of eukaryotic cells. The *axo*n conducts messages away from the cell body

Tissue level

Tissue is the aggregate of cells and intercellular matter having the common origin, structure and fulfilling similar functions.

Based on morphology, animal tissues can be grouped into four basic types:

1. Epithelium
2. Connective tissue
3. Muscle tissue
4. Neural tissue

Organ level

Example: A brain.

A brain of a vertebrate is the most complex organ of its body. The brain is composed of three parts: the *cerebrum* (seat of consciousness), the *cerebellum*, and the *medulla oblongata* (these latter two are "part of the unconscious brain"). In a typical human the cerebral cortex (the largest part) is estimated to contain 15-33 billion neurons.

Organ system level

Example: Nervous system

Chordates have a dorsal rather than ventral nervous system. The central nervous system (CNS) is composed of the brain and spinal cord. The peripheral NS consists of all body nerves. Motor neuron pathways are of two types: somatic (skeletal) and autonomic (smooth muscle, cardiac muscle, and glands). The autonomic system is subdivided into the sympathetic and parasympathetic systems

Organism level

Organism ï one or more cells characterized by a unique arrangement of DNA "information".

These can be unicellular or multicellular. The multicellular individual exhibits specialization of cell types and division of labor into tissues, organs, and organ systems

Population level

Population is the collection of inter-breeding organisms of a particular species. A population shares a particular characteristic of interest most often that of living in a given geographic area.

Human populations can be defined by many characteristics such as *mortality, migration, family* (marriage and divorce), *public health, work* and the *labor force*, and *family planning*.

Community level.

A ***community*** is the *set of all populations* that inhabit a certain area. The members of a typical community include *plants, animals,* and *other organisms* that are biologically interdependent. Communities can have different sizes and boundaries.

The structure of a biotic community is largely characterized by the trophic (feeding) relationships among its member species. These relationships are often represented simplistically as a *food chain.*

There are two basic categories of communities: terrestrial (land) and aquatic (water). These two basic types of community contain eight smaller units known as biomes.

1. Terrestrial Biomes: tundra, grassland, desert, taiga, temperate forest, tropical forest.
2. Aquatic Biomes: marine, freshwater

Ecosystem level

An ***ecosystem*** is a higher level of organization the community plus its physical environment.

Biologycal components = biotic factors are lkiving things (plants, animals, bacteria)

Physical components = abiotic factors are non living things (air, water, soil, climate é)

Biosphere level

The sum of all living things taken in conjunction with their environment. In essence, where life occurs, from the upper reaches of the atmosphere to the top few meters of soil, to the bottoms of the oceans.

We divide the earth into atmosphere (air), lithosphere (earth), hydrosphere (water), and biosphere (life)

Animal cell and its organelles

Animal cells are typical of the eukaryotic cell, enclosed by a *plasma membrane* and containing a *membrane-bound* nucleus and organelles

Cell Membrane Composition

Plasma membrane encloses cell and cell organelles

Electron microscopic examinations of cell membranes have led to the development of the lipid bilayer model (also referred to as the *fluid-mosaic model*)

Most of the lipids in the bilayer can be more precisely described as **phospholipids**, that is, lipids that feature a phosphate group at one end of each molecule. Phospholipids are characteristically **hydrophilic** ("water-loving") at

their phosphate ends and **hydrophobic** ("water-fearing") along their lipid tail regions. In each layer of a plasma membrane, the hydrophobic lipid tails are oriented inwards and the hydrophilic phosphate groups are aligned so they face outwards, either toward the aqueous cytosol of the cell or the outside environment. Phospholipids tend to spontaneously aggregate by this mechanism whenever they are exposed to water.
Plasma membrane proteins may be *peripheral proteins* or *integral proteins*.
Integral proteins interact with ñlipid bilayerò

- Passive transport pores and channels
- Active transport pumps and carriers
- Membrane-linked enzymes, receptors and transducers

Aside from phospholipid, *cholesterol* is another lipid in animal plasma membranes; related steroids are found in plants. Cholesterol stabilizes (strengthens) the plasma membrane.

Functions of cell membrane

1. Forms compartments
2. Localization of functions
3. Regulation of transport (functions as a semi-permeable barrier)
4. Detection of signals
5. Cell-to-cell communication
6. Cell identity

Cellular compartments

Cellular compartments comprise all closed parts within a cell whose lumen is usually surrounded by a single or plasma membrane. Most organelles are compartments like mitochondria, chloroplasts (in photosynthetic organisms), peroxisomes, lysosomes, the endoplasmic reticulum, the cell nucleus or the Golgi apparatus. Smaller elements like vesicles, and sometimes even microtubules can also be counted as compartments.

Types

- In general there are 3 main cellular compartments, they are:

1. The nuclear compartment comprising the nucleus
2. The intercisternal space which comprises the space between the membranes of the endoplasmic reticulum (which is continuous with the nuclear envelope)
3. The cytosol

Function

Within the membrane-bound compartments, different intracellular pH, different enzyme systems, and other differences are isolated. This enables the cell to carry out different metabolic activities at the same time.

Nucleus

The nucleus occurs only in eukaryotic cells, and is the location of the majority of different types of nucleic acids.
The nucleus is a highly specialized organelle that serves as the information processing and administrative center of the cell.

This organelle has **2 major functions**:

- it stores the cell's hereditary material (DNA), and
- it coordinates the cell activities: growth, intermediary metabolism, protein synthesis, and reproduction (cell division).

Structural components of nucleus are

1. Nucleolar envelope. It is a double-layered membrane that encloses the contents of the nucleus during most of the cell's lifecycle. The space between the layers is called the perinuclear space and appears to connect with the rough endoplasmic reticulum. The envelope is perforated with tiny holes called nuclear pores. These pores regulate the passage of molecules between the nucleus and cytoplasm, permitting some to pass through the membrane, but not others.
2. Nucleoplasm. Similar to the cytoplasm of a cell, the nucleus contains ***nucleoplasm*** or ***nuclear sap***. The nucleoplasm is one of the types of protoplasm, and it is enveloped by the nuclear membrane or nuclear envelope. The nucleoplasm is a highly viscous liquid that surrounds the ***chromatin*** and ***nucleoli***. Many substances such as nucleotides (necessary for purposes such as the replication of DNA) and enzymes (which direct activities that take place in the nucleus) are dissolved in the nucleoplasm. The nucleoplasm is also colorless. A network of fibers known as the ***nuclear matrix*** can also be found in the nucleoplasm.
3. Nucleolus. It is membrane-less organelle within the nucleus (usually 2 nucleoli per nucleus) where ribosomes are constructed
4. Chromatin. Packed inside the nucleus of every human cell is nearly 2 meters of DNA, which is divided into 46 individual molecules. Packing all this material into a microscopic cell nucleus is an extraordinary feat of packaging. For DNA to function, it can't be crammed into the nucleus like a ball of string. Instead, it is combined with proteins (histones) and organized into a precise, compact structure, a dense string-like fiber called chromatin.

Mitochondrion

Mitochondria are self-replicating organelles (because it contains own DNA)
Structure: The structure is characterized by a rod-shaped morphology and double membrane which creates two areas within the organelle. The area between the membranes houses the enzymes of the Kreb's cycle and is called the matrix. The other area, on the surface of the membranes, contains the enzymes of the electron transport system and is called the cristae.
Function: Mitochondria can be considered the power generators of the cell. The chemical reactions which produce energy and the storage of that energy as adenosine triphosphate (ATP) occur in this organelle. Glucose and Oxygen are used to produce ATP, carbon dioxide and water. ATP is the chemical energy "currency" of the cell that powers the cell's metabolic activities. This process is called **aerobic respiration** and is the reason animals breathe oxygen.
In most animal species, mitochondria appear to be primarily inherited through the maternal lineage, though some recent evidence suggests that in rare instances mitochondria may also be inherited via a paternal route.

There is a theory *(theory of endosymbiosis*) that mitochondria are prokaryotes living within eukaryotic cells. During the 1980s, Lynn Margulis proposed the theory of endosymbiosis to explain the origin of mitochondria and plastids (organells of plant cell) from permanent resident prokaryotes. According to this idea, a larger prokaryote (or perhaps early eukaryote) engulfed or surrounded a smaller prokaryote some 1.5 billion to 700 million years ago

Endoplasmic reticulum (ER)

The 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.

There are two basic kinds of endoplasmic reticulum morphologies: rough (rER) and smooth (sER).

The surface of rER is covered with ribosomes, giving it a bumpy appearance when viewed through the microscope. This type of ER is involved mainly with the **production and processing of proteins** that will be exported, or secreted, from the cell.

sER endoplasmic reticulum is chiefly involved with the **production of lipids (fats), building blocks for carbohydrate metabolism**, and the **detoxification** of drugs and poisons.

Golgi Apparatus (GA)

GA is flattened sacs composed of membranes arranged in stacks in cytoplasm/
It is visible in light microscope as a pale area in contrast to surrounding basophilic cytoplasm in cells active in protein synthesis (= negative image)
After leaving the ER, many transport vesicles travel to the GA.

Golgi functions:

- ✓ modification of secretory products (proteins and lipids)
- ✓ packaging of secretory vesicles
- ✓ storing of biological compounds
- ✓ formation of lysosomes
- ✓ membrane recycling

Structure of the Golgi apparatus and its functioning in vesicle-mediated transport

Proteins, carbohydrates, phospholipids, and other molecules formed in the ER are transported to the Golgi apparatus to be biochemically modified during their transition from the *cis*- to the *trans* poles of the complex.

The products exported by the Golgi apparatus through the trans-face eventually fuse with the plasma membrane of the cell.

Lysosomes

Lysosomes are relatively large (median ø of 25 to 200 nm) single membrane vesicles formed by the Golgi apparatus (originating from terminal cisterns of the trans-side). They contain more than 50 different hydrolytic enzymes that could destroy the cell.

The main **function** of these microbodies is *digestion*. Lysosomes break down cellular waste products and debris from outside the cell into simple compounds, which are transferred to the cytoplasm as new cell-building materials. Lysosomes are often budded from the membrane of the Golgi apparatus, but in some cases they develop gradually from late endosomes, which are vesicles that carry materials brought into the cell by a process known as **endocytosis** (phagocytosis and pinocytosis)

Phagocytosis *("cell eating")*:

- results in the ingestion of particulate matter (e.g., bacteria) from the ECF;
- the endosome is so large that it is called a **phagosome** or **vacuole**;
- occurs only in certain specialized cells (e.g., neutrophils, macrophages, the amoeba), and occurs sporadically

Pinocytosis *("cell drinking")*:

- ingestion of dissolved materials by endocytosis
- occurs in almost all cells
- occurs continuously

Exocytosis

Process by which a cell directs secretory vesicles out of the cell membrane.

It is similar in function to **endocytosis** but working in the **opposite direction**.
Memrane-bound vesicles move to the cell surface where they **fuse** with the plasma membrane.
It restores the normal amount of plasma membrane.
Any molecules dissolved in the fluid contents of these vesicles are discharged into the extracellular fluid - this is called **secretion**.
Example: the various components of the extracellular matrix are secreted by exocytosis

Peroxisomes

Spherical microbodies bound by a single membrane.
These organelles contain enzymes that convert the hydrogen peroxide to water, rendering the potentially toxic substance safe for release back into the cell.
Some types of peroxisomes, such as those in liver cells, detoxify alcohol and other harmful compounds by transferring hydrogen from the poisons to molecules of oxygen (a process termed **oxidation**).
Others are more important for their ability to initiate the production of phospholipids, which are typically used in the formation of membranes.

Ribosomes

Ribosomes are the sites of protein synthesis.
They are not membrane-bound and thus occur in both prokaryotes and eukaryotes. Eukaryotic ribosomes are slightly larger than prokaryotic ones.
Structurally the ribosome consists of a small and large subunit.
Biochemically the ribosome consists of ribosomal RNA (rRNA) and some 50 structural proteins.
Often ribosomes cluster on the endoplasmic reticulum, in which case they resemble a series of factories adjoining a railroad line

Centrioles

Centrioles are cylindrical structures that are composed of groupings of microtubules arranged in a 9 × 3 pattern.
The pattern is so named because a ring of nine microtubule "triplets" are arranged at right angles to one another.
Centrioles are found in animal cells and play a role in cell division. Centrioles replicate in interphase stage of mitosis and they help to organize the assembly of microtubules during cell division.
Centrioles called "basal bodies" form cilia and flagella

Cytoskeleton

Cytoskeleton is a network of fibers throughout the cytoplasm
Cytoskeleton is constructed from 3 types of fibers.

- ✓ microtubules (consist of *tubulin* protein) are the thickest
- ✓ microfilaments (*actin* filament) are the thinnest
- ✓ intermediate filaments are a collection of fibers.

Functions:

1. give mechanical support to the cell and help maintain its shape
2. enables a cell to change its shape
3. is associated with motility: movement of the entire cell or movement of organelles and vesicles within the cell. The fibers of the cytoskeleton are not only the cells ñbonesò but also its ñmusclesò
4. contractile component of cytoskeleton manipulate the plasma membrane to form vacuoles during phagocytosis.

Cell Movement: cilia and flagella

A eukaryotic flagellum is a bundle of 9 fused pairs of microtubule *doublets* surrounding 2 central single microtubules.
The so-called *"9+2"* structure is characteristic of the core of the eukaryotic flagellum called an *axoneme*. At the base of a eukaryotic flagellum is a basal body, "blepharoplast" or kinetosome, which is the *microtubule organizing center* (MTOC) for flagellar microtubules and is about 500 nm long.

- Flagella work as whips pulling (as in *Chlamydomonas*) or pushing (dinoflagellates, a group of single-celled Protista) the organism through the water.
- Cilia work like oars on a Viking long ship (*Paramecium* has 17,000 such oars covering its outer surface)

Pseudopodia

Pseudopodia are used by many cells, such as *Amoeba*, and human leukocytes (white blood cells). These are not structures as such but rather are associated with actin near the moving edge

Plant Cells Compared with Animal Cells

Animal cells do not have a **cell wall**. Frameworks of rigid cellulose fibrils thicken and strengthen the cell walls of higher plants. **Plasmodesmata** that connect the protoplasts of higher plant cells do not have a counterpart in the animal cell model. During telophase of mitosis, a cell plate is formed as the plant cell begins its division. Centrioles are generally

not found in higher plant cells, while they are found in animal cells. Animal cells do not have **plastids**, which are common in plant cells (**chloroplasts**). Both cell types have **vacuoles**, however, in animal cells vacuoles are very tiny or absent, while in plant cells vacuoles are generally quite large.

The Cell Wall

Not all living things have cell walls, most notably animals and many of the more animal-like Protistans. Bacteria have cell walls containing peptidoglycan. Plant cells have a variety of chemicals incorporated in their cell walls. Cellulose is the most common chemical in the plant primary cell wall. Some plant cells also have lignin and other chemicals embedded in their secondary walls. The cell wall is located outside the plasma membrane. Plasmodesmata are connections through which cells communicate chemically with each other through their thick walls. Fungi and many protists have cell walls although they do not contain cellulose, rather a variety of chemicals (chitin for fungi).

Plastids

Plastids are also membrane-bound organelles that only occur in plants and photosynthetic eukaryotes.

Chloroplasts are the sites of photosynthesis in eukaryotes. They contain chlorophyll, the green pigment necessary for photosynthesis to occur, and associated accessory pigments (carotenes and xanthophylls) in photosystems embedded in membranous sacs, thylakoids (collectively a stack of thylakoids are a granum [plural = grana]) floating in a fluid termed the stroma. Chloroplasts contain many different types of accessory pigments, depending on the taxonomic group of the organism being observed.

Vacuoles and vesicles

Vacuoles are single-membrane organelles that are essentially part of the outside that is located within the cell. The single membrane is known in plant cells as a tonoplast. Many organisms will use vacuoles as storage areas. Vesicles are much smaller than vacuoles and they function transporting compounds within and moving them outside the cell.