Cell Theory and Basics

2015-02-13 7:30 PM

Section 2.1-2.2

Cell Theory
All organisms are composed of one or more cells.
The cell is the basic building block (structural and functional unit) of all living organisms.
Cells only arise from the division of pre-existing cells.

2.1 Basic Features of a Cell Structure and Function

Cells carry out the essential processes for life. They also carry the hereditary material. Unicellular life is essentially independent.

2.1a : Cells are Small and are Visualized Using a Microscope

Most cells are too small to be seen by the unaided human eye. Microscopy is used to view these structures. Two common types of microscopes.
Light microscope: Using light to illuminate the specimen.
Electron Microscope: Using electrons to illuminate.
Cell is size is dependent on the surface volume to area ration. Some cells increase their surface area by flattening or developing surface folds (microvilli)

2.1b: Cells have a DNA-Containing Central Region Surrounded by Cytoplasm

All cells are bound by a plasma membrane. The plasma membrane is a bi layer made of lipids. This bilayer is selectively permeable. The cytoplasm contains the organelles. The organelles are small structures required for cell function. The cytol contains ions and assorted organic molecules. The cytoskeleton is a fibrous framework that helps the cell maintain shape and plays a key role in cell division.

2.1c: Cells Occur in Prokaryotic and Eukaryotic Forms Each with Distinctive Structures and Organization

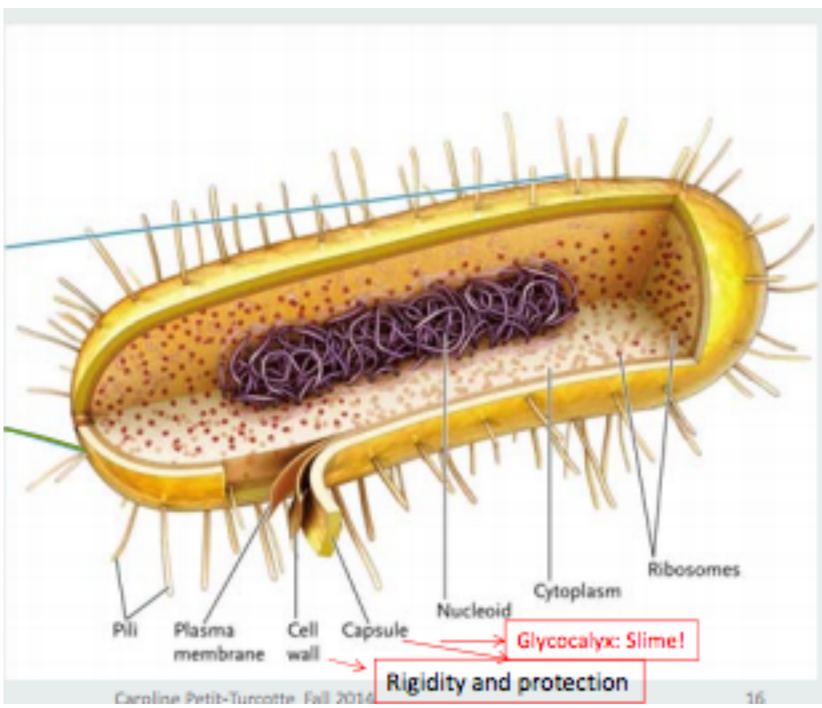
There are two main cell types

Eukaryote (Nucleus)
Prokaryote (No Nucleus)

Instead of a nucleus the prokaryotic cell has a nucleoid that has no boundary from the cytoplasm.

2.2 Prokaryotic Cells

Most are relatively small and have 3 distinct shapes; spherical, rod-like and spiral. The nucleoid in Archaea and bacteria is normally highly folded. For most organisms (prokaryotic) the genetic material is a single circular molecule called the karyotic chromosome. The ribosomes use the genetic information to build proteins. Almost all prokaryotic cells feature a cell wall that provides rigidity and protection, normally covered in sugar coating called the glycocalyx. A loose glycocalyx is called a slime layer while a tight one is called a capsule. The flagellum; a whip which extends from the cell aids in movement. The bacterial flagellum is helical and rotates in a socket.



Model Research Organisms

Model organisms have

- Rapid development

- Short life cycle
- Small adult size

Escheria Coli (E.Coli)
- Easy to grow in cultures
- Used as “factories” to produce proteins.

Saccharomyces Cervisice
- Bakers yeast
- Domesticated by humans
- Inexpensive to colonize
- Key to genetic studies

Drosophilia Melanogaster
- Fruit fly
- Key in genetic research
- Sex linked genes
- Ease of culturing
- Close to human genetics

Caenorhabditis Elegans
- Thrive off e.coli colonies
- Fixed cell numbers
- Transparent

Arabidopsis Thaliana
- White flowered thale crest
- Genetic crossing
- Can be cloned
- Chemical mutants used
- Use of recumbent DNA

Danio Rerio
- Zebra Fish
- Model vertebrate organism
- Simple diet
- Genes mapped

Mus Musculus
- Mouse
- Mammalian developmental genetics
- Breed in reasonable time

- Genome mapped

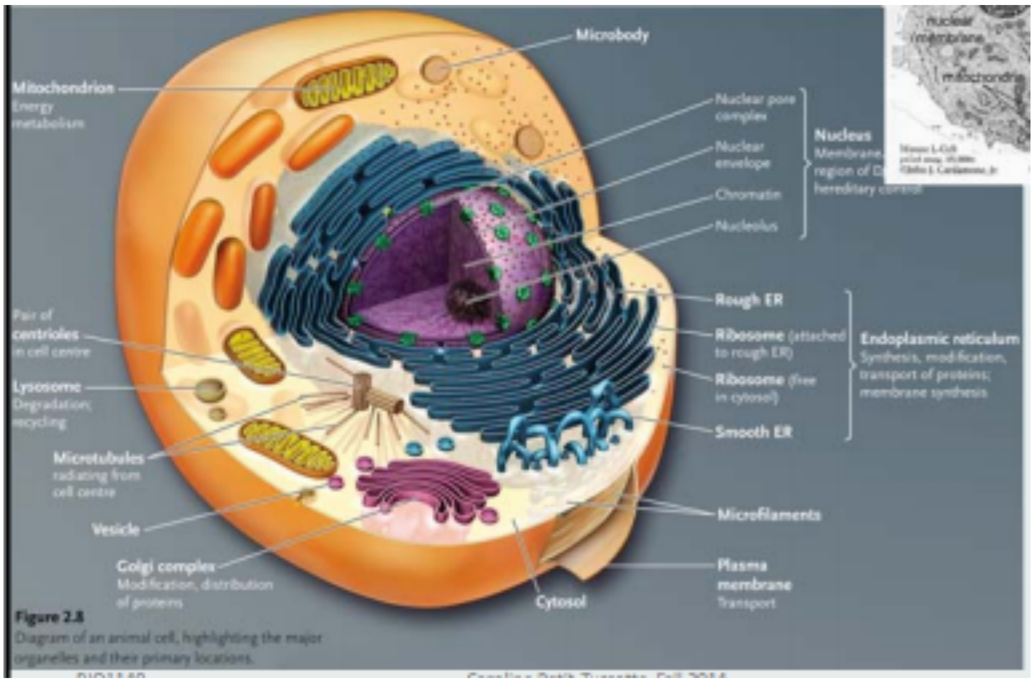
The Cell and Defining Life

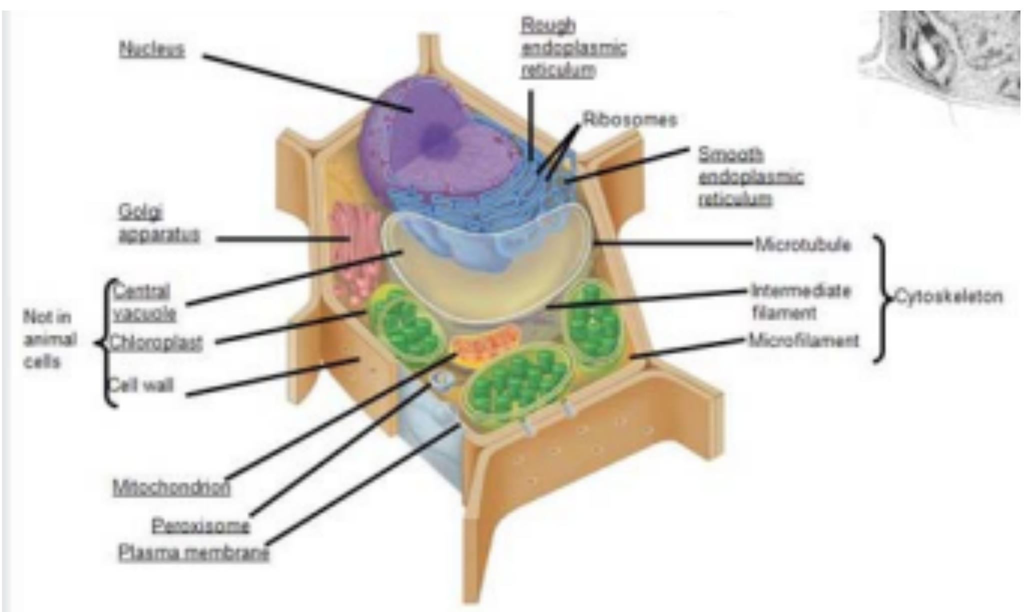
2015-02-13 7:30 PM

2.3-2.4

The Cell

2.3: Eukaryotic Cells





The domain of the eukaryotes is subdivided into

- Protists
- Fungi
- Animals
- Plants

2.3a: Eukaryotic Cells have a True Nucleus and Cytoplasmic Organelles Enclosed in a Plasma Membrane

Characteristics of a Eukaryote

- True Nucleus
- Cytoplasm contains membrane bound organelles

The plasma membrane performs many tasks through embedded proteins by forming channels that can transport proteins or act as receptors.

2.3b: The Eukaryotic Nucleus Contains Much More DNA than the Protist Nucleoid

The nucleus is separated from the cytoplasm by the nuclear envelope, which has two membranes. Embedded within the envelope are nuclear pore complexes, the largest protein complex in the cell. Within the nucleus a liquid or semi-liquid called neucleoplasm. The nucleus is mostly filled with chromatin, a combination of DNA and proteins.

2.3c: Eukaryotic Ribosomes are Either Free in Cytosol or Attached to Membranes

A eukaryotic ribosome, same as a prokaryotic one has two subunits; small and large. Characteristics of eukaryotic ribosomes:

- larger
- 4 types of rRNA
- 80+ Proteins
- Assemble amino acids into proteins
- Freely suspended in cytosol
- Attached to membranes
- May attach to organelles

- Most attached to Endoplasmic Reticulum

2.3d: An Endomembrane System Divides the Cytoplasm into Functional and Structural Parts

The endomembrane system is a collection of interrelated internal membranous sacs that divide the cell into functional and structural systems. Its functions include

- Synthesis and modification of proteins
- Transport proteins

They are connected by vesicles.
The components of this system are the:

- Nuclear Envelope
- Endoplasmic Reticulum
- Golgi complex
- Lysosomes
- Vesicles
- Plasma membrane

Endomembrane System

Organelle	Location	Function	Structure
Endoplasmic Reticulum	Located throughout the cell but particularity next to the nucleus.	Assemble proteins and synthesize lipids.	Extensive interconnected network of cisternae of the smooth and rough portions.
Golgi Complex	Located next to the rough endoplasmic reticulum.	Modifies proteins from the R.E.R then transports them.	Stack of flattened membranes.
Lysosomes	Formed from budding Golgi complexes, throughout the	Digest complex molecules by autophagy.	Formed from the Golgi complex.

	cell.		

2.3e: Mitochondria Are the Organelles in Which Cellular Respiration Occurs

Energy rich molecules broken down into water and carbon dioxide by mitochondrial activities. Energy released in captured in the form of ATP. Mitochondria require oxygen to respire. Mitochondria are enclosed by two membranes

- Inner: expanded by folds called cristae
- Outer: Smooth and covers the organelle.

2.3f: The Cytoskeleton Supports and Moves Cell Structures

An interconnected system of tubes extends through the cytoskeleton. It is most highly developed in animal cells. Three main structural elements; microtubules, intermediate filaments, microfilaments.

Microtubules

- Dynamic Structures
- Made up of Tubulin
- Found near the centrosome/ cell center
- Anchor organelles
- Myosin walk on microtubules.

Intermediate Fibers

- Appear in parallel bundles and in interlinked networks.
- Tissue specific in composition

Microfilaments

- Two polymers of Actin subunits wound around each other helically.
- Structural and locomotion functions
- Cytoplasmic Streaming

2.3g: Flagella Propel Cells, and Cilia Move Materials Over the Cell Surface

Flagella and cilia are elongated slender, motile cell extensions. They are identical except cilia are shorter and normally more abundant. They have a 9+2 arrangement of microtubules. They arise from centrioles.

3.1→ 3.5

Defining Life and Its Origins

3.1: What is Life?

3.1a: Seven Characteristics Shared by all Life-forms

1. Display Order
2. Harness and Utilize Energy
3. Reproduce
4. Respond to Stimuli
5. Exhibit Homeostasis
6. Grown and Develop
7. Evolve

Viruses straddle the line between biotic and abiotic.

3.1b: The Characteristics of Life are Emergent

Complex interactions remerge from simpler ones.
Cells → Tissues → Organs →Organ Systems → Body Systems

3.2 The Chemical Origins of Life

Cells had to arise form something.

3.2a: The earth is 4.6 Billion Years Old

The earliest forms of life began 4 billion years ago, with prokaryotic fossil evidence dating back 3.5 billion years ago.

3.2b: Earth Lies Within the Habitable Zone Around the Sun

All matter of the solar system was formed at the same time by grabitational condensation of matter formed by an interstellar cloud. Earths early history was marked largely by bombardment. Earth is within the habitable zone allowing water to be present, a prerequisite for life.

<u>3.2c: Biologically Important Molecules Can be Synthesized Outside Living Cells</u>

All forms of life are composed of

- Nucleic Acids
- Proteins
- Lipids
- Carbohydrates

However how were these produced before life? There are currently 3 major hypotheses.

Reducing Atmosphere

- The atmosphere 4 billion years ago was vastly different and contained virtually no oxygen.
- 1920's Aleksander Oparin and John Haldane independently theorized that eh early environment could have formed in a primordial earths atmosphere. (Oparin- Haldane hypothesis)
- The contents of the atmosphere would have reacted in a way allowing for the formation of large and more complex organic molecules.
- Confirmed by the Miller-Urey apparatus

Deep-Sea Vents

- Cracks in the ocean floor that form around volcanic or tectonic activity and release super heated nutrient rich water at temperatures in excess of 300 degrees Celsius.
- These areas today support a large diversity of life.
- Extremophiles

Extraterrestrial Origins

- The key organic molecules could have come from space on the back of a meteorite.
- Meteorites that have landed on earth and have been analyzed have contained key molecules.

3.2d: Life Requires the Synthesis of Polymers

Today the synthesis of proteins and nucleic acids requires protein-based catalysts called enzymes and results in macromolecules. Its unlikely however that polymerization could have occurred in the early aqueous environment of early earth. Clays would have provided the correct surface for this to happen. The charged layers of clay would have allowed for molecular adhesion forces to bring monomers together in precise orientations that could have more readily lead to polymer formation. This clay hypothesis is supported by laboratory experiments.

3.3: From Macromolecules to Life

We need to be able to describe the three key attributes of a modern cell:
1. Membrane defined compartment – the cell.
2. A system to store genetic information and use it as a guide.
3. Energy transforming pathways to bring in energy and harness it.

3.3a: Lipid Spheres May Have Led to the Development of Cells

The formation of a membrane defined compartment is a critical step towards life. This compartment would allow for metabolic reactions to take place in a separate environment. The protobiont is a group of abiotically produced organic molecules that are surrounded by a membrane or membrane-like structure. The early protobiont could have been similar to a liposome. Liposomes similar to a plasma membrane feature a bilayer and are selectively permeable.

3.3b RNA Can Carry Information and Catalyze Reactions

The flow of information from DNA → RNA is common to all forms of life and is referred to as the **central dogma.** The information flow is aided by enzymes that catalyze the reactions. Thomas Cech discovered a group of RNA molecules that could act themselves as catalysts, he called them ribozymes. They have catalytic properties due to their unique folding. Proving that the early world may have been a RNA world.

<u>3.3c: RNA is Replaced by DNA for Information Storage and Proteins for Catalysis.</u>

DNA developed from the RNA world because it did a much better job at its respective tasks then RNA. DNA is a much better way to carry information for three main reasons.

- DNA is more stable
- Mutations don't occur as often due to the double strand that carries the same information.

<u>3.3d: Simple Oxidation-Reduction Reactions Probably Preceded Metabolism</u>

Oxidation-reduction reactions were probably among the first energy releasing reactions of the primitive cells. This process is not very efficient and would have led to a lot of wasted energy. ATP gradually became the primary substance connecting energy-releasing and energy-requiring reactions in early cells.

<u>**3.4: The Earliest Forms of Life**</u>

<u>3.4a: The Earliest Evidence of Life is Found in Fossils</u>

The earliest conclusive evidence of life is found in the fossilized remains of structures called stromatolites. Stromatolites are a type of layered rock that is formed when microorganisms bind particles of sediment together forming thin sheets. Indirect evidence of life is found from looking at the carbon composition of life in ancient rocks that show life was happening. These can be found on the ocean floor in rocks and sediments as old as 3.9 billion years old.

3.4b: The First Cells Relied on Anaerobic Metabolism

The earliest forms of life were most likely heterotrophs, which are organisms that obtain carbon from the organic molecules. Since the early atmosphere contained nearly no oxygen they would have had to rely on anaerobic respiration. Compared to autotrophs that get their carbon in carbon dioxide.

3.4c: Oxygenic Photosynthesis Led to the Rise in Oxygen in the Atmosphere

Starting about 2.5 billion years ago, oxygen levels began to increase. Cyanobacteria (the ancient stromatolites) are able to use water as a electron donor. The oxidation of water released molecular oxygen (oxygenic photosynthesis). This meant that the cyanobacteria could thrive almost anywhere that there was light. This type of photosynthesis remains the dominant form.

3.4d: Could Life have Come to Earth from Space?

Panspermia is the hypothesis that the simple life forms that exist in space arrived on earth on meteorites or other space debris. Evidence proves that extremophiles would be able to survive in the harsh conditions of space.

3.4e: All Present-Day Organisms Are Descended from a Common Ancestor

All present day organisms can be categorized into one of the three domains

- Archaea
- Bacteria
- Eukarya

Because both Archaea and Bacteria share a similar cell architecture and lack a nucleus they are referred to as the prokaryotes. All life-forms currently on earth share a remarkable set of common attributes, the most fundamental being

- Cells made of lipid molecules brought together forming a bilayer
- Genetic system based on DNA
- A system of information transfer (DNA to RNA)

- A system of protein assembly from a pool of amino acids by translation using mRNA
- Reliance on proteins as the major structural and catalytic molecules
- Use of ATP as energy
- Breakdown of glucose by the metabolic pathway to generate ATP.

The fact that all organisms share these properties gives rise to the idea of a common ancestor (LUCA)

3.5 The Eukaryotic Cell and the Rise of Multicellularity

The oldest fossils of eukaryotes are about 2.1 billion years old. Present day eukaryotic cells have two major characteristics that distinguish them from either the Archaea or bacteria.

- Separation of DNA and cytoplasm by a nuclear envelope
- The presence in the cytoplasm of membrane bound compartments (organelles).

Eukaryotic cells most likely arose from prokaryotic cells.

3.5a: The Theory of Endosymbiosis Suggest that Mitochondria and Chloroplasts Evolved from Ingested Prokaryotes

The mitochondria is found in nearly all eukaryotic cells as the energy transforming organelle. A large amount of evidence suggests that the mitochondria and chloroplasts actually descended from an aerobic bacteria and chloroplasts from cyanobacteria. The theory of endosymbiosis states that prokaryotic ancestors were engulfed by larger prokaryotic cells forming a mutually beneficial relationship.

3.5b: Several Lines of Evidence Support the Theory of Endosymbiosis

1. Morphology; the form of shape of both mitochondria and chloroplasts is similar to that of bacteria and archaea.
2. Reproduction; a cell cannot synthesize a mitochondrion or a chloroplast. They instead divide by binary fission.
3. Genetic Information; They contain there own DNA, where the DNA is circular.

4. Transcription and Translation; They contain a complete transcription and translational machinery.
5. Electron Transport; have electron transport chains (ETC) to generate chemical energy, found within the double membrane of the organelles.
6. Sequence Analysis; sequencing the RNA that makes up the ribosomes of the chloroplast and the mitochondria firmly establishes that they belong on the bacterial branch of the tree of life.

3.5c: Horizontal Gene Transfer Followed Endosymbiosis

The term genome is defined as the complete complement of an organisms genetic material. Following endosymbiosis, the early eukaryotic cell would have contained at least two compartments each with its own complete genome that would have functioned independently allowing it to code for proteins required for its own structure and function. This contradicts the modern view of a highly interconnected cell. Two major processes led to this integration:

- Some of the genes were lost as they would have been redundant
- Genes within the protomitchondria were relocated to the nucleus through the process of horizontal gene transfer.

Remaining Question: Why do the mitochondria and chloroplasts retain a genome.

3.5d: The Endomembrane System May be Derived from the Plasma Membrane

The widely held hypothesis is that the endomembrane system developed from the in folding of the plasma membrane. The membranes formed around the DNA forming the nuclear envelope defining the nucleus. The remaining membranes formed around vesicles defining the other aspects of the EMS.

3.5e: Solving and Energy Crisis May have Led to Eukaryotes

The reason that bacteria and archaea have remained simple is that increased complexity requires increased energy, and while eukaryotic cells can generate huge amounts of it, prokaryotic cells cannot. The ability of early eukaryotes to generate more ATP led to remarkable changes.

3.5f: The Evolution of Multicellular Eukaryotes Led to Increased Specialization

Clear evidence of multicellular eukaryotes (small algae) appears in the fossil record around 1.2 billion years ago. It is easy to hypothesize how this may of happened; a group of individual cells may have come together to form a colony. In the most simple multicellular beings, all cells are structurally and functionally independent. It is believed that multicellular life arose and developed more than once through the lines of plants, animals and fungi.

F 8-21

Macromolecules

Matter has mass and occupies space.

The Organization of Matter

Elements and Compounds
All matter composed of elements
Element composed of only one atom
A compound contains two or more elements

The Atom
Elements are composed of atoms
Smallest unit that retain the chemical and physical characteristics of an element.
All atoms contain
Positive protons
Negative electrons
Neutral Neutrons

Isotopes
Same number of protons with more of less neutrons (different mass)
Some isotopes are unstable and will decay (electrons ejected form the nucleus)
Use of Isotopes
Medical imaging
Carbon dating

Electron and Electron Shells
Electrons move around nucleus in orbitals which are grouped into shells.
Chemical behavior dependent on valence shell

Chemical Bonds

An interaction between atoms with the sharing or exchange of valence electrons.
4 types
Ionic
Covalent
Hydrogen
Van der Wall

Ionic
Between atoms which gain/loose electrons to form an octet
Exert a forcer over great distances
Attractive in all directions
Vary in strength in varying environment.

Covalent Bonds
Share valence electrons
Molecules formed through covalent bonds
Structural formulas explain covalent bonds
Bonds form over discrete angles.

Polarity and Hydrogen Bonding
Polar molecules are hydrophilic
Non-polar molecules are hydrophobic
Numerous hydrogen bonds are very strong.

Van der Waals Forces
Weaker than hydrogen bonds
Zones of +/- charges
Weak and transient

Chemical Reactions
Atoms are molecules interact by breaking an forming new bonds.
Accelerated by enzymes
Made up of products and reactants

Water

Organisms range from 50-95% water.

Hydrogen Bonds and The Properties of Water
Hydrogen bonds form readily and water and give it many of its chemical properties
Called a water lattice

Specific Heat and Heat of Vaporization
High heat capacity
High heat of vaporization (allows humans to cool off in the heat).

Surface Tension
Molecules attracted to each other due to cohesion.
Strong surface tension allows certain insects to walk along the top of water.

Aqueous Solution
Readily surround other polar molecules in a hydration shell.
Water is a universal Solvent.

Cytoskeleton / ECM

2015-02-13 7:30 PM

2.5,8.4,31.2,34.6

2.5: The Animal Cell Surface

Animal cells have specialized structures that help:

- Hold cells together
- Communication
- Organize body structures

Molecular systems that perform these functions are organized at three levels

- Cell adhesion molecules; bind individual cells
- Cell complexes; more complex and seal the spaces between cells.
- Extracellular matrix; supports and protects cells while providing mechanical linkages.

2.5a: Cell Adhesion Molecules Organize Animal Cells into Tissues and Organs

Cell adhesion molecules are embedded in the plasma membrane and help maintain form and structure. They make initial connections in the embryonic stages, which are broken and remade as tissues change position in the developing embryo. As the tissue develops in the adult the adhesions become permanent.

2.5b: Cell Junctions Reinforce Cell Adhesions and Provide Avenues of Communication

Three types of cell junctions are common in animal tissues.

- Anchoring Junctions; form button like sports that run entirely around cells welding adjacent cells together.
    - Some anchoring junctions known as desmosomes intermediate filaments anchor the junction in the underlying cytoplasm
    - Adherens junctions have microfilaments as the anchoring component.
- Tight Junctions; regions of tight connections between membranes of adjacent cells. The connection is tight hat it can keep particles as small as ions from moving between the cells in the layers.

- Gap Junctions; open direct channels hat allow ions and small molecules to pass directly from one cell to another, providing cell to cell communication (plasmodesmata in plant cells).

These junctions allow cells to organize themselves into separate tissues.

2.5c: The Extracellular Matrix Organizes the Cell Exterior

The primary function of the ECM is protection and support. The ECM also affects cell division, adhesion, motility and embryonic development. Glycoproteins are the main component of the ECM (collagen in particular). The consistency of the ECM depends on the proteoglycans that surround the collagen fibers which determines how much water can be trapped in it.

8.4: Formation and Action of the Mitotic Spindle

The mitotic spindle is central to both mitosis and cytokinesis. The spindle is made up of microtubules and their proteins.

8.4a: Animals and Plants Form Spindles in Different Ways

Animal cells and many protists have a centrosome, a site near the nucleus from which microtubules radiate outward in all directions. The centrosome is the main microtubule organizing center of the cell. The centrosome contains a pair of centrioles arranged at right angles to each other. They generate the microtubules required for cell motility (flagellum and cilia).

8.4b: Mitotic Spindles May Move Chromosomes by a Combination of Two Mechanisms

The kinetochore microtubules connect the chromosomes to the spindle poles, while the nonkinetochore microtubules extend between the spindle poles without connecting to chromosomes. Data suggests that chromosomes walk along stationary microtubules toward the poles. The tubulin subunits of the kinetochore microtubules disassemble as the kinetochores pass along the; thus the microtubules become shorter as the movement progresses.

31.2: Animal Tissues

Animal tissues can be classified into four main types of tissues

- Epithelial
- Connective
- Muscle
- Nervous

The structure and function of a tissue depend on the structure and organization of the cytoskeleton within the cell, the extracellular membrane, junctions holding the cell together.

31.2a: Epithelial Tissue Forms Protective, Secretory and Absorptive Coverings and Linings of Body Structures

Epithelial tissue consist of sheet like layers of cells that are usually jointed tightly together with little ECM material between them. They have a free outer surface called the apical surface which may be exposed to water, air or fluids within the body. The inner, basal surface adheres to a layer of ECM secreted by the epithelial cells called basal lamina. The entire system is called the basement membrane.

Types of Epithelia

- Simple
- Stratified

Shapes of Epithelia

- Squamos
- Cuboidal
- Columnar

Glands Formed by Epithelia

- Exocrine
- Endocrine

31.2b: Connective Tissue Supports Other Body Tissues

Connective tissues support body tissues, transmit mechanical and other forces. They consist of cells that form networks or layers in and around body structures. The mechanical properties of connective tissue depend on the type and quantity of its ECM. The ECM consist primarily of collagen. In some tissue elastin adds elasticity to the ECM.

There are 6 major types of connective tissue.

- Loose Connective Tissue; sparsely distributed cells. Fibroblasts secrete most of the collagen.
- Fibrous Connective Tissue; fibroblasts are sparsely distributed among dense masses of collagen and elastin fibers that are lined up in highly ordered bundles.
- Cartilage; sparely distributed cells called chondrocytes. Serves as a precursor for bone in embryonic development.
- Bone; densest form of connective tissue. Mature bone primarily consists of cells called osteocytes embedded in a ECM containing collagen fibers and glycoproteins impregnated with hydroxyapatite, a calcium phosphate mineral.
- Adipose; Contains mostly large densely clustered cells called adipocytes that are specialized for fat storage.
- Blood; The fluid portion of blood is essentially a fluid form of ECM.

31.2c Muscle Tissue Produces Movement

Muscle tissue consist of cells that have the ability to contract, which depends on the interaction of two proteins; actin and myosin. Three types of muscle tissue exist, skeletal, cardiac and smooth.

Skeletal Muscle

- Attached by tendons to the skeleton. These cells contain many nuclei. They contract in response to stimulus from the nervous system.

Cardiac Muscle

- Contractile tissue of the heart. Each cell is connecting to several neighboring cells.

Smooth Muscle

- Found in the walls of tubes and cavities in the body. Its contractions can be maintained at a steady level without fatigue.

Invertebrate Muscle

- Most have striate muscle throughout the body.

31.2d: Nervous Tissue Receives, Integrates, and Transmits Information

Nervous tissue contains cells called neurons that serve as lines of communication between body parts. Glial cells physically support and nourish neurons. A neuron is composed of a cell body and two extensions the dendrites and the axon.

34.6 Cellular Basis of Development

The orientation of cell division have special significance in development. The orientation of cell division refers the angle the daughter cells form with the older cells.

34.6a: Microtubules and Microfilaments: Movements of Cells

Embryonic cells undergo changes in shape that generate movements, such as the folding to create the endoderm or mesoderm.

3.4b: Change in Cell Shape: Adjusting to New Roles

Changes in cell shape typically result from reorganization of the cytoskeleton. Microtubules and microfilaments have a role in changing the shape of developmental movements.

3.4c: Movements of Whole Cells to new Positions in the Embryo

Cell movements during gastrulation and long distance migrations of neural crest cells are striking examples of movements of whole cells during embryonic development. These movements involve coordinated activity by microtubules and microfilaments. This typical pattern of movement is a repeating cycle of extension, anchoring, and contracting.

- Cell attaches to the substrate
- Moves forward by elongating from the point of attachment
- Makes a new attachment at the advancing tip
- The front attachment now serves as the base for another movement.

Cells normally follow either molecular gradients or concentration gradients.

34.6d: Induction: Interactions between Cells

Induction is the process in which a group of inducing cells causes or influences a nearby group of responding cells to follow a particular developmental pathway. The signaling molecules may be located on the surface of the inducing cells or released by inducing cells. The organizer acts on other cells to alter the course of development.

Membranes

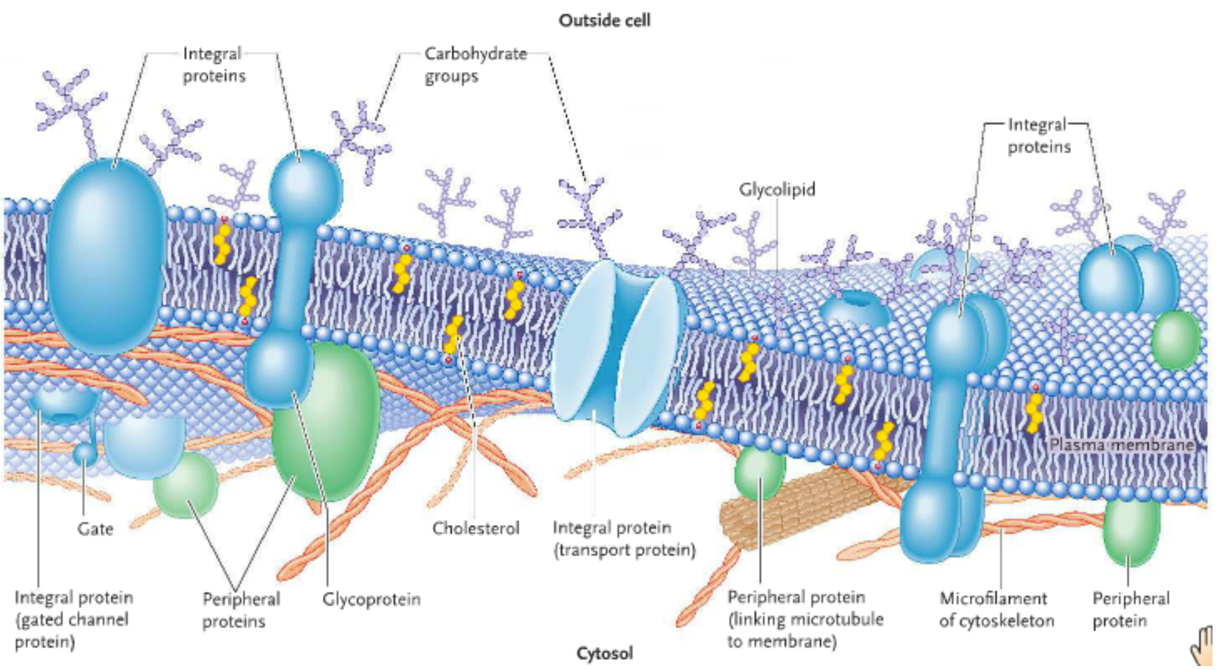
2015-02-13 7:30 PM

5.1 → 5.6

5.1: An Overview of the Structure of Membranes

One of the keys of evolution was the development of the cell or plasma membrane. The key functions of the membrane are:

- Uptake of nutrients
- Elimination of Waste
- Protected environment



5.1a: A Membrane Consist of Proteins in a Fluid of Lipid Molecules

The membrane structure is based on the fluid mosaic model. The model proposes that membranes are not rigid with molecules locked into place but rather consist of proteins within a mixture of lipid molecules. The lipids molecules of all biological membranes exist in a bilayer. The proteins involved consist of

- Transport
- Attachment
- Signaling

5.1b: Experimental Evidence in Support of the Fluid Mosaic Model

The model is supported by two major pieces of evidence.

Membranes are Fluid

- Based on the measured rates at which molecules mix in biological membranes, the membrane bilayer appears to be about as fluid as olive oil.

Membrane Asymmetry

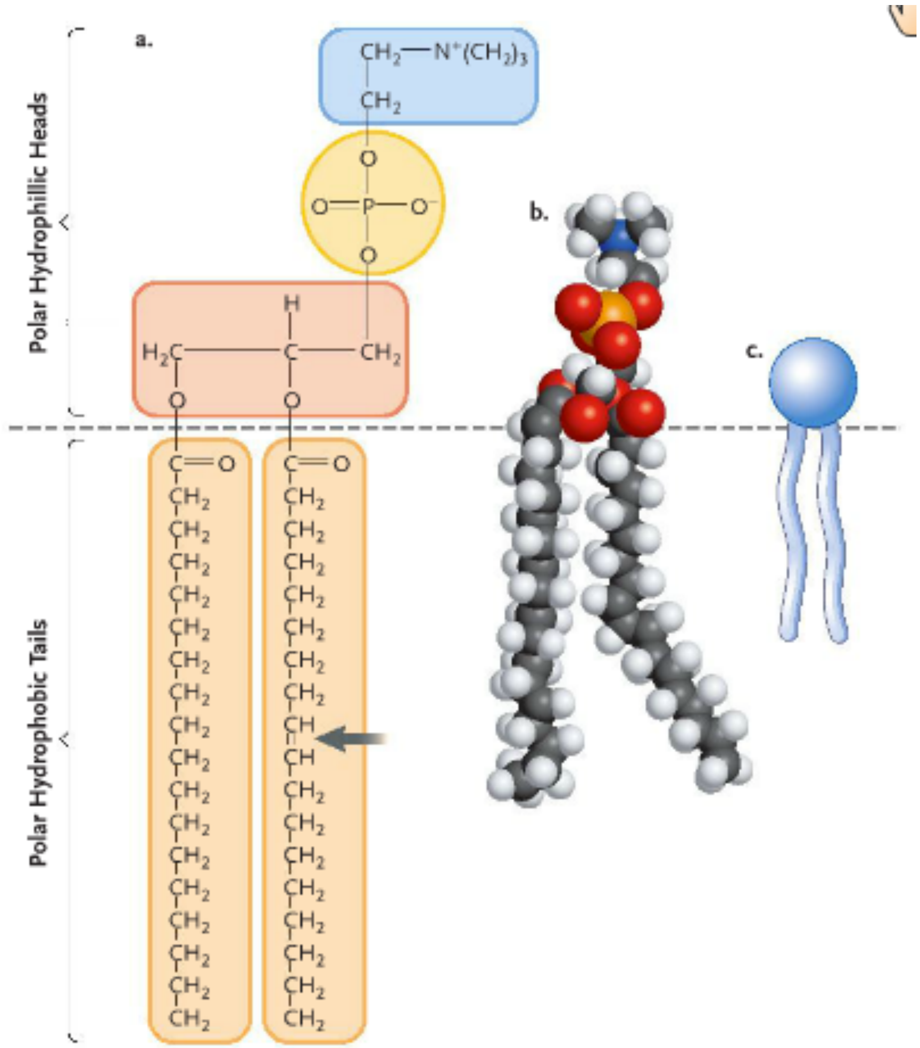
- From the images obtained in the experiments it is clear that the particles on either side of the membrane differ in size, number and shape providing evidence that they are different.

5.2: The Lipid Fabric of a Membrane

The foundation of al biological membranes are the lipid molecules. Phospholipids are dominant in membranes.

5.2a: Phospholipids are the Dominant Lipids in Membranes

The lipid bilayer is formed by phospholipids. Phospholipids will spontaneously form micelles are liposomes. Which structure forms is determined by the phospholipid concentration.



<u>5.2b: Fatty Acid Composition and Temperature Affect Membrane Fluidity</u>

The fluidity of the bilayer is influenced primarily by two factors

- The type of fatty acids that make up the lipid molecules
  - Saturated molecules can be packed tightly decreasing fluidity while unsaturated lipids are much more difficult to pack.
- Temperature
  - When temperature decreases fluidity is lost.

<u>5.2c: Organisms Can Adjust Fatty Acid Composition</u>

The fluidity of the plasma membrane is essential, and since many organisms can’t voluntarily change their temperature when it suits them the ability to adjust fatty acid composition is crucial. Desaturases act on saturated fatty acids by catalyzing a reaction that removes two hydrogen atoms introducing a double bond between carbons. Sterols also influence membrane fluidity which act as membrane buffers.

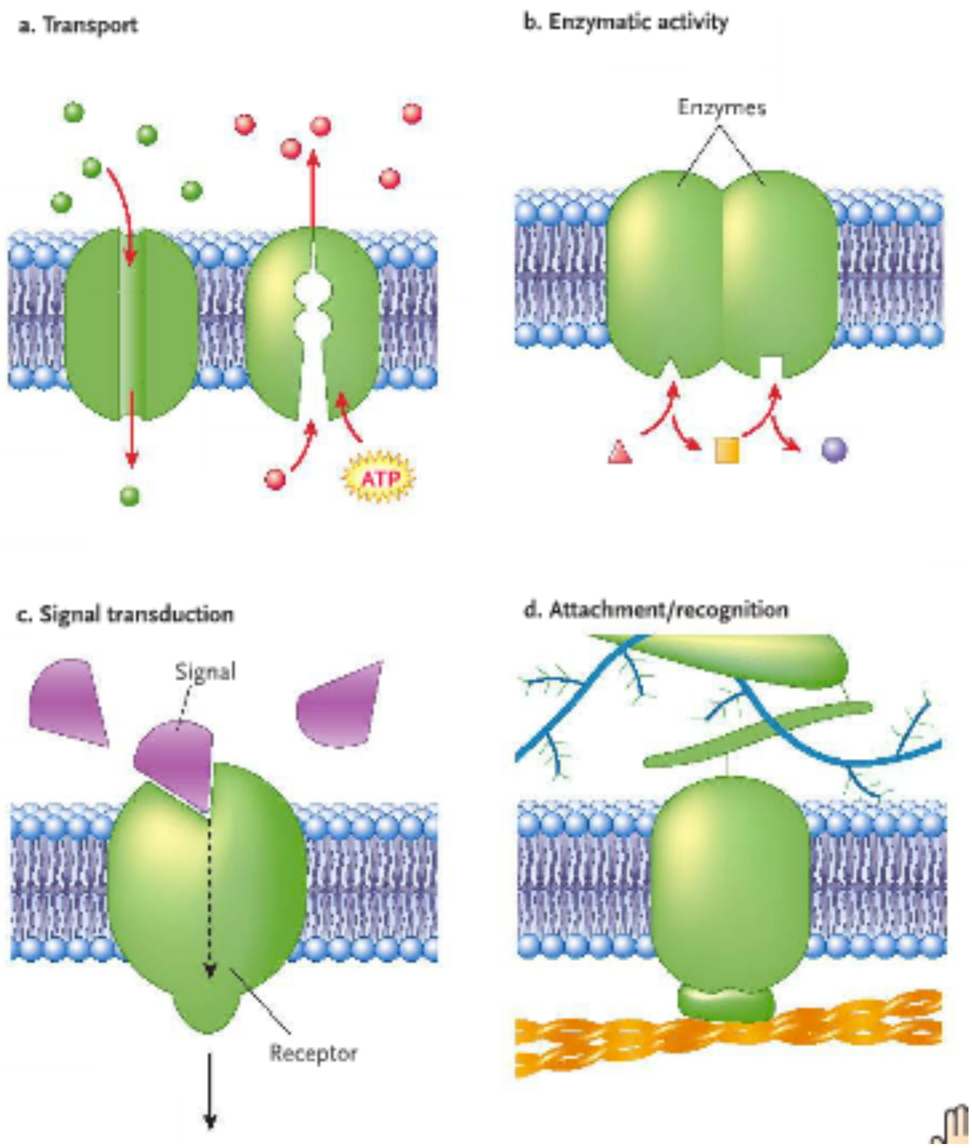
5.3: Membrane Proteins

The unique set of proteins that are associated with the membrane determine its function and makes each membrane unique.

5.3a: The Key Functions of Membrane Functions

Membrane proteins can be separated into four major functional categories.

- Transport
  - A protein may provide a channel for the movement of a specific compound.
- Enzymatic Activity
  - Enzymes associated with electron transport chains.
- Signal Transduction
  - These receptors trigger changes on the inside surface of the membrane that lead to transduction of the signal though the cell.
- Attachment/recognition
  - Proteins exposed on both the internal and external membranes act as attachment points for the cytoskeleton and components involved in cell-cell recognition.



5.3b: Integral membrane Proteins Interact with the Membrane Hydrophobic Core

Proteins embedded in the phospholipid bilayer are called integral membrane proteins. Transmembrane proteins span across the entire lipid bilayer. Most transmembrane proteins span the membrane more than once.

5.3c: Peripheral Membrane Proteins Interact with the membrane Hydrophilic Surface

Peripheral membrane proteins only interact with the hydrophilic portion of the membrane. Many of them are found on the cytoskeleton side and form part of the cytoskeleton. They are made up of a mixture of polar and nonpolar amino acids.

5.4: Passive Membrane Transport

The hydrophobic nature of the plasma membrane hinders the passive diffusion of many molecules. Many ions and macromolecules cannot diffuse easily.

5.4a: Passive Transport is Based on Diffusion

Passive transport is defined as the movement of a substance across a membrane without the need to expend chemical energy such as ATP. Passive transport is powered by diffusion. Diffusion is the primary movement of solutes.

5.4b: There are Two Types of Passive Transport: Simple and Facilitated

Simple diffusion is the movement of molecules directly across a membrane without the involvement of a transporter. The rate of diffusion depends on molecular size and lipid solubility. While facilitated diffusion depends on the help of a transporter to speed up ion passage.

5.4c: Two Groups of Transport Proteins Carry Out Facilitated Diffusion

Channel proteins and carrier proteins carry out facilitated diffusion. Channel proteins form hydrophilic pathways that allow molecules to pass through. The diffusion of water is facilitated by water specific transport proteins called aquaporins. The gated channel is another form of channel protein that are critical to the movement of most ions.

5.4d: Osmosis Is the Passive Diffusion of Water

Osmosis occurs constantly in living cells. The movement of water due to osmosis is controlled by solute concentrations.

5.5: Active Membrane Transport

This type of energy-dependent transport moves molecules from a region of lower concentration to a higher one, against the concentration gradient.

5.5a: Active Transport Requires Energy

The energy is usually in the form of ATP, it is estimated that 25% of a cells ATP requirements are used in active transport. The three main functions of active transport are:

- Uptake of essential nutrients
- Removal of secretory or waste materials.
- Maintenance of essential cell concentration gradients.

There are two main classes of active transport, primary and secondary. In secondary transport ATP indirectly powers the transport system.

5.5b: Primary Active Transport Moves Positively Charged Ions

All primary active transport pumps involve positively charged ions. The sodium-potassium pump located in the plasma membrane of all animal cells, pushes 3 Na ions out of the cell and two K ions into the cell in the pumping cycle. As a result, positive charges accumulate in excess outside the membrane and the inside of the cell becomes negatively charged with respect to the outside voltage. The voltage created across the membrane is called the membrane potential.

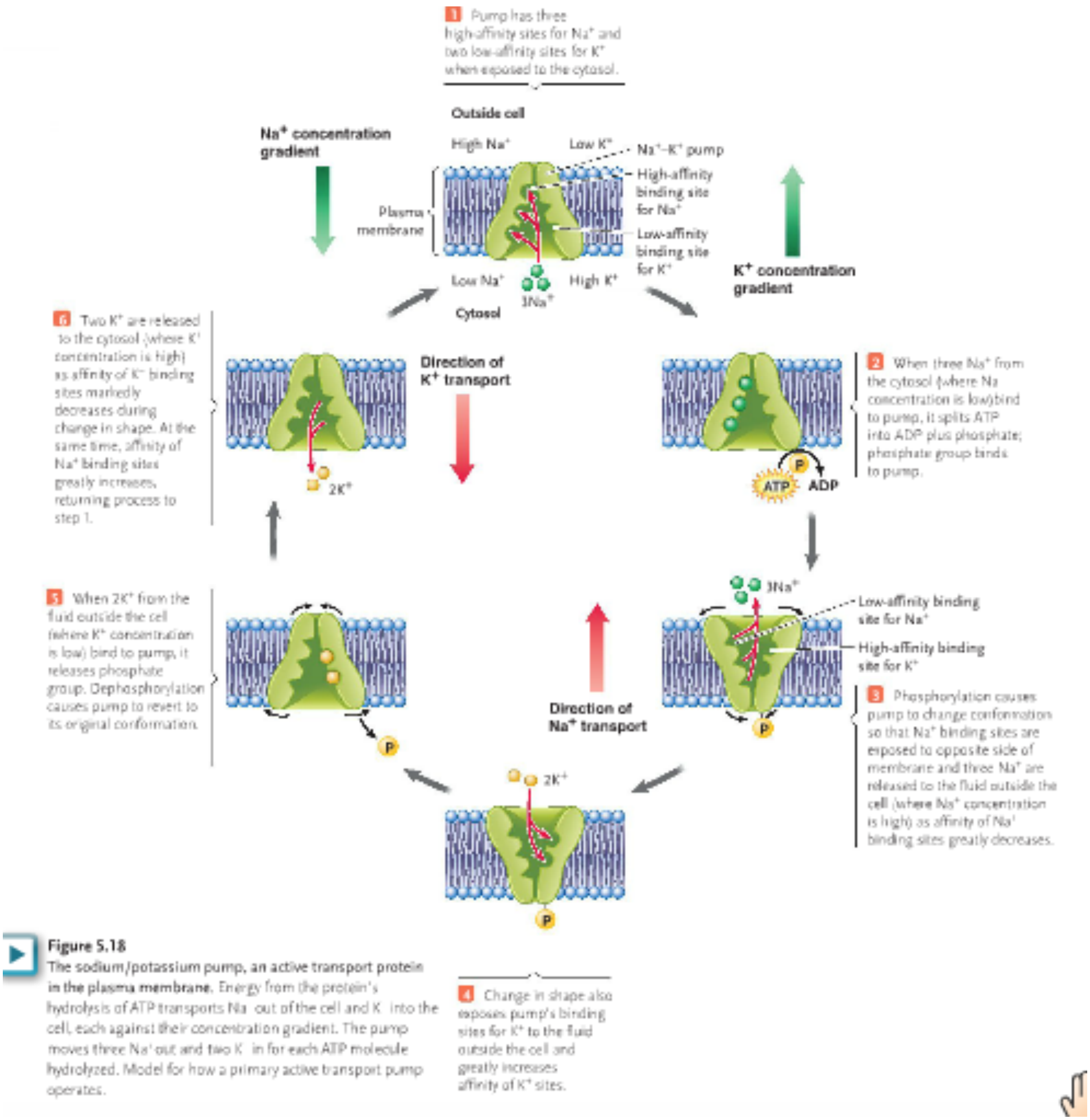


Figure 5.18
The sodium/potassium pump, an active transport protein in the plasma membrane. Energy from the protein's hydrolysis of ATP transports Na^+ out of the cell and K^+ into the cell, each against their concentration gradient. The pump moves three Na^+ out and two K^+ in for each ATP molecule hydrolyzed. Model for how a primary active transport pump operates.

5.5c: Secondary Active Transport Moves Both Ions and Organic Molecules

Secondary transport occurs by two mechanisms known as symport and antiport. In symport the cotransported solute moves through the membrane channel in the same direction as the driving force. In antiport energy for the opposite movement is also provided.

5.6 Exocytosis and Endocytosis

Eukaryotic cells import and export larger materials.

- Exocytosis = export
- Endocytosis = Import

They both require ATP to function.

5.6a: Exocytosis Releases Molecules to the outside by Means of Secretory Vesicles

Secretory vesicles move through the cytoplasm and contact the plasma membrane. The vesicle fuses with the membrane and releases its contents to the cell exterior.

5.6b: Endocytosis Brings materials into Cells in Endocytic Vesicles

In endocytosis, proteins and other substances are trapped in pit like depressions that bulge inward from the plasma membrane. The substances then pinch off. In bulk-phase endocytosis (pinocytosis) extracellular water is taken in. Receptor-mediated endocytosis the molecules to be taken in are bound to the outer cell surface by receptor proteins (integral proteins). Phagocytosis is performed by certain cells (WBC) and is a type of cell eating.

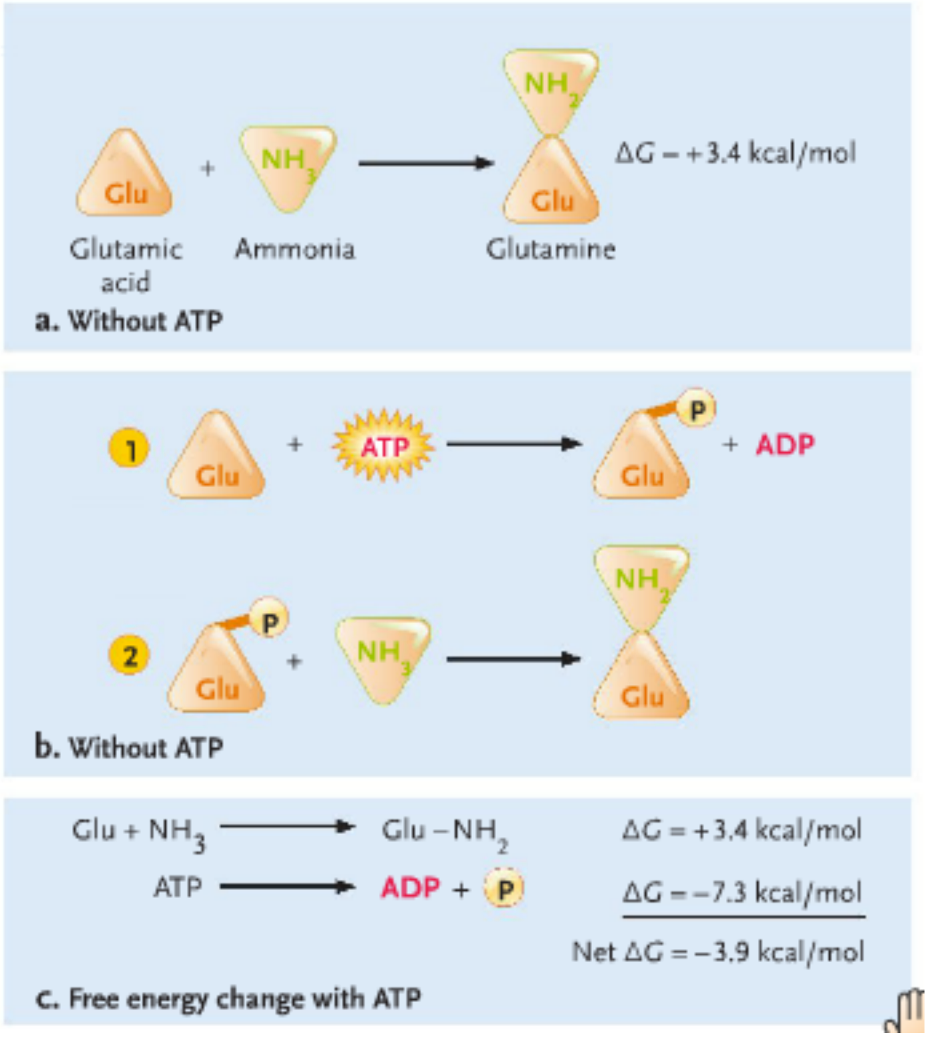
4.3 Adenosine Triphosphate is the Energy Currency of the Cell

4.3a: ATP Breakdown Releases Free Energy

ATP consists of a five carbon sugar, ribose linked to the nitrogenous base adenine. The breakdown of ATP in an aqueous environment is a hydrolysis reaction.

4.3b: Energy Coupling Links the Energy of ATP to Other Molecules

Cells harness the high free energy available in ATP in a process called energy coupling. The exergonic release of energy when ATP is converted to ADP and P is used to drive an endergonic reaction.



4.3c: Cells also Couple Reactions to Regenerate ATP

ATP is a renewable resource that is made by recombining ADP and P. Food provides an abundant sources of energy. The continued breakdown and resysnthesis of ATP is called the ATP cycle.

6.1: The Cellular Basis of Cellular Respiration

Cellular respiration is defined as the collection of metabolic reactions within cells that breaks downs food molecules to produce ATP.

6.1a: Food is Fuel

The abundance of C-H bonds makes glucose good fuel.

<u>6.1b: Coupled Oxidation-Reduction Reactions are Central to Energy Metabolism</u>

The potential energy contained in fuel molecules is released when the molecules lose electrons, becoming oxidized. The electrons released from am molecule that is oxidized are gained by another molecule that becomes reduced. The involvement of oxygen is required for many common oxidation reactions.

<u>6.1c: Cellular Respiration is Controlled Combustion</u>

Within a cell the combustion of glucose undergoes a series of enzyme catalyzed reactions, each having a small activation energy. The most common energy carrier is the coenzyme nicotinamide adenine dinucleotide (NADH).

6.2 Cellular Respiration: An Overview

The primary goal of cellular respirations to transform the potential energy found in food molecules into a form that can be used for metabolic processes.

<u>6.2a: Cellular Respiration Can Be Divided into Three Phases</u>

The three phases of cellular respiration are

- *Glycolysis,* Enzymes break down a molecule of glucose into molecules of pyruvate.
- *Pyruvate Oxidation and the Citric Acid Cycle,* Acetyl-CoA if formed from the oxidation of pyruvate, enters a metabolic cycle where it is completely oxidized to carbon dioxide, some ATP and NADH is synthesized.
- *Oxidative Phosphorylation,* The NADH synthesized by both glycolysis and the citric acid cycle is oxidized, with the liberated electrons begin passed along an electron transport chain until they

are transferred to oxygen, producing water. The free energy released during electron transport is used to generate a proton gradient across a membrane, which in turn is sued to synthesize ATP.

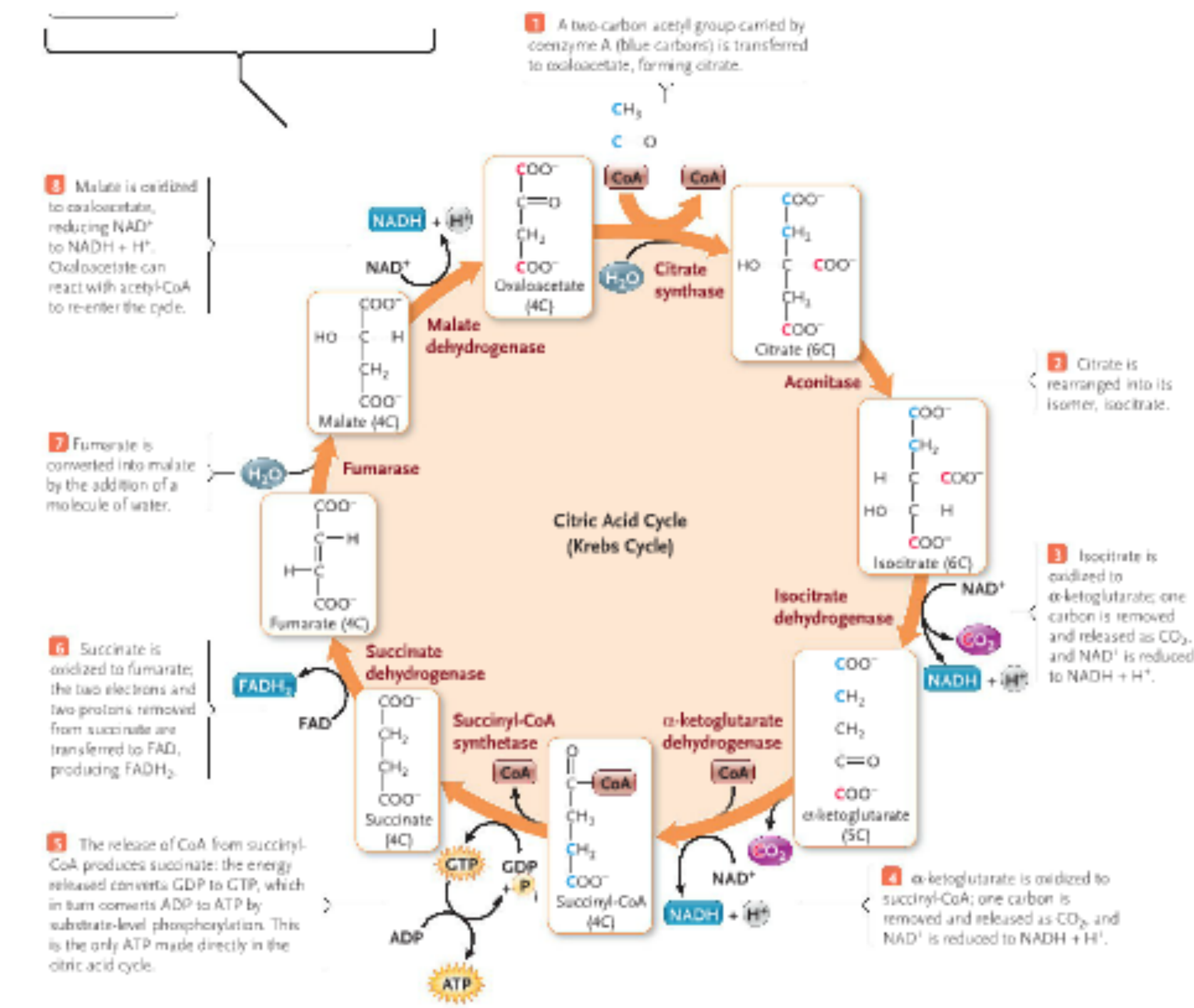
All three stages are required to extract the maximum amount of energy that is biologically possible.

6.2b: The Mitochondrion Is the Site of Cellular Respiration in Eukaryotes

In archaea and bacteria the citric acid cycle take place in the cytosol. In eukaryotic organisms the citric acid cycle and the oxidative phosphorylation occur in the mitochondria.

6.5 : Oxidative Phosphorylation: Electron Transport and Chemiosmosis

Following the citric acid cycle all the carbon atoms originally present in glucose have been completely oxidized and release as carbon dioxide. It is the role of the electron transport chain coupled with the process of chemiosmosis to extract the potential energy in these molecules and synthesize additional ATP.



6.5a: The Electron Transport Chains Converts the Potential Energy in NADH and FADH into a Proton-Motive Force

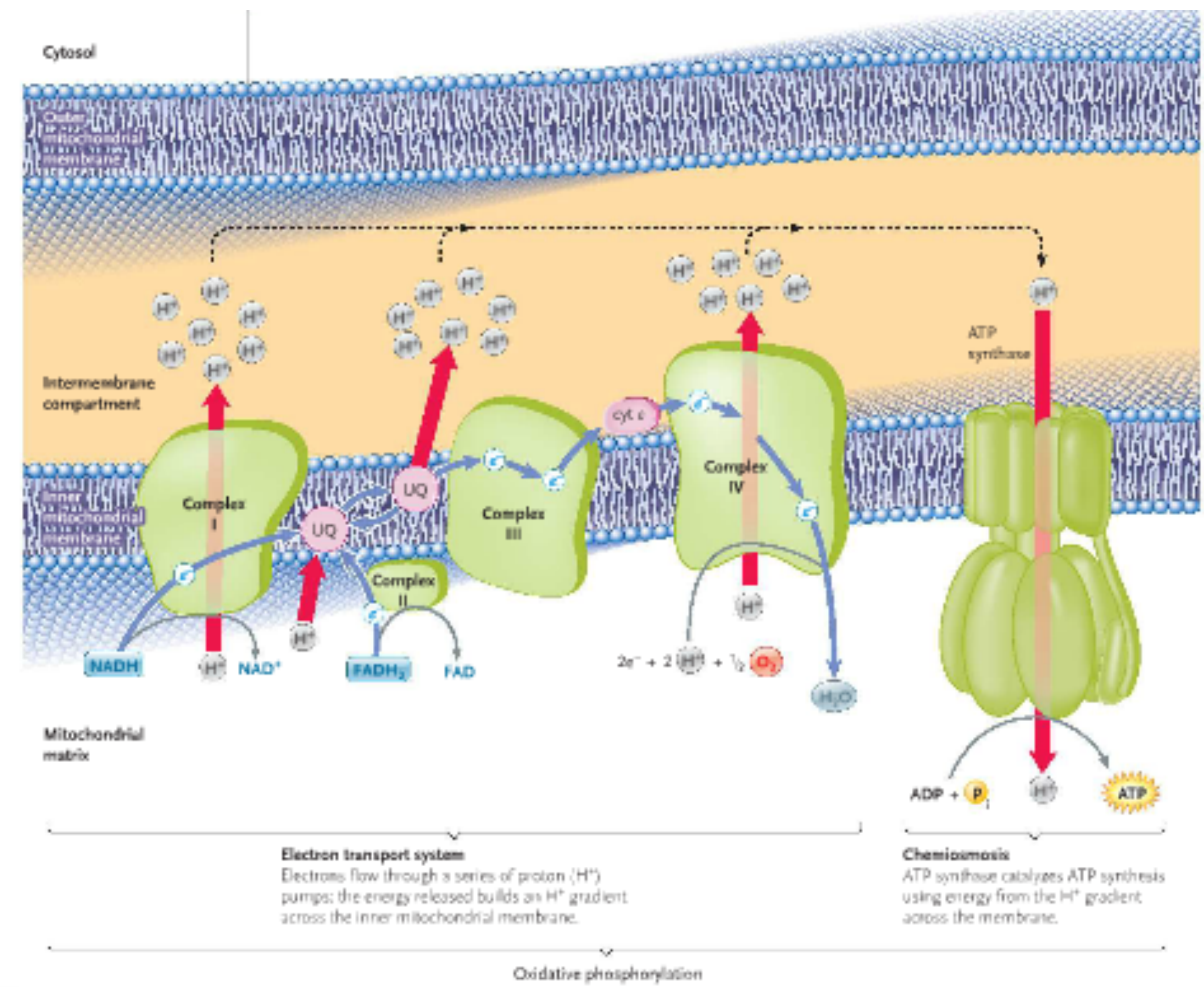
The chain facilitates the transfer of electrons from NADH and FADH to oxygen. The chain contains 4 protein complexes. Electron flow from one complex to another is facilitated by two mobile electron shuttles.

6.5b: Electrons Move Spontaneously Along the Electron Transport Chain

Electron transfer is facilitated by non-protein molecules called prosthetic groups. Prosthetic groups are redox-active cofactors that alternate between reduced and oxidized states as they accept electrons from upstream molecules and subsequently donate electrons to downstream molecules. This carries on until finally the electrons are donated to oxygen.

6.5c: Chemiosmosis Powers ATP Synthesis by a Proton Gradient

Although the goal of cellular respiration is the synthesis of ATP, electron transport from NADH or FADH to O does not actually produce any ATP. Electrons are simply passed along a chain of electron carriers until they are donated to O.



The combination of a concentration gradient and a voltage difference across the membrane produces stored energy known as the proton-motive force.

Harnessing the proton-motive force to do work is referred to as chemiosmosis. The mode of ATP synthesis that is linked to the oxidation of energy rich molecules by an electron transport chain is called oxidative phosphorylation, which relies on the ATP synthase.

6.5d: ATP Synthase is a Molecular Motor

The proton-motive force is what propels protons in the intermembrane space through the channel in the enzymes basal unit down the concentration gradient.

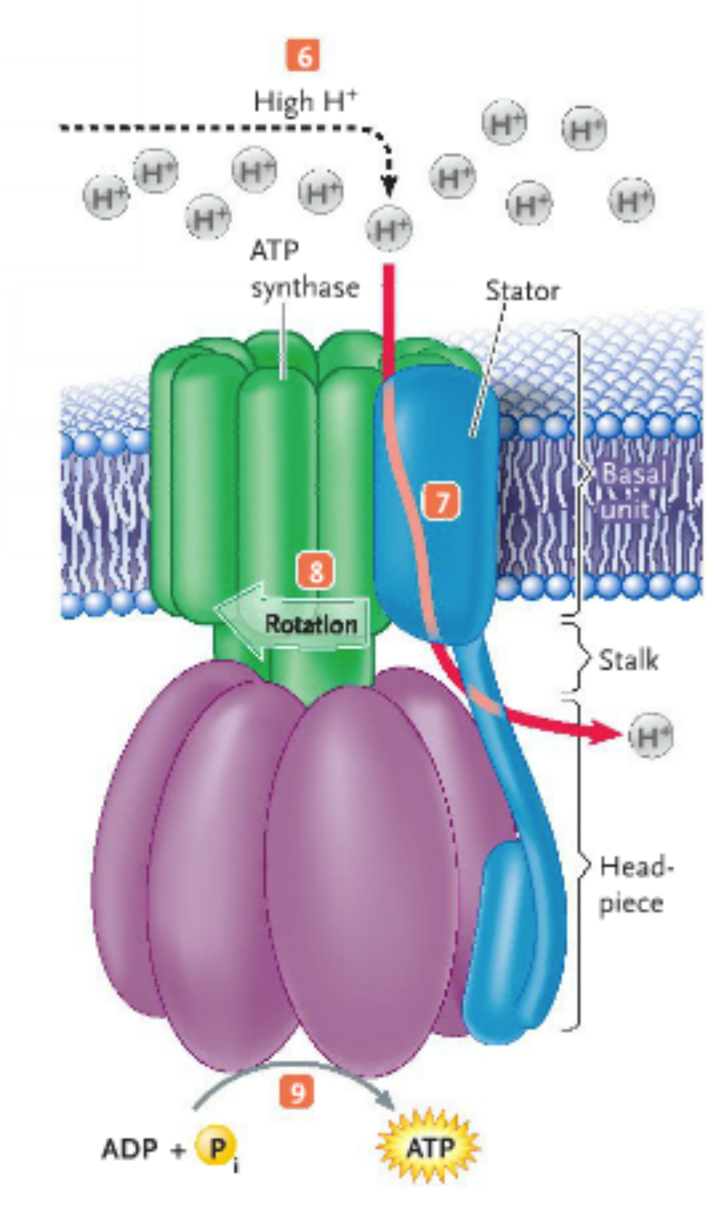


Figure 6.17
Detailed structure of ATP synthase—a molecular motor. The enzyme consists of a *basal unit*, which is embedded in the inner mitochondrial membrane, connected to a *headpiece* by a *stalk*, and with the *stator* bridging the basal unit and headpiece. Protons move through a channel between the basal unit and the stator, making the stalk and headpiece spin. This results in ATP synthesis.

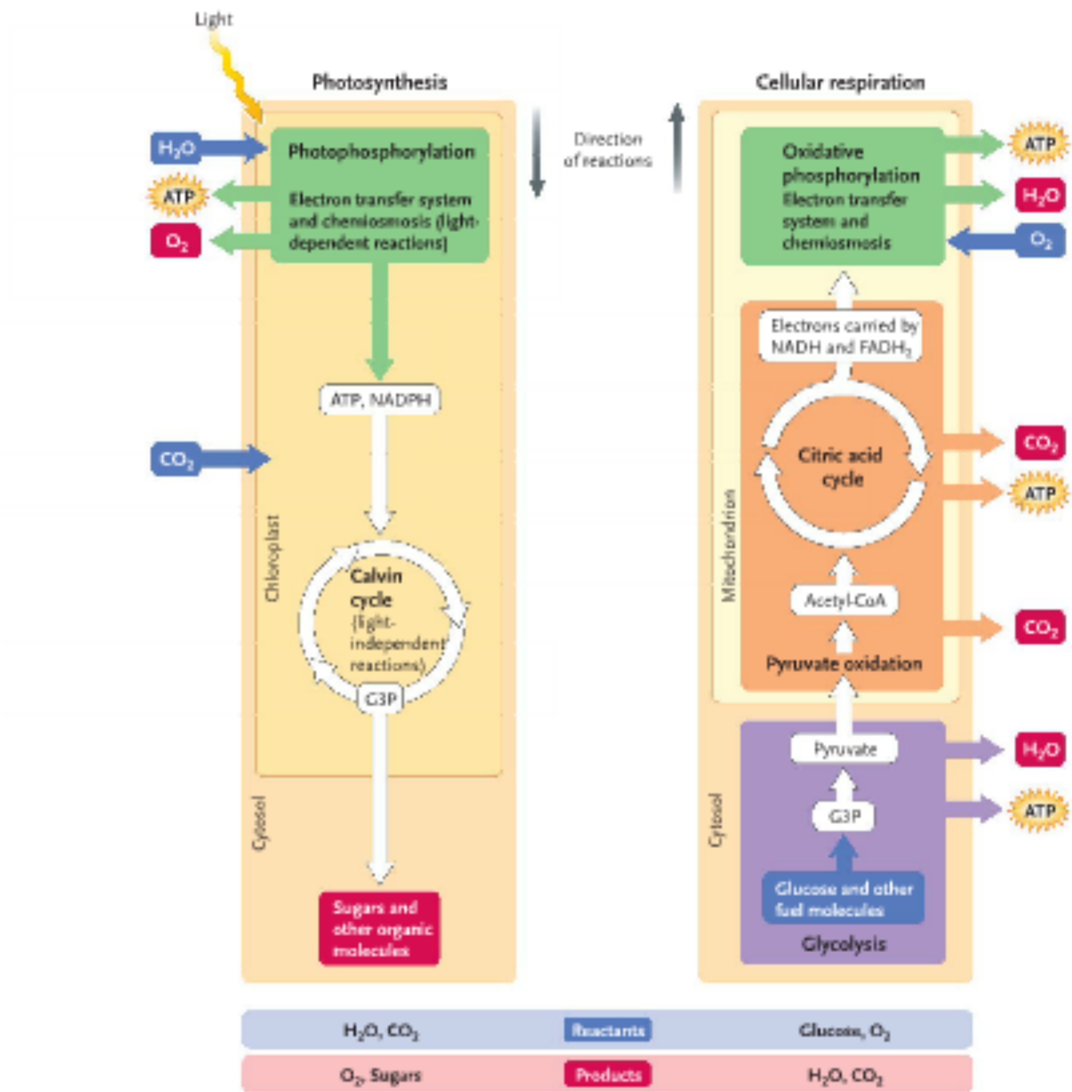


Figure 7.21

Schematic diagrams of the process of photosynthesis (left) and cellular respiration (right). Cellular respiration is shown upside down with respect to the direction of reactions to help illustrate the similarities of the process with photosynthesis.