Introduction to Biochemistry

By
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Introduction

Cell Structure and Function

What is Biochemistry

- Biochemistry is the application of chemistry to the study of biological processes at the cellular and molecular level.
- It emerged as a distinct discipline around the beginning of the 20th century when scientists combined chemistry, physiology and biology to investigate the chemistry of living systems by:

Conti...

A. Studying the structure and behavior of the complex molecules found in biological material and
B. the ways these molecules interact to form cells, tissues and whole organism
C. Biochemistry has become the foundation for understanding all biological processes. It has provided explanations for the causes of many diseases in humans, animals and plants."

Principles of Biochemistry

- Cells (basic structural units of living organisms) are highly organized and constant source of energy is required to maintain the ordered state.
- Living processes contains thousands of chemical rxns. Precise regulation and integration of these rxns are required to maintain life
- Certain important rxns E.g. Glycolysis is found in almost all organisms.
- All organisms use the same type of molecules: CHO, proteins, lipids & nucleic acids.
- Instructions for growth, reproduction and developments for each organism is encoded in their DNA

Cells

- Basic building blocks of life
- Smallest living unit of an organism
- Grow, reproduce, use energy, adapt, respond to their environment
- Many cannot be seen with the naked eye
- A cell may be an entire organism or it may be one of billions of cells that make up the organism

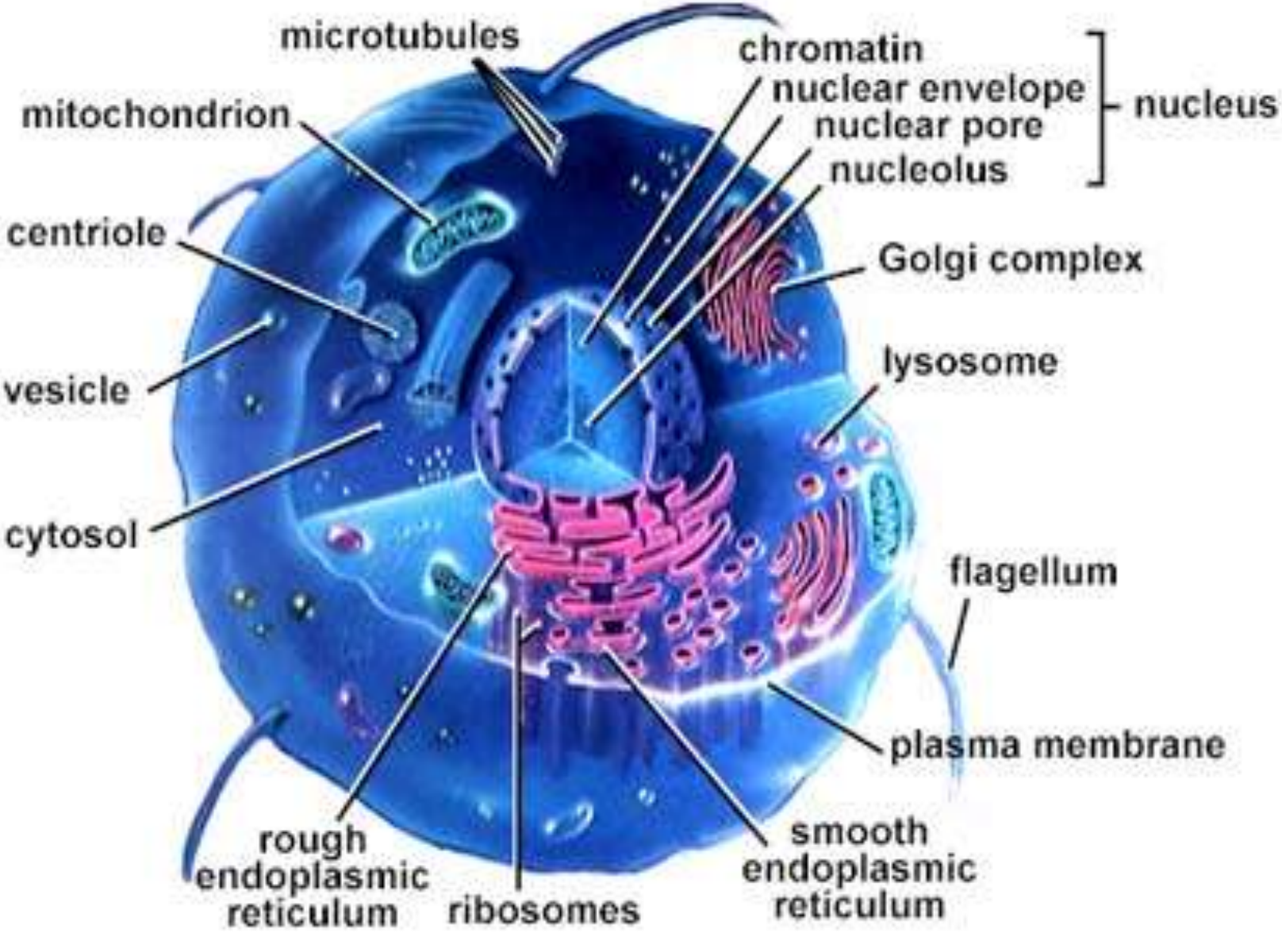
- Basis Types of Cells

Conti..

- ✓**Cell is the basic unit of structure and function of all living organism.**
- ✓**Or simply we can say cell is the basic unit of life.**
- ✓**In 1665, an English biologist Robert Hooke invented first compound microscope and observed the sections of corks and leaves under this microscope.**
- ✓ **He noticed in them small box like chambers of same size which he called “cells”.**
- ✓**After this, biologists observed different organisms under the microscope.**
- ✓**They found that structure of cells was complex.**

What is a cell?

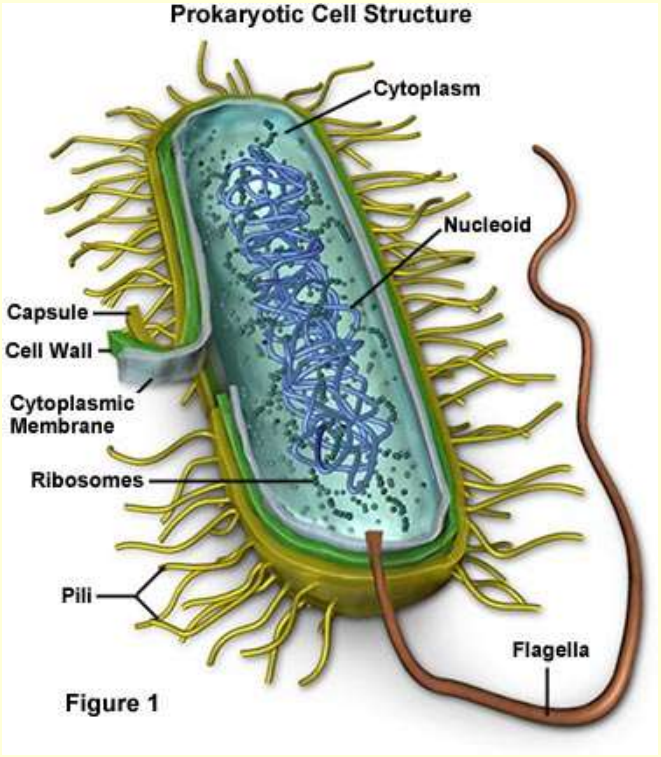
- ✓ The word cell comes from the Latin word "cella", meaning "small room", and it was first coined by a microscopist observing the structure of cork.
- ✓ The cell is the basic unit of all living things, and all organisms are composed of one or more cells.
- ✓ Cells are so basic and critical to the study of life, in fact, that they are often referred to as "the building blocks of life".
- ✓ Organisms - bacteria, amoebae and yeasts, for example - may consist of as few as one cell, while a typical human body contains about a trillion cells.

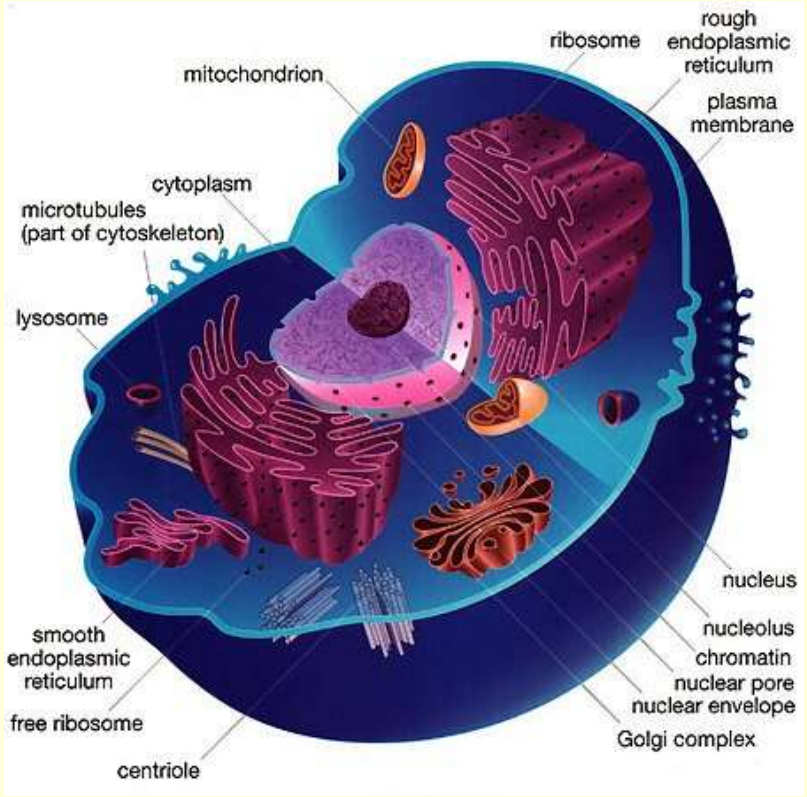

microtubules
mitochondrion
centriole
vesicle
cytosol
chromatin
nuclear envelope
nuclear pore
nucleolus
nucleus
Golgi complex
lysosome
flagellum
plasma membrane
rough endoplasmic reticulum
ribosomes
smooth endoplasmic reticulum

Cells May be Prokaryotic or Eukaryotic

- Prokaryotes include bacteria & lack a nucleus or membrane-bound structures called organelles

- Eukaryotes include most other cells & have a nucleus and membrane-bound organelles (plants, fungi, & animals)





Nucleoid region contains the DNA
•Cell membrane & cell wall
• Contain ribosomes (no membrane) to make proteins in their cytoplasm

Contain 3 basic cell structures:
• Nucleus
• Cell Membrane
• Cytoplasm with organelles

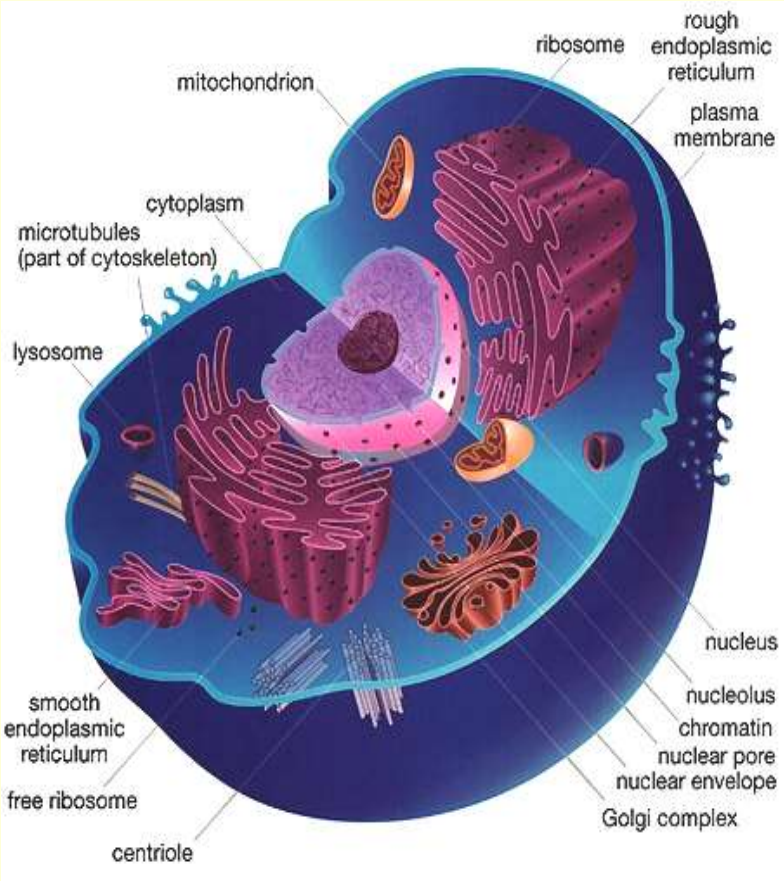
Prokaryotic Cell

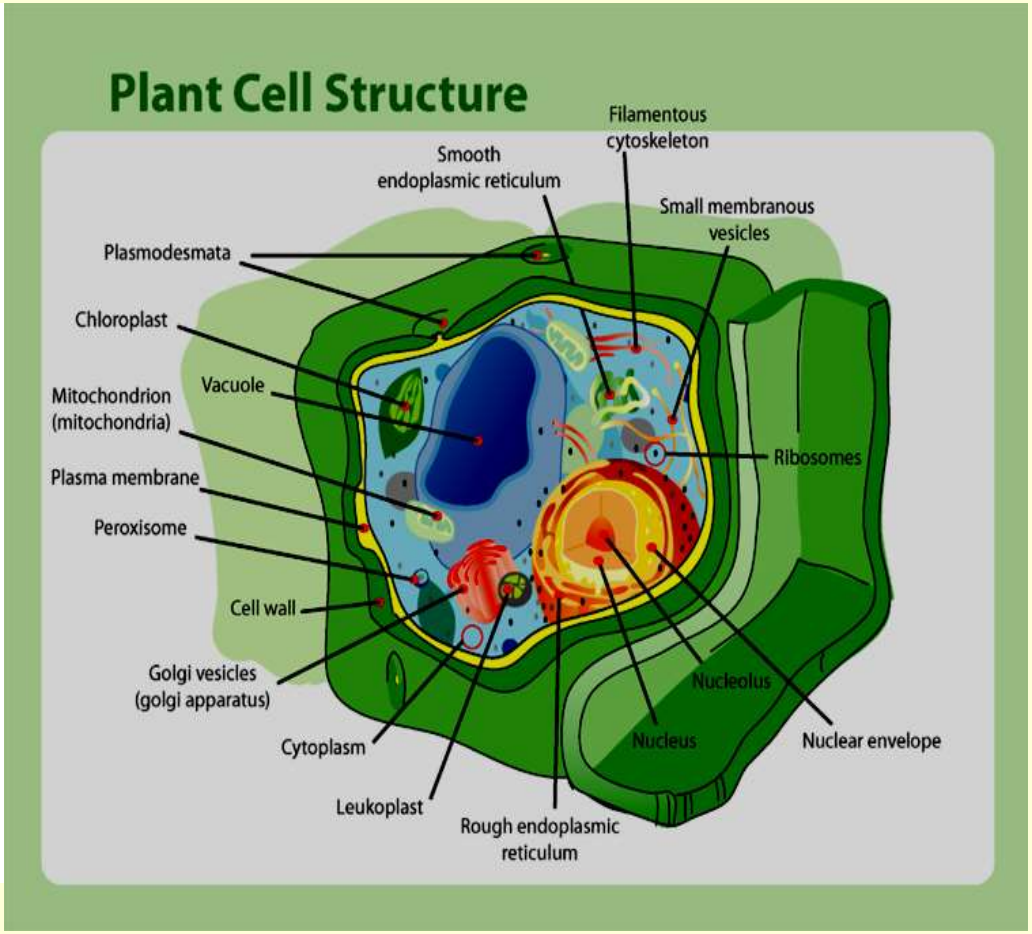
- The organisms made of prokaryotic cells are called prokaryotes e.g. bacteria and cyanobacteria.
- These cells lack a membrane bound nucleus.
- The hereditary material (DNA) is found in cytoplasm.
- These cells lack membrane bound organelles.
- Ribosome's are of small size in and freely scattered cytoplasm.
- Cellulose is absent in cell wall, rather it is made up of peptido-glycan or murrain.
- These cells are simple and of smaller size (average diameter 0.5 – 10 nm)

Eukaryotic Cell

- The organisms made of Eukaryotic cells are called Eukaryotes, e.g. animals, plants fungi and protista.
- These cells have a membrane bound nucleus; and hereditary material is found inside the nucleus.
- These cells have membrane bound organelles.
- Ribosome's are of large size and are present in endoplasmic reticulum free in cytoplasm.
- Cellulose is present in cell wall of plant cells. The cell wall of most of fungi is composed of chitin.
- These cells are complex and of larger size (Average diameter 10-100nm).

Two Main Types of Eukaryotic Cells

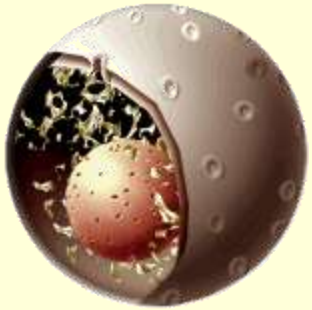




Characteristic Bio-membranes and Organelles

Plasma Membrane

A lipid/protein/carbohydrate complex, providing a barrier and containing transport and signaling systems.



Nucleus

Double membrane surrounding the chromosomes and the nucleolus. Pores allow specific communication with the cytoplasm. The nucleolus is a site for synthesis of RNA making up the ribosome

Mitochondrion

Surrounded by a double membrane with a series of folds called cristae. Functions in energy production through metabolism. Contains its own DNA, and is believed to have originated as a captured bacterium.

Chloroplasts (plastids)

Surrounded by a double membrane, containing stacked thylakoid membranes. Responsible for photosynthesis, the trapping of light energy for the synthesis of sugars. Contains DNA, and like mitochondria is believed to have originated as a captured bacterium.

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Rough endoplasmic reticulum (RER)

A network of interconnected membranes forming channels within the cell. Covered with ribosomes (causing the "rough" appearance) which are in the process of synthesizing proteins for secretion or localization in membranes.

Ribosomes

Protein and RNA complex responsible for protein synthesis

Smooth endoplasmic reticulum (SER)

A network of interconnected membranes forming channels within the cell. A site for synthesis and metabolism of lipids. Also contains enzymes for detoxifying chemicals including drugs and pesticides.

Golgi apparatus

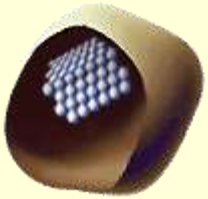
A series of stacked membranes. Vesicles (small membrane surrounded bags) carry materials from the RER to the Golgi apparatus. Vesicles move between the stacks while the proteins are "processed" to a mature form. Vesicles then carry newly formed membrane and secreted proteins to their final destinations including secretion or membrane localization.

Lysosymes

A membrane bound organelle that is responsible for degrading proteins and membranes in the cell, and also helps degrade materials ingested by the cell.

Vacuoles

Membrane surrounded "bags" that contain water and storage materials in plants.



Peroxisomes or Microbodies

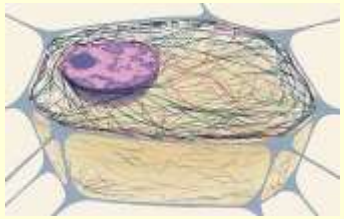
Produce and degrade hydrogen peroxide, a toxic compound that can be produced during metabolism.

Cell wall

Plants have a rigid cell wall in addition to their cell membranes

Cytoplasm

enclosed by the plasma membrane, liquid portion called cytosol and it houses the membranous organelles.



Cytoskeleton

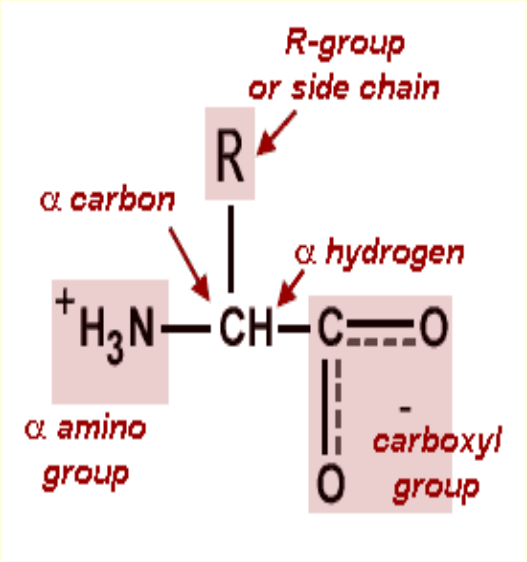
Arrays of protein filaments in the cytosol. Gives the cell its shape and provides basis for movement.
E.g. microtubules and microfilaments.

Bio-molecules

- Just like cells are building blocks of tissues likewise molecules are building blocks of cells.
- Animal and plant cells contain approximately 10, 000 kinds of molecules (bio-molecules)
- Water constitutes 50-95% of cells content by weight.
- Ions like Na^+, K^+ and Ca^+ may account for another 1%
- Almost all other kinds of bio-molecules are organic (C, H, N, O, P, S)
- Infinite variety of molecules contain C.
- Most bio-molecules considered to be derived from hydrocarbons.
- The chemical properties of organic bio-molecules are determined by their functional groups. Most bio-molecules have more than one.

Major Classes of small Bio-molecules

- 1. Amino acids:



- Building blocks of proteins.
- 20 commonly occurring.
- Contains amino group and carboxyl group function groups (behavioral properties)
- R Group (side chains) determines the chemical properties of each amino acids.
- Also determines how the protein folds and its biological function.
- Individual amino acids in protein connected by peptide bond.
- Functions as transport proteins, structural proteins, enzymes, antibodies, cell receptors.

Sugars

- Carbohydrates most abundant organic molecule found in nature.
- Initially synthesized in plants from a complex series of reactions involving photosynthesis.
- Basic unit is monosaccharides.
- Monosaccharides can form larger molecules e.g. glycogen, plant starch or cellulose.

Functions

- Store energy in the form of starch (photosynthesis in plants) or glycogen (in animals and humans).
- Provide energy through metabolism pathways and cycles.
- Supply carbon for synthesis of other compounds.
- Form structural components in cells and tissues.
- Intercellular communications

Fatty acids

- Are monocarboxylic acid contains even number C atoms
- Two types: saturated (C-C sb) and unsaturated (C-C db)
- Fatty acids are components of several lipid molecules.
- E,g. of lipids are triacylglycerol, streiods (cholestrol, sex hormones), fat soluble vitamins.

Functions

- Storage of energy in the form of fat
- Membrane structures
- Insulation (thermal blanket)
- Synthesis of hormones

Biochemical Reactions

- Metabolism: total sum of the chemical reaction happening in a living organism (highly coordinated and purposeful activity)
  a. Anabolism- energy requiring biosynthetic pathways
  b. Catabolism- degradation of fuel molecules and the production of energy for cellular function

- All reactions are catalyzed by enzymes

- The primary functions of metabolism are:
  a. acquisition & utilization of energy
  b. Synthesis of molecules needed for cell structure and functioning (i.e. proteins, nucleic acids, lipids, & CHO
  c. Removal of waste products

Even though thousands of rxns sound very large and complex in a tiny cell:

- The types of rxn are small
- Mechanisms o biochemical rxns are simple
- Reactions of central importance (for energy production & synthesis and degradation of major cell components) are relatively few in number

Frequent reaction encountered in biochemical processes

1. Nucleophilic Substitution
- One atom of group substituted for another

2. Elimination Reactions
- Double bond is formed when atoms in a molecule is removed

3. Addition Reactions:
- Two molecules combine to form a single product.
- A. Hydration Reactions
- Water added to alkene > alcohol (common addition rxn)

4. Isomerization Reactions.

- Involve intramolecular shift of atoms or groups

5. Oxidation-Reduction (redox) Reactions

- Occur when there is a transfer of e- from a donor to an electron acceptor

6. Hydrolysis reactions

- Cleavage of double bond by water.

Energy for Cells

- Living cells are inherently unstable.
- Constant flow of energy prevents them from becoming disorganized.
- Cells obtains energy mainly by the oxidation of bio-molecules (e- transferred from 1 molecule to another and in doing so they lose energy)
- This energy captured by cells & used to maintain highly organized cellular structure and functions

How do complex structure of cells maintain high internal order?

1. Synthesis of bio-molecules

2. Transport Across Membranes

- Cell membranes regulate the passage of ions and molecules from one compartment to another.

3. Cell Movement

- Organised movement- most obvious characteristics of living cells. The intricate and coordinated activities required to sustain life require the movement of cell components.

4. Waste Removal

- Animal cells convert food molecules into CO_2, H_2O & NH_3. If these not disposed properly can be toxic.

Cell membrane

- ✓**It is a thin membrane which is also called Plasma membrane.**
- ✓**It is present in cells of all plants and animals.**
- ✓**It is outer most boundary of animal cell while in plant cells; it is present inner to cell wall.**
- ✓**Both nucleus and cytoplasm are surrounded by cell membrane.**
- ✓**Phospholipid bilayer, which contains great amount of proteins.**
- ✓**According to fluid mosaic model, cell membrane is composed of two layers of lipids in which protein molecules are partially or completely embedded.**
- ✓**This model was developed in 1972 by cellular biologists J. Singer and L. Nicholson.**

Functions

- **Cell membrane is selectively permeable membrane.**
- **It Communicates with other cells.**
- **It means that it allows some things to pass through easily while some not.**
- **Thus, it controls the movement of material inside or outside the cell.**

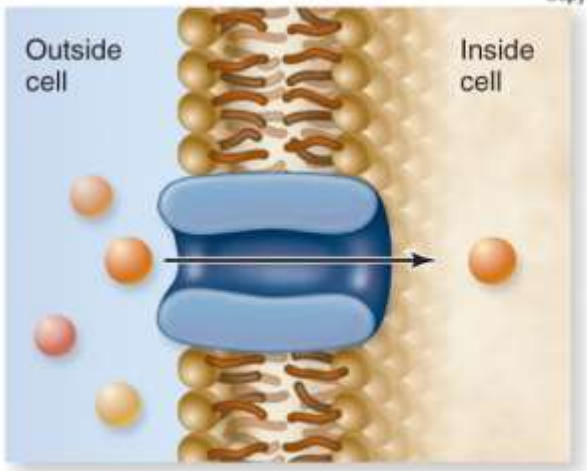
- Cellular membranes have 4 components
  1. Phospholipid bilayer
     - Flexible matrix, barrier to permeability
  2. Transmembrane proteins
     - Integral membrane proteins
  3. Interior protein network
     - Peripheral membrane proteins
  4. Cell surface markers
     - Glycoproteins and glycolipids

Carrier proteins

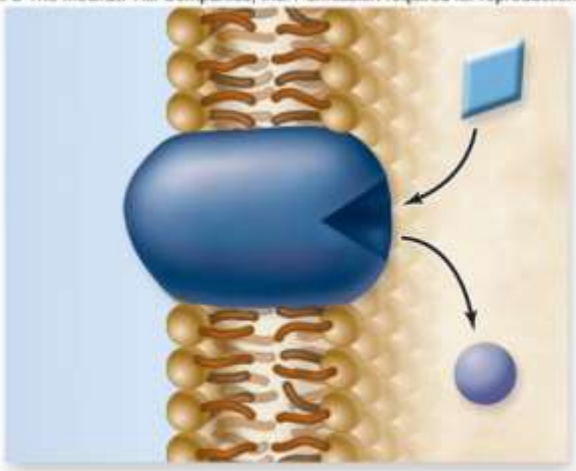
- Can help transport both ions and other solutes, such as some sugars and amino acids
- Requires a concentration difference across the membrane
- Must bind to the molecule they transport
  - Saturation – rate of transport limited by number of transporters

Membrane Proteins

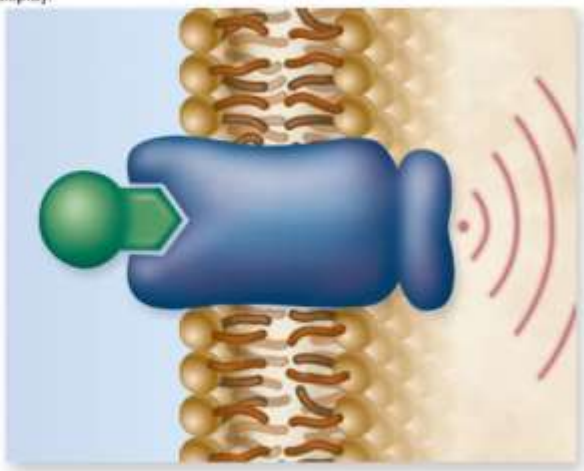
- Various functions:
  1. Transporters
  2. Enzymes
  3. Cell-surface receptors
  4. Cell-surface identity markers
  5. Cell-to-cell adhesion proteins
  6. Attachments to the cytoskeleton



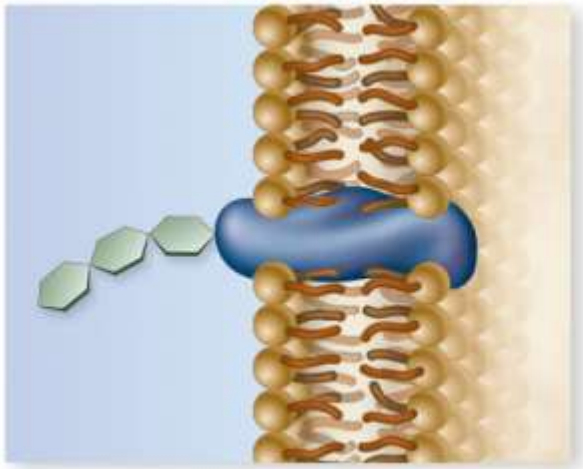
Transporter



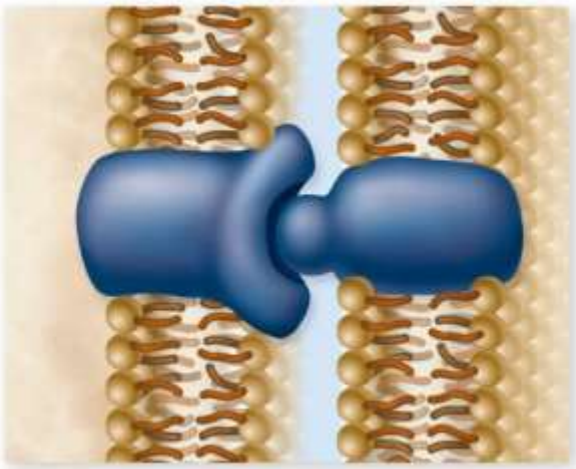
Enzyme



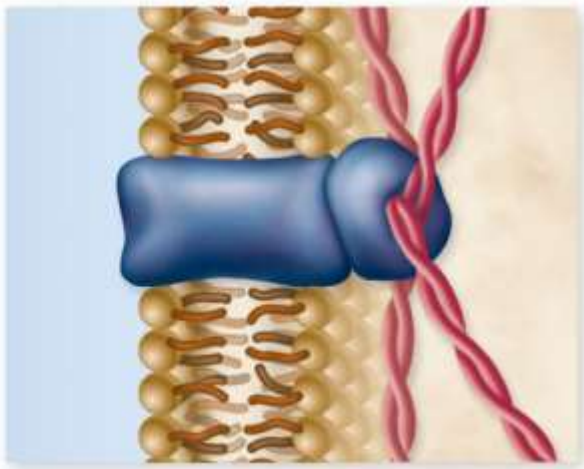
Cell surface receptor



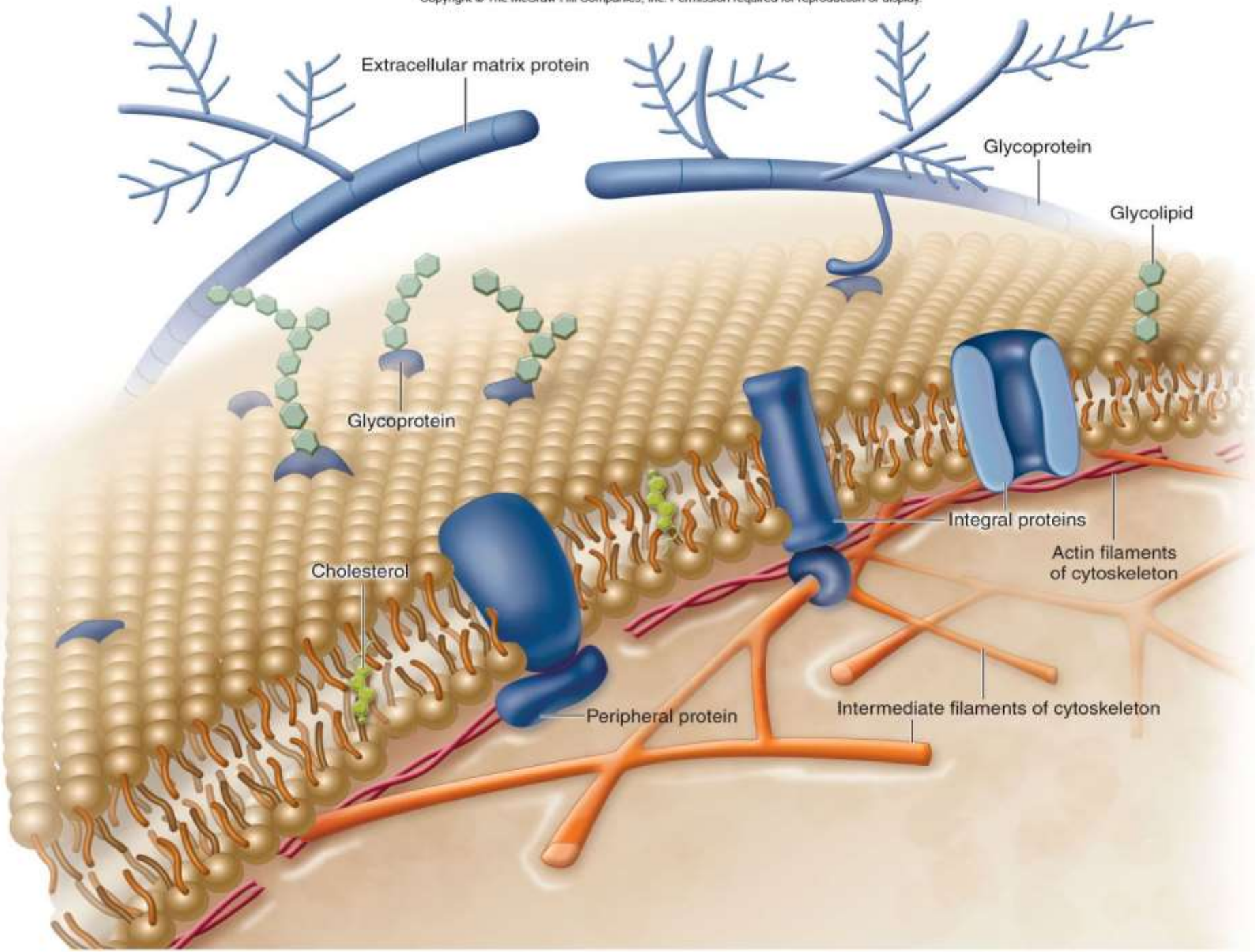
Cell surface identity marker



Cell-to-cell adhesion



Attachment to the cytoskeleton



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