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المحاضرة الاولى: ماهي الحياة

What is Life?

Introduction

In this chapter we will learn how living organisms change as they become better adapted to their environment. Over billions of years, these changes have produced a large number of different kinds of organisms. It has been estimated that there may be 15 to 30 million species of organisms living on earth.

Living organisms are comprised of the same chemical elements that make up nonliving things. They obey the same laws of physics and chemistry as nonliving objects. We can better understand what distinguishes living from nonliving by examining characteristics that all living organisms have in common. Some of these characteristics are discussed below.

Characteristics Common to All Living Organisms

Living things are composed of cells

Small organisms such as bacteria and many protists are composed of a single cell. Larger organisms are composed of many cells; they are ***multicellular***.

Living things are organized

The list below shows increasing levels of biological organization.

atoms
molecules
macromolecules
organelles
cells ← The smallest unit of life is the cell.
tissues
organs

organ systems
individual organism
population
community
ecosystem

.

Cells are considered to be the smallest structure that is alive. They are often too small to see without the aid of a microscope. All living organisms are composed of cells. The smallest organisms are composed of a single cell; larger organisms are composed of more than one cell.

Similar kinds of cells may be arranged together to form a ***tissue***. Tissues have specific properties and functions. For example muscle tissue is composed of muscle cells. It functions to move body components.

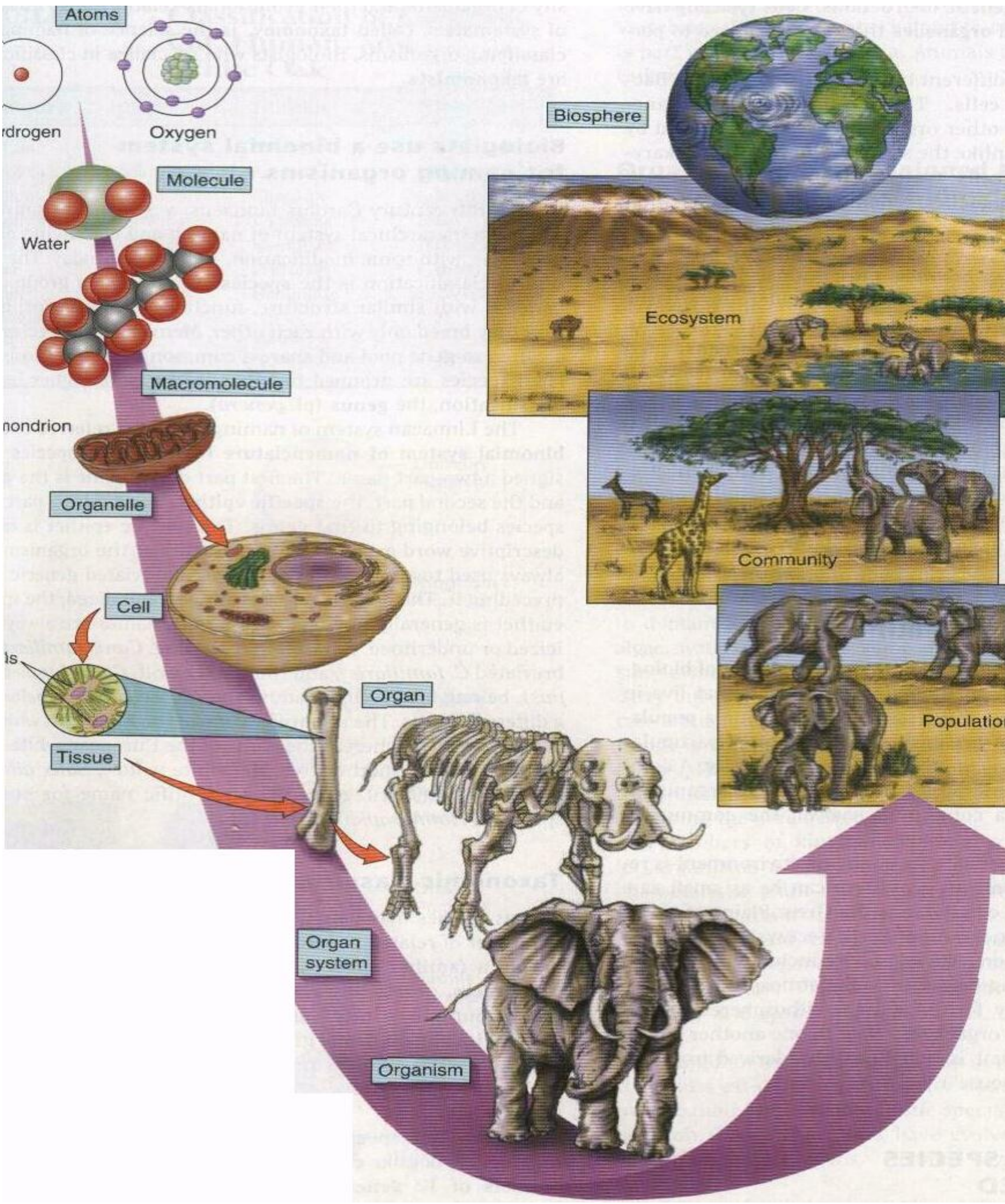
Two or more tissues that form a structure with a specific function is an ***organ***. For example, the heart is an organ formed from muscle tissue, nervous tissue, connective tissue, and epithelial tissue. It functions to pump blood.

An ***organ system*** consists of two or more organs which perform a specific task. Some organ systems are: the integumentary, nervous, sensory, endocrine, skeletal, muscular, circulatory, immune, lymphatic, digestive, respiratory, excretory, and reproductive systems.

A ***population*** is an interbreeding group of organisms (the same species) that occupies a particular area.

Two or more populations form a ***community***.

The word community refers to the organisms. The word ***ecosystem*** refers to the organisms of a community and also the nonliving environment.


Atoms
Oxygen
Molecule
Water
Macromolecule
Organelle
Cell
Tissue
Organ
Organ system
Organism
Population
Community
Ecosystem
Biosphere

Living things require nutrients and energy

Organisms need nutrients and energy for their activities, organization, growth, and maintenance.

Chemical reactions are needed to store and release energy and to synthesize compounds needed by the organism. The word ***metabolism*** refers to the chemical reactions that occur within a cell.

Energy cannot be created or destroyed, but it can be transferred from one form to another. In living organisms, it can be transferred from one chemical to another.

Plants, some algae, and some bacteria obtain their energy from light. The light energy is used to bond molecules of carbon dioxide together to form sugar (glucose). The energy is stored in glucose. This process is called photosynthesis. When a cell needs energy, chemical reactions within the cell are able to release this stored energy for it's needs. The energy stored in glucose can be used to form other chemicals. The new chemicals now contain some of the energy. Whenever energy is transferred from one chemical to another, a little is lost as heat. Animals that eat plants obtain their energy from the chemicals in the plants. As with plants, chemical reactions within the animal cells release the energy stored in their food and make it available for the cell.

Living things respond to their environment

Organisms must sense, interact with, and respond to their environment because they need nutrients and energy from the environment.

Organisms need to protect themselves to prevent other organisms from taking their energy (by eating them).

The internal environment of an organism fluctuates less than the external environment. For example the temperature of some organisms remains fairly constant even though the outside temperature fluctuates. The maintenance of constant internal conditions is called ***homeostasis***.

Living things contain DNA

The genetic instructions of all living organisms is contained in molecules of deoxyribonucleic acid.

Living things reproduce

Asexual Reproduction

The advantage of asexual reproduction is that it can produce large numbers of offspring very rapidly and it does not require a mate.

Asexual reproduction, however, produces offspring which are identical to the parent. Populations in which all of the individuals are identical are more likely to go extinct if the environment fluctuates. Moreover, these populations are less likely to change over time in response to environmental change.

Sexual Reproduction

Sexual reproduction requires two parents and thus promotes genetic variation. Populations which show variability are more likely to survive environmental fluctuations because there is an increased likelihood that at least some individuals are going to be able to survive due to their being better adapted.

Populations of living things evolve

Evolution refers to changes in the genetic composition of a population. Genetic changes may result in changes in the physical or behavioral characteristics of the individuals.

A ***mutation*** is a change in the genetic instructions (DNA) of an individual.

The change is usually harmful but occasionally it is beneficial.

Any beneficial mutations that occur are likely to spread within a population because individuals that possess the mutations will have higher reproductive output and they will reproduce the mutation. Beneficial mutations are therefore likely to result in evolutionary change.

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what is Biology ?

Biology (Greek. Bios= life; logos = science or study) is the science which deals with the study of living objects. The plants and animals are living objects. Biology has , thus , two branches:
Botany or Plant Biology. (Greek. Botane = herb or plant is the study of plants).
Zoology or Animal Biology (Greek. Zoon = animal) is the study of animals.

BRANCHES OF ZOOLOGY
There are several branches of Zoology. They deal with different aspects of animal life. The most important branches of Zoology are following :
1. Morphology : It is the study of external and internal form structure of the animals. It is studied under two branches :
(a) External Morphology : It is the study of external structure of animals.
(b) Internal Morphology : It is the study of internal structure of animals. It has three sub-branches:
(i) Anatomy : It is the study of the of different parts of internal structure^fr animal as seen by the naked eye after dissection.
(ii) Histology : it is the study of the microscopic structure of the tissues of which the animal body *is* composed.
(iii) Cytology : It ii the detailed Microscopic study of a cell and its contents
2. Physiology : It deals with the bodily functions of the animals such as nutrition, respiration, excretion, movements, reproduction etc.
3. Taxonomy or Systematic Zoology : It deals with the classification and naming of animals.
4. Ecology : It is the study of animals in relation to their environments such as temperature, heat, water, soil etc.
5. Embryology : It is the study of the development of an animal from egg to adult.

6. Paleontology or Pales-Zoology : It is the study of fossils which are the stonified remains or impressions of the animals which existed in the past.
7. Zoo-geography : It is the study of distribution of animals in different parts of the world.
8. Pathology : It deals with the animal diseases caused by other animals or plants.
9. Economic Zoology : It deals with the economic importance of animals.
10. Evolution : It is tlie study of the origin of new and complex forms from older and simpler forms by modifications due to changed conditions (adaptations).
11. Genetics: It is the study of Heredity and Variations. *Heredity is the transmission of characters from parents to offspring. Variations are the differences which occur in structure and functions among individuals of the same species.*
12. Eugenics: It is the study of improvement of human races.
13. Euthenics : It is the study of environment and its influence on mankind.

. Space Zoology : It is the study of survival problems of animals in the
١٤outer space.
15. Molecular Biology : It, is the study of living objects up to molecular level.
16. Parasitology : It is the study of parasitic forms.
17. Natural History : It is the study of habits of animals.
18. Ethology : It is the study of behaviour of animals in response to stimuli.

Besides this, there are certain specialized branches of Zoology. They deal with particular kinds of animals or their particular systems. The following are some important pecies branches:
(i) Protozoology : It deals with the study of Protozoa (uni-cellular animals).
(ii) Helminthology : It deals with the study of worms
(iii) Entomology ; It is the study of insects,.
(iv) Malacology : It is the study of Molluscs,
(v) Ichthyology ; It is the study of fishes,
(vi) Herpetology : It is the study of snakes and lizards,
(vii) Ornithology : It is the study of birds,
(viii) Mammalogy : It is the study of mammals.
(Ix) Osteology : It is the study of skeleton of animals,
(x) Myology : It *a* the study of muscular system of animal,

(xi) Syndesmology : It is the study of joints of animals,
(xii) Angiology: It is the study of circulatory system *of animals.*
(xiii) Splanchnology: It is the study of visceral system of animals,
(xiv) Neurology : It is the study of nervous system of animals
(xv) Endocrinology: It is the study of endocrine glands. *(xvi)* Virology: It is the study of viruses.
(xvii) Anthropology : It deals with the study of physical *and* social nature of primitive and modern man.
(xviii) Haematology : It is the study of blood.

The above branches mostly deal with the basic phenomenon of animal life. They are put together as a sub-division of zoology called pure zoology.

There is another sub-division of zoology-44«d applied zoology. This includes those branches of zoology which are of economic value to man. The main branches of applied zoology are the following :
(i) Medicine : It deals with the study of curing the diseases of man by drugs.
(ii) Surgery : It is the study of removal of human sufferings by surgical operations.
(iii) Dietetics : It is the study of nutrition.
iv) Dentistry: It is the study of teeth.
(v) Veterinary science : It deals with the study of domestic animals.
(vi) Fishery or Pisciculture : It deals with the study of rearing fish.
(vii) Sericulture : It is the study of rearing silk-worm for silk.
(viii) Apiculture :It deals with the study of bee-keeping for obtaining honey and wax
(ix) Poultry: It is the study of raising fowl for eggs and meat
(x) Dairying: It is the study of keeping cattle (buffaloes and cows)
(xi) Piggery: It is the study of keeping pigs for meat for milk. and pickles.
(xii) Animal husbandry : It deals with the study of breeding and care of animals,
(xiii) Hygiene : It deals with the health problems of man.

Because of recent researches with new techniques, modern Biology is divided into the following branches :
(i) Molecular Biology: It deals with the study of various aspects of Biology at the molecular level.
(ii) Cellular Biology: It deals with the structure and functions of the

cells.
(iii) Organisms Biology: It deals with the anatomy, physiology, ecology and phylogeny of whole organisms.
(iv) Developmental Biology: It is the Study of development, healing and aging of organisms.
(v) Population Biology: It is the study of biological principles *(i.e.* food chains, energy flow ecological crisis etc.) observed in ecosystems.
(vi) Space Biology: It deals with the study of survival problems of plants and animals in the outer space.
(vii) Applied Biology: It is the study of application of biological laws to improve the economy of man and to eradicate diseases.
(viii) Radio-biology: It deals with the study of effects of radioactivity on biological system
(ix) Marine Biology: It is the study of marine life.
(x) Immunology: It is the study of immunity i.e. resistance of organism against infection.
(xi) Ethology: It is the study of behaviour of animals.
(xii) Pollution: It is the study of pollution of water, air and atmosphere and their check and Control measures

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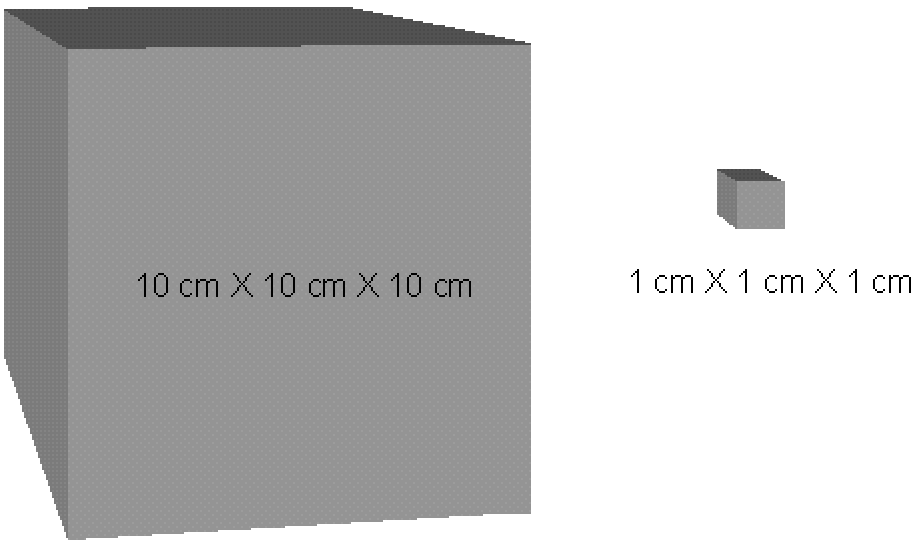
المحاضرة الثالثة: الخلايا

Cells

Exercise - Surface:Volume

Compare the surface to volume ratio (surface:volume) of a cube that is 1 cm X 1 cm X 1 cm with that of a cube that is 10 cm X 10 cm X 10 cm.



Smaller cube (1 cm X 1 cm X 1 cm)

The surface area of one side = 1 cm X 1 cm = 1 square cm (or 1 cm^2).

There are 6 sides, so the total surface area = 6 X cm^2 = 6 cm^2.

Volume = 1 cm X 1 cm X 1 cm = 1 cubic cm (or 1 cm^3)

Surface:Volume = 6 cm^2/1 cm^3 = 6 cm^2/cm^3 (or 6 square cm of surface area for each cubic cm of volume)

Larger cube (10 cm X 10 cm X 10 cm)

The surface area of one side = 10 cm X 10 cm = 100 square cm (or 100 cm^2).

There are 6 sides, so the total surface area = 600 X cm^2 = 600 cm^2.

Volume = 10 cm X 10 cm X 10 cm = 1000 cubic cm (or 1000 cm^3)

Surface:Volume = 600 cm^2/1000 cm^3 = 0.6 cm^2/cm^3 (or 0.6 square cm of surface area for each cubic cm of volume).

Cells

Notice that the larger cube has more surface area and more volume but less surface area for each cubic centimeter of volume. For any given geometric object (cubes, spheres, etc.), smaller objects have a greater surface to volume ratio (surface:volume) than larger objects of the same shape.

Every cell is surrounded by a plasma membrane (discussed below and in the next chapter). Most cells are very small and therefore have a high ratio of plasma membrane surface to cell volume.

Cell Theory

All organisms are composed of cells, and a cell is the smallest unit of living matter.

Cells come only from preexisting cells.

Major Kinds of Cells

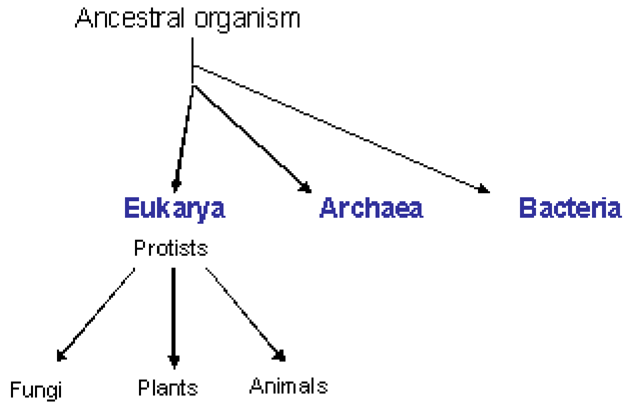
Prokaryotic Cells

Bacteria are prokaryotes. Their cells are very small and very simple. They will be discussed later.

Eukaryotic cells

All other cells are eukaryotic cells. These include protists, fungi, plants, and animals.

The diagram below shows evolutionary relationships between bacteria, archaea, and the four kingdoms of eukaryotic organisms.



Eukaryotic Cells

Cells contain structures called ***organelles***. The structure and function of the major organelles found in eukaryotic cells are described below.

Plasma membrane

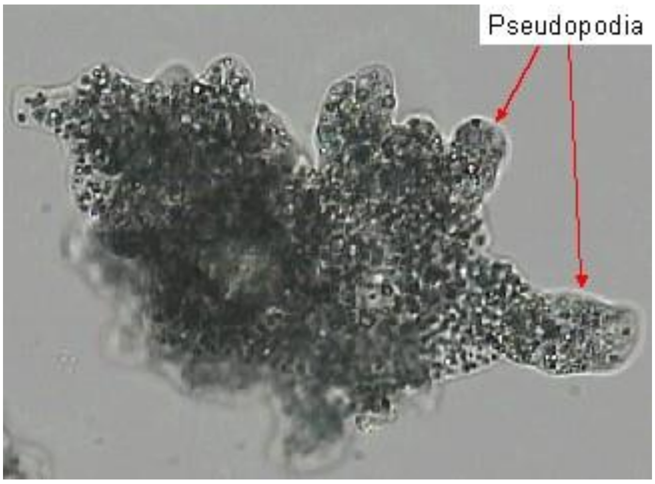
All cells are surrounded by a plasma membrane. It separates the contents of the cell from its environment and regulates the passage of molecules into and out of the cell.

The membrane contains proteins that have a variety of functions. For example, some proteins are receptors which can detect the presence of certain kinds of molecules in the surrounding fluids. The function of membrane proteins will be discussed in more detail in the chapter on membranes.

An actively metabolizing cell needs a large surface area. Cells are limited in size because larger cells have a smaller surface to volume ratio.

Cells that are specialized for absorption (ex: intestinal cells) have folds in the plasma membrane called ***microvilli*** that increase the surface area.

Pseudopodia are temporary extensions of the plasma membrane used for movement or to engulf particles. Pseudopodia can be seen in the *Amoeba* below.

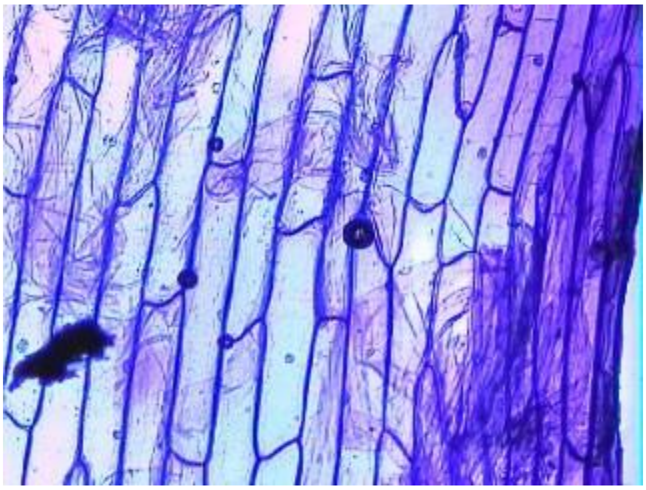


Cell Wall

The cell wall functions to support and protect the cell.

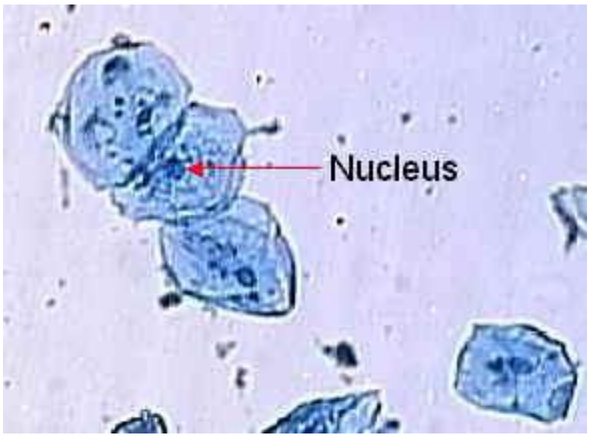
Plants have cell walls composed of cellulose; fungi have walls composed of chitin.

The cell walls of these onion skin cells can be easily seen.



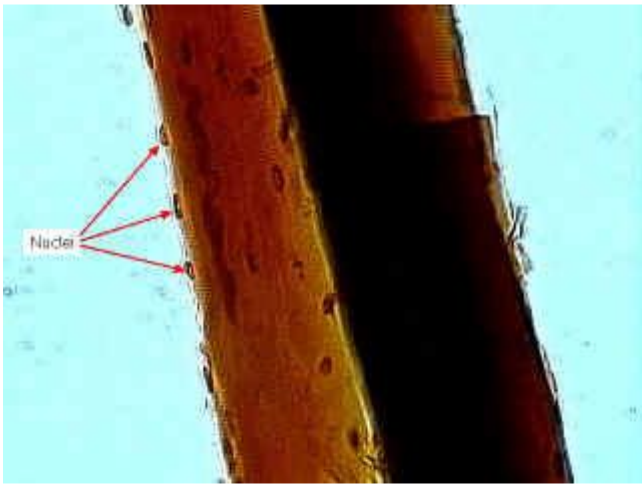
Nucleus

The nuclei can be seen in the photograph of human cheek cells below.



The nucleus contains DNA; it is therefore the control center of the cell because DNA contains instructions needed to produce proteins that control metabolism and other cell functions.

One nucleus can serve a limited amount of cytoplasm, so large cells are often ***multinucleate***, that is, they contain several nuclei.



Teased skeletal muscle X 200

Note the many nuclei visible in the cell on the left.

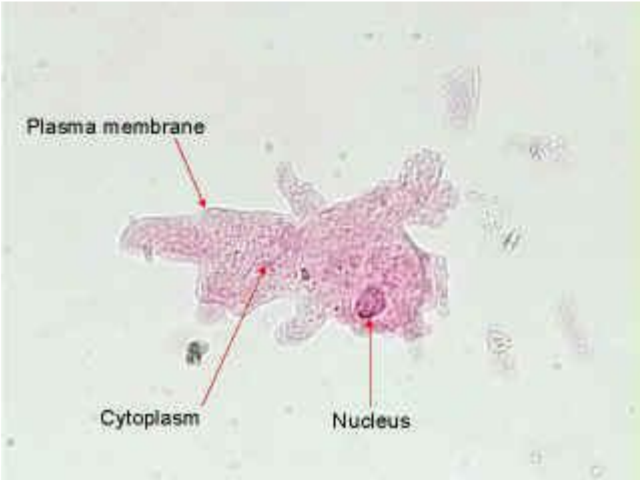
Chromatin is the grainy threadlike DNA. During cell division, the nuclear membrane disintegrates and the DNA becomes coiled producing visible structures called ***chromosomes***.

The material within the nucleus is referred to as the ***nucleoplasm***.

A double membrane (nuclear envelope) surrounds the nucleus. ***Nuclear pores*** allow materials to pass into and out of the nucleus.

Cytoplasm

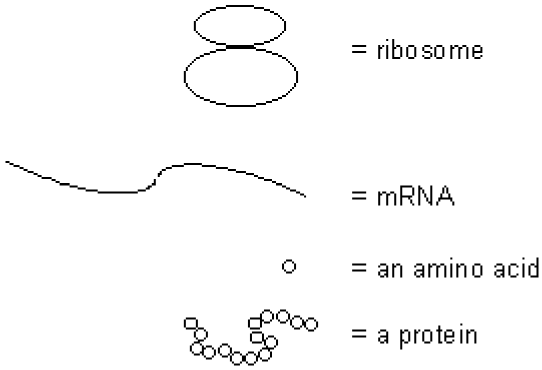
Cytoplasm is the material enclosed by the plasma membrane, excluding the nucleus.

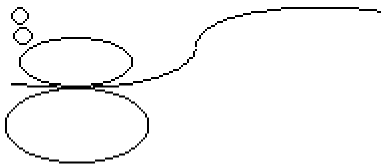


Ribosomes

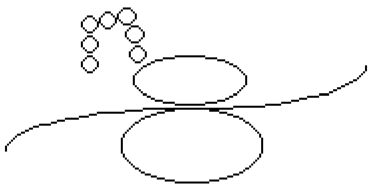
Ribosomes read the code in mRNA and synthesize protein accordingly.

The symbols to the right are used in the drawings of protein synthesis below.

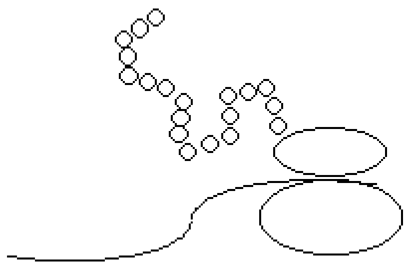




The ribosome attaches to the mRNA.



As ribosomes move along messenger RNA (mRNA), the amino acids are added to a growing chain to form a particular protein. In these drawings, the ribosome moves from left to right.



In this drawing, the protein is nearly complete. When the ribosome reaches the end of the genetic message, it will become detached from the mRNA.

Several ribosomes may be attached to a strand of mRNA forming a unit called a polysome.

A ribosome is composed of 2 subunits. In eukaryotic cells, the subunits are synthesized in the ***nucleolus*** and move into the cytoplasm. During the process of protein synthesis, two subunits will come together along with mRNA..

Ribosomes are composed of both ***RNA*** (called ribosomal RNA or rRNA) and ***protein***.

Ribosomes in eukaryotes about 1/3 larger than those in prokaryotes.

Nucleolus

The nucleolus is a structure within the nucleus where the ribosomal subunits are produced.

In cells that have been stained, it appears darker than the nucleus.

Endoplasmic Reticulum

The endoplasmic reticulum is a membranous network that extends throughout the cell.

It is continuous with the nuclear envelope and the plasma membrane.

Rough Endoplasmic Reticulum

The rough appearance of rough endoplasmic reticulum is due to the presence of ribosomes on the membrane.

The rough ER functions in protein synthesis, especially proteins that are to be secreted to outside the cell (example: hormones). Proteins enter the lumen (interior) of the endoplasmic reticulum while being synthesized.

In addition to protein synthesis, the rough endoplasmic reticulum also functions in the modification of newly formed proteins. For example, some enzymes may add carbohydrate chains forming glycoproteins. Other enzymes function to fold the newly-synthesized proteins into their proper shape.

Vesicles are small sacs that pinch off the endoplasmic reticulum or Golgi apparatus (discussed below) and transport molecules to other parts of the cell.

Smooth Endoplasmic Reticulum

Smooth endoplasmic reticulum has no ribosomes attached to it. It is continuous with rough endoplasmic reticulum.

The smooth endoplasmic reticula have a variety of different functions but often function to produce lipid compounds such as phospholipids, steroids, and fatty acids.

Certain kinds of cells have smooth endoplasmic reticulum with a specialized function. The following are some examples:

Smooth endoplasmic reticulum is abundant in the adrenal cortex and the testes where it produces steroid hormones.

The smooth endoplasmic reticulum of liver cells helps detoxify drugs in the blood.

Calcium ions needed for contraction are stored in the smooth endoplasmic reticulum of muscle cells.

Vesicles pinch off the smooth endoplasmic reticulum and carry materials to other parts of the cell such as the plasma membrane or Golgi apparatus.

Golgi Complex (also Golgi Apparatus or Golgi Body)

The Golgi complex is a stack of 3 to 20 flattened, slightly curved saccules which appear like a stack of pancakes.

It receives vesicles that contain molecules from the endoplasmic reticulum. Chemical reactions within the Golgi complex modify the molecules. Materials are passed from one saccule to the next through vesicles that form at the end of the saccule, pinch off, and fuse with the next. Processed molecules are pinched off in a vesicle.

Vesicles arriving at the Golgi complex from the endoplasmic reticulum are received into the forming face. The processed molecules leave at the maturing face.

Lysosomes

Lysosomes are membrane-bound vesicles containing *hydrolytic* (digestive) enzymes produced by the Golgi complex.

They fuse with other vesicles formed around material that has entered the cell, allowing the digestion of the vesicle contents. For example, bacteria that are engulfed by white blood cells are destroyed by enzymes contained within the lysosomes.

Cells also use lysosomes to kill themselves. This important process occurs during the formation of fingers during embryonic development, the reduction in the size of a tadpole tail as it matures, and the abscission of tree leaves in the autumn.

Peroxisomes

Peroxisomes are vesicles that contain enzymes which oxidize (remove hydrogen) from a variety of different compounds and pass the hydrogen to oxygen. During these reactions, hydrogen peroxide (H_2O_2) is formed. Hydrogen peroxide is toxic but the enzyme ***catalase*** converts it to water and oxygen.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Vacuoles

Vacuoles are membranous sacs similar to, but larger than vesicles.

Vacuoles store water and dissolved substances.

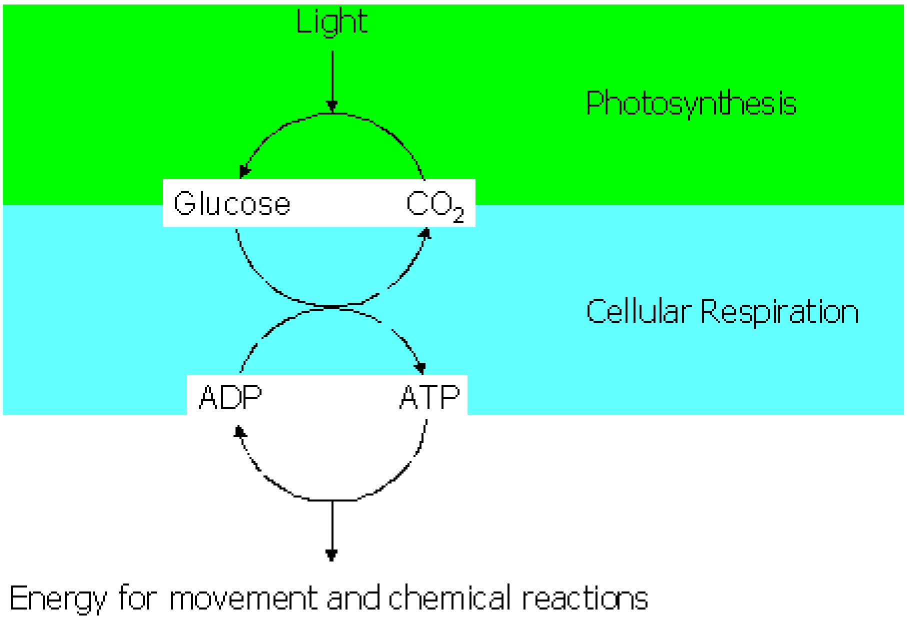
They are more important in plant cells. Most of the center of a plant cell is occupied by a ***central vacuole.***

The central vacuole gives support because pressure within the vacuole makes the cell rigid (turgid). The cell wall prevents the cell from bursting.

Some protists have specialized ***contractile vacuoles*** for eliminating excess water and ***food vacuoles*** that contain food within the cell.

Chloroplasts

The diagram below illustrates how energy from sunlight is used for the energy requirements of cells.

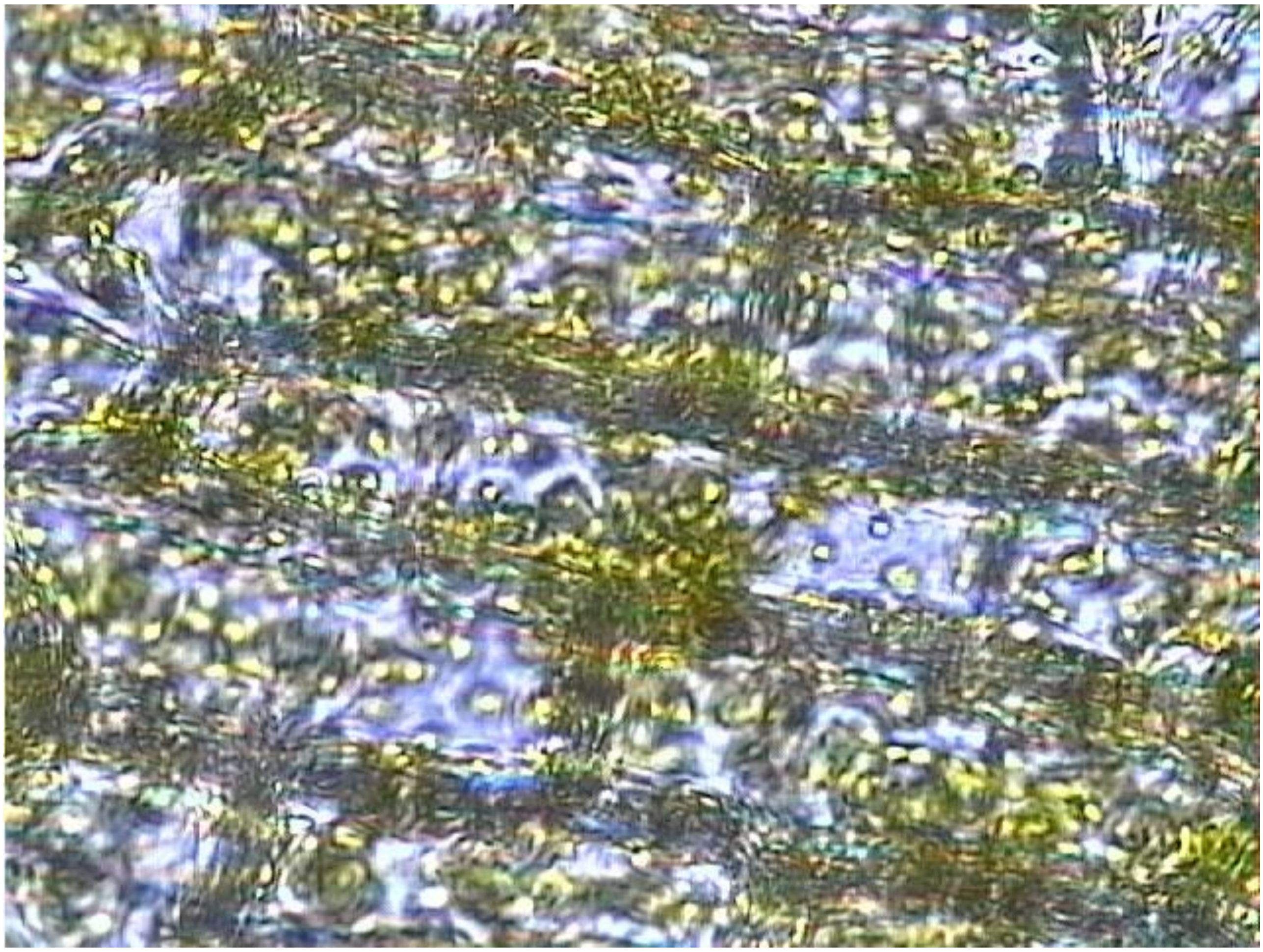


Photosynthesis is a process by which light energy is used to make sugar from CO_2 and H_2O. The equation that summarizes these reactions is:

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

In eukaryotes, photosynthesis occurs in ***chloroplasts***. Photosynthetic prokaryotes do not have chloroplasts.

The photograph below is an *Elodea* leaf (X 400). The numerous green structures are chloroplasts.



A double membrane surrounds the chloroplast.

Chloroplasts contain membranous disk-like structures called ***thylakoids*** that are stacked together in larger structures (grana) that resemble stacks of coins (see diagram below). Molecules that absorb light energy (called photosynthetic pigments) are located in the thylakoid membranes.

The fluid-filled space surrounding the grana is the ***stroma***. Many enzymes needed in photosynthesis are found embedded in the thylakoid membranes and in the stroma.

The diagram below shows a chloroplast that has been cut lengthwise to reveal the interior.

Cellular Respiration

Cellular respiration refers to the chemical reactions that break down glucose to CO_2 and H_2O, releasing the energy stored within its bonds.

The energy is temporarily stored in the bonds of ATP (adenosine triphosphate).

ADP + P_i + energy $\rightarrow$ ATP

This process requires oxygen in ***aerobic*** organisms. ***Anaerobic*** organisms do not require oxygen, but produce much less ATP per glucose molecule.

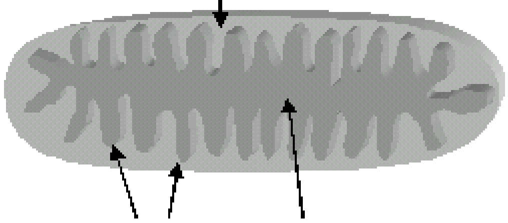
Aerobic cellular respiration occurs in the ***mitochondria***.

Prokaryotes do not have mitochondria.

Mitochondria

Mitochondria have an external membrane and an inner membrane with numerous folds called ***cristae***.

The cristae that project into the gel-like ***matrix.*** Enzymes involved in cellular respiration are found in the matrix and embedded in the membrane of the cristae.



Cytoskeleton

The cytoskeleton is a network of protein elements that extend through the cytoplasm in eukaryotic cells.

It provides for the distinctive shape of cells such as red blood cells, muscle cells, and nerve cells (neurons). It produces movement of cells and is associated with movement of materials within cells.

It is composed of three types of protein fibers: ***microtubules***, ***actin filaments***, and ***intermediate filaments***. The general function of each of these is listed in the table below.

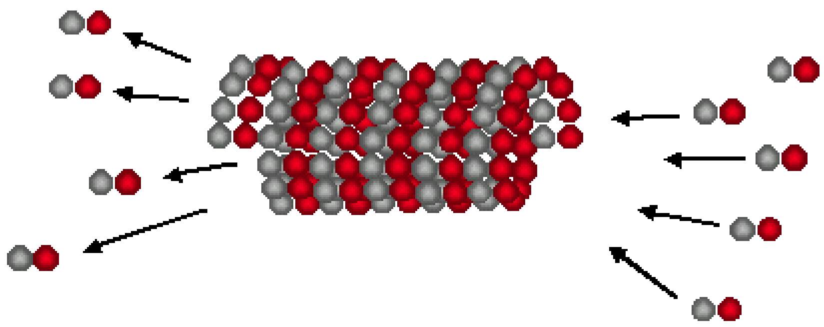
Cytoskeleton Element	General Function
Microtubules	Move materials within the cell Move the cilia and flagella
Actin Filaments	Move the cell
Intermediate Filaments	Provides mechanical support

Microtubules

Microtubules are small cylindrical fibers that change in length by assembling (polymerizing) and disassembling (depolymerizing).

They are made of a protein called tubulin. Tubulin dimers are arranged to form a long hollow cylinder.

The fibers are lengthened and shortened as tubulin dimers assemble or disassemble from one or both ends of the filament.



The assembly of microtubules is controlled by an area near the nucleus called the ***centrosome*** or microtubule organizing area..

Microtubules act as tracts along which organelles can move. For example, they are associated with movement of vesicles from the Golgi complex to the plasma membrane.

Microtubules are responsible for the movement of cilia and flagella.

They move the chromosomes during cell division.

Cilia and Flagella

Cilia and ***flagella*** are hairlike structures projecting from the cell that function to move the cell by their movements. They contain cytoplasm and are enclosed by the plasma membrane.

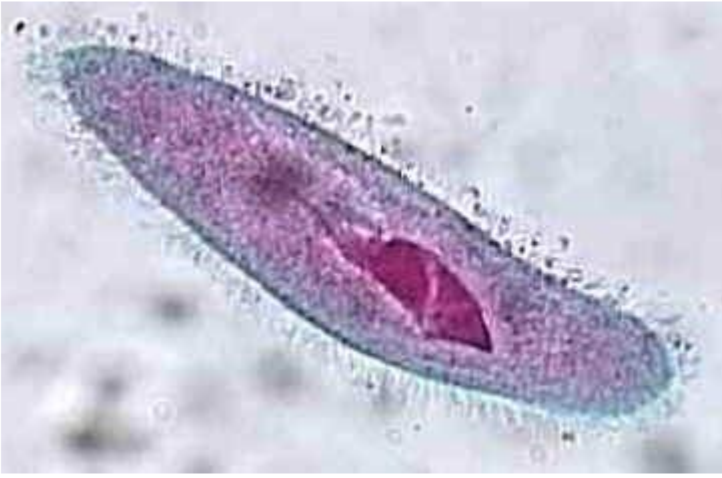
Cells that contain cilia are ***ciliated***.

Cilia are shorter than flagella but are similar in construction.

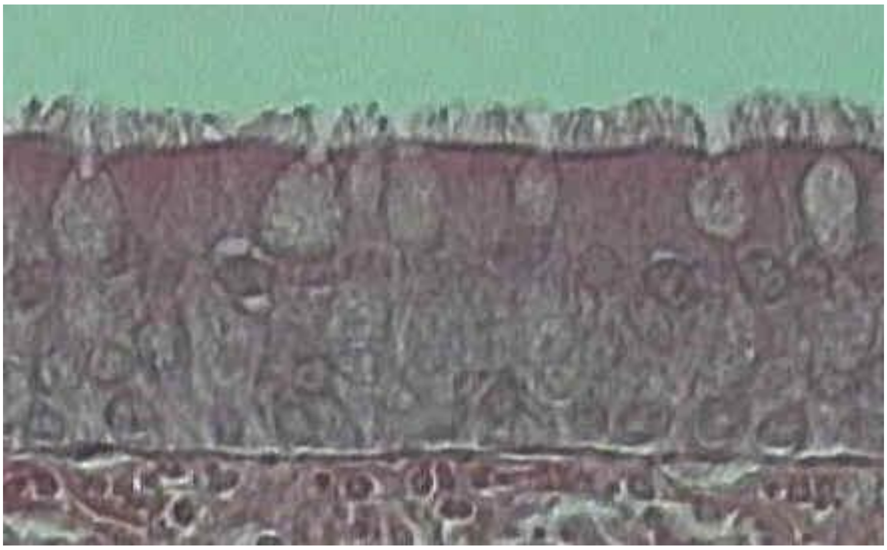
Examples:

Sperm use flagella to move.

Many kinds of single-celled organisms such as the *Paramecium* in the photograph below move by cilia or flagella. The cilia can be seen covering the cell in the photograph.

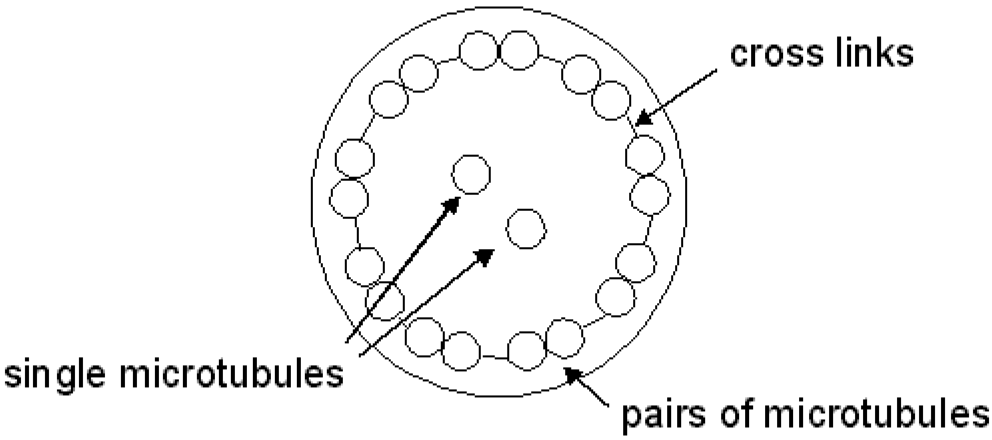


Cells lining the human upper respiratory tract are ciliated (have cilia). The cilia move mucous and debris upward to the mouth where it is swallowed. The photograph below is a cross section of a human trachea (400 X). Note the cilia on the upper surface.



Eukaryotes have 9 doublets (pairs) of microtubules arranged in a circle around 2 central microtubules. This 9 + 2 pattern is characteristic of all eukaryotic cilia and flagella but not those of prokaryotes.

The pairs of microtubules are cross-linked. The shifting positions of the cross-links move the cilia or flagella.



Basal Body

Each cilium or flagellum has a ***basal body*** located at its base.

Basal bodies anchor the cilia or flagella and are thought to be responsible for their formation.

Basal bodies contain triplets of microtubules along the periphery but do not have central microtubules (9 + 0).

They look like centrioles (discussed below) and are believed to be derived from them.

Centrioles and Centrosome

The structure of centrioles is similar to that of basal bodies in that they have 9 triplets of microtubules. Centrioles occur in pairs; each one oriented at a right angle to the other.

Centrioles are contained within a structure called a ***centrosome***. The centrosome and centrioles are involved in the formation of the microtubules.

Actin Filaments (Microfilaments)

Actin filaments are long, thin fibers composed of 2 chains of protein wrapped around each other.

They occur in bundles or meshlike networks which provide mechanical support and determine the shape of the cell.

Because they can assemble and disassemble quickly, the shape of a cell can change rapidly.

Movement in eukaryotic cells

Actin filaments assist in the movement of nearly all eukaryotic cells.

Microvilli and pseudopodia move by the action of actin filaments.

Actin filaments are important in muscle contraction.

During cell division a ring of actin filaments that surrounds the cell constricts, pinching the cell into two.

The chloroplasts of plant cells move (circulate) by following actin filaments, a process called ***cytoplasmic streaming***.

Intermediate Filaments

Intermediate filaments are composed of long, threadlike protein molecules wrapped around one another like the strands of a cable.

As the name suggests, they are intermediate in size. Actin filaments are smallest and microtubules are largest.

Intermediate filaments are important in maintaining the cell's shape, providing mechanical support; preventing excessive stretching, and supporting other organelles. For example, some intermediate filaments support the plasma membrane and others support the nuclear membrane. Skin cells contain intermediate filaments that provide mechanical strength. They also function to attach cells together (desmosomes).

Prokaryotic Cells

Prokaryotic cells are small; eukaryotic cells are typically 10 times bigger in diameter and 100 to 1000 times bigger in volume.

Prokaryotic cells do not have a true ***nucleus***. They have few organelles, and have ***no membrane-bound organelles***. In cyanobacteria, the cell membrane folds inward in a number of places allowing for the attachment of enzymes.

The DNA of prokaryotes is a single, circular ***chromosome*** located in a region called the ***nucleoid***. There may be small rings of accessory DNA called ***plasmids***.

Some prokaryotic cells are photosynthetic (example: cyanobacteria).

The cells have a cell wall and some contain a gelatinous sheath outside the cell wall.

Motile bacteria have ***flagella***.

Prokaryote ***ribosomes*** are smaller than those in eukaryotes.

Cell reproduction is by ***binary fission***, not mitosis. By this process, a second chromosome is produced that is an identical copy of the first. The cell elongates and the chromosomes separate so that each new cell receives a chromosome. The elongated cell pinches into two, forming two cells each with one chromosome.

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المحاضرة الرابعة: الاغشية

Membranes

Plasma Membrane

The plasma membrane surrounds the cell and functions as an interface between the living interior of the cell and the nonliving exterior.

All cells have one.

It regulates the movement of molecules into and out of the cell.

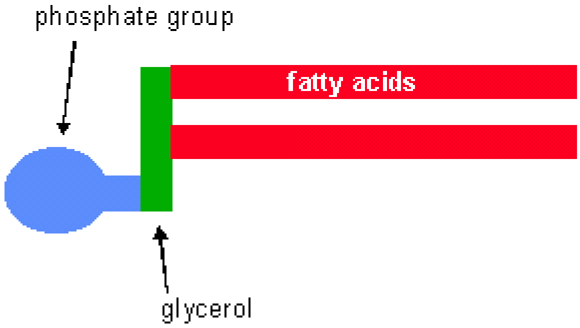
Membrane Structure

The **fluid-mosaic model** states that membranes are phospholipid bilayers with protein molecules embedded in the bilayer.

Phospholipids

Most of the lipids in a membrane are phospholipids.

Phospholipids contain glycerol, two fatty acids, and a phosphate group. The phosphate group is polar (***hydrophilic***), enabling it to interact with water. The fatty acid tails are nonpolar (***hydrophobic***) and do not interact with water.

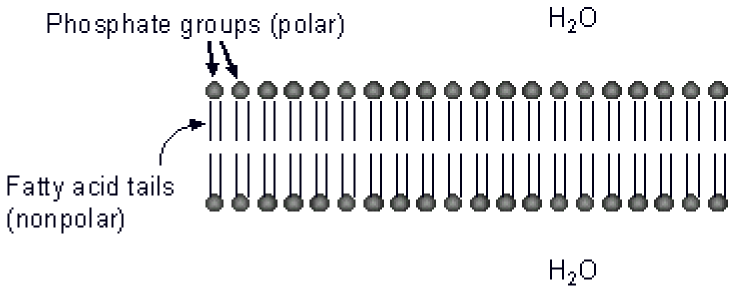


Phospholipid Bilayers

Phospholipids spontaneously form a bilayer in a watery environment. They arrange themselves so that the polar heads are oriented toward the water and the fatty acid tails are oriented toward the inside of the bilayer (see the diagram below).

In general, nonpolar molecules do not interact with polar molecules. This can be seen when oil (nonpolar) is mixed with water (polar). Polar molecules interact with other polar molecules and ions. For example table salt (ionic) dissolves in water (polar).

The bilayer arrangement shown below enables the nonpolar fatty acid tails to remain together, avoiding the water. The polar phosphate groups are oriented toward the water.



Flexibility

The fatty acid tails are flexible, causing the lipid bilayer to be fluid. This makes the cells flexible. At body temperature, membranes are a liquid with a consistency that is similar to cooking oil.

Cholesterol

In animals, cholesterol is a major membrane lipid. It may be equal in amount to phospholipids.

It is similar to phospholipids in that it one end is hydrophilic, the other end is hydrophobic.

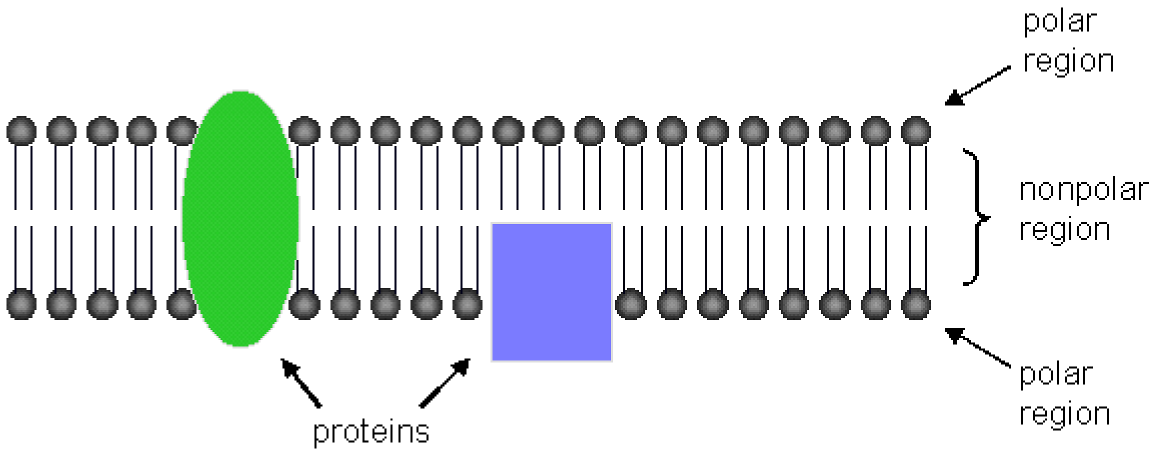
Cholesterol makes the membrane less permeable to most biological molecules.

Proteins Embedded in the Membrane

Proteins are scattered throughout the membrane.

They may be attached to inner surface, embedded in the bilayer, or attached to the outer surface.

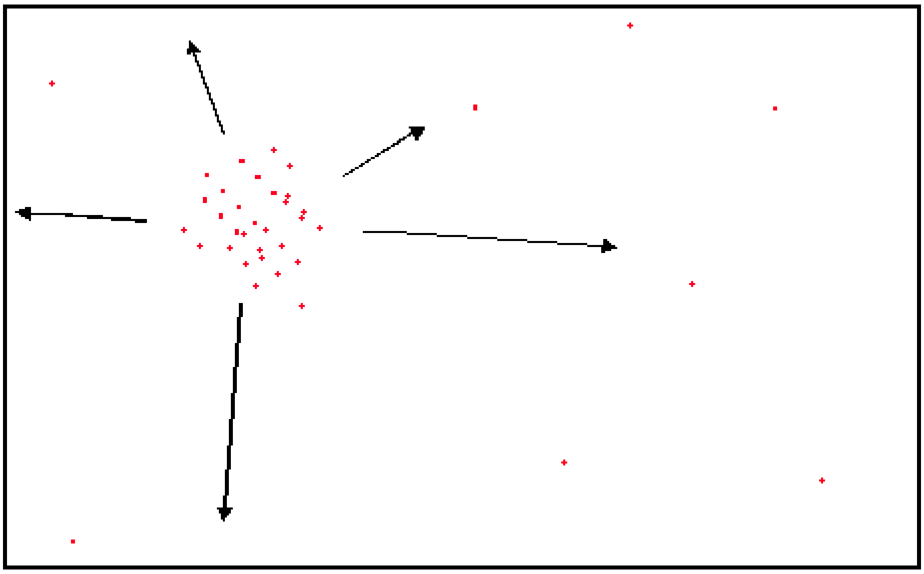
Hydrophilic (polar) regions of the protein project from the inner or outer surface. Hydrophobic (nonpolar) regions are embedded within the membrane.



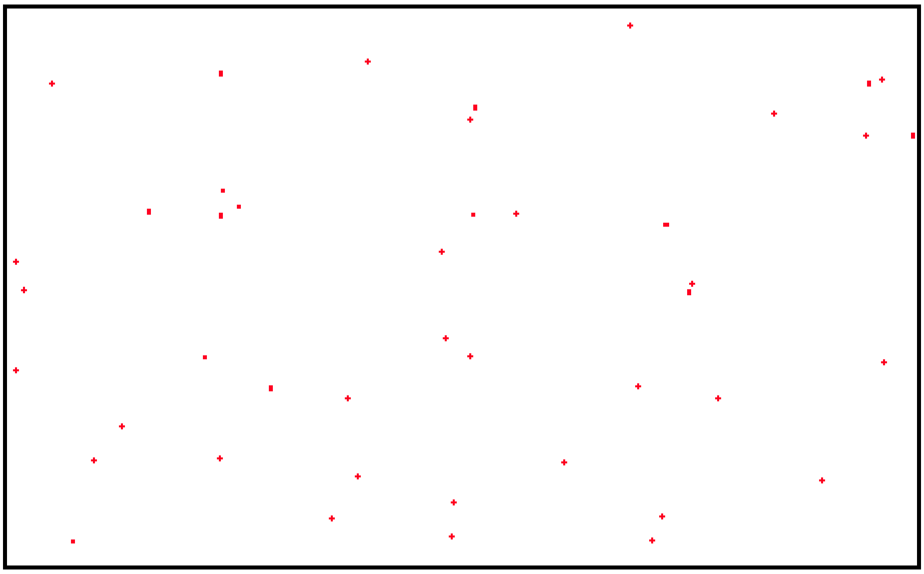
Membrane proteins are capable of lateral movement.

Diffusion

Diffusion is the movement of particles from an area of higher concentration to an area of lower concentration. The movement is due to collisions, which occur more frequently in areas of higher concentration.



The dots on the diagram above represent molecules or ions. After a period of time, the particles becoming dispersed (below). Overall, the movement is from the area of initial high concentration to areas that have a lower concentration.



Membranes are Differentially Permeable

The plasma membrane is differentially permeable because some particles can pass through, others cannot. It can control the extent to which certain substances pass through.

Nonpolar molecules pass through cell membranes more readily than polar molecules because the center of the lipid bilayer (the fatty acid tails) is nonpolar and does not readily interact with polar molecules.

The following substances can pass through the cell membrane:

Nonpolar molecules (example: lipids)

Small polar molecules such as water

The following substances cannot pass through the cell membrane:

Ions and charged molecules (example: salts dissolved in water)

Large polar molecules (example: glucose)

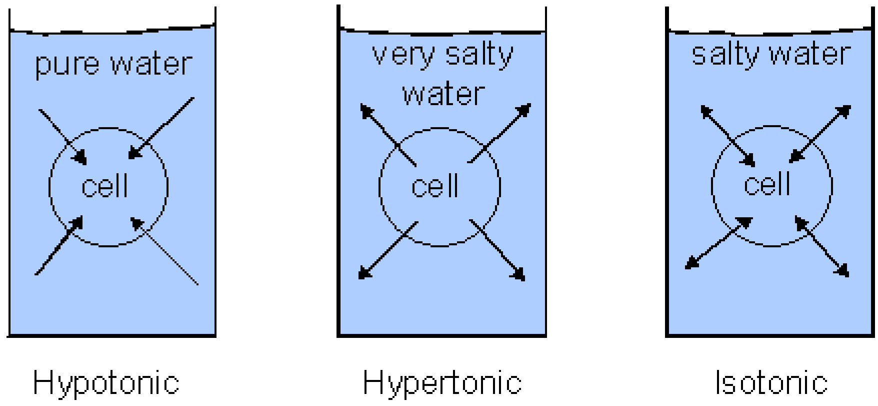
Macromolecules

Osmosis

Osmosis is the diffusion of water across a differentially permeable membrane (see "Diffusion" above).

It occurs when a solute (example: salt, sugar, protein, etc.) cannot pass through a membrane but the solvent (water) can. Water always moves from where it is most concentrated (has less solute) to where it is less concentrated.

In general, water moves toward the area with a higher solute concentration because it has a lower water concentration.



In the container on the left side of the diagram, water will enter the cell because it is more concentrated on the outside. In the center drawing, water is more concentrated inside the cell, so it will move out. If the solute concentration is the same inside as it is out, the amount of water that moves out will be approximately to the amount that moves in.

Osmotic pressure is the force of osmosis. In the diagram above, the cell on the left will swell. The pressure within the cell is osmotic pressure.

Tonicity

Tonicity refers to the relative concentration of solute on either side of a membrane.

Isotonic

In an isotonic solution, the concentration of solute is the same on both sides of the membrane (inside the cell and outside). A cell placed in an isotonic solution neither gains or loses water. Most cells in the body are in an isotonic solution.

Hypotonic

A hypotonic solution is one that has less solute (more water). Cells in hypotonic solution tend to gain water.

Animal cells can ***lyse*** (rupture) in a hypotonic solution due to the osmotic pressure.

Freshwater organisms live in a hypotonic solution and have a tendency to gain water. The contractile vacuole in freshwater protozoans removes water that enters the cell.

The cell wall of plant cells prevents the cell from rupturing. The osmotic pressure, called ***turgor pressure***, helps support the cell. A cell in which the contents are under pressure is ***turgid***.

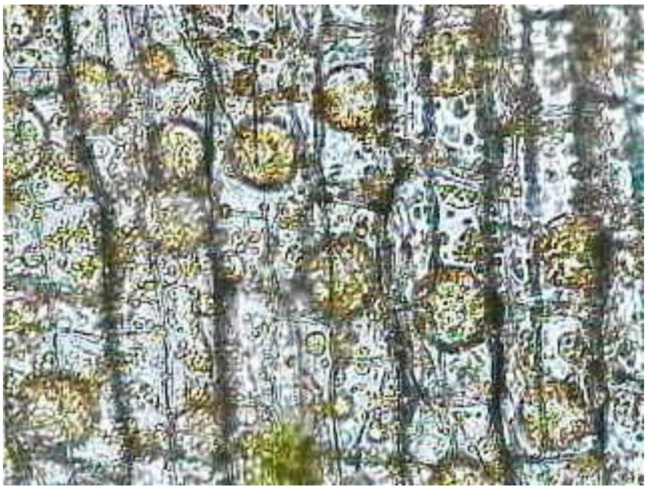
Hypertonic solution

A hypertonic solution is one that has a high solute concentration. Cells in a hypertonic solution will lose water.

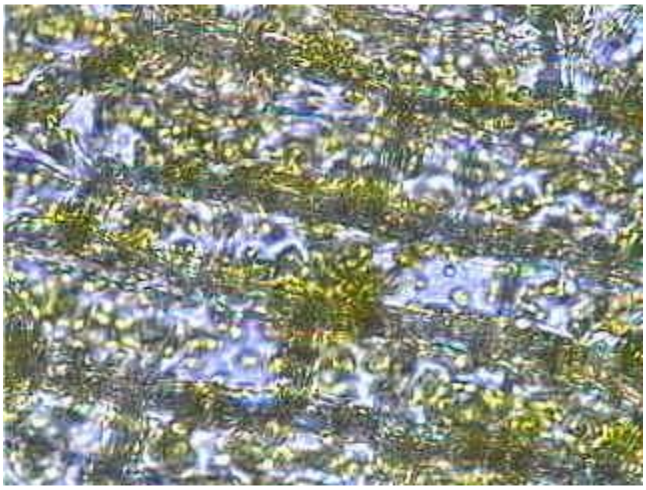
The marine environment is a hypertonic solution for many organisms. They often have mechanisms to prevent dehydration or to replace lost water.

Animal cells placed in a hypertonic solution will undergo crenation, a condition where the cell shrivels up as it loses water.

Plant cells placed in a hypertonic solution will undergo ***plasmolysis***, a condition where the plasma membrane pulls away from the cell wall as the cell shrinks. The cell wall is rigid and does not shrink.



Left: The *Elodea* cells below (X 200) have been placed in a 10% NaCl solution. The contents of the cells have been reduced to the spherical structures shown. Compare these cells to normal cells in the second photograph.

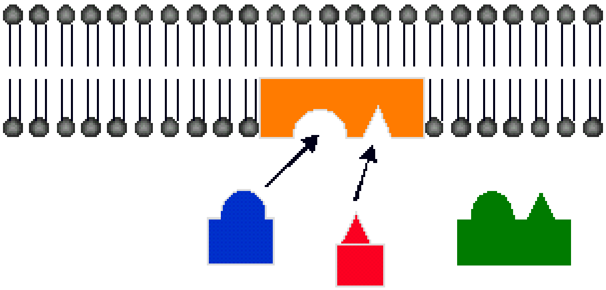


Left: Normal *Elodea* cells X 400

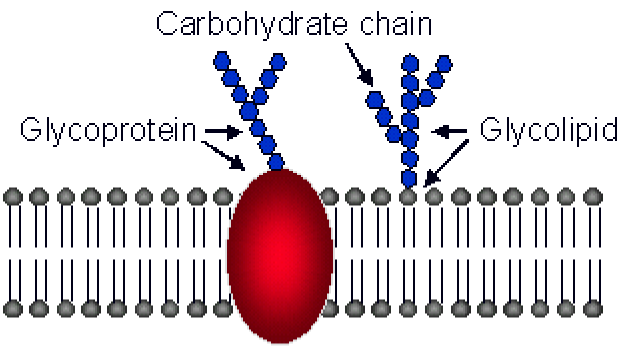
Functions of Membrane Proteins

Enzymes

Some enzymes are embedded within membranes.



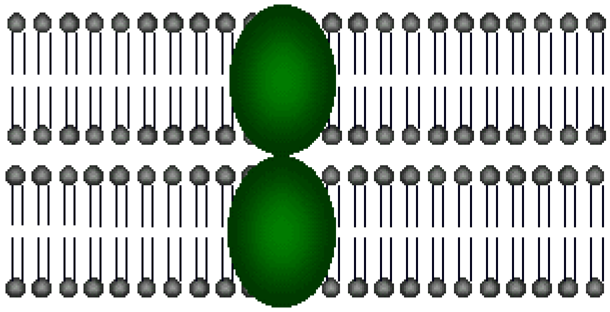
Cell Identification Markers



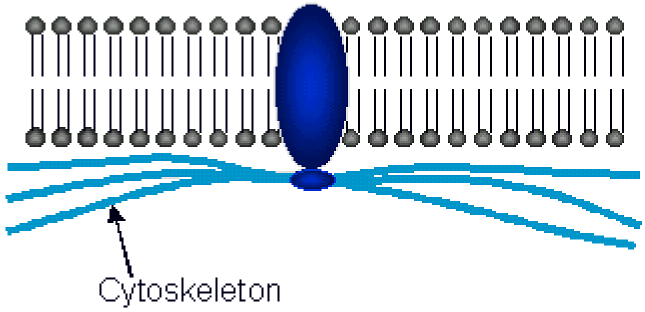
Lipids and proteins within the membrane may have a carbohydrate chain attached. These glycolipids and glycoproteins often function as cell identification markers, allowing cells to identify other cells. This is particularly important in the immune system where cells patrolling the body's tissues identify and destroy foreign invaders such as bacteria or viruses.

Cell Adhesion - Junctions

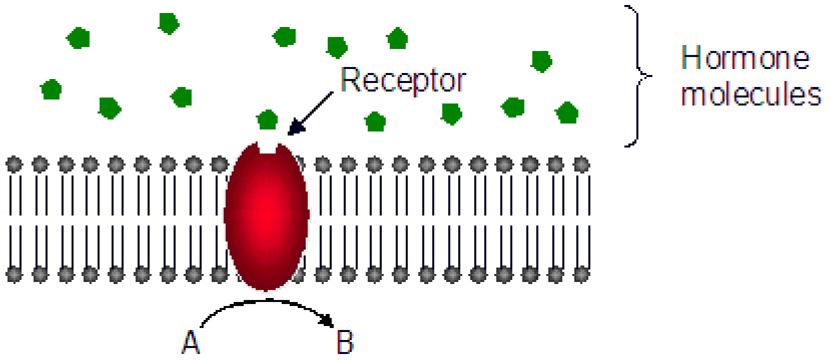
Proteins associated with the cell membranes of animal cells may bind to proteins of adjacent cells. These connections, called junctions may serve to bind cells together, to prevent the movement of material between the cells, or to allow cells to communicate with each other.



Attachment of the Cytoskeleton



Receptors



Receptors enable cells to detect hormones and a variety of other chemicals in their environment. The binding of a molecule and a receptor initiates a chemical change within the cell. In the diagram above, the binding of hormone and receptor initiates the conversion of chemical A to chemical B.

Hormones are molecules that cells use to communicate with one another. For example, cells in the pancreas produce the hormone insulin when glucose levels in the blood become elevated. The hormone travels within the blood to other parts of the body. It stimulates liver and muscle cells to begin removing the glucose and storing it as glycogen.

Vesicle Trafficking

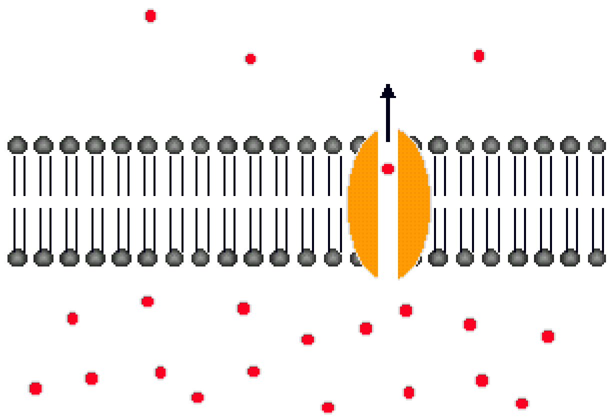
Vesicles may follow microtubules to their destination.

Proteins within the membrane of the vesicle recognize and attach to proteins in other membranes. This allows vesicles to attach to the membranes of other organelles such as the endoplasmic reticulum, golgi apparatus, or lysosomes.

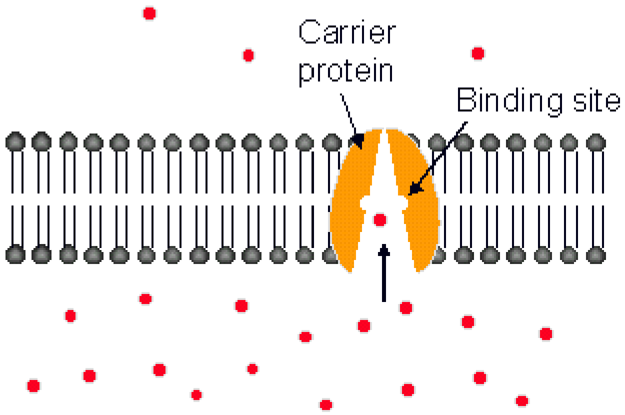
Transport of Materials Across Cell Membranes

Facilitated Diffusion

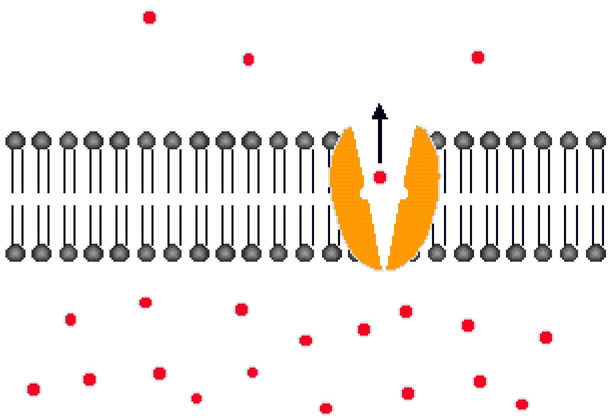
Facilitated diffusion involves the use of a protein to facilitate the movement of molecules across the membrane. In some cases, molecules pass through channels within the protein.



In other cases, the protein changes shape, allowing molecules to pass through.



As can be seen below, the protein changes shape and releases the molecule to the side of the membrane that has the lower concentration.



Additional energy is not required because the molecule is traveling down a concentration gradient (high concentration to low concentration). The energy of movement comes from the concentration gradient.

Active Transport

Active transport is used to move ions or molecules ***against*** a concentration gradient (low concentration to high concentration).

Active transport is like a water pump; it uses energy to pump water uphill where a siphon cannot. Facilitated diffusion (see above) is like a siphon in that additional energy is not required but it can only allow movement downhill.

Movement against a concentration gradient requires energy. The energy is supplied by ATP which is released by breaking a phosphate bond to produce ADP:

$ATP \rightarrow ADP + P_i + energy$

Cells that use a lot of active transport have many mitochondria to produce the ATP needed.

The Sodium-Potassium Pump

The sodium-potassium pump uses active transport to move 3 sodium ions to the outside of the cell for each 2 potassium ions that it moves in.

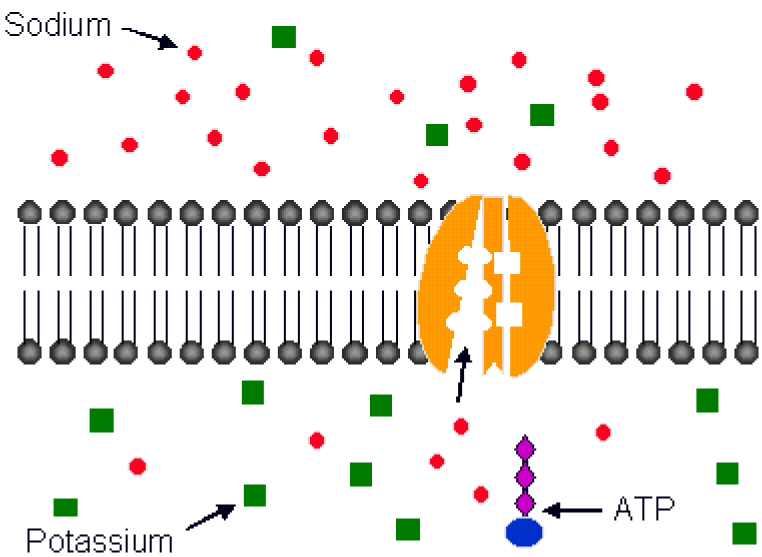
It is found in all human cells, especially nerve and muscle cells.

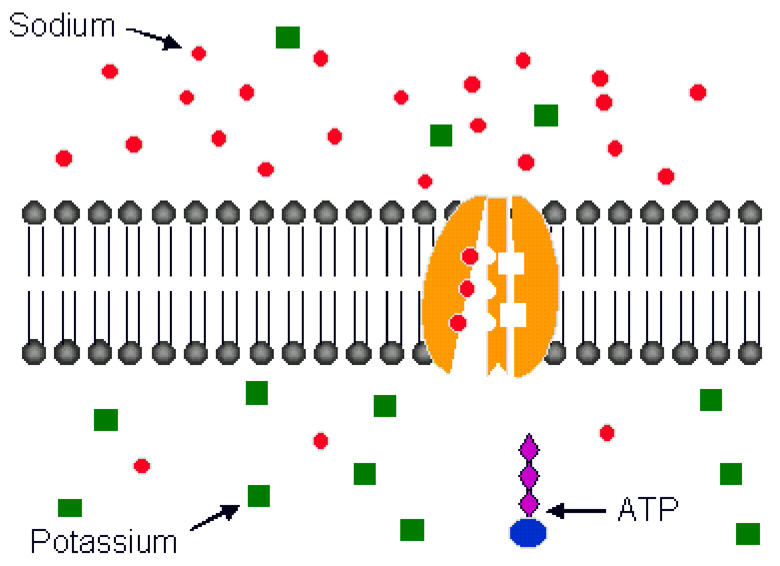
One third of the body's energy expenditure is used to operate the sodium-potassium pump.

Mechanism of operation of the Sodium-Potassium Pump

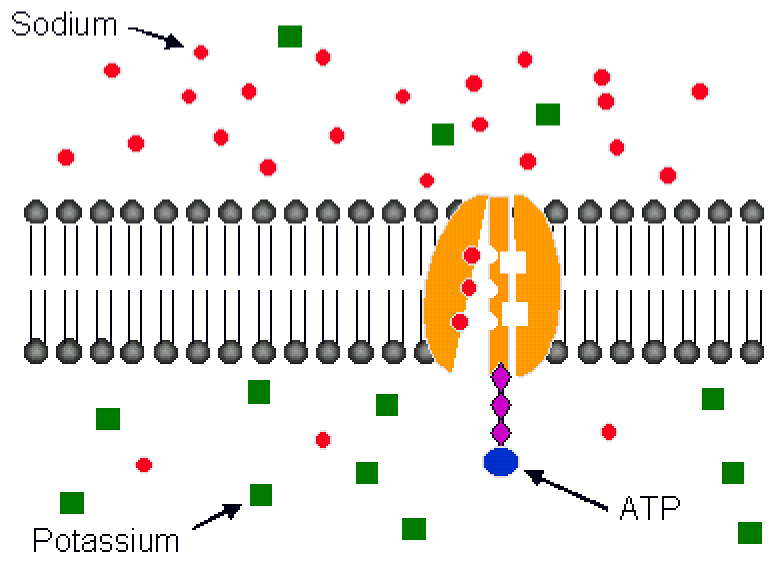
The diagrams below illustrate the mechanism of operation of the sodium-potassium pump. In these diagrams, orange is used to represent the pump protein. Circles are used to represent sodium ions and squares are used to represent potassium ions. Notice that the pump has three sodium binding sites and two potassium binding sites.

Three sodium ions enter the pump.

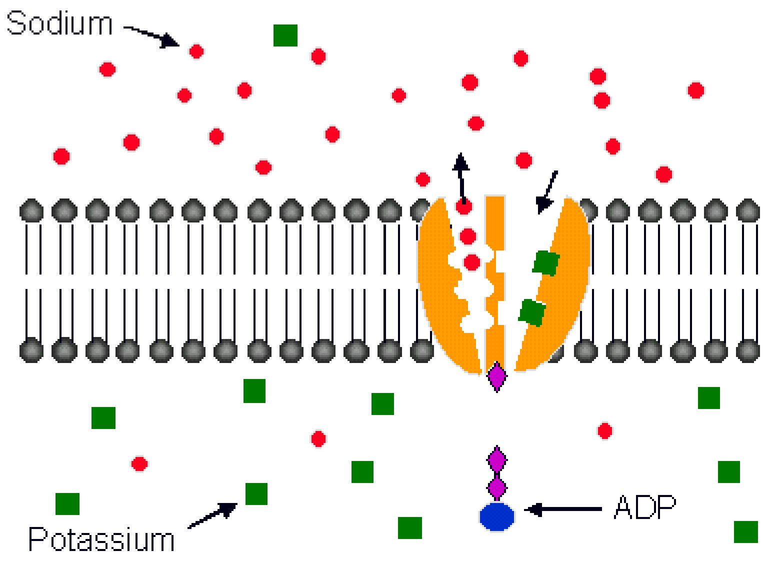




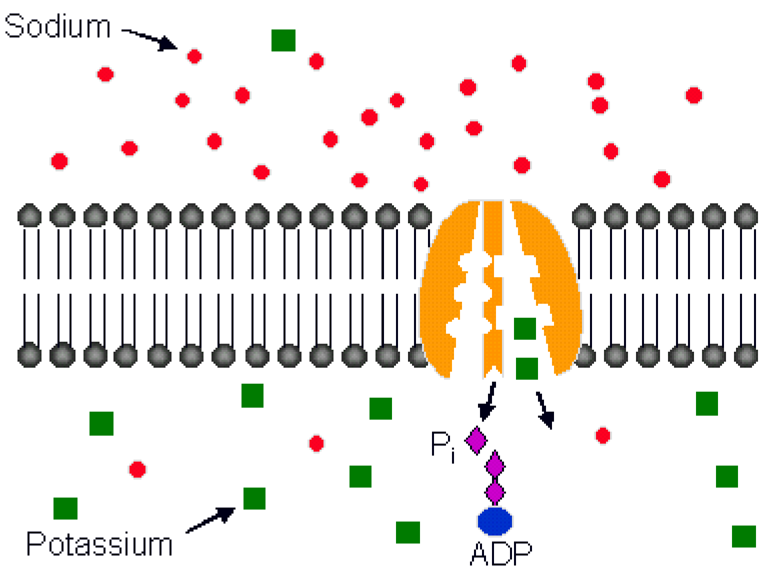
ATP bonds to the pump.



One phosphate bond in the ATP molecule breaks, releasing its energy to the pump protein. The pump protein changes shape, releasing the sodium ions to the outside. The two potassium binding sites are also exposed to the outside, allowing two potassium ions to enter the pump.



When the phosphate group detaches from the pump, the pump returns to its original shape. The two potassium ions leave and three sodium ions enter. The cycle then repeats itself.



Examples of Active Transport

Plants move minerals (inorganic ions) into their roots by active transport.

The gills of marine fish have cells that can remove salt from the body by pumping it into the salt water.

The thyroid gland cells bring in iodine for use in producing hormones.

Cells in the vertebrate kidney reabsorb sodium ions from urine.

Endocytosis and Exocytosis

These processes are used for materials that are too big to pass through the plasma membrane via protein transport.

Endocytosis

The process by which a cell engulfs material to bring it into the cell is called endocytosis. Two major forms of endocytosis described below.

Phagocytosis

Phagocytosis refers to the process of engulfing large particles.

A vacuole is formed that contains the material that has been engulfed.

Pinocytosis

Pinocytosis refers to engulfing macromolecules.

As in phagocytosis, a vesicle is formed which contains the molecules that were brought into the cell.

Vacuoles and vesicles produced by phagocytosis and pinocytosis can fuse with lysosomes (lysosomes are vesicles that contain digestive enzymes).

Phagocytosis and pinocytosis remove membrane from cell surface to form vacuoles that contain the engulfed material.

Receptor-Mediated endocytosis

Macromolecules bind to receptors on the surface of the cell.

Receptors with bound macromolecules aggregate in one area and are brought into the cell by endocytosis.

The vesicle containing the macromolecules can release the macromolecules into the cell directly or they can be processed by chemicals contained within lysosomes after fusing with the lysosomes.

The vesicle (and receptors) then returns to the cell surface.

Exocytosis

Exocytosis moves material to the outside. A vesicle fuses with the plasma membrane and discharges its contents outside. This allows cells to secrete molecules.

The fusion of vesicles to the plasma membrane adds membrane to the cell surface.

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ا.م.د. رشيد محمد رشيد

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Cellular Respiration

Introduction

Photosynthesis

Photosynthesis is therefore a process in which the energy in sunlight is stored in the chemical bonds of glucose ($C_6H_{12}O_6$) for later use.

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

Carbon dioxide is ***reduced*** to glucose and water is ***oxidized***. Oxidation is the loss of an electron or hydrogen atom. Reduction is the gain of an electron or hydrogen atom. Oxidation reactions release energy and reduction reactions store energy in chemical bonds.

What is Cellular Respiration?

Cellular respiration allows organisms to use (release) the energy stored in glucose. The energy in glucose is first used to produce ATP. Cells use ATP to supply their energy needs. Cellular respiration is therefore a process in which the energy in glucose is transferred to ATP.

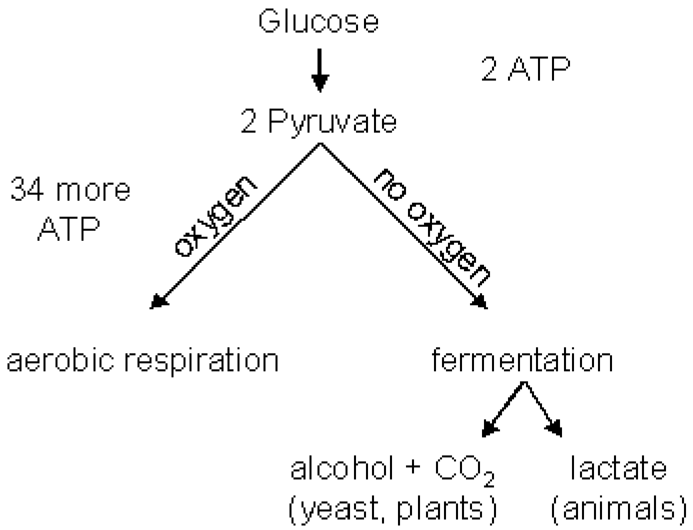
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + energy\ (36\ ATP)$$

In respiration, glucose is ***oxidized*** (releasing energy) and oxygen is ***reduced*** to form water.

The carbon atoms of the sugar molecule are released as ***carbon dioxide*** (CO_2).

The complete breakdown of glucose to carbon dioxide and water requires two major steps: 1) glycolysis and 2) aerobic respiration. Glycolysis produces two ATP. Thirty-four more ATP are produced by aerobic pathways if oxygen is present.

In the absence of oxygen, fermentation reactions produce alcohol or lactic acid but no additional ATP.



Review of Electron Carriers

$NAD^+ + 2H \rightarrow NADH + H^+$

$FAD + 2H \rightarrow FADH_2$

Glycolysis

During glycolysis, glucose (C_6) is broken down to two molecules of pyruvate (C_3). (*Compounds that end in "___ate" can be called "___ic acid". Example lactate is lactic acid and malate is malic acid.)

Glycolysis occurs in the ***cytoplasm*** (***cytosol***) and does not require oxygen.

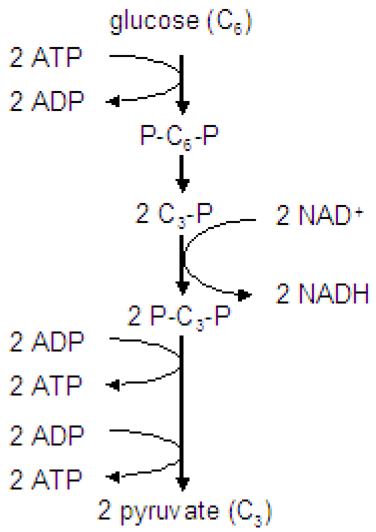
There are ten steps in glycolysis and each one is catalyzed by a specific enzyme. A brief summary of these reactions is presented here.

2 ATP molecules are used to phosphorylate and activate compounds that will eventually become converted to ***pyruvate*** (or ***pyruvic acid***) (see diagram below).

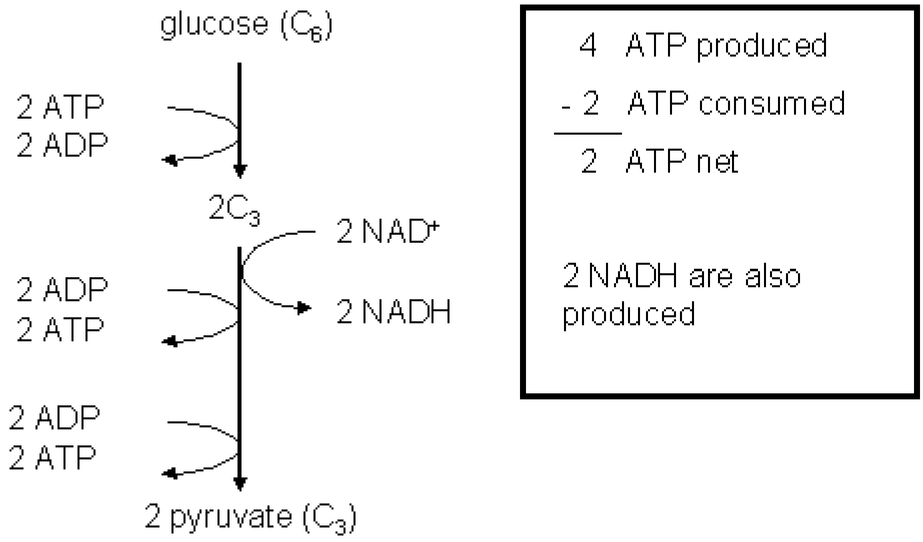
Two hydrogen atoms are removed by NAD^+ forming 2 NADH (see diagram).

Additional phosphorylation results in intermediate 3-carbon molecules with 2 phosphate groups.

Four ATP are produced by ***substrate-level phosphorylation***. Recall that substrate-level phosphorylation is the production of ATP using energy from other high-energy compounds but without the use of the electron transport system in the mitochondria.



The net yield of ATP in glycolysis is 2 for each glucose molecule (2 are used but 4 are produced).



Some bacteria have alternative energy-producing reactions. Two of these are the pentose phosphate pathway and the Entner-Doudoroff pathway.

Formation of Acetyl CoA

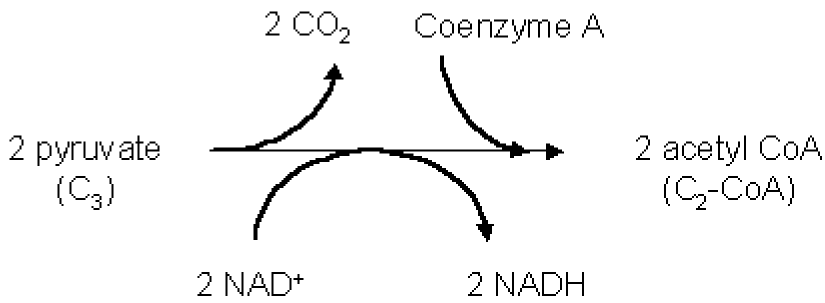
Pyruvate produced by glycolysis (see above) enters the ***mitochondrion*** and is converted to ***acetyl CoA*** by the reaction below. The remainder of the reactions of cellular respiration occur in the ***mitochondrion***.

pyruvate (C_3) → acetyl CoA (C_2) + CO_2

During this step, NADH is produced from NAD^+ + 2H (oxidation).

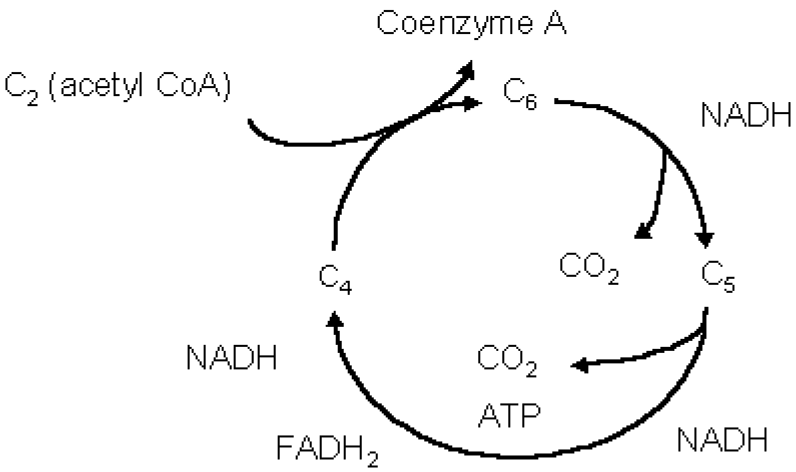
This step must occur twice for each glucose molecule because each glucose molecule produces two pyruvate molecules in glycolysis (above).

The two-carbon compound produced is attached to Coenzyme A to produce acetyl CoA.



Krebs Cycle

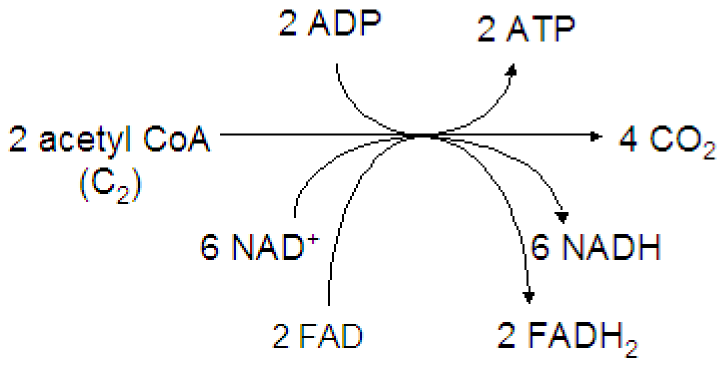
The Krebs cycle can be summarized by either of the diagrams below. The diagram below occurs twice, once for each acetyl CoA.



When acetyl CoA attaches to a C_4 molecule in the Krebs cycle, the Coenzyme A is released.

Two acetyl CoA molecules are consumed to produce 4 CO_2, 2ATP, 6 NADH and 2 $FADH_2$. The ATP molecules are produced by substrate-level phosphorylation.

The diagram below also summarizes the Krebs Cycle.



Electron Transport and Oxidative Phosphorylation

Mitochondrion structure

The inner membrane forms folds called ***cristae***. These folds contain the carriers of the electron transport system.

Acetyl CoA formation and the Krebs cycle occur in the inner space called the matrix.

The space outside the inner membrane is the ***intermembrane space***. The electron transport system pumps hydrogen ions (H^+) into this space for oxidative phosphorylation.

Oxidative Phosphorylation

The ***electron transport system*** is found in the mitochondrion and chloroplast of eucaryotes and in the plasma membrane of procaryotes. It consists of a series of carrier molecules which pass electrons from a high-energy compound to a final low-energy electron acceptor. Energy is released during these oxidation-reduction reactions to produce ATP.

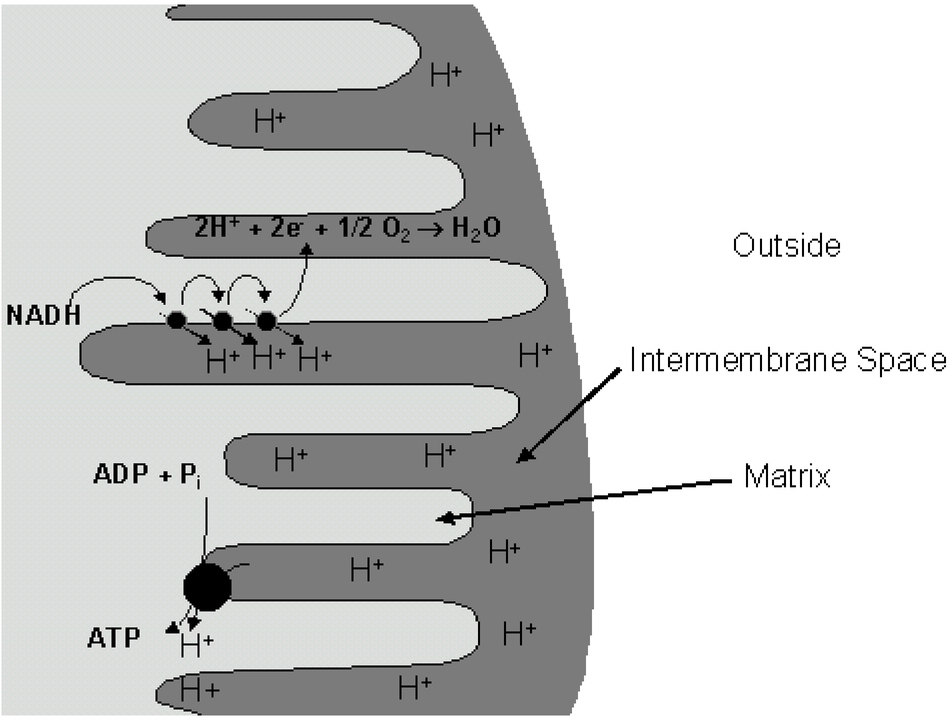
The discussion below applies to the mitochondria of eucaryotes.

NADH or $FADH_2$ bring electrons to the electron transport system in the mitochondria.

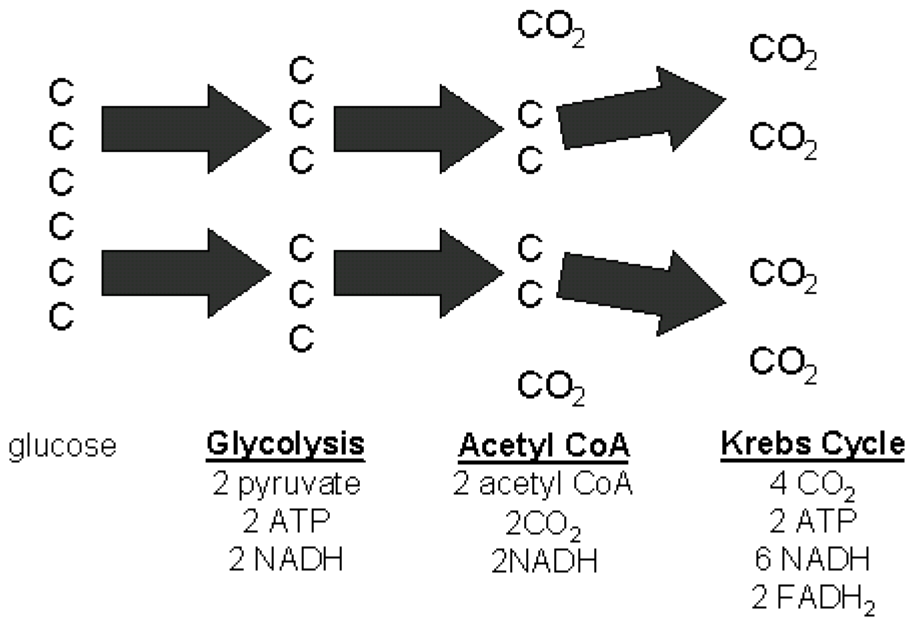
The system contains membrane-bound electron carriers that pass electrons from one to another. When a carrier reduces another, some of the energy that is released as a result of that reduction is used to pump hydrogen ions across the membrane into the intermembrane space. The remaining energy is used to reduce the next carrier.

As a result of the electron transport system, hydrogen ions become concentrated in the intermembrane space. These concentrated ions contain energy much like a dam. The enzyme ***ATP synthase*** is able to use the energy of this osmotic gradient to produce ATP as the hydrogen ions move under osmotic pressure through the enzyme back into the matrix of the mitochondrion.

Oxygen is the final electron acceptor. The low-energy electrons that emerge from the electron transport system are taken up by O_2. The negatively charged oxygen molecules take up protons from the medium and form water ($2H^+ + 2e^- + 1/2\ O_2 \rightarrow H_2O$).



Summary of Glycolysis and Cellular Respiration



Glycolysis

During glycolysis, glucose (C_6) is converted to two pyruvates (C_3).

C-C-C-C-C-C $\rightarrow$ C-C-C + C-C-C

Formation of Acetyl CoA

One acetyl CoA is formed for each pyruvate produced by glycolysis (see the step above).

C-C-C $\rightarrow$ C-C + CO_2

pyruvate $\rightarrow$ acetyl CoA + CO_2

Krebs Cycle

C-C $\rightarrow$ 2 CO_2

The Krebs Cycle produces NADH, $FADH_2$, and ATP.

NADH and $FADH_2$ carry electrons to the electron transport system.

Electron Transport System

In the electron transport system, NADH and $FADH_2$ are oxidized and the energy is used to produce ATP.

Total ATP yield per glucose

Conversions

NADH produced in the cytoplasm produces two ATP by the electron transport system.

NADH produced in the mitochondria produces three ATP.

$FADH_2$ adds its electrons to the electron transport system at a lower level than NADH, so it produces two ATP.

Glycolysis

2 ATP

2 NADH (= 4 ATP; these are converted to ATP in the mitochondria during cellular respiration)

Formation of Acetyl CoA

2 NADH (= 6ATP)

Krebs Cycle

6 NADH (= 18 ATP)

2 $FADH_2$ (= 4 ATP)

2 ATP

Total Yield

Glycolysis produces 2 ATP; aerobic respiration produces 34 more ATP

Pathway	Substrate-Level Phosphorylation	Oxidative Phosphorylation	Total ATP
Glycolysis	2 ATP	2 NADH = 4 - 6 ATP*	6 - 8*
CoA		2 NADH = 6 ATP	6
Krebs Cycle	2 ATP	6 NADH = 18 ATP 2 $FADH_2$ = 4 ATP	24
TOTAL	4 ATP	32 ATP	36 - 38

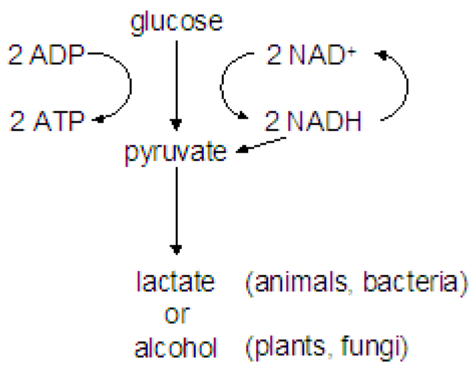
Fermentation

Without oxygen, cellular respiration could not occur because oxygen serves as the final electron acceptor in the electron transport system. The electron transport system would therefore not be available.

Glycolysis can occur without oxygen. Although glycolysis does not require oxygen, it does require NAD^+. Cells without oxygen available need to regenerate NAD^+ from NADH so that in the absence of oxygen, at least some ATP can be made by glycolysis.

To regenerate NAD^+ from NADH, the electrons from NADH are added to pyruvate to produce alcohol (plants, yeast) or lactate (animals, bacteria).

The total ATP yield of fermentation comes from glycolysis; 2 ATP molecules are produced per glucose.



Usefulness of Fermentation

Anaerobic exercise

During vigorous exercise, oxygen is consumed faster than it is needed. Additional ATP energy is provided to the muscles by glycolysis and the result is a buildup of lactate in the muscles.

When lactate builds up, the blood pH drops and the muscles fatigue.

At rest, lactate is converted back to pyruvate (the oxygen debt is repaid). This is why you continue to breathe hard after you have finished running or rapid stair climbing.

Yeast

Yeast produce alcohol which accumulates in their environment. As the concentration of alcohol in their environment increases, it becomes more and more toxic to them. Beer and wine have a maximum alcohol concentration because a higher concentration will kill the yeast cells.

Evolution of Cellular Respiration

Early cells probably fermented organic molecules in the oceans.

Today, nearly all organisms show some form of fermentation which indicates that it evolved early in evolutionary history.

Evolution typically operates by building upon or adding to what is already there. Aerobic respiration appears to have been added to fermentation.

Summary

Glycolysis

Two ATP molecules are used to phosphorylate and activate glucose.

Two hydrogen atoms are removed by NAD^+ forming 2 NADH.

Four ATP molecules are produced by substrate-level phosphorylation.

The net yield of ATP is two; two are used and four are produced.

Fermentation

Fermentation is needed to regenerate NAD^+ from NADH so that at least some ATP can be made in glycolysis.

Electrons from NADH are added to pyruvate (reduction) to produce alcohol (plants, yeast) or lactate (animals, bacteria)

Aerobic Respiration

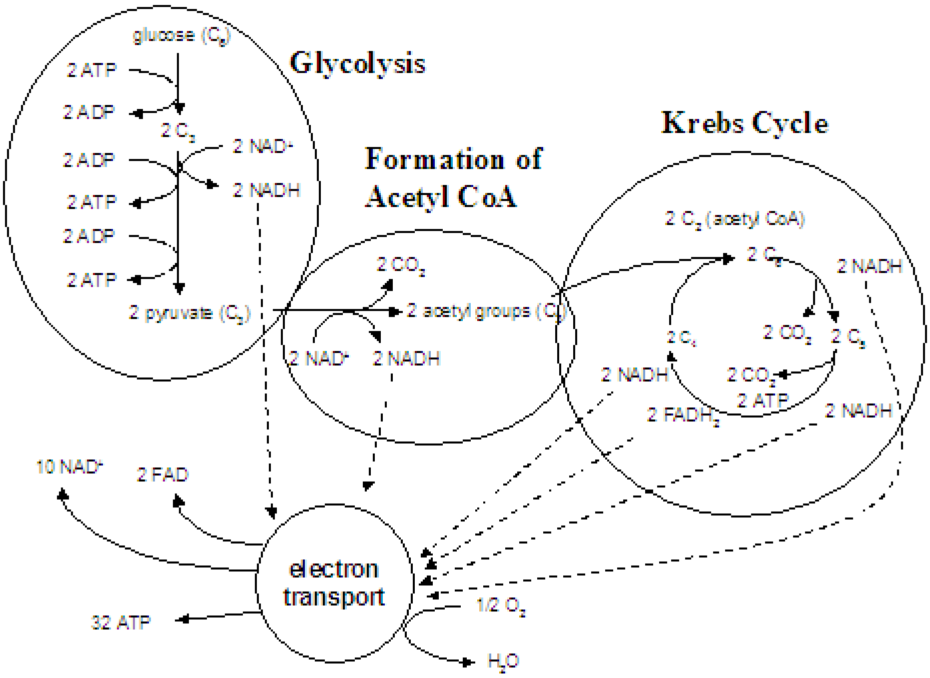
Aerobic respiration occurs when oxygen is available.

pyruvate $\rightarrow CO_2 + H_2O$

It occurs in the mitochondrion.

NAD+ and FAD carry electrons to the electron transport system.

In the electron transport system, NADH and $FADH_2$ are used to produce ATP as electrons are passed from one carrier to another. Eventually the electrons combine with hydrogen ions and oxygen (reduction) to form water.



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Photosynthesis

What is Photosynthesis?

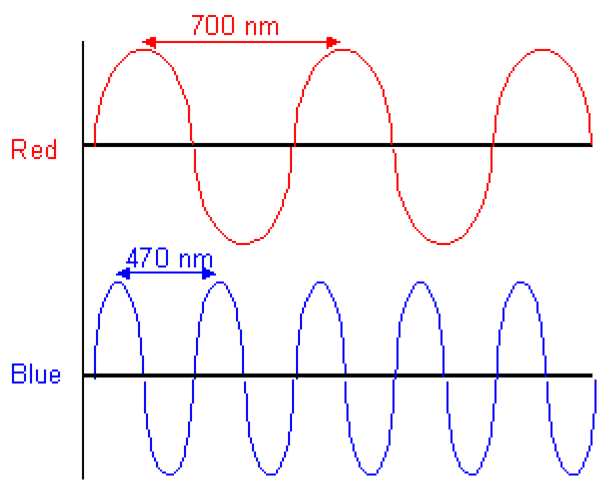
All organisms require energy for their chemical reactions. These reactions may be involved with reproduction, growth, or other activities. Photosynthetic organisms such as plants use light energy to produce carbohydrate (glucose). Glucose can be used at a later time to supply the energy needs of the cell. Photosynthesis is therefore a process in which the energy in sunlight is stored in the bonds of glucose for later use.

Light

Electromagnetic Spectrum

Light behaves as if it were composed of "units" or "packets" of energy that travel in waves. These packets are ***photons***.

The ***wavelength*** of light determines its color. For example, The wavelength of red is about 700 nm and the wavelength of blue light is about 470 nm.



Visible light is a part of a larger spectrum of radiation called the electromagnetic spectrum.

Ultraviolet radiation (UV) is dangerous to cells because it breaks chemical bonds.

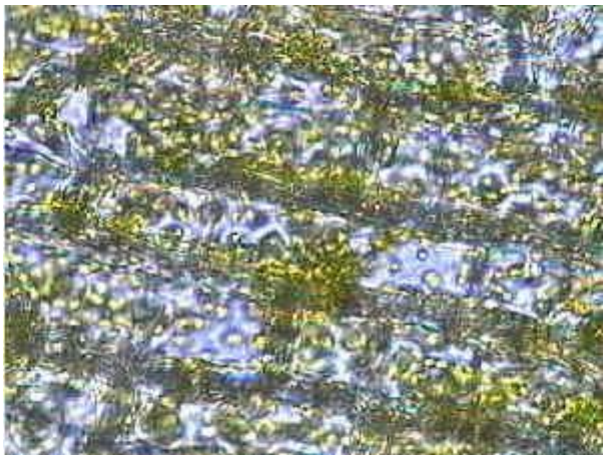
Photosynthetic Pigments

Chlorophyll A is the main photosynthetic pigment in all organisms except bacteria. Other pigments called ***accessory pigments*** absorb slightly different wavelengths of light. The combination of all of the pigments increases the range of colors that plants can use in photosynthesis.

Accessory pigments include chlorophyll b and a group of pigments called ***carotenoids***. They do not participate directly in photosynthetic reactions but are able to pass their energy to chlorophyll a.

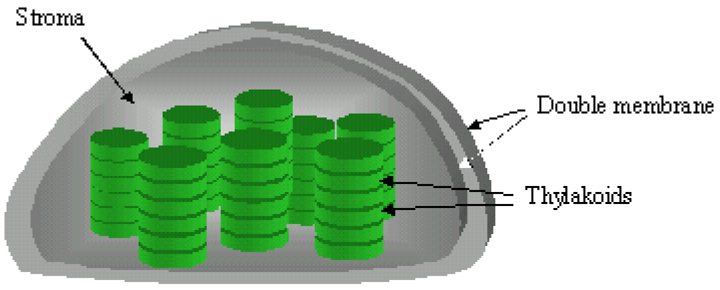
Chloroplast structure

The photograph below is an elodea leaf X 400. Individual cells are clearly visible. The tiny green structures within the cells are chloroplasts.



Thylakoids are membranous disk-like structures that are stacked together in larger structures that resemble stacks of coins. Chlorophyll and carotenoid pigments are located in the membranes of the thylakoids. The thylakoid membranes also contain the electron transport system.

The diagram below is a drawing of a chloroplast showing the thylakoids.



The fluid-filled space surrounding the grana is the ***stroma***. Many enzymes needed in photosynthesis are found in the stroma.

2 Sets of Reactions

Light-Dependent Reactions

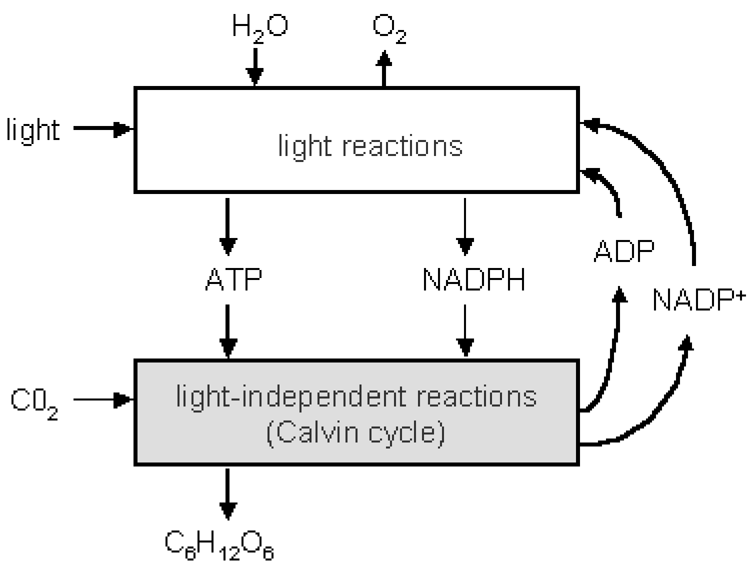
The light-dependent reactions require light.

These reactions occur in the thylakoid membrane.

They produce ATP and NADPH, which are needed to produce glucose in the light-independent reactions (below).

Notice how the equation for photosynthesis relates to the reactions shown in the diagram below.

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



Light-Independent Reactions

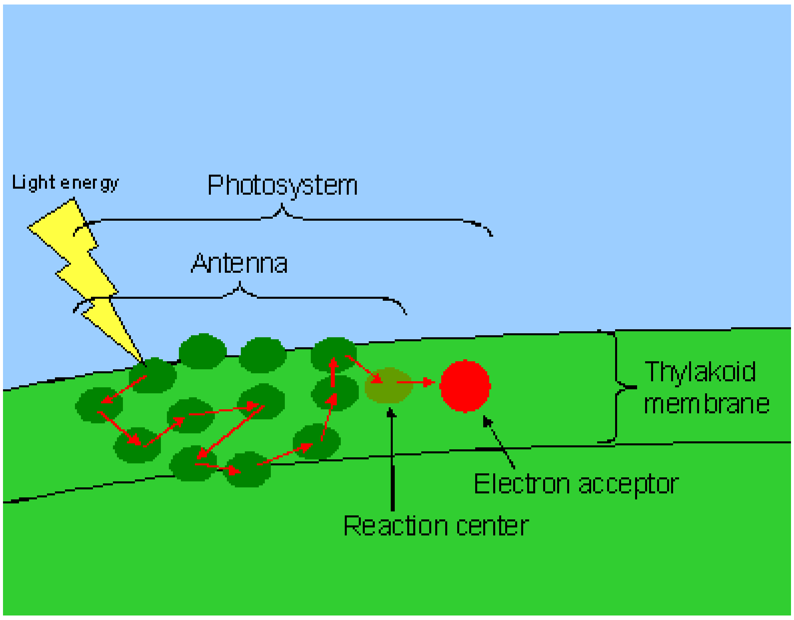
Light-independent reactions occur in stroma of the chloroplast in light or dark conditions.

They function to reduce CO_2 to glucose.

Photosystems

The closely packed pigment molecules and the reaction center form a unit referred to as an ***antenna complex***.

Photons of light that are picked up by any of the pigment molecules in the antenna pass their energy to nearby pigment molecules until it is eventually passed to a special molecule of chlorophyll a called the ***reaction center***.



The reaction center molecule becomes ionized and it loses its electron to an electron acceptor. This electron will need to be replaced.

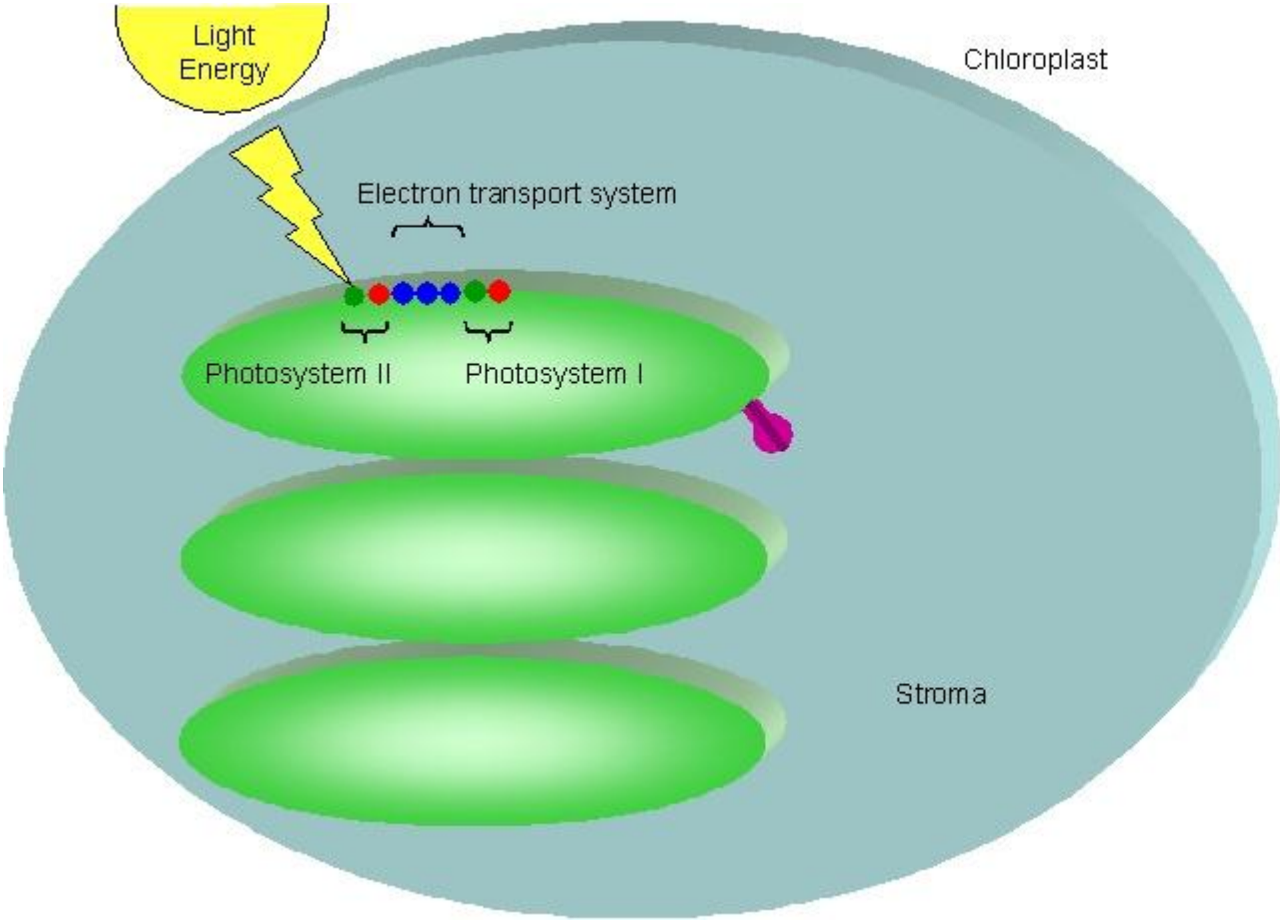
The antenna, the reaction center, and the electron transport molecules make up a photosystem. There are two kinds of photosystems in eucaryotes. The reaction center chlorophyll molecule of photosystem I absorbs 700 nm light best and is therefore called P_{700}. The reaction center of photosystem II absorbs 680 nm light best and is called P_{680}.

Photosystem I evolved very early; photosystem II evolved later.

Details of the Light-Dependent Reactions

Photosystem II

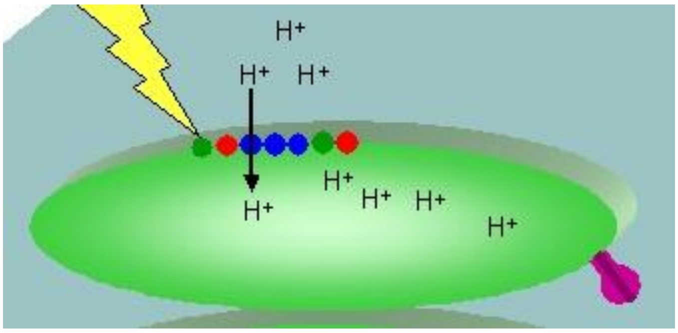
The diagrams that follow are less magnified views of the chloroplast and thylakoid shown in the diagram above. The antenna shown above is represented by a single green circle below. Notice that there are two photosystems and therefore two antennas. The blue circles represent the electron transport system (discussed later).



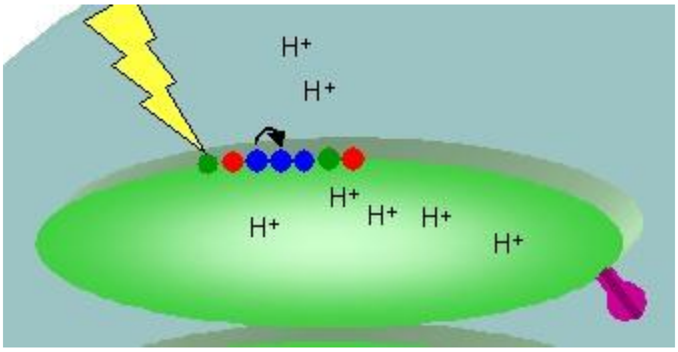
During the light reactions, pigment molecules within the P_{680} antenna absorb a photon of light energy. The energy from that molecule is passed to neighboring molecules and eventually makes its way to the reaction center molecule as previously described. When the reaction center molecule becomes excited, it loses its electron to an electron acceptor.

Photophosphorylation

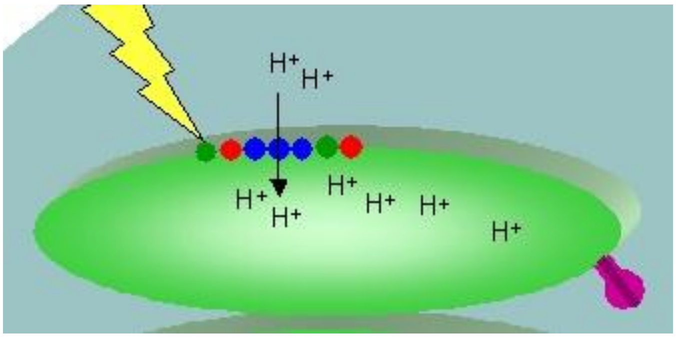
The ***electron transport system*** is found embedded within the thylakoid membrane and functions in the production of ATP. The system contains membrane-bound electron carriers that pass electrons from one to another. As a result of gaining an electron (reduction), the first carrier of the electron transport system gains energy. It uses some of the energy to pump H^+ into the thylakoid.



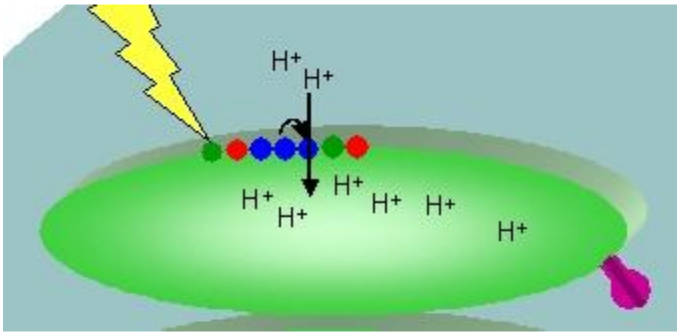
The carrier then passes the electron to the next carrier. Because it used some energy to pump H^+, it has less energy (reducing capability) to pass to the next H^+ pump.



This carrier uses some of the remainder of the energy to pump more H^+ into the thylakoid.

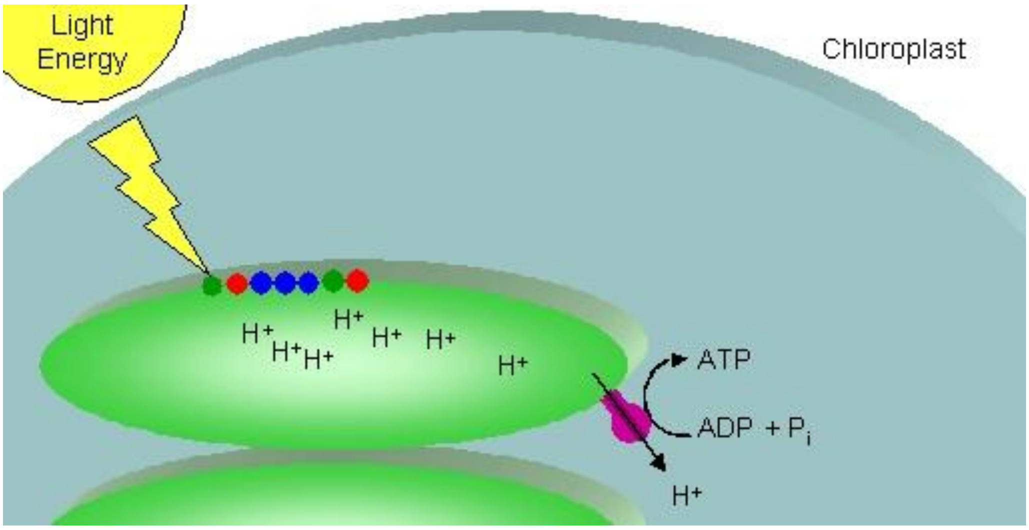


The electron is passed to the next carrier which also pumps H^+.



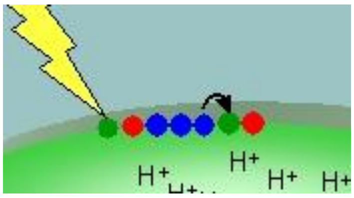
The electron transport system functions to create a concentration gradient of H^+ inside the thylakoid. The concentration gradient of H^+ is used to synthesize ATP.

ATP is produced from ADP and P_i when hydrogen ions pass out of the thylakoid through ***ATP synthase***. This method of synthesizing ATP by using a H+ gradient in the thylakoid is called ***photophosphorylation***.

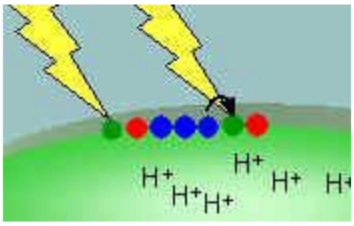


Photosystem I

At this point, the electron has little reducing capability (little energy is left). It is passed to the P700 antenna.

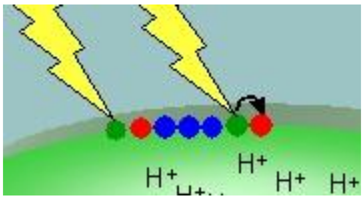


A pigment molecule in the P700 antenna absorbs a photon of solar energy.



The energy from that molecule is passed to neighboring molecules within the antenna. The energy is eventually passed to the reaction center of this antenna.

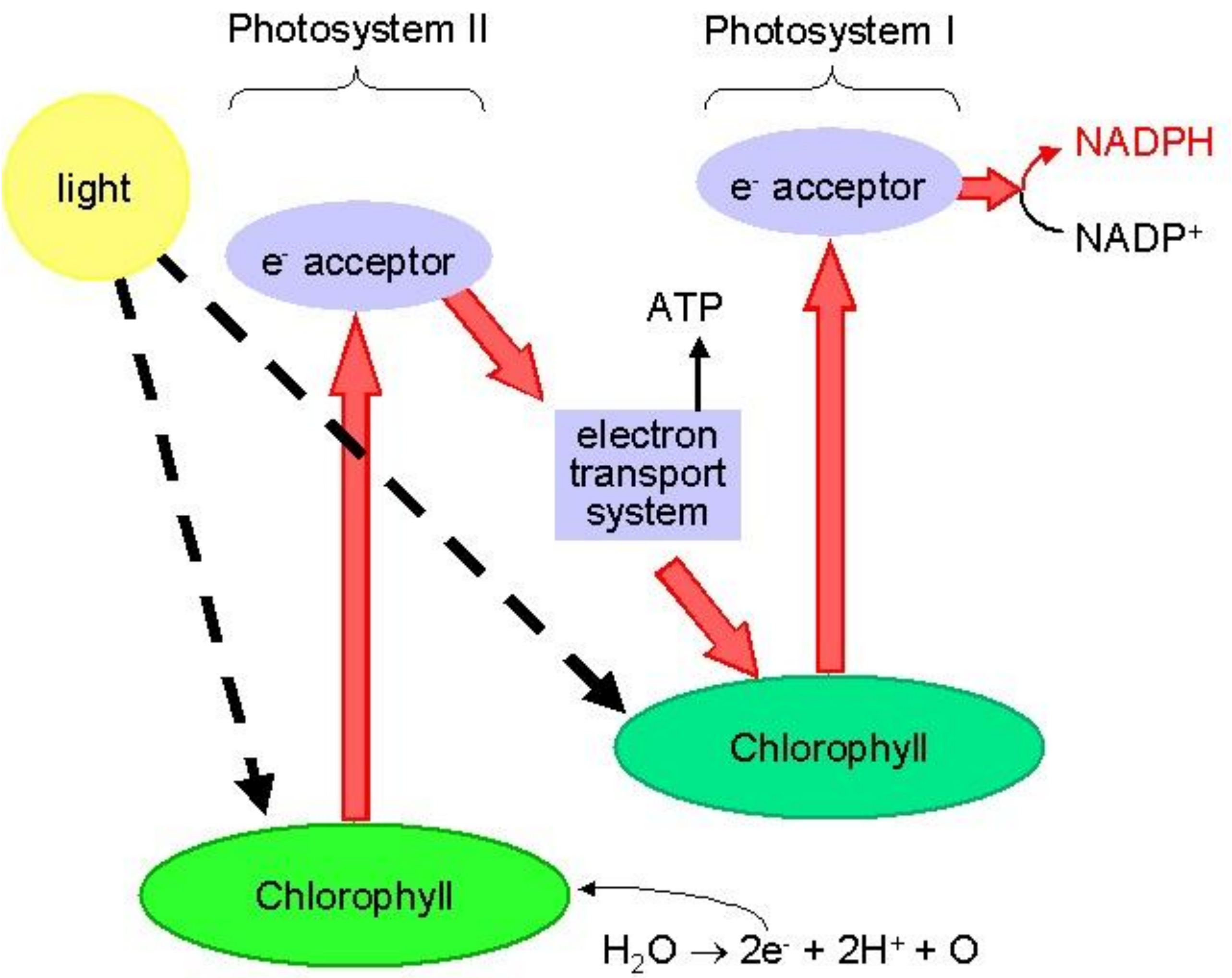
As a result of being energized, the P700 reaction center loses the electron to an electron acceptor.



The acceptor passes it to NADP$^+$, which becomes reduced to NADPH. According to the following equation, NADP$^+$ has the capacity to carry two electrons. NADP$^+$ + 2e$^-$ + H$^+$ $\rightarrow$ NADPH

The electron transport system and photophosphorylation in the chloroplast is similar to the system found in the mitochondria to produce ATP during cellular respiration.

The diagram below is a summary of the light reactions. High-energy components of the system are shown near the top of the diagram.



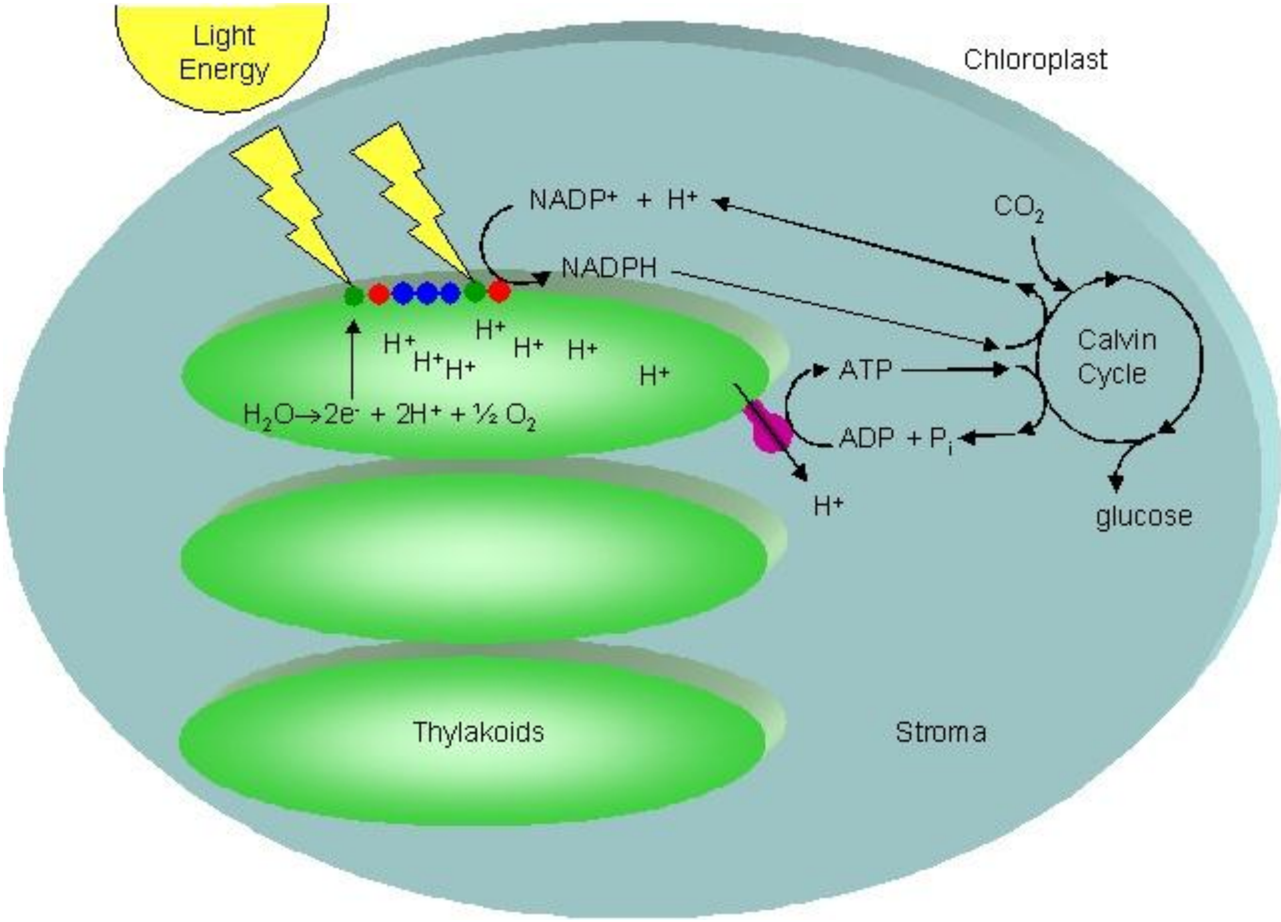
Water

The electron that was lost from the antenna complex of photosystem I is replaced by splitting water (see diagram above).

In the light reactions, electrons move one way from water to NADPH and the energy of sunlight is used to produce ATP.

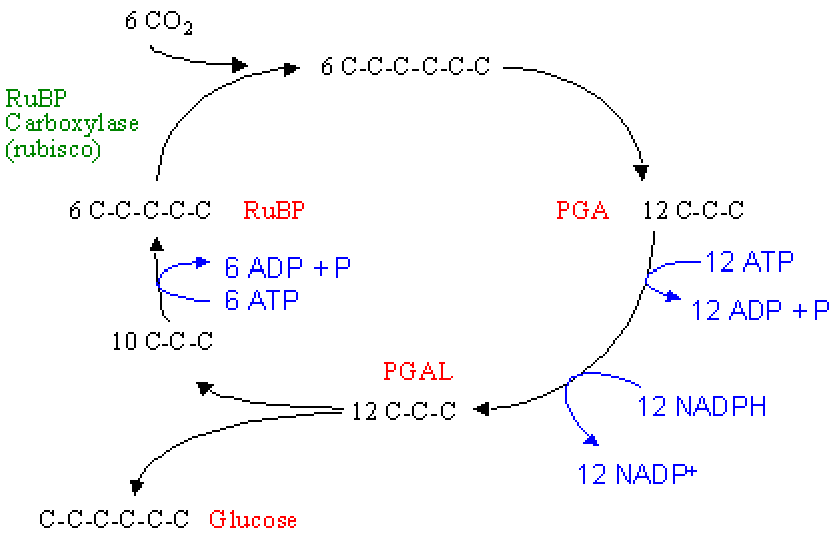
Calvin Cycle (Light-independent Reactions)

The products of the light reactions (ATP and NADPH) are used to reduce CO_2 to carbohydrate in the Calvin cycle.



The words "CO_2 fixation" refer to the attachment of CO_2 to an organic compound: each CO_2 binds to a 5-carbon ***ribulose biphosphate (RuBP***) molecule.

Carbon dioxide fixation is catalyzed by RuBP carboxylase (***rubisco***).



For each six CO_2 molecules that enter the cycle one glucose molecule is produced.

About 30% of the energy available in ATP and NADPH is finally present in the glucose produced.

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المحاضرة السابعة: الوراثة ١

- Genetics - Part 1 - Genes

Mendel

Mendel was an Austrian monk who taught natural science and worked on plant breeding experiments.

He developed a basic understanding of genetics and inheritance.

Mendel's Work

It took him 2 years to select the pea plant as his subject.

He collected data for 10 years.

His sample sizes were large; he tabulated results from 28,000 pea plants.

He replicated his experiments.

He analyzed his data with statistics (probability theory).

Characteristics of Garden Peas:

Peas are easy to grow, and take little space.

They are inexpensive.

They have a short generation time compared to large animals so that a large number of offspring can be obtained in a short amount of time.

They have some distinct characteristics that are easy to recognize. These characteristics can be used when trying to determine patterns of inheritance.

They are easily self-fertilized or cross fertilized.

Traits Studied by Mendel

smooth or wrinkled seeds
yellow or green seeds
red or white flowers
inflated or constricted pods
green or yellow pods
axial or terminal flowers
tall or dwarf plants

Mendels Crosses

Mendel used pure-breeding individuals in the first (P_1) generation.

P_1 yellow X green
↓
F_1 all yellow
↓
F_2 3/4 yellow, 1/4 green

Mendel's Results for 7 different crosses

P_1	**F_1**	**F_2**	**F_2 ratio**
smooth X wrinkled seeds	all smooth	5474 smooth 1850 wrinkled	2.96:1
yellow X green seeds	all yellow	6022 yellow 2001 green	3.01:1
axial X terminal flowers	all axial	651 axial 207 terminal	3.14:1
red X white flowers	all red	705 red 224 white	3.15:1
inflated X constricted pods	all inflated	882 inflated 299 constricted	2.95:1
green X yellow pods	all green	428 green 152 yellow	2.82:1
tall X dwarf plants	all tall	787 tall	2.84:1

		277 dwarf	

Conclusions from Mendel's Crosses

The F_1 generation showed only one character that was present in the P_1. The other character reappeared in the F_2 (25%).

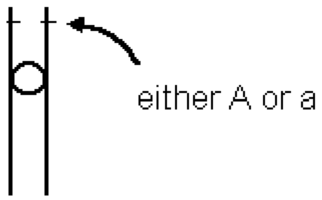
The sex of the parent did not matter.

The traits did not blend.

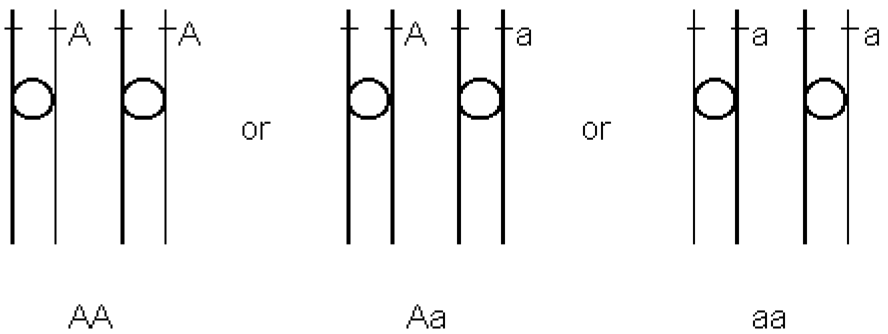
Mendel concluded that the F_1 plants must contain 2 discrete factors, one for each character. The character that was seen in the F_1 is called ***dominant***. The character not seen in the F_1 is called ***recessive***.

Letters Can Represent Genes

The characteristics studied by Mendel were due to single genes. On the pair of chromosomes diagrammed below, the letter "A" represents a gene for yellow seeds. The letter "a" on the homologous chromosome represents a gene for green seeds. By convention, upper case letters are used to represent dominant genes and lower case letters are used for recessive genes.



Because individuals are diploid, two letters can be used to represent the genetic makeup of an individual. In the case of seed color, the following three gene combinations are possible: AA, Aa, and aa.



Heterozygote (also called hybrid) refers to an individual that has two different forms of the gene. Example: Aa

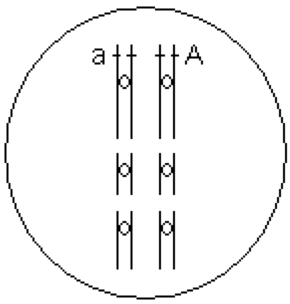
Homozygote refers to an individual that has two identical genes. Example: AA or aa

A **hybrid** is a heterozygote. Example: Aa

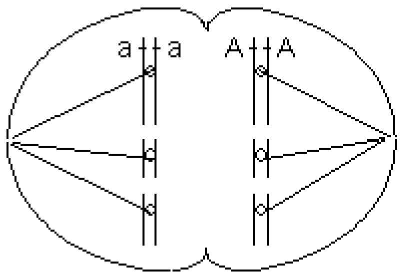
Meiosis, Gamete Formation

The three diagrams below show metaphase I, anaphase I and telophase I in an "Aa" individual.

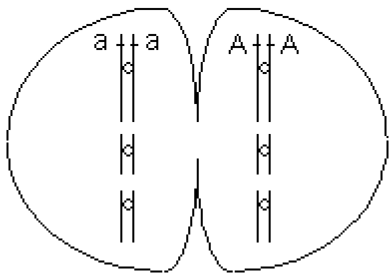
As can be seen in the diagrams, an "Aa" individual can produce gametes that have "A" and gametes that have "a".



Metaphase 1



Anaphase 1



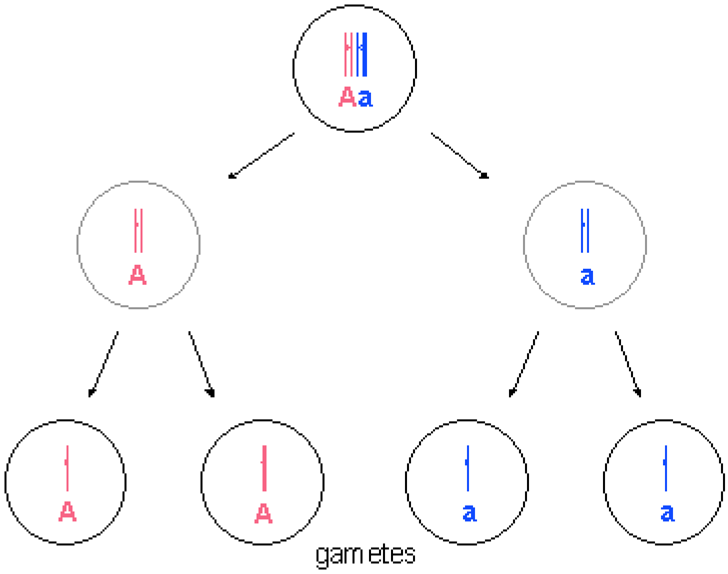
Telophase 1

Principle of Segregation

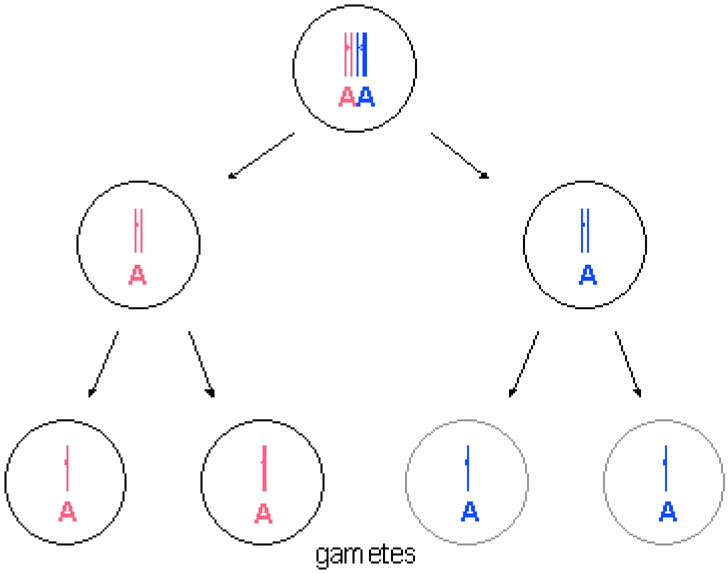
Mendel's principle of segregation states that paired factors (genes) separate during gamete formation (meiosis). Because the pair of genes (Aa, AA, or aa) separate, one daughter cell will contain one gene and the other will contain the other gene. (See diagram above.)

Gametes

Because pairs of chromosomes separate during meiosis I, gametes are haploid, that is, they carry only one copy of each chromosome. An Aa individual therefore produces two kinds of gametes: A and a.



Below: An "AA" individual produces all "A" gametes. Similarly, an "aa" individual produces all "a" gametes.



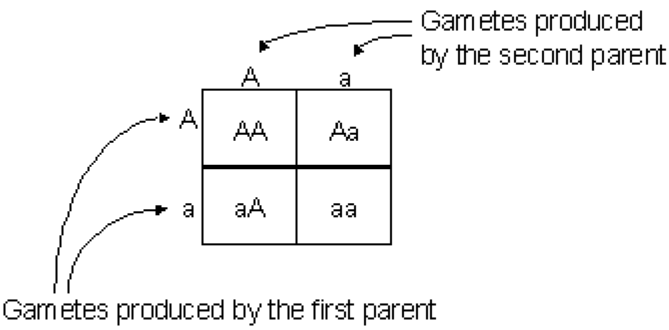
Individual (genotype)	**Type of gametes produced**
AA	all gametes will contain an "A"
Aa	1/2 will contain "A" and 1/2 will contain "a"

aa	all "a" gametes

Punnett Squares

Suppose that an "Aa" individual is crossed with another "Aa" individual. One will produce "A" eggs and "a" eggs. The other will produce "A" sperm and "a" sperm. What are all of the possible combinations of eggs and sperm? A Punnett square can be used to show all of these combinations.

The Punnett square in the diagram below is used to show between two Aa individuals.



The square below is used for this cross: AA X Aa.

	A	a
A	AA	Aa
A	AA	Aa

One half of the offspring produced by this cross will be AA, the other half will be Aa.

The cross can also be written as shown below because the AA parent can produce only one kind of gamete (all A).

	A	a
A	AA	Aa

A Closer look at Mendel’s Crosses (One Gene Locus)

Y = yellow y = green

P_1 YY X yy

↓

F_1 Yy

Yy X Yy ← A cross between two individuals that are heterozygous for a trait is called a ***<u>monohybrid cross</u>***.

F_2 The above cross is illustrated below.

	Y	y
Y	YY	Yy
y	yY	yy

Genotype and Phenotype

The genetic makeup of P_1 plants was different from that of F_1 because the P_1 plants were true breeding and the F_1 plants were not. The genetic makeup of an individual is referred to as its ***genotype***. Because the plants are diploid, two letters can be used to write the genotype. In this case, the genotype of the P_1 plants was YY; the genotype of the F_1 plants was Yy.

The characteristics of an individual are its ***phenotpye***. This word refers to what the individual looks like so ddjectives are used to write the phenotype. For example, "yellow" or "tall" are phenotypes. The yellow P_1 plants looked like the F_1; they had the same phenotype but different genotypes.

An individual with a recessive phenotype has two recessive genes. A dominant phenotype results from either one or two dominant genes. In the cross above, YY or Yy are yellow; yy is green. The phenotype ratio in the F2 is 3 yellow:1 green. The genotype ratio is 1YY:2Yy:1yy.

Genotype	Phenotype
AA or Aa	Yellow
aa	Green

Other Crosses

S = smooth s = wrinkled

P_1 SS X ss

↓

F_1 Ss

Ss X Ss

	S	s
S	SS	Ss
s	sS	ss

F_2 genotype ratio = 1:2:1 (1SS : 2Ss : 1ss)

phenotype ratio = 3:1 (3Smooth : 1 wrinkled)

F = full f = constricted

P_1 FF X ff

↓

F_1 Ff

Ff X Ff

	F	f
F	FF	Ff
f	fF	ff

F_2 genotype ratio = 1:2:1 (1FF : 2Ff : 1ff)

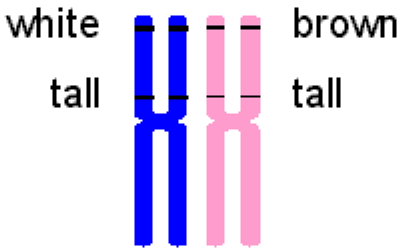
phenotype ratio = 3:1 (3full: 1 constricted)

Alleles and Loci

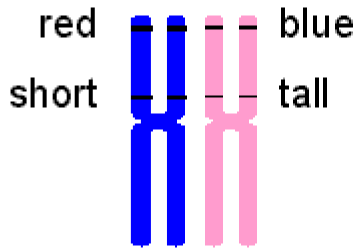
An **allele** is a gene that has more than one form. Each of the forms is referred to as an allele. For example, the gene for red flowers and the gene for white flowers are two different alleles.

A **locus** (plural: **loci**) is the location of a gene on a chromosome. The gene for red flowers and the gene for white flowers are two different alleles at the same locus. A single chromosome can have a gene for white flowers or a gene for red flowers but not both.

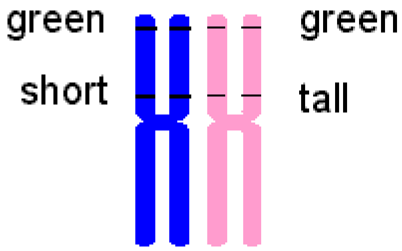
There are two **loci** illustrated below, one is for flower color and the other is for stem length. Flower color has five **alleles** and stem length has two.



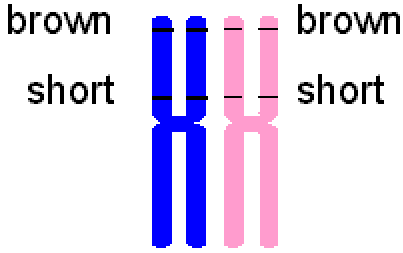
plant #1



plant #2



plant #3



plant #4

Testcross - One Locus

let A = red

a = white

Is a red flower AA or Aa?

Solution: cross it with aa

P_1 A? X aa

The A? individual can produce these kinds of gametes: "A" and "?"

gametes: A, ? and a

F_1 Aa and ?a

If the ?a individual is red, then ? = A. If it is white, then ? = a.

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- Genetics - Part 2 - Chromosomes

Linkage

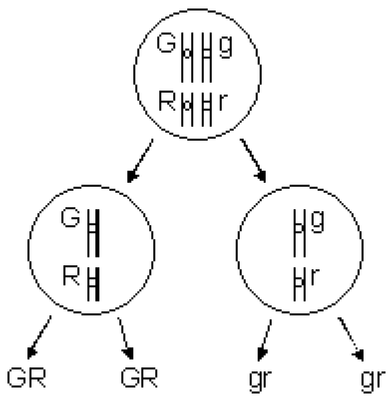
Genes on the same chromosome are linked.

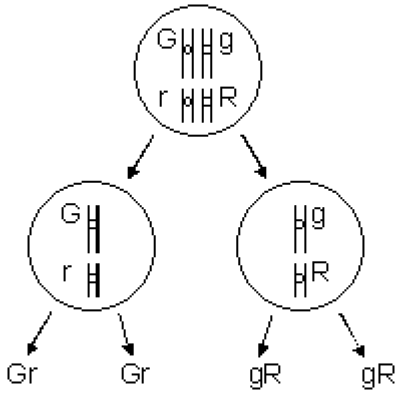
Example: Unlinked Genes

G = gray body
g = black (ebony) body

R = red eyes
r = purple eyes

The diagrams below show that the locus for body color (G or g) is on a different chromosome than the locus for eye color (R or r). These two loci will assort independently to produce either GR and gr gametes or Gr and gR gametes.





cross: GgRr X ggrr

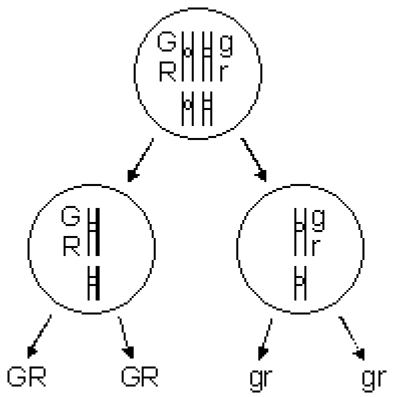
gametes: GR, Gr, gR, gr X gr

	GR	Gr	gR	gr
gr	GgRr	Ggrr	ggRr	ggrr
	gray red	gray purple	black red	black purple

Ratio expected: 1:1:1:1

Example: Linked Genes

Suppose G and R are linked as shown below. If the body color and eye color loci are on the same chromosome, they will not assort independently unless crossing-over occurs frequently.



In this case, GgRr can produce only two kinds of gametes: GR and gr.

GgRr X ggrr

gametes: GR, gr X gr

	GR	gr
gr	GgRr	ggrr
	gray red	black purple

If G and R are linked, then whenever you have a G, you have an R. Any gray, purple offspring (G-rr) would result from crossing over because a Gr gamete is needed.

Suppose out of 100 offspring, you got 46 gray, red, 46 black purple, 4 gray purple and 4 black red. Eight percent of the offspring resulted from crossing over. These offspring are ***recombinant***.

Crossing Over

Crossing over is more likely to occur between genes that are far apart. The farther apart genes are, the greater the probability that crossing over will occur between them.

In the example above, we had 8% crossing over.

The percent of recombination (crossing over) can beused as a measure of how far apart genes are. 1% crossing over = 1 map unit.

Example

G = gray body
g = black (ebony) body

R = red eyes
r = purple eyes

Suppose that G and R are linked (on the same chromosome) in a particular individual and g and r are also linked

P_1 GgRr X ggrr

If there is no crossing-over, possible gametes for the first parent are GR and gr.

If there is crossing-over, possible gametes are gR and Gr.

the following results were obtained:

	GR	gr	gR	Gr
gr	40 GgRr	40 ggrr	10 ggRr	10 Ggrr
	gray red	black purple	black red	gray purple

How far apart are the G and R loci?

Sex Chromosomes

Humans have 23 pairs of chromosomes (46 total) chromosomes. Two of these are called ***sex chromosomes***, the other 44 are called ***autosomes***.

There are two kinds of sex chromosomes, called the X chromosome and the Y chromosome. The X chromosome is larger and contains many genes. The Y chromosome is much smaller and contains very few genes.

Normally, human females have two X chromosomes (XX) and males have one X and one Y chromosome (XY).

Occasionally, an accident happens in which a person is born with too many or too few sex chromosomes. In these cases, the person will be male if they inherit a Y chromosome and female if they do not.

Examples of four different possibilities that produce males are shown below. The last three are abnormal.

XY
XXY
XXXY
XYY

Examples of four different possibilities that produce females are shown below. Normal females are XX.

X
XX
XXX
XXXX

The cross below shows that normal females produce eggs that have one X chromosome. Half of the sperm produced by normal males have an X chromosome and the other half have a Y chromosome.

XX x XY

↓

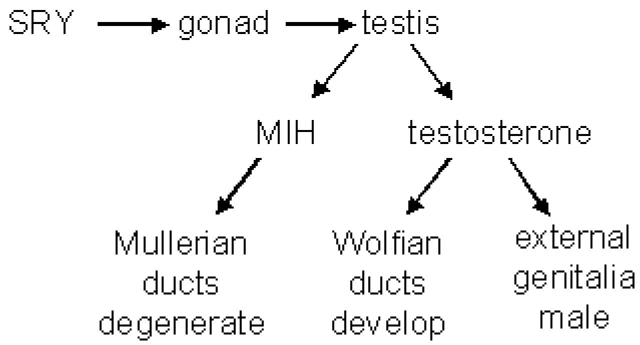
	X	Y
X	XX	XY

This analysis shows that half of the offspring are expected to be male, half are expected to be female.

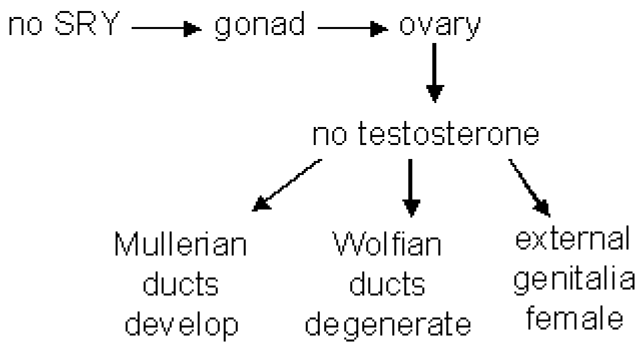
Chromosomal Determination of Sex

Males

The Y chromosome contains a gene called SRY (for sex-determining region of Y).



Females



Testicular Feminization

The body cells of people with testicular feminization are insensitive to testosterone and therefore develop the female phenotype even though they have a Y chromosome.

It has an X-linked recessive mode of inheritance.

Guevodoces

Guevodoces refers to a condition in which the male phenotype develops after puberty.

It is due to delayed testosterone production.

X-Linkage

Morgan (Columbia U):

P_1 red-eyed X white-eyed

↓

F_1 all red-eyed

F_2 3:1 (red:white) but all white were male

explanation:

These genes are found on the X chromosome but not on the Y chromosome. An X^rY male will therefore have red eyes. Details of this cross are below.

P_1 X^RX^R X X^rY

female male

gametes: X^R (female) and X^r, Y (male)

	X^r	Y
X^R	X^rX^R	X^RY
	female red	male red

The offspring produced from the above cross are crossed with each other (below):

F_1 X^RX^r X X^RY

↓

gametes: X^R and X^r (from female); X^R and Y (from male)

F_2:

	X^R	Y
X^R	X^RX^R	X^RY
X^r	X^rX^R	X^rY

Notice that there are three possible genotypes for females and two possible genotypes for males.

Females		Males	
Genotypes	Phenotypes	Genotypes	Phenotypes
X^RX^R	red	X^RY	red
X^RX^r	red	X^rY	white
X^rX^r	white		

X-Linked Inheritance

Males inherit their X chromosome from their mother. Their Y chromosome comes from their father. A male, therefore, cannot pass an X-linked trait to his sons. Males inherit all of their X-linked traits from their mother.

If a male inherits an X-linked recessive trait, it will be expressed because males do not have a homologous X chromosome.

Females can be carriers of X-linked traits without expressing them because they might carry the dominant allele on the other X chromosome. For example, the following genotype will have a dominant phenotype: X^AX^a.

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DNA

The Search to Identify the Genetic Material

Discovery of Nucleic Acids - Friedrich Miescher, 1869

Miescher isolated the nuclei of white blood cells obtained from pus cells. His experiments revealed that nuclei contained a chemical that contained nitrogen and phosphorus but no sulfur. He called the chemical nuclein because it came from nuclei. It later became known as nucleic acid.

Proteins Produce Genetic Traits - Archibald Garrod, 1909

Garrod noticed that people with certain genetic abnormalities (inborn errors of metabolism) lacked certain enzymes. This observation linked proteins (enzymes) to genetic traits.

Genetic Material can Transform Bacteria - Frederick Griffith, 1931

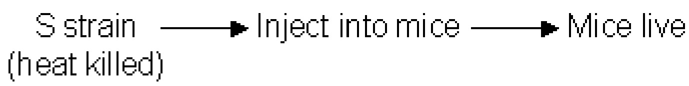
When Streptococcus pneumoniae (pneumococcus) bacteria are grown on a culture plate, some produce smooth shiny colonies (S) while others produce rough colonies (R). This is because the S strain bacteria have a mucous (polysaccharide) coat, while R strain does not.

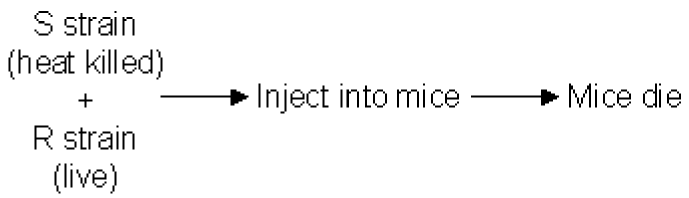
Mice infected with the S strain die from pneumonia infection but mice infected with the R strain do not develop pneumonia.

S strain → Inject into mice → Mice die

R strain → Inject into mice → Mice live

Griffith was able to kill bacteria by heating them. He observed that heat-killed S strain bacteria injected into mice did not kill them. When he injected a mixture of heat-killed S and live R bacteria, the mice died. Moreover, he recovered living S bacteria from the carcasses.





He concluded that some substance needed to produce the mucous coat was passed from the dead bacteria (S strain) to the live ones (R strain); they became ***transformed***.

This must be due to a change in the genotype associated with the transfer of the genetic material.

The transforming material is DNA - Oswald Avery, Colin MacLeod, and Maclyn McCarty, 1944

Prior to the work of Avery, MacLeod, and McCarty, the genetic material was thought to be protein. Avery, MacLeod, and McCarty worked to determine what the transforming substance was in Griffith's experiment (above).

They purified chemicals from the heat-killed S cells to see which ones could transform live R cells into S cells. They discovered that DNA alone from S bacteria caused R bacteria to become transformed.

They also discovered that protein-digesting enzymes (proteases) and RNA-digesting enzymes (RNAse) did not affect transformation, so the transforming substance was not a protein or RNA. Digestion with ***DNase*** did inhibit transformation, so DNA caused transformation.

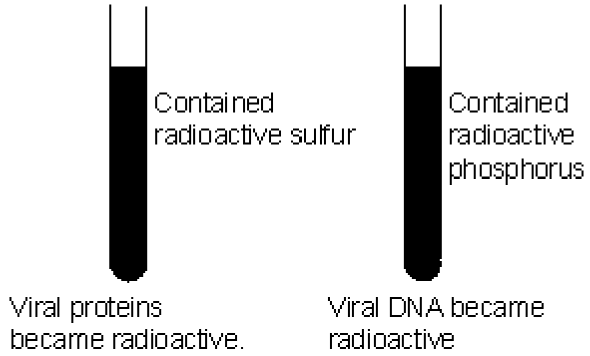
They concluded that DNA is the hereditary material, but not all biologists were convinced.

More Evidence: The Genetic Material is DNA - Alfred D. Hershey and Martha Chase, 1952

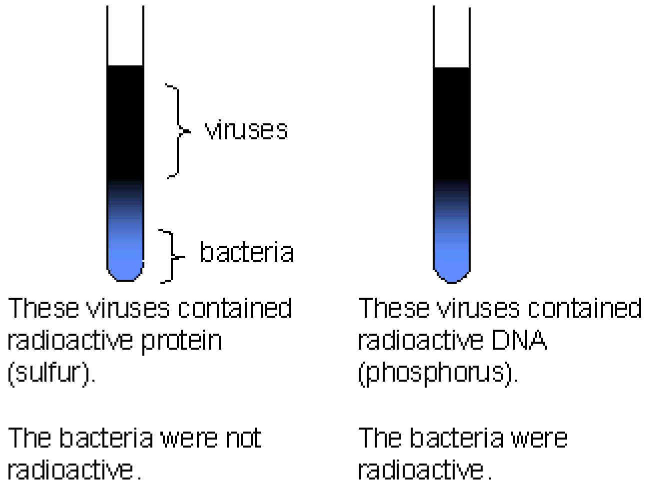
Hershey and Chase worked with viruses that infect bacteria called bacteriophages.

The bacteriophage becomes attached to the bacteria and its genetic material then enters the bacterial cell. The bacterial cell treats the viral genetic material as if it was its own and subsequently manufactures more virus particles. Hershey and Chase worked to discover whether it was protein or DNA from the viruses that entered the bacteria.

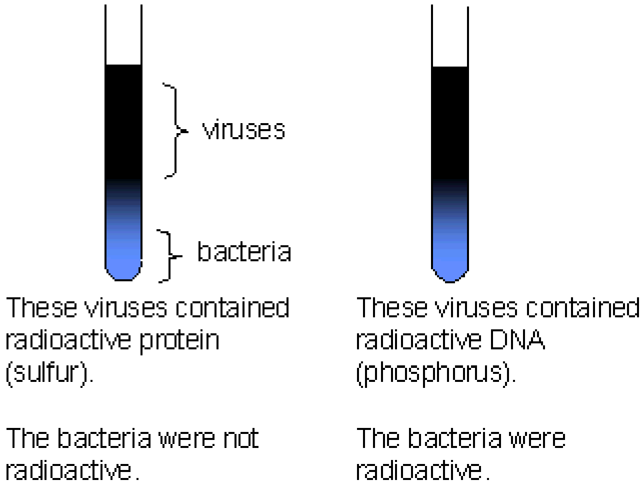
They grew a virus population in medium that contained radioactive phosphorus and another in medium that contained radioactive sulfur. Viruses grown in the presence of radioactive phosphorus contained radioactive DNA but not radioactive protein because DNA contains phosphorus but protein does not. Similarly, viruses grown on radioactive sulfur contained radioactive protein but not radioactive DNA because DNA does not contain sulfur.



Radioactive bacteriophages were allowed to attach to E. coli bacteria. Then as the infection proceeded, the viral coats were removed from the bacteria by agitating them in a blender. The viruses particles were separated from the bacteria by spinning them in a centrifuge.



Bacteria that were infected with viruses that had radioactive DNA were radioactive, indicating that DNA was the material that passed from the virus to the bacteria. Bacteria that were infected with viruses that had radioactive proteins were not radioactive. This indicates that proteins did not enter the bacteria from the viruses. DNA is therefore the genetic material that is passed from virus to bacteria.



Discovery of the Structure of DNA

Erwin Chargaff, 1940's and early 50's

DNA was thought to contain equal amounts of A, T, T, and C. Chargaff found that the base composition of DNA differs among species.

His data showed that in each species, the percent of A equals the percent of T, and the percent of G equals the percent of C. so that 50% of the bases were purines (A + G) and 50% were pyrimidines (T + C)

Chargafff's rule: The amount of A = T and the amount of G = C.

M.H.F. Wilkins and Rosalind Franklin, early 50's

Wilkins and Franklin studied the structure of DNA crystals using X-rays.

They found that the crystals contain regularly repeating subunits.

Structures that are close together cause the x-ray to bend more than structures that are further apart. The X pattern produced by DNA suggested that DNA contains structures with dimensions of 2 nm, 0.34 nm, and 3.4 n. The dark structures at the top and bottom indicate that some structure was repeated, suggesting a helix.

James Watson and Francis H.C. Crick, 1953

Watson and Crick used Chargaff's base data and Franklin's X-ray diffraction data to construct a model of DNA.

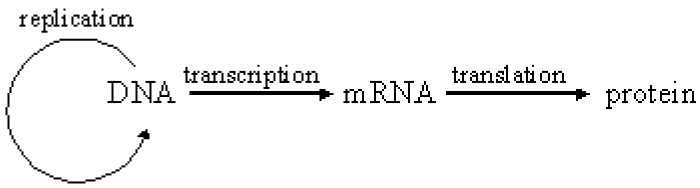
The model showed that DNA is a double helix with sugar-phosphate backbones on the outside and the paired nucleotide bases on the inside, in a structure that fit the spacing estimates from the X-ray diffraction data.

Chargaff's rules showed that A = T and G = C, so there was complementary base pairing of a purine with a pyrimidine, giving the correct width for the helix.

The paired bases can occur in any order, giving an overwhelming diversity of sequences.

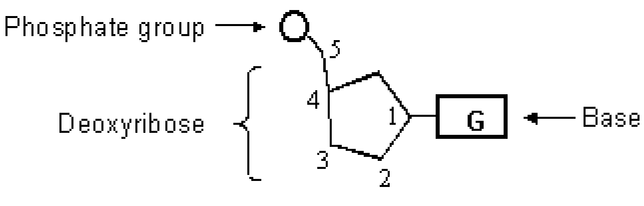
Properties of Genetic Material

DNA is an ideal genetic material because it can store information, is able to replicate, and is able to undergo changes (mutate).

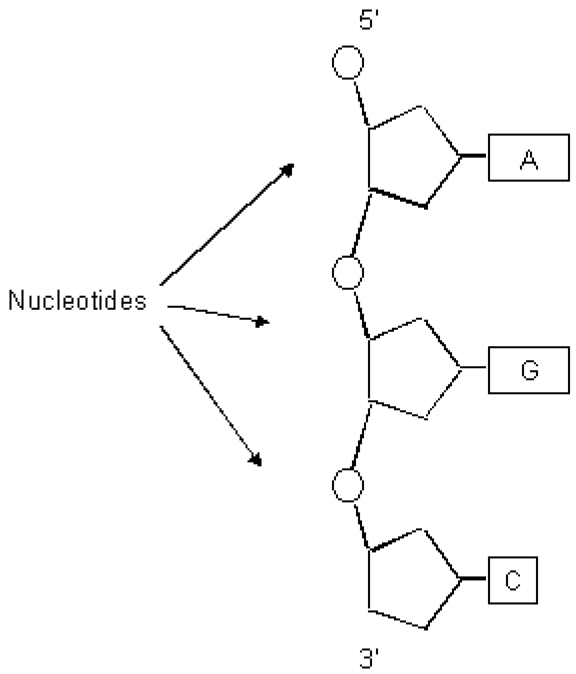


Structure of DNA

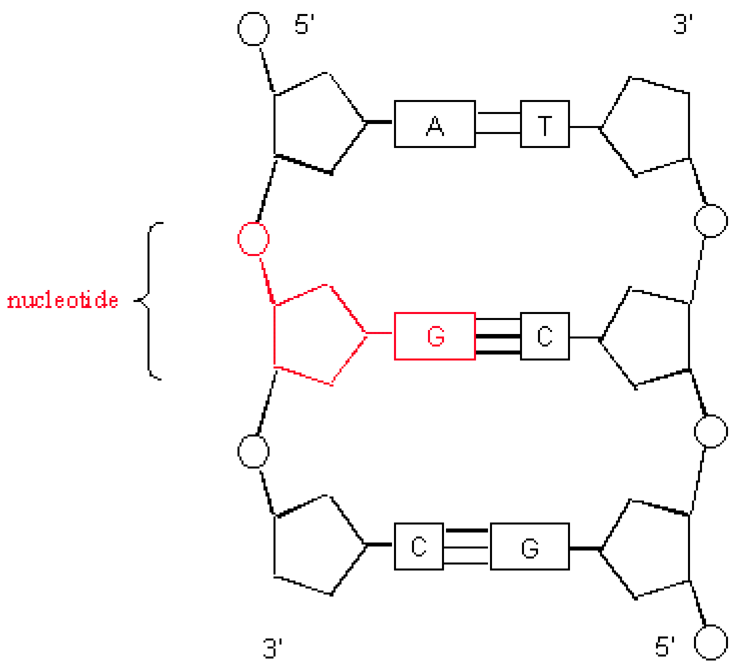
DNA is composed of units called nucleotides. Each nucleotide contains a phosphate group, a deoxyribose sugar, and a nitrogenous base.



The nucleotides joined together to form a chain. The phosphate end of the chain is referred to as the 5' end. The opposite end is the 3' end.



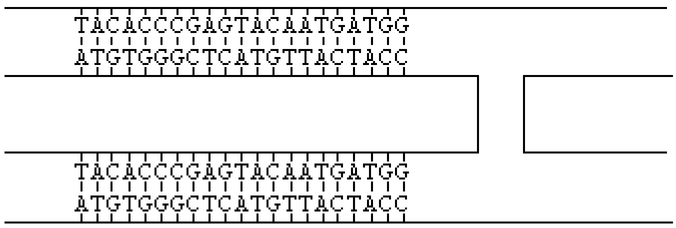
DNA is composed of two chains of nucleotides linked together in a ladder-like arrangement with the sides composed of alternating deoxyribose sugar and phosphate groups and the rungs being the nitrogenous bases as indicated by the diagram below.



The "A" of one strand is always paired with a "T" on the other. Similarly, the "G" of one strand is paired with a "C" on the other.

The two strands are held together by hydrogen bonds (electrostatic attraction). Two hydrogen bonds hold adenine to thymine. Three bonds attach cytosine to guanine as indicated in the diagram above.

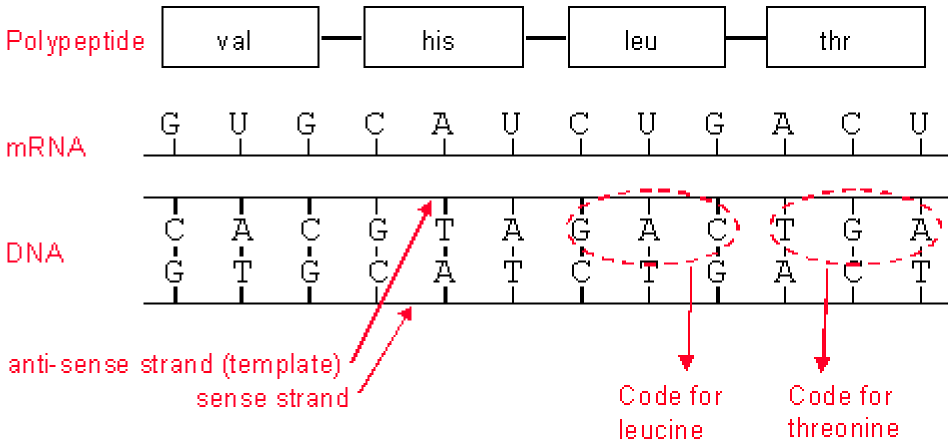
During the process of cell division, the DNA becomes tightly coiled, forming structures called ***chromosomes***. The diagram below is a portion of a double-stranded chromosome showing the centromere and a portion of the base sequence. The diagram does not show the extensive looping and coiling and the proteins associated with coiling. Notice that the base sequence in the two chromatids is identical.



How is Information Stored?

The diagram below shows that one strand of the DNA double-helix serves as a template for the construction of mRNA. The sequence of nucleotides in this DNA strand is complimentary (opposite) the sequence in mRNA. The diagram also shows that the sequence of nucleotides in mRNA determines the amino acids in the protein. For example GUG in mRNA (or CAC in DNA) codes for valine (see below).

The strand of DNA that contains the genetic code is called the anti-sense. It is often referred to as the coding strand or the template strand. The other strand (the sense strand) is not used. Notice that the sense strand has the same base sequence as mRNA except that mRNA has U instead of T.



The codes in DNA are copied to produce mRNA. Each three-letter code in mRNA (called a ***codon***) codes for one amino acid. The sequence of amino acids in proteins is therefore most directly determined by the sequence of codons in mRNA, which in turn, are determined by the sequence of bases in DNA.

There are four letters in the genetic alphabet (A, T, G, and C) and each codon contains three letters. It is therefore possible to have 64 different codons. Because there are only 20 different amino acids and 64 possible codons, some amino acids have several different codons.

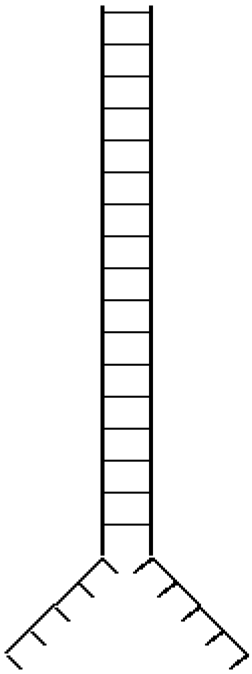
Terminators are codes that indicate the end of a genetic message (gene).

An initiator codon (usually AUG) indicates where the genetic information begins.

DNA replication

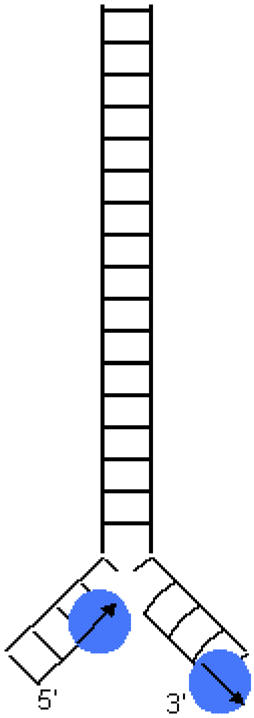
DNA replication involves:

Unwinding



The DNA must be unwound and bonds between the bases broken so that the two strands become separated.

Complimentary Base Pairing

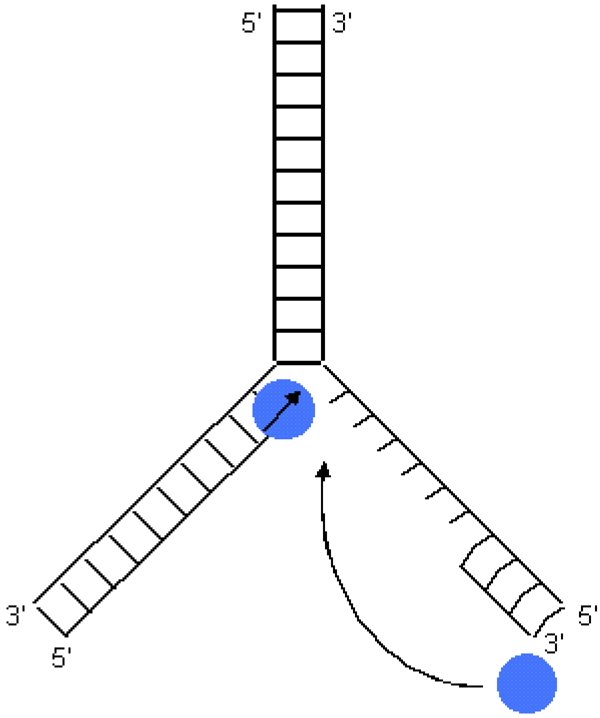


Each strand serves as a template for the synthesis of a new strand.

DNA polymerase adds nucleotides to match to the nucleotide present on the template strand. A is paired with T and G with C. Because each molecule of DNA contains one strand from the original strand, the replication process is ***semiconservative replication.***

The nucleotides used for synthesis are ATP, GTP, CTP and TTP. Each of these DNA nucleotides has three phosphate groups. Two of the phosphates will be removed when the nucleotide is attached to the growing chain of new DNA.

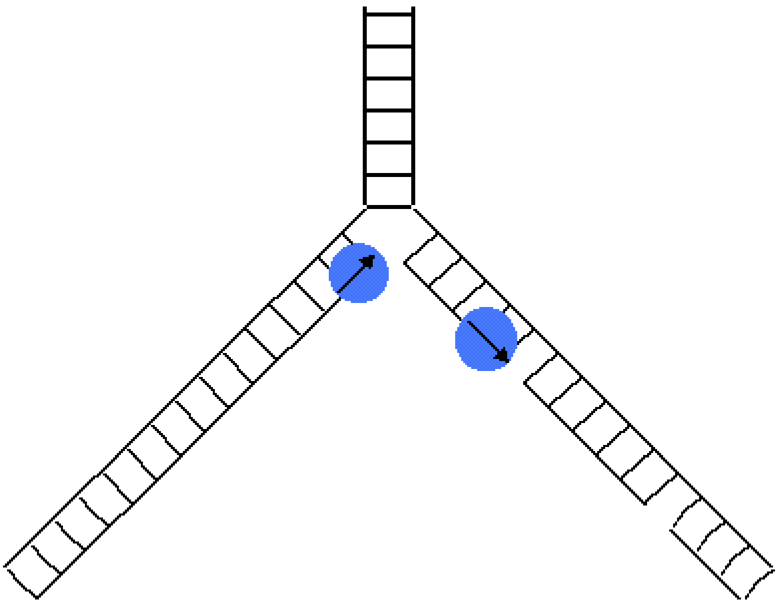
5' to 3'



The strand shown on the right side of the diagram must be synthesized in fragments because DNA polymerase always moves in the direction of 5' to 3'.

The area in a DNA molecule where unwinding is occurring is called a ***replication fork***. In the diagram, it looks like an upside-down Y.

Okazaki Fragments

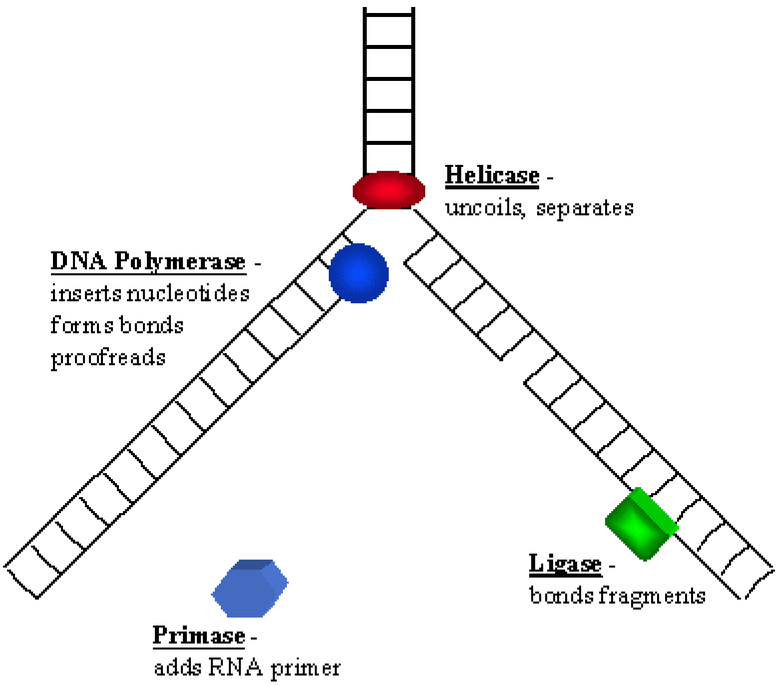


The resulting fragments are called ***Okazaki fragments***.

Joining

Covalent bonds must be formed between the newly-added nucleotides.

Enzymes



DNA Helicase

DNA helicase unwinds the DNA molecule by breaking hydrogen bonds.

DNA Polymerase

DNA polymerase lengthens the strand that is being synthesized by adding nucleotides that are complimentary to those on the template strand (A paired with T and G paired with C).

It proofreads the new strand as it synthesizes it. Incorrectly paired bases are removed and the correct one is inserted (discussed below).

Primase

DNA polymerase cannot initiate a new strand, it can only elongate a strand that is already present. Synthesis of new DNA therefore cannot begin until a short strand of nucleotides is added. This short strand is called a primer. Primase creates an RNA primer. DNA polymerase can extend this strand by adding DNA nucleotides. The RNA primer will be removed and replaced by DNA.

DNA Ligase

DNA ligase catalyzes the formation of the covalent bonds between the Okazaki fragments.

Replication Forks

DNA synthesis occurs at numerous different locations on the same DNA molecule (hundreds in a human chromosome).

These form bubbles of replication with a ***replication fork*** at the growing edge.

The replication rate of eukaryotic DNA is 500 to 5000 base pairs per minute.

A human cell typically requires a few hours to duplicate the 6 billion base pairs.

Repair of damaged DNA

Changes in the DNA code are called ***mutations.*** Repair enzymes repair most of the errors that occur in DNA. There are three different classes of repair mechanisms.

1. Proofreading corrects errors made during the DNA replication process.
2. Mismatch repair corrects base pair mismatching (A-T and G-C).
3. Excision repair removes and replaces small segments of damaged DNA.

Organization of DNA

Chromosome Structure

Chromosomes are structures composed of condensed DNA and associated proteins. When DNA condenses, the molecule becomes wrapped around proteins called ***histones***. The histones are then arranged in a coiled pattern to produce a larger fiber. This larger fiber is further compacted by looping to produce looped domains. The looped domains are coiled and compacted to produce chromosomes.

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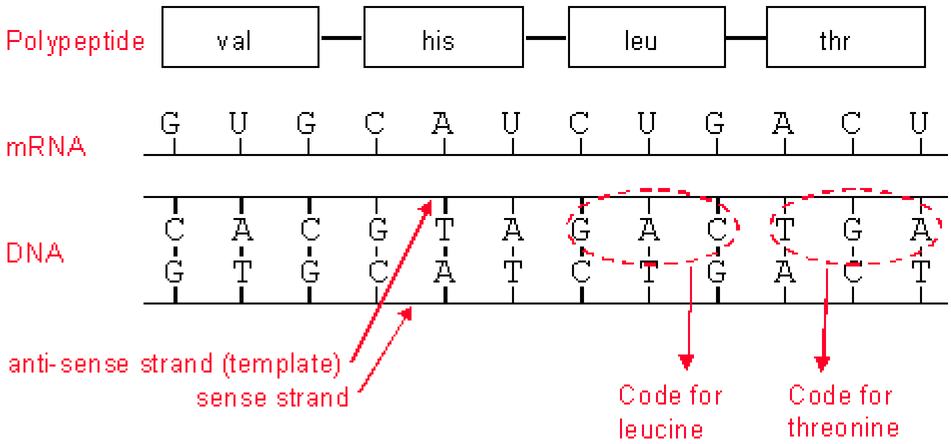
Protein Synthesis: Transcription and Translation

DNA contains codes

Three bases in DNA code for one amino acid. The DNA code is copied to produce mRNA. The order of amino acids in the polypeptide is determined by the sequence of 3-letter codes in mRNA.



DNA vs RNA

	DNA	RNA
Sugar:	deoxyribose	ribose
Bonds with Adenine:	thymine	uracil
# of Strands:	two	one

Kinds of RNA

Messenger RNA (mRNA)

Messenger RNA contains genetic information. It is a copy of a portion of the DNA.

It carries genetic information from the gene (DNA) out of the nucleus, into the cytoplasm of the cell where it is translated to produce protein.

Ribosomal RNA (rRNA)

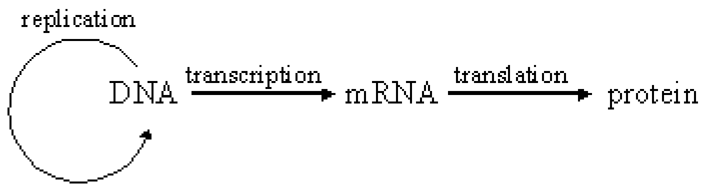
This type of RNA is a structural component of the ribosomes. It does not contain a genetic message.

Transfer RNA (tRNA)

Transfer RNA functions to transport amino acids to the ribosomes during protein synthesis.

Transcription

Transcription is the synthesis of mRNA from a DNA template.



It is like DNA replication in that a DNA strand is used to synthesize a strand of mRNA.

Only one strand of DNA is copied.

A single gene may be transcribed thousands of times.

After transcription, the DNA strands rejoin.

Steps involved in transcription

DNA unwinds.

RNA polymerase recognizes a specific base sequence in the DNA called a ***promoter*** and binds to it. The promoter identifies the start of a gene, which strand is to be copied, and the direction that it is to be copied.

Complementary bases are assembled (U instead of T).

A ***termination code*** in the DNA indicates where transcription will stop.

The mRNA produced is called a ***mRNA transcript***.

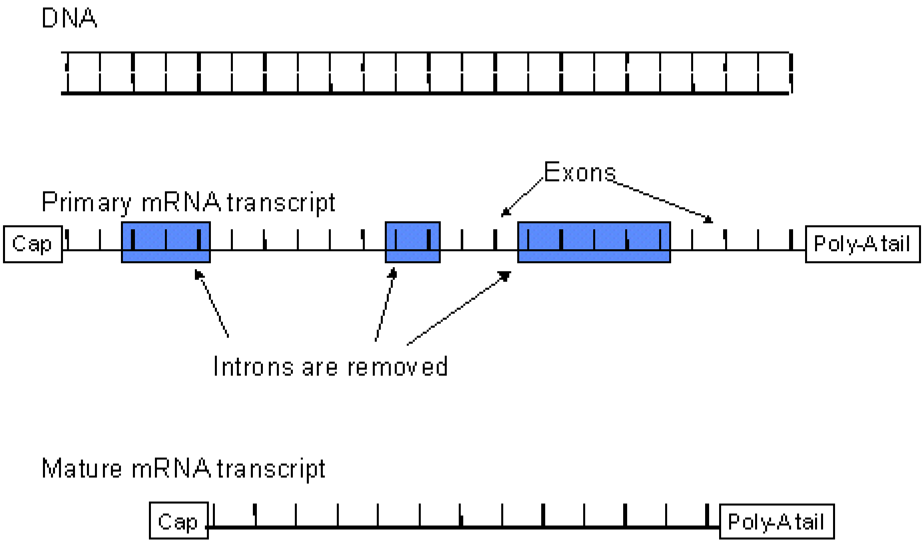
Processing the mRNA Transcript

In eukaryotic cells, the newly-formed mRNA transcript (also called heterogenous nuclear RNA or hnRNA) must be further modified before it can be used.

A cap is added to the 5' end and a poly-A tail (150 to 200 Adenines) is added to the 3'end of the molecule.

The newly-formed mRNA has regions that do not contain a genetic message. These regions are called ***introns*** and must be removed. Their function is unknown.

The remaining portions of mRNA are called ***exons***. They are spliced together to form a ***mature mRNA transcript***.



The Nucleus

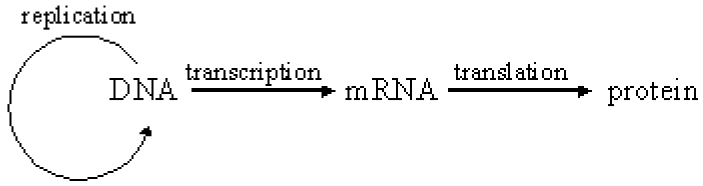
DNA is located in an organelle called the ***nucleus***.

Transcription and mRNA processing occur in the nucleus.

The nucleus is surrounded by a double membrane. After the mature mRNA transcript is produced, it moves out of the nucleus and into the ***cytoplasm*** through ***pores*** in the ***nuclear membrane***.

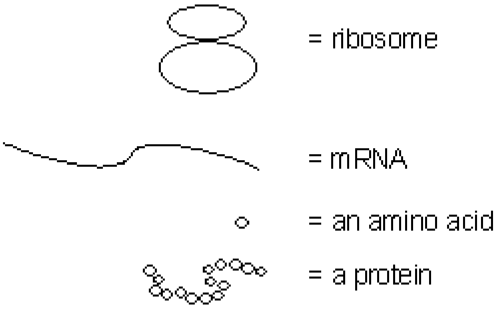
Translation

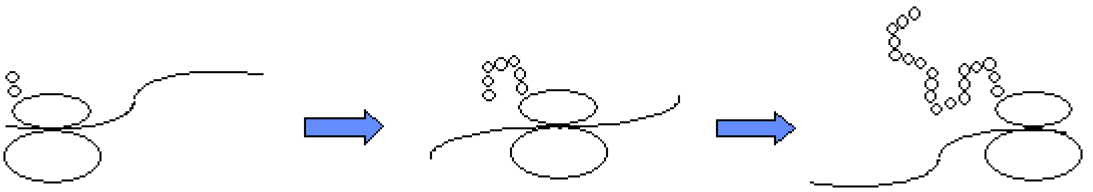
Translation is the process where ribosomes synthesize proteins using the mature mRNA transcript produced during transcription.



Overview

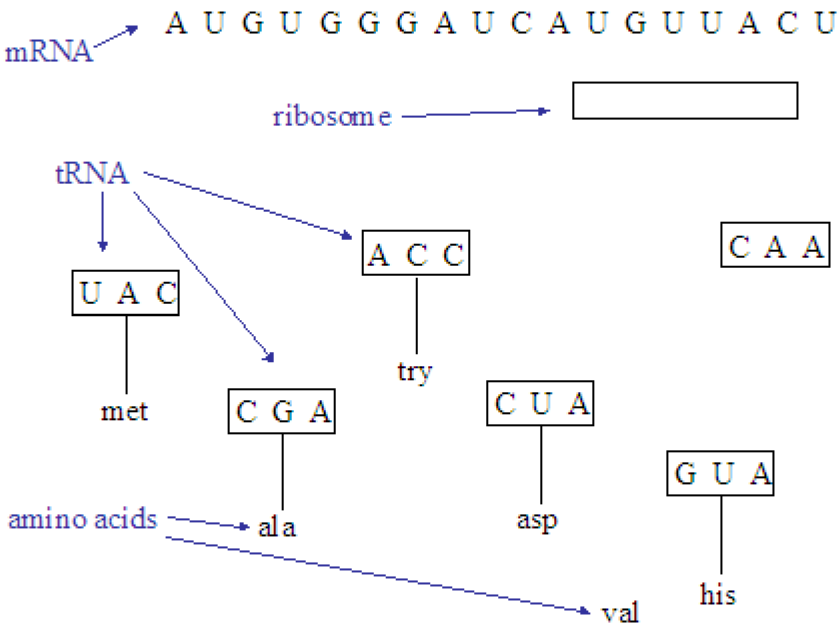
The diagram below shows a ribosome attach to mRNA, and then move along the mRNA adding amino acids to the growing polypeptide chain.



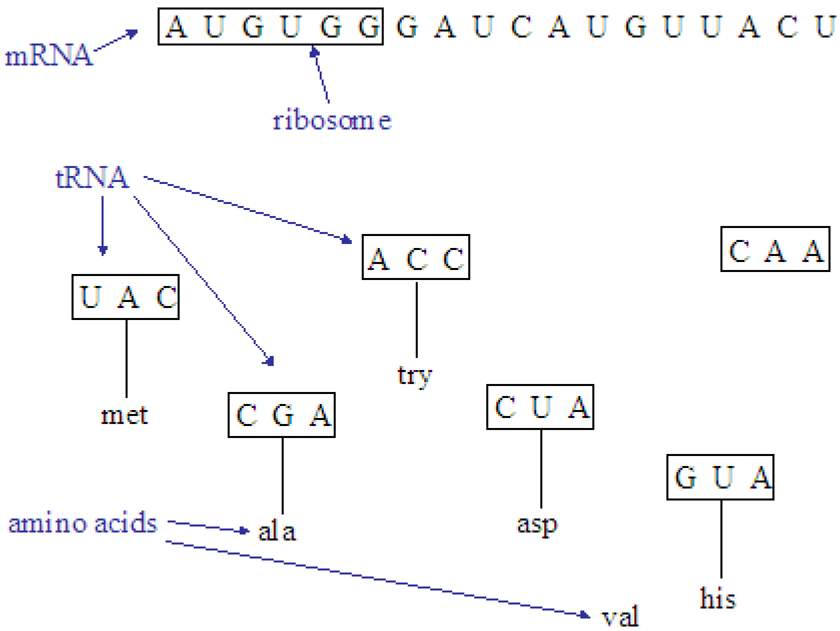


Translation - Details

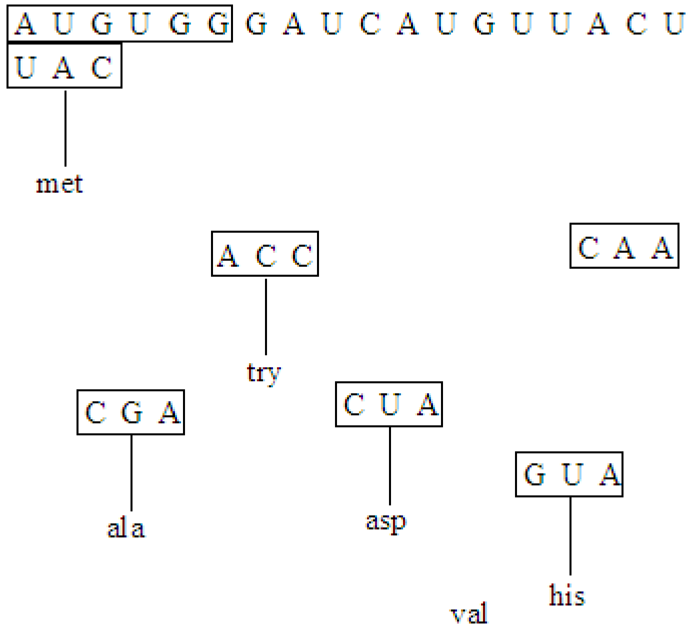
A mature mRNA transcript, a ribosome, several tRNA molecules and amino acids are shown. There is a specific tRNA for each of the 20 different amino acids.



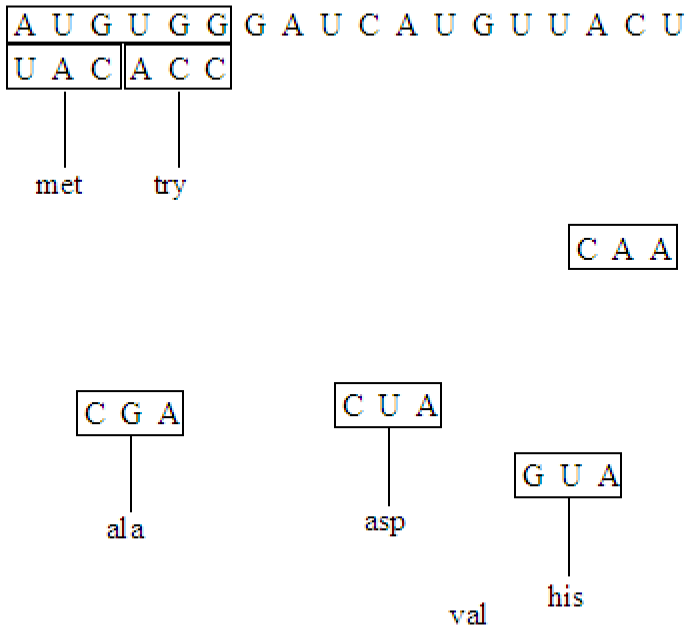
Below: A ribosome attaches to the mRNA transcript.



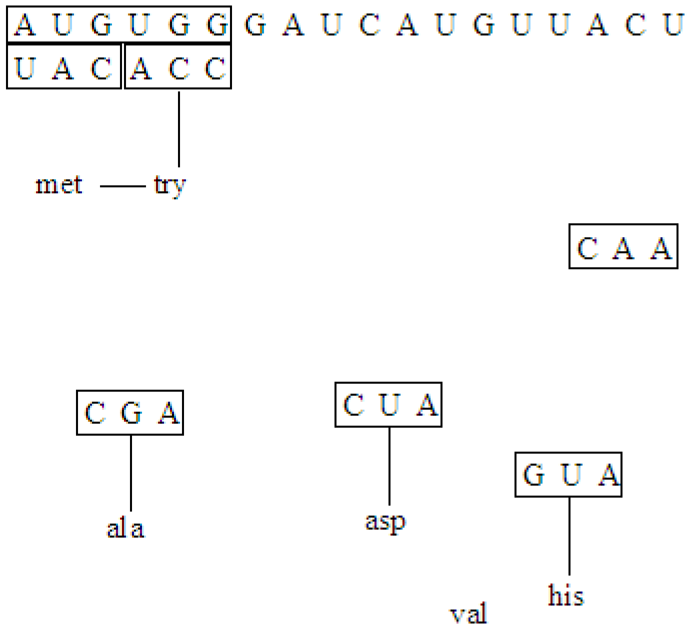
A tRNA molecule transports an amino acid to the ribosome. Notice that the 3-letter ***anticodon*** on the tRNA molecule matches the 3-letter code (called a ***codon***) in the mRNA. The tRNA with the anticodon "UAC" bonds with methionine. It always transports methionine. Transfer RNA molecules with different anticodons transport other amino acids.



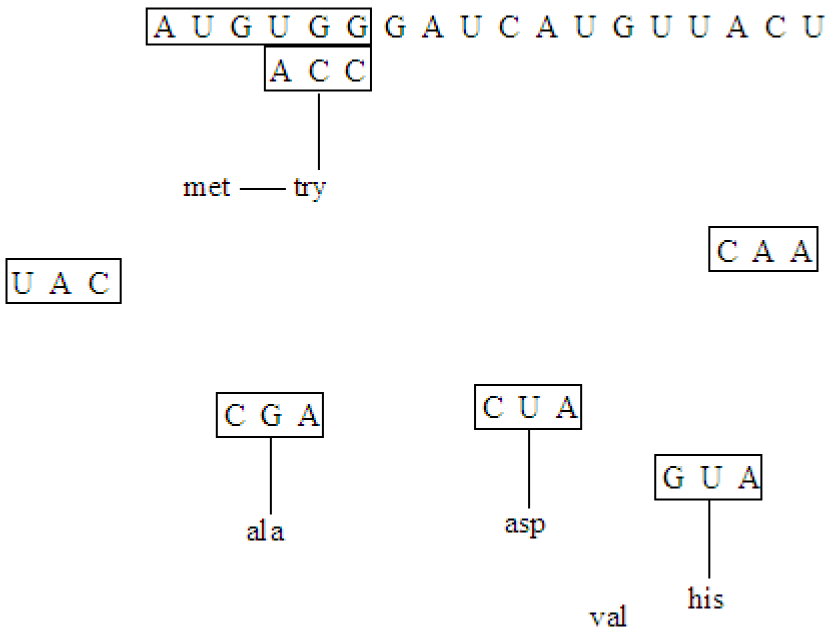
A second tRNA molecule bonds to the mRNA at the ribosome. Again, the codes must match.



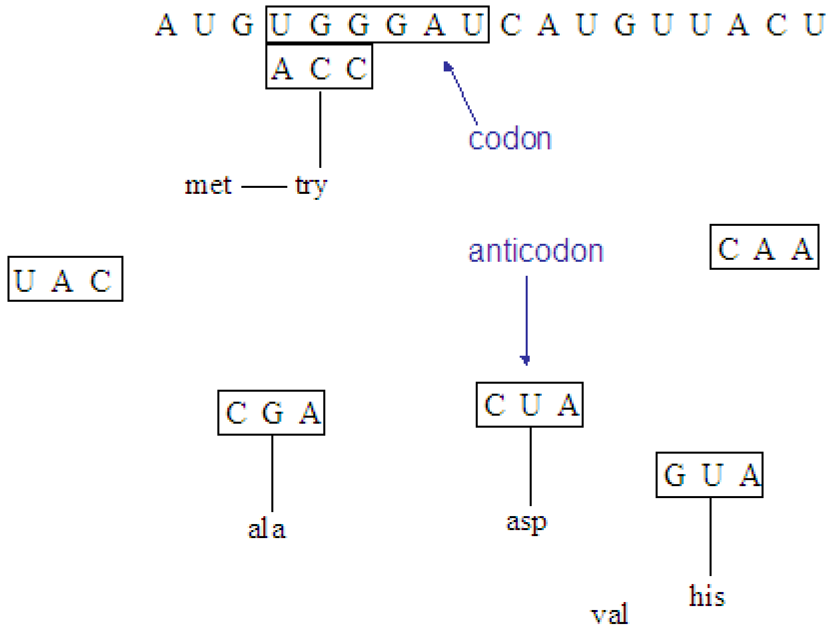
A bond is formed between the two amino acids.



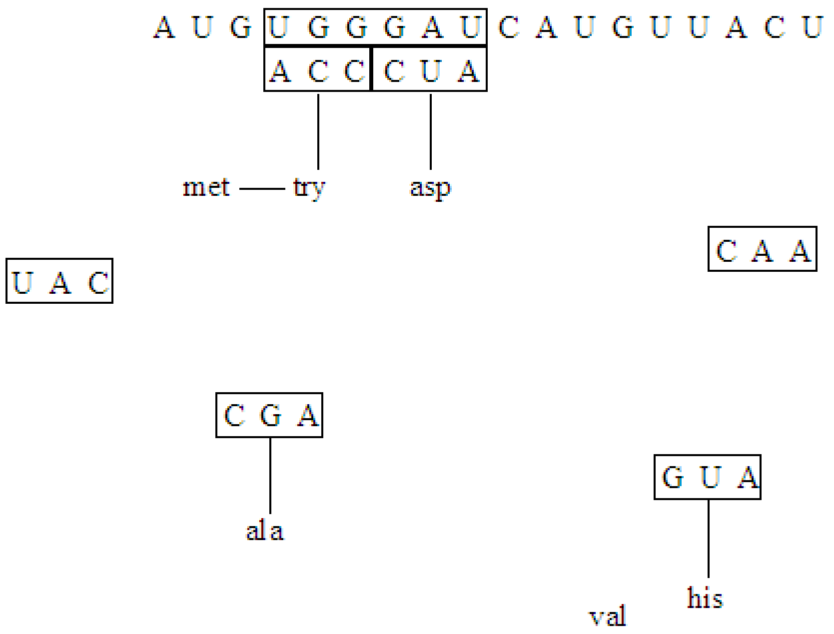
The tRNA bonded to methionine drops off and can be reused later.



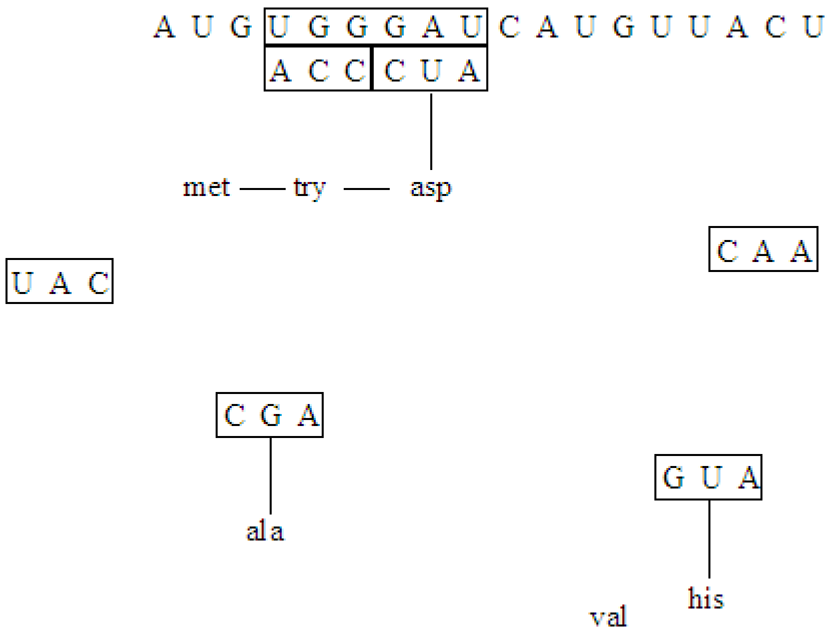
The ribosome moves along the mRNA to expose another codon (GAU) for a tRNA molecule.

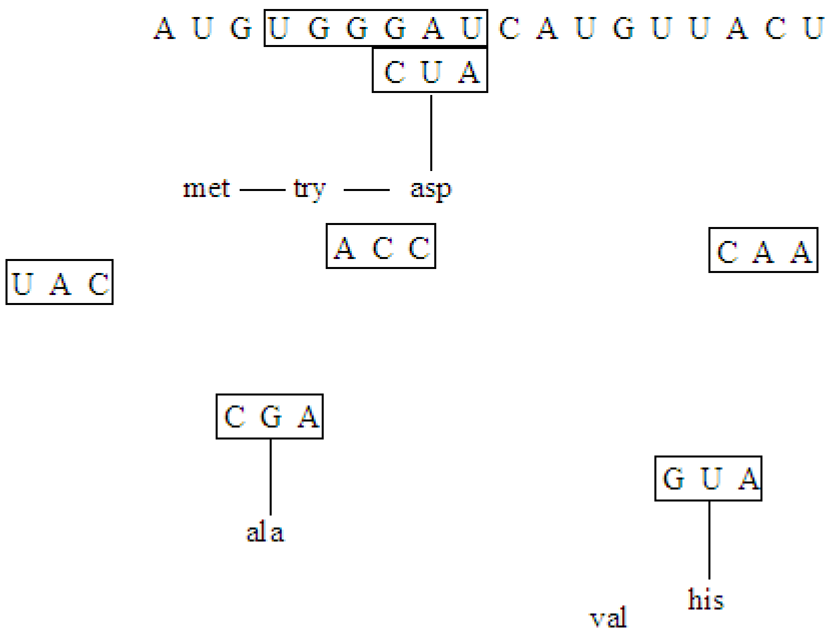


The only tRNA molecule that can bond to the GAU site is a molecule with a CUA anticodon. Transfer RNA molecules with CUA anticodons are specific for asparagine.



Asparagine is now added to the growing amino acid chain.





Summary Animation of Translation on the Internet

Click here to view an animation of translation.

Click here to go to a web page that shows an animation of translation. Go to the bottom of the page and then click translation.

Initiation and Termination Codes

An ***initiation code*** signals the start of a genetic message. As the ribosome moves along a mRNA transcript, it will not begin synthesizing protein until it reaches an initiation code.

Termination codes signal the end of the genetic message. Synthesis stops when the ribosome reaches a terminator codon.

Genetic Code

The table below can be used to determine what amino acid corresponds to any 3-letter codon.

First Base	**Second Base**				**Third Base**
	U	**C**	**A**	**G**	
U	UUU phenylalanine	UCU serine	UAU tyrosine	UGU cysteine	**U**
	UUC phenylalanine	UCC serine	UAC tyrosine	UGC cysteine	**C**
	UUA leucine	UCA serine	UAA stop	UGA stop	**A**
	UUG leucine	UCG serine	UAG stop	UGG tryptophan	**G**
C	CUU leucine	CCU proline	CAU histidine	CGU arginine	**U**
	CUC leucine	CCC proline	CAC histidine	CGC arginine	**C**
	CUA leucine	CCA proline	CAA glutamine	CGA arginine	**A**
	CUG leucine	CCG proline	CAG glutamine	CGG arginine	**G**
A	AUU isoleucine	ACU threonine	AAU asparagine	AGU serine	**U**
	AUC isoleucine	ACC threonine	AAC asparagine	AGC serine	**C**
	AUA isoleucine	ACA threonine	AAA lysine	AGA arginine	**A**
	AUG (start) methionine	ACG threonine	AAG lysine	AGG arginine	**G**
	GUU	GCU	GAU	GGU	**U**

G	valine	alanine	aspartate	glycine	
	GUC valine	GCC alanine	GAC aspartate	GGC glycine	**C**
	GUA valine	GCA alanine	GAA glutamate	GGA glycine	**A**
	GUG valine	GCG alanine	GAG glutamate	GGG glycine	**G**

Mutation

Mutations are changes in the DNA.

Frameshift

A frameshift mutation is usually severe, producing a completely nonfunctional protein.

The priniciple of a frameshift can be explained using the sentence below. If the letters are read three at a time and one is deleted, the second sentence becomes meaningless.

Original DNA:THE BIG RED ANT ATE ONE FAT BUG
Frameshift mutation: THB IGR EDA NTA TEO NEF ATB UG?

Point Mutation

Point mutations involve a single nucleotide, thus a single amino acid.

In the sentence below, eliminating one letter does not change in the remaining three-letter words and therefore may not cause a significant change in the meaning of the sentence.

Original DNA:THE BIG RED ANT ATE ONE FAT BUG
Point mutation:THA BIG RED ANT ATE ONE FAT BUG

Silent, Missense, and Nonsense Mutations

Three kinds of point mutations can occur. A mutation that results in an amino acid substitution is called a missense mutation.

A mutation that results in a stop codon so that incomplete proteins are produced, it is called a nonsense mutation.

A mutation that produces a functioning protein is called a silent mutation.

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Digestive System

Introduction

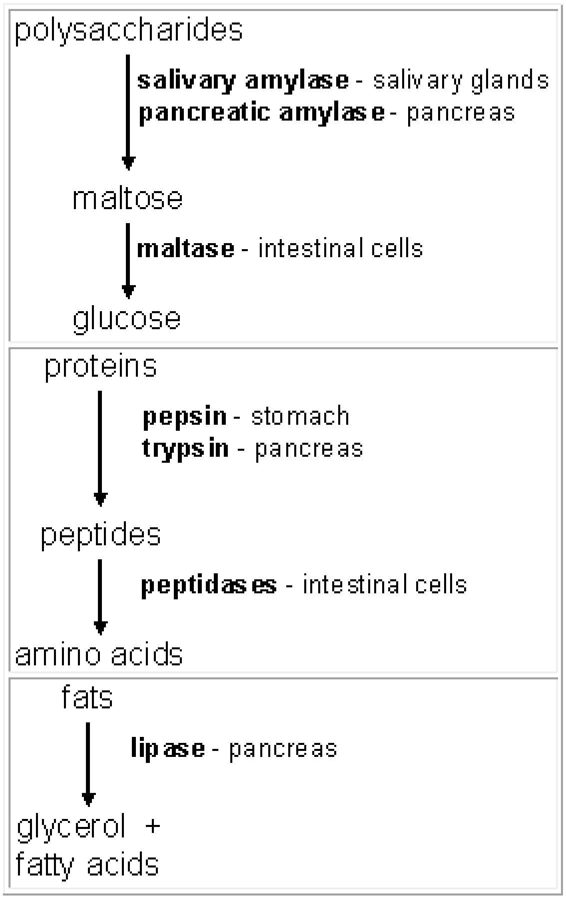
Digestion is the chemical breakdown of large food molecules into smaller molecules that can be used by cells. The breakdown occurs when certain specific enzymes are mixed with the food.

Enzymes involved in Digestion

polysaccharides → maltose → glucose

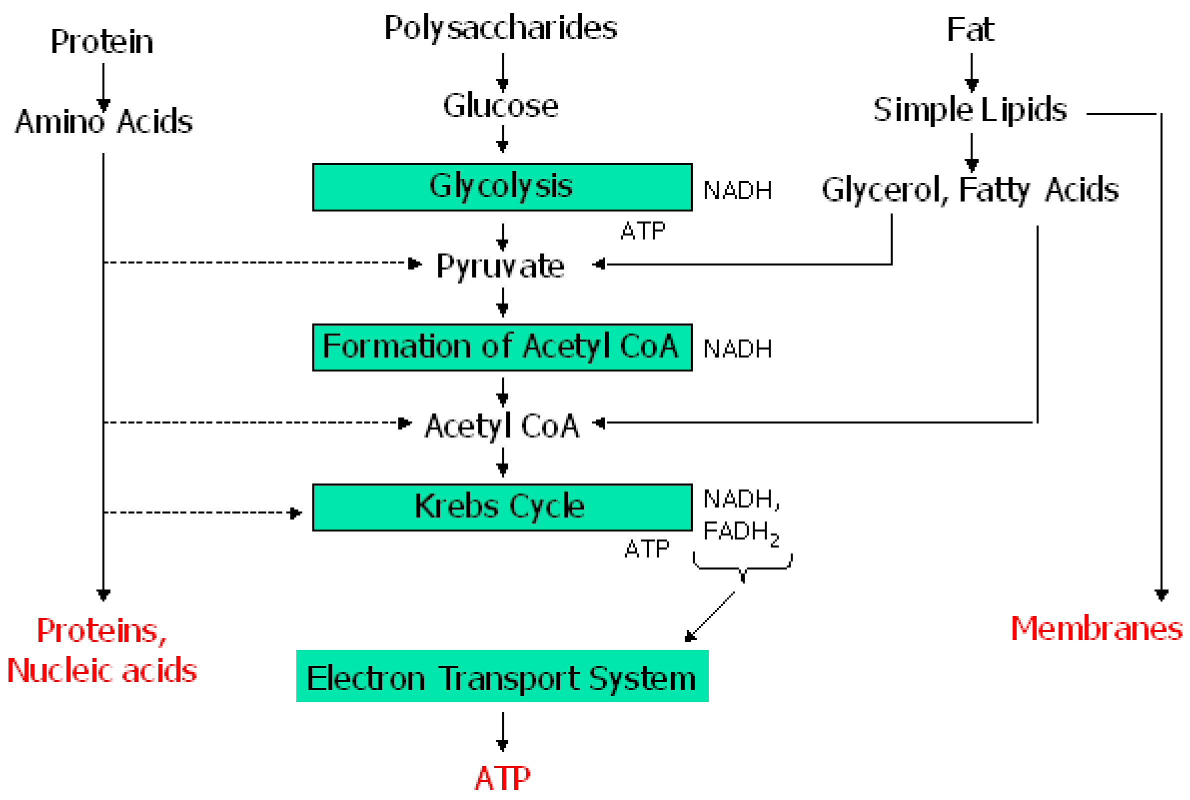
proteins → peptides → amino acids

fats → fatty acids and glycerol



Carbohydrates, Proteins, Lipids

The process of digestion produces glucose, amino acids, glycerol, and fatty acids (see above). The energy in glucose is used to produce ATP via the reactions of glycolysis, cellular respiration, and the electron transport system (see diagram below). The body uses amino acids to construct proteins. Excess amino acids can be used to synthesize pyruvate, acetyl CoA, and alpha ketogluterate, which enters the Krebs cycle. Glycerol and fatty acids can be converted to pyruvate and Acetyl CoA and then enter cellular respiration.



Mouth

Chewing breaks food into smaller particles so that chemical digestion can occur faster.

Enzymes

Salivary amylase breaks starch (a polysaccharide) down to maltose (a disaccharide).

Bicarbonate ions in saliva act as buffers, maintaining a pH between 6.5 and 7.5.

Mucins (mucous) lubricate and help hold chewed food together in a clump called a bolus.

The tongue contains chemical receptors in structures called taste buds. Theses are discussed in the chapter on sensory systems.

The tongue is muscular and can move food. It pushes food to back where it is swallowed.

Pharynx

The respiratory and digestive passages meet in the pharynx. They separate posterior to the pharynx to form the esophagus (leads to the stomach) and trachea (leads to the lungs).

Swallowing is accomplished by reflexes that close the opening to the trachea.

When swallowing, the epiglottis covers the trachea to prevent food from entering.

In the mouth, food is mixed with saliva and formed into a ***bolus***.

Peristalsis refers to rhythmic contractions that move food in the gut. Peristalsis in the esophagus moves food from the mouth to the stomach.

Stomach

The stomach stores up to 2 liters of food.

Gastric glands within the stomach produce secretions called **gastric juice**.

The muscular walls of the stomach contract vigorously to mix food with gastric juice, producing a mixture called ***chyme***.

Gastric juice

Pepsinogen is converted to pepsin, which digests proteins. Pepsinogen production is stimulated by the presence of gastrin in the blood (discussed below).

HCl

Hydrochloric acid (HCl) converts pepsinogen to ***pepsin*** which breaks down proteins to peptides. HCl maintains a pH in the stomach of approximately 2.0.

It also dissolves food and kills microorganisms.

Mucous protects the stomach from HCl and pepsin.

Secretion of Gastric Juice

Seeing, smelling, tasting, or thinking about food can result in the secretion of gastric juice.

Gastrin is a hormone that stimulates the stomach to secrete gastric juice. (See the discussion of hormones below.)

Ulcer

An ulcer is an irritation due to gastric juice penetrating the mucous lining of the stomach or duodenum. It is believed that ulcers are caused by the bacterium *Helicobacter pylori*, which, can thrive in the acid environment of the stomach. The presence of the bacteria on portions of the stomach lining prevents it from secreting mucous, making it susceptible to the digestive action of pepsin.

Duodenum

The duodenum is the first part of the small intestine.

Chyme enters through a ***sphincter***.

It enters in tiny spurts.

At this point, proteins and carbohydrates are only partially digested and lipid digestion has not begun.

Pancreas

The pancreas acts as an exocrine gland by producing ***pancreatic juice*** which empties into the small intestine via a duct.

The pancreas also acts as an endocrine gland to produce insulin. (See the discussion on the Islets of Langerhans or Pancreatic Islets in the chapter on the endocrine system.)

Pancreatic Juice

Pancreatic juice contains sodium bicarbonate which neutralizes the acidic material from the stomach.

Pancreatic amylase digests starch to maltose.

Trypsin and ***Chymotrypsin*** digest proteins to peptides. Like pepsin (produced in the stomach), they are specific for certain amino acids, not all of them. They therefore produce peptides.

Lipase digests fats to glycerol and fatty acids.

Liver

The liver produces ***bile*** which is stored in ***gallbladder*** and sent to the duodenum through a duct.

Bile emulsifies fats (separates it into small droplets) so they can mix with water and be acted upon by enzymes.

Other Functions of the Liver

The liver detoxifies blood from intestines that it receives via the hepatic portal vein.

The liver stores glucose as glycogen (animal starch) and breaks down glycogen to release glucose as needed. This storage-release process maintains a constant glucose concentration in the blood (0.1%). If glycogen and glucose run short, proteins can be converted to glucose.

It produces blood proteins.

It destroys old red blood cells and converts hemoglobin from these cells to bilirubin and biliverdin which are components of bile.

Ammonia produced by the digestion of proteins is converted to a less toxic compound (urea) by the liver.

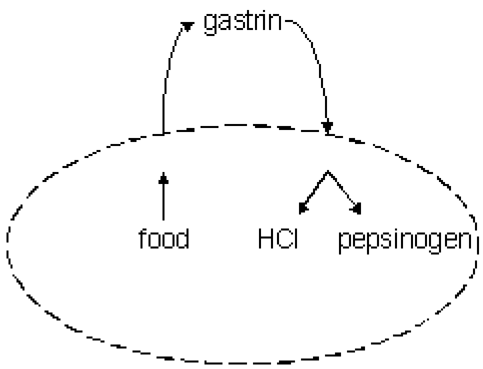
Hormones Involved in Digestion

The hormones listed below, like all hormones, reach their target cells by the circulatory system.

Gastrin

The presence of food in the stomach stimulates stretch receptors which relay this information to the medulla oblongata. The medulla stimulates endocrine cells in the stomach to secrete the hormone ***gastrin*** into the circulatory system. Gastrin stimulates the stomach to secrete gastric juice. This pathway of information is summarized below.

stretch receptors → medulla oblongata → endocrine cells in the stomach → gastrin → circulatory system → stomach → secretes gastric juice

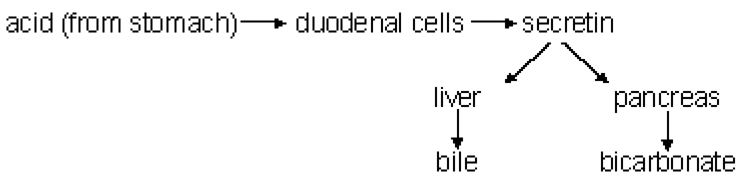


Secretin

Secretin is produced by cells of the duodenum.

It's production is stimulated by acid chyme from stomach.

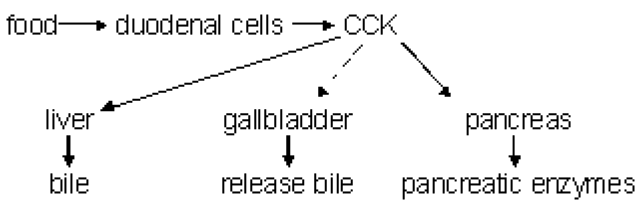
It stimulates the pancreas to produce sodium bicarbonate, which neutralizes the acidic chyme. It also stimulates the liver to secrete bile.



CCK (cholecystokinin)

CCK production is stimulated by the presence of food in the duodenum.

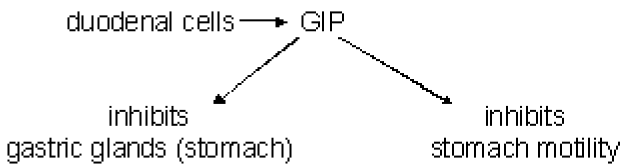
It stimulates the gallbladder to release bile and the pancreas to produce pancreatic enzymes.



GIP (Gastric Inhibitory Peptide)

Food in the duodenum stimulates certain endocrine cells to produce GIP.

It has the opposite effects of gastrin; it inhibits gastric glands in the stomach and it inhibits the mixing and churning movement of stomach muscles. This slows the rate of stomach emptying when the duodenum contains food.



Small Intestine

The small intestine is approximately 3 m long.

Like the stomach, it contains numerous ridges and furrows. In addition, there are numerous projections called ***villi*** that function to increase the surface area of the intestine. Individual villus cells have ***microvilli*** which greatly increase absorptive surface area.

The total absorptive surface area is equivalent to 500 or 600 square meters.

Each villus contains blood vessels and a ***lacteal*** (lymph vessel).

Peptidases and maltase are embedded within the plasma membrane of the microvilli.

Peptidases complete the digestion of peptides to amino acids.

Maltase completes the digestion of disaccharides.

Absorption

Absorption is an important function of the small intestine.

Active transport moves glucose and amino acids into the intestinal cells, then out where they are picked up by capillaries.

Glycerol and fatty acids produced by the digestion of fat enter the villi by diffusion and are reassembled into fat (triglycerides). They combine with proteins and are expelled by exocytosis. They move into the lacteals for transport via the lymphatic system.

Large Intestine

The large intestine is also called the colon.

It receives approximately 10 liters of water per day. 1.5 liters is from food and 8.5 liters is from secretions into the gut. 95% of this water is reabsorbed.

The large intestine also absorbs sodium and other ions but it excretes other metallic ions into the wastes.

If water is not absorbed, diarrhea can result, causing dehydration and ion loss.

It absorbs vitamin K produced by colon bacteria.

The last 20 cm of the large intestine is the rectum.

Feces is composed of approximately 75% water and 25% solids. One-third of the solids is intestinal bacteria, 2/3's is undigested materials.

The cecum is a pouch at the junction of the small intestine and large intestine. In herbivorous mammals, it is large and houses bacteria capable of digesting cellulose. In human ancestors, the cecum was larger but has been reduced by evolutionary change to form the appendix.

Polyps

Polyps are small growths in the epithelial lining of the colon.

They can be benign or cancerous and can be removed individually.

A low-fat, high-fiber diet promotes regularity and is recommended as a protection against colon cancer.

Appendix

The appendix is attached to cecum.

Appendicitis is an infection. The appendix may swell and burst, leading to peritonitis (infection of the abdominal lining).

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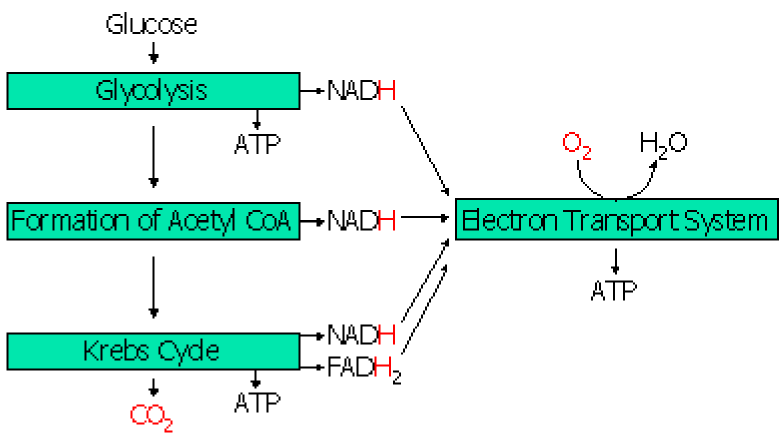
المحاضرة الحادية عشر: الجهاز التنفسي

Respiratory System

Introduction

Oxygen is needed by aerobic organisms because it is the final electron acceptor during cellular respiration. The diagram below shows that Cellular respiration is a process in which electrons are removed from glucose in a series of steps. The electrons are carried by NADH and FADH2 to the electron transport system. The electron transport system uses the energy in the electrons to synthesize ATP. The remaining carbon atoms in the glucose molecule are released as CO_2, a waste product. The equation for the complete breakdown of glucose by aerobic eukaryotes is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36\ ATP$$



Atmosphere

78% N_2, 21% O_2, 1% argon, noble gases, CO_2

Some Properties of Gases

Diffusion refers to movement of molecules from an area of higher concentration to an area of lower concentration.

Partial pressure is the pressure exerted by one gas in a mixture.

Total atmospheric pressure at sea level = 760 mm Hg.

Partial pressure O_2 = 760 X .21 = 160 mm Hg.

Diffusion is movement from an area of higher partial pressure to an area of lower partial pressure.

Respiratory Surfaces

All animals need to take in O_2 and eliminate CO_2. ***Lungs*** are membranous structures designed for gas exchange in a terrestrial environment. ***Gills*** are designed for gas exchange in an aquatic environment.

Oxygen must be dissolved in water before animals can take it up. Therefore, the respiratory surfaces of animals (gills, lungs, etc.) must always be moist. This is true of all animals.

Very small organisms don't need respiratory surfaces because they have a high surface:volume ratio.

Skin

The skin can be used as a respiratory surface but it does not have much surface area compared to lungs or gills. Animals that rely on their skin as a respiratory organ are small and either have low metabolic rates or they also have lungs or gills.

Like all respiratory surfaces, the skin must remain moist to function in gas exchange.

Amphibians, most annelids, some mollusks, and some arthropods use their skin as a respiratory organ.

Gills

Gills provide a large surface area for gas exchange in aquatic organisms.

It is difficult to circulate water past gills because water is dense and the O_2 concentration in water is low. There is 5% as much oxygen in water as there is in air. To circulate water past the gills, amphibian larvae physically move their gills, mollusks pump water into mantle cavity which contains the gills, and some crustacean gills are attached to branches of the walking legs.

The flow of blood in the gills of fish is in the opposite direction that water passes over the gills. This arrangement (called ***countercurrent flow***) enables fish to extract more oxygen from the water than if blood moved in the same direction as the passing water.

Gills cannot be used in air because they lack structural support; they would collapse. Their use in air would also result in too much water loss by evaporation.

Tracheal System

Insects, centipedes, and some mites and spiders have a tracheal respiratory system.

Tracheae are a network of tubules that bring oxygen directly to the tissues and allow carbon dioxide to escape. The openings to the outside, called ***spiracles***, are located on the side of the abdomen.

Trachea and lungs are internal to reduce water loss.

Vertebrate Lungs

Simple lungs evolved 450 million years ago in fish.

Some evolved into swim bladders.

Others evolved into more complex lungs.

Paired lungs are the respiratory surfaces in all reptiles, birds, and mammals.

Amphibians

lung is a simple convoluted sac

have small lungs but obtain much O_2 by diffusion across moist skin

ventilate lungs by ***positive pressure***; (reptiles, birds and mammals use negative pressure)

Reptiles

watertight skin; not used as a respiratory surface

lungs possess alveoli

all diffusion occurs across alveolar surface

Birds and Mammals

lungs are more branched with smaller, more numerous alveoli

Bird

Respiratory System

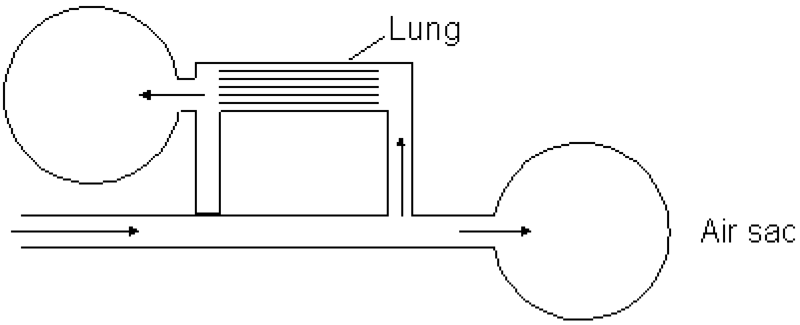
Birds have one-way flow of air in their lungs. As a result, the lungs receive fresh air during inhalation and again during exhalation.

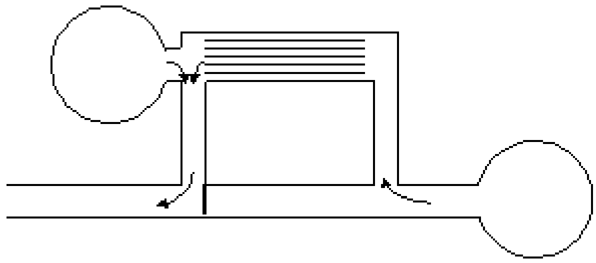
advantages of one-way flow:

no residual volume; all old (stale) air leaves with each breath

crosscurrent flow (crosscurrent = 90° ; countercurrent = 180°; crosscurrent is not as efficient but is still more efficient than mammalian lung)

One-way flow is accomplished by the use of air sacs as illustrated below. During inspiration, the air sacs fill. During expiration, they empty.





Human Respiratory System

Surface area of human lung is 60 to 80 sq. meters

Structures

pharynx → epiglottis (open space is the glottis) → larynx with vocal cords → trachea → bronchi → bronchioles → alveoli

Nasal Cavities

hair and cilia filter dust and particles.

Blood vessels warm air and mucus moistens air.

Ventilation

To inhale, the diaphragm contracts and flattens.

Muscles move the rib cage which also contributes to expanding the chest cavity.

To exhale, the muscles relax and elastic lung tissue recoils.

The Heimlich Maneuver

Choking results when food enters the trachea instead of the esophagus.

The Heimlich maneuver can force air out of the lungs to dislodge the obstruction.

Respiratory pigments

Hemoglobin

Hemoglobin is a protein that carries oxygen and is found in the blood of most animals.

It is synthesized by and is contained within erythrocytes (red blood cells).

Oxygen is bound reversibly to the iron portion.

Hemoglobin increases the oxygen-carry capacity of the blood by 70 times. 95% of the oxygen is transported by hemoglobin, 5% in blood plasma.

The bright red color occurs when it is bound with oxygen.

Hemocyanin

Hemocyanin is a carrier protein found in many invertebrates

It uses copper instead of iron.

It does not occur within blood cells; it exists free in the blood. (Their blood is called hemolymph.)

It is bright blue when bound with oxygen.

Gas Exchange and Transport

Gas Exchange in humans occurs in alveoli. Gasses must diffuse across the alveolar wall, a thin film of interstitial fluid, and the capillary wall.

Partial pressures

	LUNGS	**TISSUES**
OXYGEN	high	low
CO_2	low	high

The partial pressure of CO_2 is higher in the tissues because respiring tissues produce CO_2 as a result of the breakdown of glucose ($C_6H_{12}O_6$) during cellular respiration.

Oxygen Transport

1 hemoglobin molecule + 4 oxygen molecules $\rightarrow$ oxyhemoglobin.

The amount of oxygen that combines depends upon the partial pressure. More oxygen is loaded at higher partial pressures of oxygen.

Hemoglobin does not necessarily release (unload) all of its oxygen as it passes through the body tissues. Oxyhemoglobin releases its oxygen when:

the partial pressure of O_2 is low.

the partial pressure of CO_2 is high. High CO_2 causes the shape of the hemoglobin molecule to change and this augments the unloading of oxygen.

the temperature is high.

the pH is low.

Active tissues need more oxygen and all of the conditions listed above are characteristic of actively metabolizing tissues. Therefore, these tissues receive more oxygen from hemoglobin than less active tissues.

CO (carbon monoxide) binds to hemoglobin 200 times faster than O_2 and does not readily dissociate from the hemoglobin. Small amounts of CO can cause respiratory failure.

Carbon Dioxide Transport

Carbon dioxide is transported to the lungs by one of the following ways:

dissolved CO_2

bound to hemoglobin ($HbCO_2$)

HCO_3^- (bicarbonate ions).

Most is transported as bicarbonate ions because...

$CO_2 + H_2O \leftrightarrow$ □ $H_2CO_3 \leftrightarrow HCO_3^- + H^+$

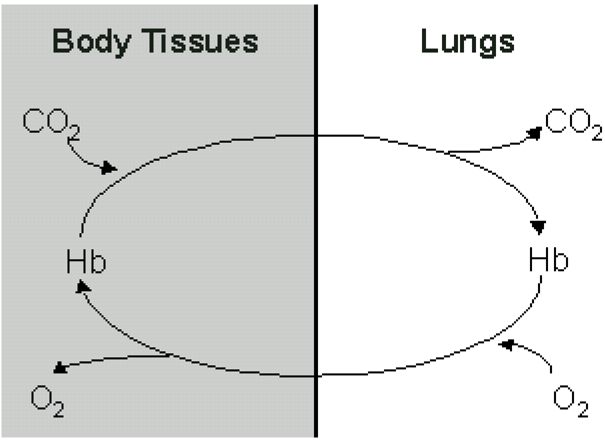
← low partial pressure high partial pressure → ← lungs tissues →

The equation above moves toward the right when the partial pressure of CO_2 is high. When the partial pressure of CO_2 is low, it moves to the left and CO_2 comes out of solution.

In the active tissues, the CO_2 partial pressure is high, so CO_2 becomes dissolved in water, forming H_2CO_3, which then forms HCO_3^- and H^+. In the lungs, the partial pressure of CO_2 is low because the concentration of CO_2 in the atmosphere is low. As blood passes through the lungs, HCO_3^- + H^+ form H_2CO_3 which then forms $CO_2 + H_2O$.

Carbonic anhydrase (in red blood cells) speeds up this reaction 150 times.

HCO_3^- tends to diffuse out of the red blood cells into the plasma.



<u>Control of breathing rate</u>

Eliminating CO_2 is usually a bigger problem for terrestrial vertebrates than obtaining O_2. The body is therefore more sensitive to high CO_2 concentration than low O_2 concentration.

Aquatic vertebrates are more sensitive to low O_2 because O_2 is more limited in aquatic environments.

Neural Control Mechanisms in terrestrial vertebrates

During inhalation, the diaphragm and intercostal muscles are stimulated. Other neurons inhibit these when exhaling.

Respiration is not under voluntary control.

Monitoring H^+ and CO_2

Chemoreceptors in the respiratory control center of the brain (medulla oblongata) detect changes in CO_2 by monitoring pH of cerebrospinal fluid. High CO_2 lowers the pH (an acid is a solution with a high H^+ concentration).

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$

Chemoreceptors in the aorta and carotid artery are also sensitive to pH and to greatly reduced amounts of O_2.

<u>Bronchiole diameter</u>

The primary bronchus branches extensively into bronchioles. Terminal bronchioles are surrounded by smooth muscle.

The diameter of the bronchioles (and blood vessels) increases or decreases in response to needs. It is adjusted by smooth muscle under the control of the nervous system. The parasympathetic nervous system (discussed in the chapter on nervous systems) stimulates these muscles to contract, reducing the diameter of the airways. This is advantageous when the body is relaxing and breathing is shallow. Narrow bronchioles result in less air remaining within the lungs after each exhalation.

The sympathetic nervous system relaxes these muscles as a response to stressful situations. This allows a more rapid rate of intake and expulsion of air.

Allergens trigger histamine release which constricts muscles.

Narrower bronchioles result in decreased ventilation of the lungs.

Severe attacks may be life-threatening.

Defense Mechanisms in the Respiratory Tract

Large particles are filtered out by the nose.

Small particles are filtered out by cilia lining the bronchi and bronchioles.

Bronchitis

Bronchitis is an inflammation of the airways that causes mucous to accumulate. The normal cleansing activity of cilia is reduced and not sufficient to remove the mucous. Coughing attempts to clear the mucus.

Smoking and other irritants increase mucus secretion and diminish cilia function.

Emphysema

Emphysema occurs when the alveolar walls lose their elasticity. Damage to the walls also reduces the amount of surface available for gas exchange.

Emphysema is associated with environmental conditions, diet, infections, and genetics. It can result from chronic bronchitis when the airways become clogged with mucous and air becomes trapped within the alveoli.

Effects of Cigarette Smoke

Cigarette smoke prevents the cilia from beating and stimulates mucus secretion.

Coughing is necessary to expel excess mucous but it contributes to bronchitis and emphysema.

Cigarette smoke also kills phagocytic cells in respiratory epithelium. These cells normally help rid the lungs of foreign particles and bacteria.

Cigarette smoke contains compounds that are modified in the body to form carcinogens.

Smoking causes 80% of lung cancer deaths**.**

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Excretory System

Function of the Excretory System

The excretory system functions in ridding the body of nitrogenous (nitrogen-containing, discussed below) and other wastes.

It also regulates the amount of water and ions present in the body fluids.

Review of Excretory Systems in Animals

Water Balance

Isotonic Animals

The concentration of solutes in isotonic animals is approximately equal to that of their environment. As a result, they do not gain or lose water.

Only marine invertebrates and cartilaginous fish (chondrichthyes) are isotonic.

The concentration of solutes in the tissues of isotonic animals is approximately equal to that of the ocean. This is 100 times higher than that found in the mammalian bodies. The high concentration of solutes in chondrichthyes is due mostly to the presence of urea.

Marine Bony Fish

The rate of water loss is high in marine bony fish. They drink water seawater at a rate of approx. 1% of their body weight/hour.

Specialized cells in the gills excrete excess salt.

Freshwater Bony Fish

Freshwater bony fish tend to gain water from their environment due to osmosis.

They produce large quantities of dilute urine (approx. 1/3 of their body weight/day) and do not drink water.

Salt-absorbing cells in he gills use active transport (energy is required) to pump salts into their body.

Birds and reptiles near the sea

Birds and reptiles living near the sea consume a large amount of salt in their diet. Nasal salt glands remove remove this excess salt from their body by secreting a concentrated salt solution.

Sea Mammals

The kidneys of sea mammals (ex: seals, whales, porpoises) are able to maintain a constant salt concentration in their bodies by producing urine that has a high concentration of salt.

They are able to drink seawater because the salt concentration of their urine is higher than that of sea water.

Terrestrial Animals

Most terrestrial animals drink water, some do not.

Metabolic water produced from cellular respiration may be sufficient to meet the needs of some animals. The equation below shows that six molecules of water are produced for every molecule of glucose oxidized.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6\mathbf{H_2O} + 36\ ATP$

Example: Kangaroo Rat

Kangaroo rats of southwestern US deserts never have to drink. Their water comes from metabolic water released during cellular respiration and water present in their food.

They emerge from their burrows only at night, when the air is cooler and more humid than during the day. This helps prevent water loss from their bodies and reduces the amount needed to keep cool (sweating).

They avoid movement while in their burrow. This minimizes heat production and thus, the need for sweating.

Dry food stored in their burrows absorbs moisture lost in breathing. This moisture is taken back in when the food is eaten.

Their noses become cooled during inhalation as a result of evaporating water but the cooled membranes cause the moisture to condense during exhalation.

Their large intestine absorbs almost all water present in the digestive tract. Their feces are dry, hard pellets.

Their kidneys conserve water by excreting concentrated urine.

Organs of Excretion

Contractile Vacuoles

paramecium

Flame Cells, Protonephridia

Planarians have two protonephridia composed of branched tubules that empty wastes through excretory pores on their surface. The protonephridia contain numerous bulblike flame cells with clustered, beating cilia that propel fluid into the tubules.

These structures function in waste excretion and osmotic regulation.

Nephridia

Earthworms have two ***nephridia*** in almost all of the body segments.

Each nephridium consists of a tubule with ciliated opening (nephridiostome) on one end and an excretory pore (nephridiopore) that opens to the outside of the body at the other end. Fluid is moved in by cilia. Some substances and water are reabsorbed in a network of capillaries that surround the tubule.

This system produces large amount of urine (60% of body wt./day).

Malpighian Tubules

The excretory organs of insects are ***malpighian tubules***. They collect water and uric acid from surrounding hemolymph (blood) and empty it into the gut. Water and useful materials are reabsorbed by the intestine but wastes remain in the intestine.

Kidneys

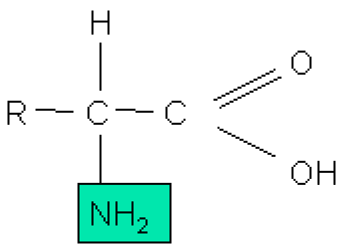
The kidneys of vertebrates (discussed below) function in the removal of nitrogenous and other wastes and in osmotic regulation of the body fluids.

Nitrogenous wastes

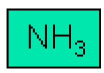
Cells use amino acids to construct proteins and other nitrogen-containing molecules. Amino acids can also be oxidized for energy or converted to fats or carbohydrates.

When amino acids are oxidized or converted to other kinds of molecules, the amino (NH_2) group must be removed. The nitrogen-containing compounds produced as a result of protein breakdown are toxic and must be removed by the excretory system.

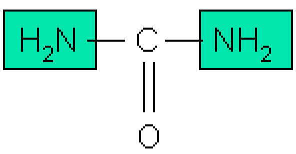
Nitrogenous wastes of animals are excreted in form of ammonia, urea, or uric acid.



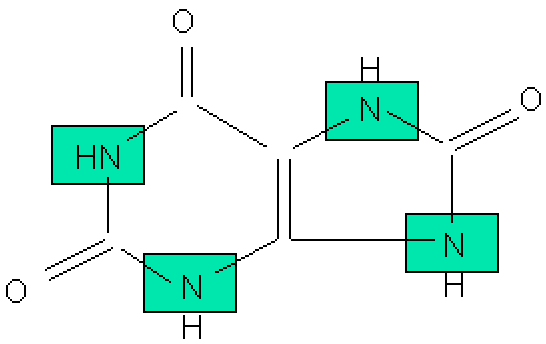
Amino Acid



Ammonia



Urea



Uric Acid

Ammonia

Ammonia is formed immediately after the amino group is removed from protein. This process requires very little energy.

Ammonia is highly soluble in water but very toxic. Aquatic animals such as bony fishes, aquatic invertebrates, and amphibians excrete ammonia because it is easily eliminated in the water.

Urea

Terrestrial amphibians and mammals excrete nitrogenous wastes in the form of urea because it is less toxic than ammonia and can be moderately concentrated to conserve water.

Urea is produced in the liver by a process that requires more energy to produce than ammonia does.

Uric Acid

Insects, reptiles, birds, and some dogs (Dalmatians) excrete uric acid. Reptiles and birds eliminate uric acid with their feces. The white material seen in bird droppings is uric acid.

It is not very toxic and is not very soluble in water. Excretion of wastes in the form of uric acid conserves water because it can be produced in a concentrated form due to its low toxicity.

Because it is relatively insoluble and nontoxic, it can accumulate in eggs without damaging the embryos.

The synthesis of uric acid requires more energy than urea synthesis.

Mammals

Structures of the excretory system

kidneys

ureters

urinary bladder

urethra

Regions of the Kidney

cortex (outer)

medulla (inner)

renal pelvis (innermost chamber)- collects the urine

Nephrons

microscopic; about 1 million/kidney

some are primarily in the cortex, others dip down into the medulla

Parts

glomerulus- a capillary tuft from which fluid leaves the circulatory system (filtration)

Bowman's capsule- a funnel-like structure that collects filtrate from the glomerulus

proximal convoluted tubule

loop of the nephron

distal convoluted tubule

collecting duct- delivers urine to renal pelvis

Blood Supply

The path of blood flow through a kidney is listed below.

Blood enters the kidney through a branch of the aorta called the ***renal artery***.

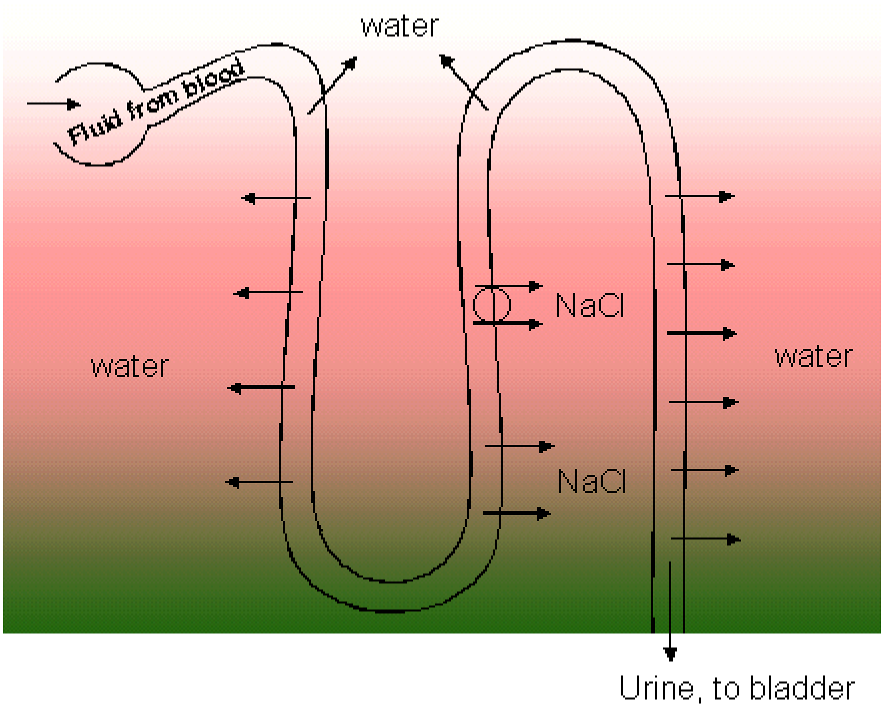
Branches of the renal artery within the kidney produce ***afferent arterioles***.

Each afferent arteriole leads to a network of capillaries called a ***glomerulus***. Fluid leaks out of the capillaries of the glomerulus but large molecules and cells do not fit through the pores. This process is called filtration.

Blood leaves the capillaries of the glomerulus via an ***efferent arteriole*** and enters capillaries in the medulla called ***peritubular capillaries***, which collect much of the water that was lost through the glomerulus.

Venules from the peritubular capillaries lead to the ***renal vein***, which exits the kidney and returns blood to the ***inferior vena cava***.

Urine Formation



Glomerulus

Pressure filtration occurs in the glomerulus.

Blood enters the glomerulus via an afferent arteriole where blood pressure forces water and small molecules out through pores in the glomerular capillaries.

The filtrate has approximately the same composition as tissue fluid.

Blood leaves the glomerulus via the efferent arteriole.

Approximately 45 gallons of liquid per day are filtered from the blood in the glomerulus.

Proximal Convoluted Tubule

A large amount of nutrients and water is filtered from the blood in the glomerulus. It is necessary to reabsorb most of the nutrients and water but leave wastes in the tubule.

Selective reabsorption occurs in the proximal convoluted tubule. Glucose, vitamins, important ions and most amino acids are reabsorbed from the tubule back into the capillaries near the proximal convoluted tubule.

These molecules are moved into the peritubular capillaries by ***active transport***, a process that requires energy.

Cells of the proximal convoluted tubule have numerous microvilli and mitochondria which provide surface area and energy.

When the concentration of some substances in the blood reaches a certain level, the substance is not reabsorbed; it remains in the urine. This prevents the composition of the blood from fluctuating. This process regulates the levels of glucose and inorganic ions such as sodium, potassium, bicarbonate phosphate, and chloride.

Urea remains in the tubules.

Without reabsorption, death would result from dehydration and starvation.

Loop of Henle

In mammals, the loop of Henle conserves water resulting in concentrated urine.

This is done by the gut in birds and reptiles.

Descending Loop

Water moves out of the descending loop as it passes through the area of high salt concentration produced by the ascending loop.

The descending loop is not permeable to ions.

Ascending Loop

Salt is actively pumped out in the ascending loop.

This part of the loop is impermeable to water reentry.

This creates a concentration gradient with a higher concentration in the medulla (interior region).

Countercurrent Mechanism, Collecting Duct

The movement of sodium out of the ascending loop and into the medulla results in water loss and concentrated urine in the descending loop. The concentrated urine further enhances the ability of the ascending loop to pump more salt out into the medulla. High salt in the medulla acts to help remove water in the descending loop. This phenomena is called the ***countercurrent multiplier***.

Urea is concentrated in the fluid; some is able to move out of the lower portion of the ***collecting duct***. It does not enter the blood stream, however, so little urea is lost once a concentration gradient is established.

The combination of urea and salt produces a high osmotic concentration in the medulla.

Length of the Loop of Henle

A longer loop of Henle will function to produce a greater concentration of urea and salt in the medulla. The higher concentration gradient enables the removal of more water as fluid moves through the collecting duct.

The length of the loop of Henle varies among mammals. The beaver, which does not need to conserve water, has a relatively short loop.

Desert-dwelling mammals have very long loops and are capable of producing extremely concentrated urine resulting in very little water loss.

Distal Convoluted Tubule

Some wastes are actively secreted into the fluid in the distal convoluted tubule by a process called ***tubular secretion***. Some of these are H^+, K^+, NH_4^+ toxic substances and foreign substances (drugs, penicillin, uric acid, creatine).

Secretion of H^+ adjusts the pH of the blood.

Collecting Duct

Several renal tubules drain into a common collecting duct.

The collecting ducts pass through the concentration gradient that was established by the loops of Henle. As fluid passes through the collecting ducts, much of the water moves out due to osmosis. The permeability of the collecting duct to water is regulated by hormones (discussed below).

Hormones that Regulate Water Loss

Antidiuretic Hormone (ADH)

ADH increases the permeability of the distal convoluted tubule and collecting duct.

It is released by posterior lobe of the pituitary.

If the osmotic pressure of blood increases (becomes more salty, not enough water); the posterior pituitary will release ADH and the permeability of the collecting ducts will increase, allowing water to leave by osmosis. The water returns to the blood.

If osmotic pressure of blood decreases, pituitary does not release ADH and more water is lost in urine due to decreased permeability of the collecting duct.

Alcohol inhibits the secretion of ADH, thus increases water loss.

Diuretic drugs cause increased water loss in urine, lowering blood pressure.

Aldosterone

Aldosterone secretion is not under the control of the anterior pituitary.

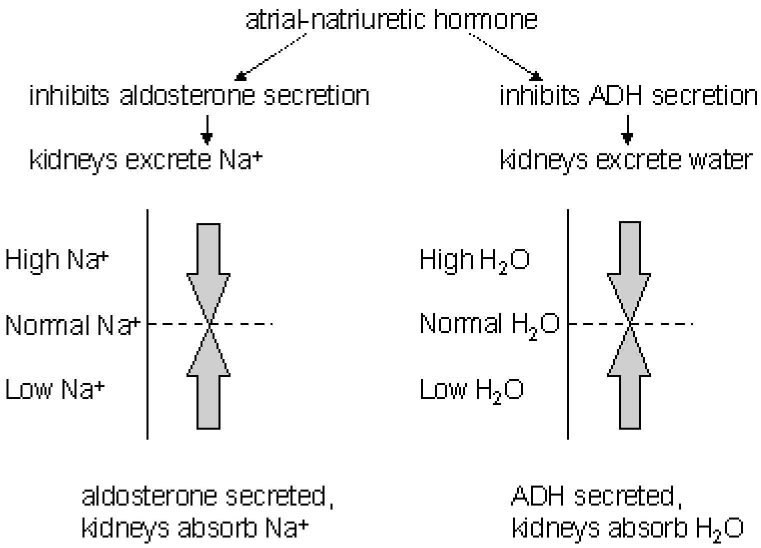
When pressure is low, the afferent arteriole cells secrete renin.

Renin initiates a series of chemical reactions that ultimately result in the adrenal cortex releasing aldosterone, which acts primarily on the distal convoluted tubule to promote absorption of sodium and excretion of potassium. (renin => adrenal cortex => aldosterone => distal convoluted tubule => reabsorption of sodium and excretion of potassium

The increased osmotic pressure associated with increased sodium levels contributes to the retention of water and thus increased blood volume. In the absence of aldosterone, sodium is excreted and the lower sodium levels result in decreased blood volume and lower blood pressure.

Atrial Natriuretic Hormone

The presence of too much blood in the circulatory system stimulates the heart to produce ***atrial natriuretic hormone***. This hormone inhibits the release of aldosterone by the adrenal cortex and ADH by the posterior pituitary causing the kidneys to excrete excess water. The loss of water and sodium contribute to lowering the blood volume.



pH of the Blood

Breathing

Adjustment of the breathing rate can make slight alterations in the pH of the blood by reducing the amount of carbonic acid. Rapid breathing moves the equation below to the left, thus increasing the pH (less acidic). Slow breathing results in less CO_2 being given off and the equation moves to the right..

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$

Kidneys

The kidneys provide a slower but more powerful means to regulate pH. They excrete or absorb hydrogen ions (H^+) and bicarbonate ions (HCO_3^-) as necessary for adjusting pH.

When the pH is low (acidic), hydrogen ions are excreted and bicarbonate ions are reabsorbed. The loss of hydrogen ions from the blood make it less acidic. Bicarbonate ions in the blood also reduce pH by taking up hydrogen ions (see the equation above).

When the pH is too high (too basic), fewer hydrogen ions are excreted and fewer sodium and bicarbonate ions are reabsorbed.

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Animal hormones

Endocrine Vs Nervous System

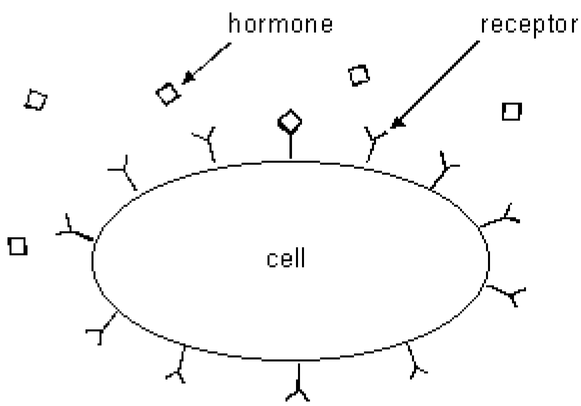
The endocrine system acts with nervous system to coordinate the body's activities.

Both systems enable cells to communicate with others by using chemical messengers.

The endocrine system uses chemical messengers called ***hormones*** that are transported by the circulatory system (blood). They act on target cells that may be anywhere in the body.

The endocrine system is slower than the nervous system because hormones must travel through the circulatory system to reach their target.

Target cells have ***receptors*** that are specific to the signaling molecules. The binding of hormones to the receptors on or within the target cell produces a response by the target cell.



The chemical messengers used by the nervous system are neurotransmitters. Neurotransmitters travel across a narrow space (the synaptic cleft) and bind to receptors on the target cell.

The nervous system conducts signals much quicker than the endocrine system.

Endocrine Vs Exocrine glands

Endocrine glands do not have ducts. Exocrine glands have ducts that carry their secretions to specific locations.

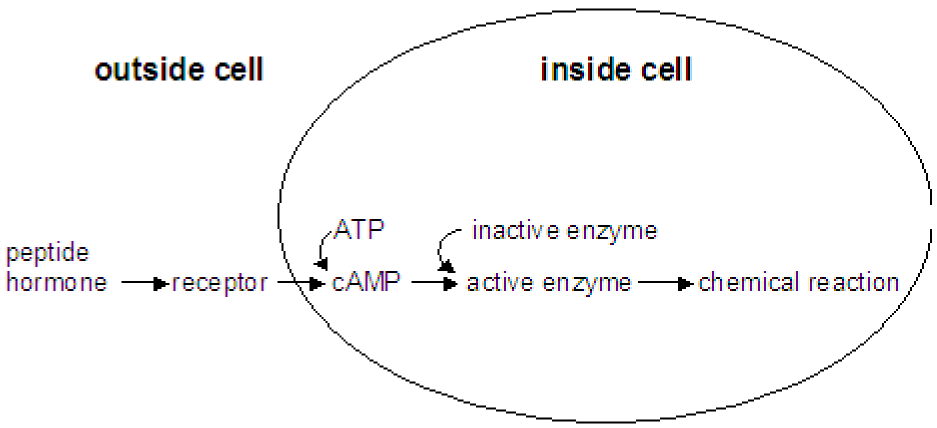
Two Kinds of Hormones

Peptide Hormones

Peptide hormones are composed of amino acids.

A peptide hormone binds to a cell-surface receptor, it does not enter the cell.

The resulting complex activates an enzyme that catalyzes the synthesis of cyclic AMP from ATP. Cyclic AMP activates other enzymes that are inactive.

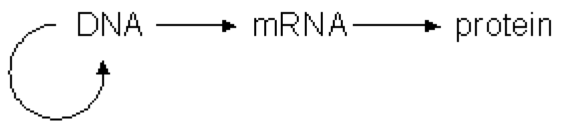


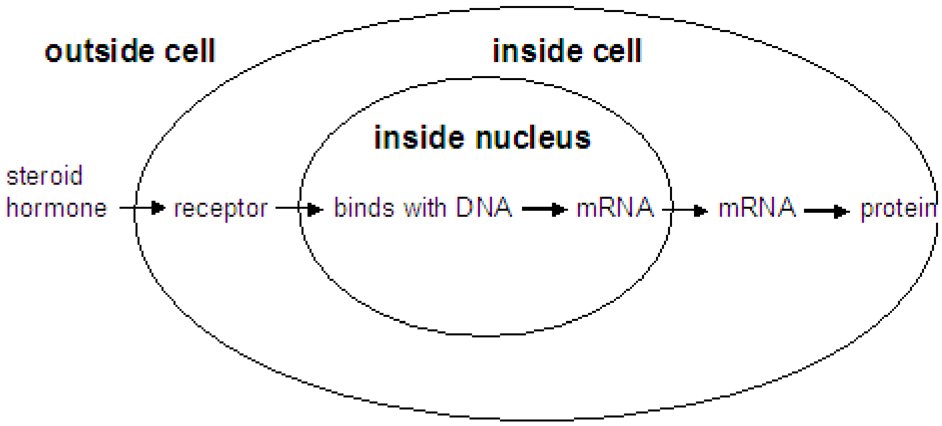
Cyclic AMP is a second messenger; the hormone is the first messenger. Other second messengers have been discovered.

Steroid Hormones

Steroid hormones enter the cell and bind to receptors in the cytoplasm.

The hormone-receptor complex enters the nucleus where it binds with chromatin and activates specific genes. Genes (DNA) contain information to produce protein as diagrammed below. When genes are active, protein is produced.





Steroid hormones act more slowly than peptide hormones because of the time required to produce new proteins as opposed to activating proteins that are already present.

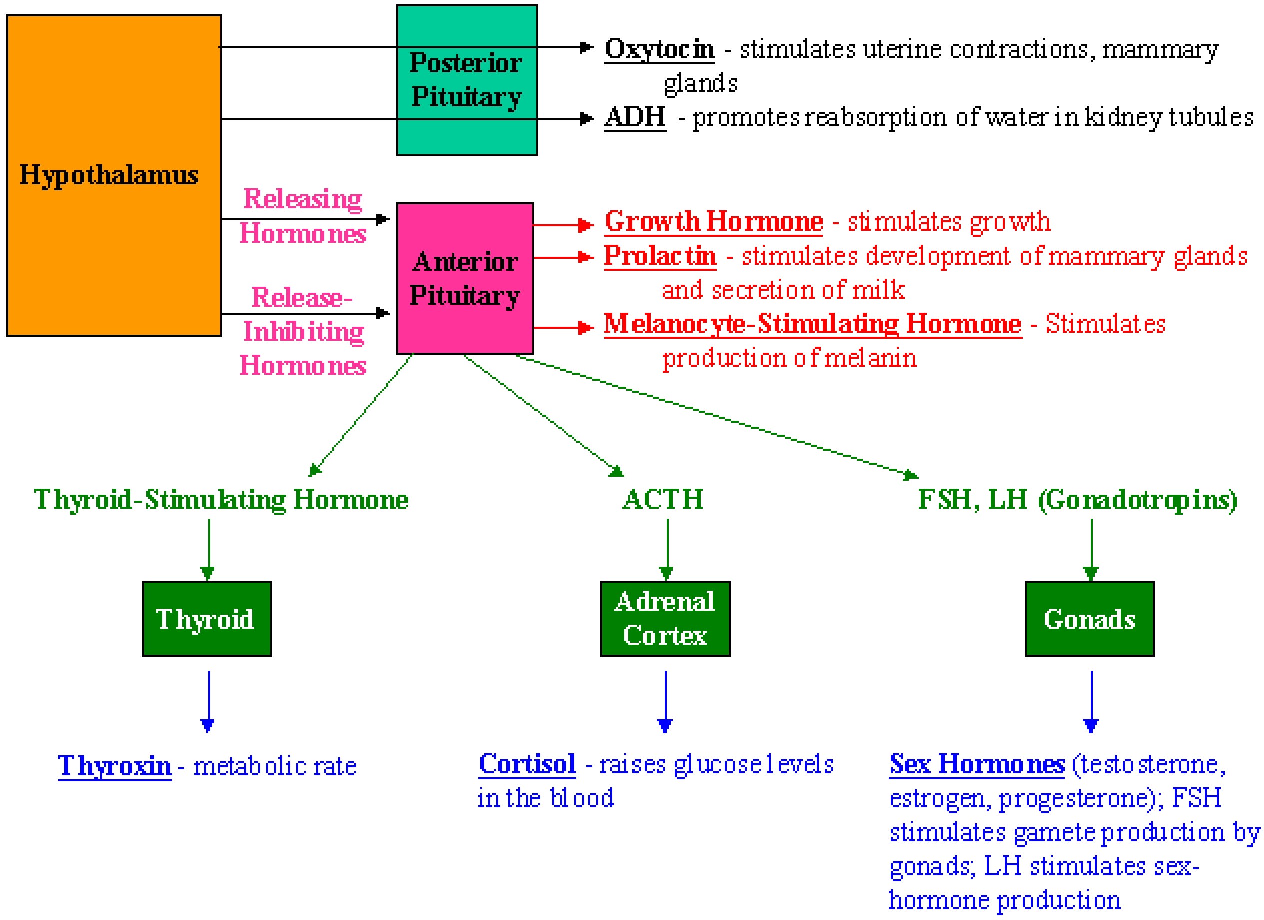
Hypothalamus

The hypothalamus is part of the brain. It maintains homeostasis (constant internal conditions) by regulating the internal environment (examples: heart rate, body temperature, water balance, and the secretions of the pituitary gland).

Pituitary Gland

The pituitary contains two lobes. Hormones released by the posterior lobe are synthesized by neurons in the hypothalamus. Unlike the posterior lobe, the anterior lobe produces the hormones that it releases.

Refer to the diagram below as you read about the hypothalamus, pituitary, and each of the glands they control.



Posterior pituitary

The posterior pituitary contains axons of neurons that extend from the hypothalamus. Hormones are stored in and released from axon endings in the posterior lobe of the pituitary.

Oxytocin

Oxytocin stimulates uterine contractions of labor that are needed to move the child out through the birth canal.

The hormone stimulates the release of milk from the mammary glands by causing surrounding cells to contract. After birth, stimulation of the breast by the infant feeding stimulates the posterior pituitary to produce oxyticin.

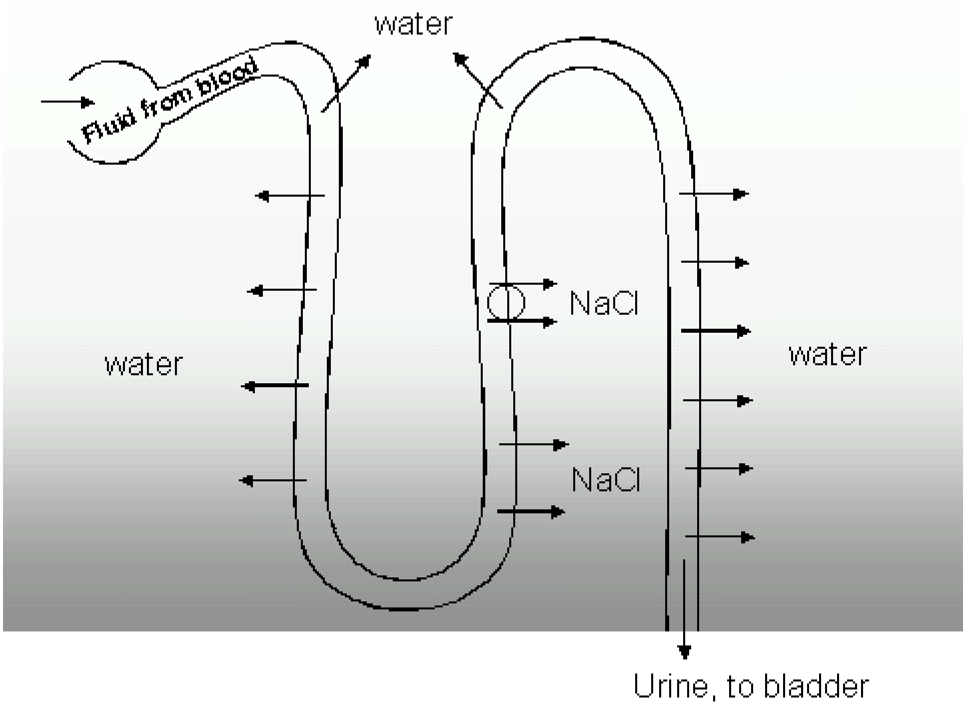
Antidiuretic Hormone (ADH)

Antidiuretic hormone increases the permeability of the distal convoluted tubule and collecting duct of the kidney nephron resulting in less water in the urine. The urine becomes more concentrated as water is conserved.

The secretion of ADH is controlled by a negative feedback mechanism as follows:

concentrated blood (too little water) → hypothalamus → ADH → kidney → reabsorbs water, makes blood more dilute

Below: Within the kidney, fluid and dissolved substances are filtered from the blood and pass through tubules where some of the water and dissolved substances are reabsorbed. The remaining liquid and wastes form urine. Details of this process are discussed in the chapter on the excretory system.



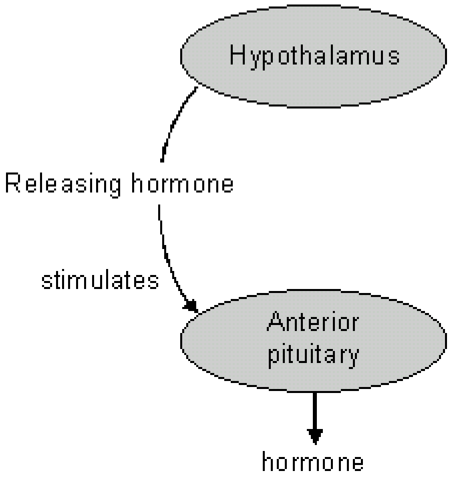
The presence of too much blood in the circulatory system stimulates the heart to produce a hormone called ***atrial natriuretic factor*** (ANF). This hormone inhibits the release of ADH by the posterior pituitary causing the kidneys to excrete excess water.

Alcohol inhibits the release of ADH, causing the kidneys to produce dilute urine.

Control of the Anterior Pituitary

The hypothalamus produces hormones that travel in blood vessels to the anterior pituitary, stimulating it to produce other hormones.

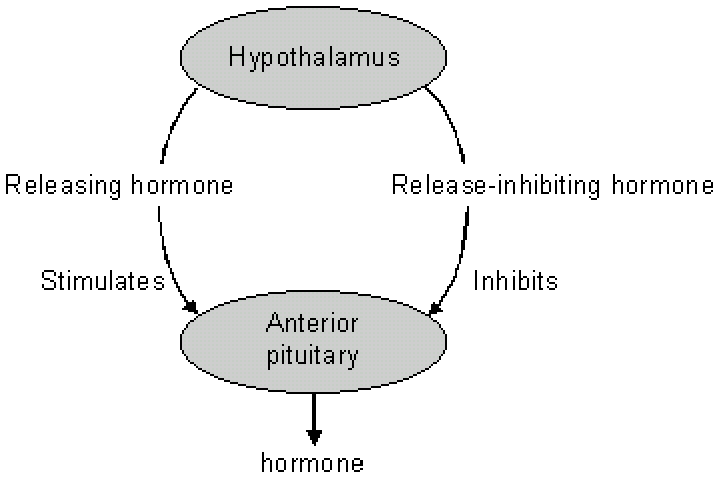
The hormones produced by the hypothalamus are called ***hypothalamic-releasing hormones***.



The anterior pituitary produces at least six different hormones. Each one is produced in response to a specific hypothalamic-releasing hormone.

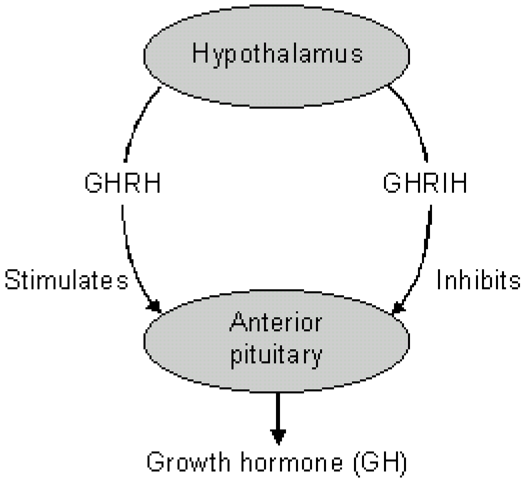
The blood vessel that carries hypothalamic-releasing hormones from the hypothalamus to the pituitary is called a ***portal vein*** because it connects two capillary beds. One capillary bed is in the hypothalamus and the other is in the anterior pituitary.

Release-inhibiting hormones produced by the hypothalamus inhibit the pituitary from secreting its hormones.

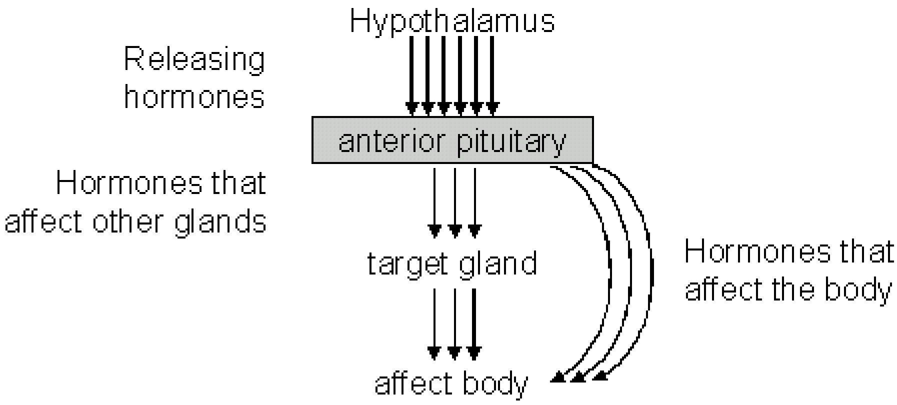


Example

The pituitary is stimulated to release growth hormone (GH) by growth hromone releasing hormone (GHRH) produced in the hypothalamus. It is inhibited from releasing growth hormone by growth hormone release-inhibiting hormone(GHRIH), also produced by the hypothalamus.



Six different hormones produced by the anterior lobe will be studied here. Three of these have direct effects on the body, the other three control other glands.



Anterior Pituitary Hormones that Directly Affect the Body

Growth Hormone (GH or Somatotropic Hormone)

Growth hormone stimulates body cells to grow. If too little hormone is produced, pituitary dwarfism results. The secretion of too much hormone results in a pituitary giant.

Acromegaly is a genetic disease in which growth hormone is produced throughout a persons lifetime.

Prolactin

Prolactin is produced in quantity after childbirth.

It stimulates the development of the mammary glands and the production of milk.

It is also involved in the metabolism of fats and carbohydrates.

Melanocyte-Stimulating Hormone (MSH)

This hormone causes skin color changes in some fishes, amphibians, and reptiles.

In humans, it stimulates the melanocytes to synthesize melanin.

Anterior pituitary hormones that regulate other glands

The pituitary also controls other glands and is often referred to as the "master gland".

Three kinds of pituitary hormones that regulate other glands are discussed below. The glands that they regulate will be discussed in the following section.

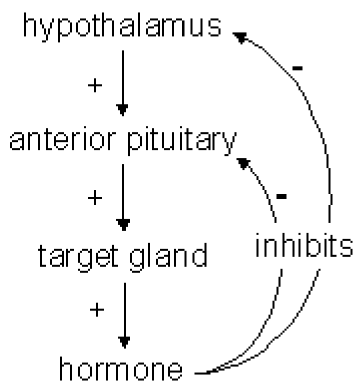
Thyroid Stimulating Hormone (TSH) →□ thyroid → thyroxin

Adrenocorticotropic Hormone (ACTH) → adrenal cortex → cortisol

Gonadotropic Hormones (FSH and LH) → ovaries and testes → sex hormones; controls gamete production

Negative Feedback Inhibition

Hormone secretions by glands that are under the control of the hypothalamus are controlled by ***negative feedback.*** When the hormone levels are high, they inhibit the hypothalamus and anterior pituitary, resulting in a decline in their levels.

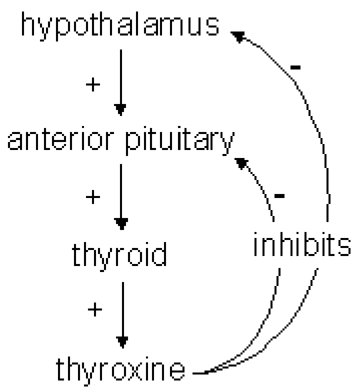


Thyroid gland

The thyroid produces ***thyroxin*** (also called T_4 because it contains 4 iodine atoms) and ***triiodothyronine*** (also called T_3 because it contains 3 iodine atoms).

Both T_4 and T_3 have similar effects on target cells. In most target tissues, T_4 is converted to T_3. They influence metabolic rate, growth, and development.

Thyroxin production is regulated by a negative feedback mechanism in which it inhibits the hypothalamus from stimulating the thyroid.



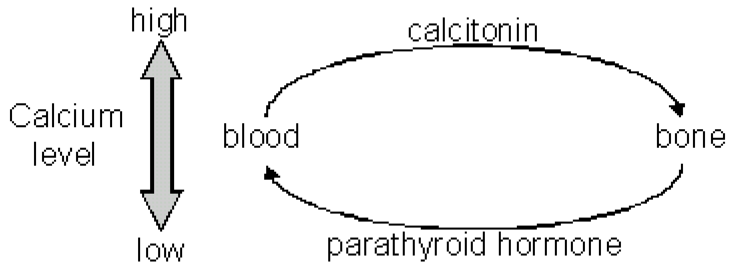
Hypothyroidism occurs when the thyroids produce too little hormone. In adults, it results in lethargy and weight gain. In infants, it causes cretinism, which is characterized by dwarfism, mental retardation, and lack of sexual maturity. Administering thyroid hormones treats these affects.

Too much T_3 and T_4 (hyperthyroidism) increases heart rate and blood pressure, and causes weight loss.

Iodine is needed to manufacture thyroid hormones. A deficiency in iodine prevents the synthesis of thyroid hormones which, in turn, results in an excess of thyroid stimulating hormone being produced by the anterior pituitary. A **goiter** results when constant stimulation of the thyroid causes it to enlarge.

Calcitonin

The thyroid gland also secretes ***calcitonin***, which stimulates calcium deposition in the bones. This is the opposite of the action of parathyroid hormone (see below).



Calcitonin production ***is not*** regulated by the anterior pituitary. It's secretion is stimulated by high calcium levels in the blood.

Parathyroid glands

The parathyroid glands are 4 small glands embedded in posterior surface of the thyroid gland.

They secrete ***parathyroid hormone (PTH)***, which increases blood levels of Ca^{++}.

Bone tissue acts as a storage reservoir for calcium and PTH stimulates the removal of calcium from the bone to increase levels in the blood.

It increases the kidney's reabsorption of Ca^{++} so that less is lost in urine.

It activates vitamin D which enhances Ca^{++} absorption from food in the gut.

Secretion is regulated by the Ca^{++} level in the blood, (not hypothalamic or pituitary hormones).

Adrenal Cortex

The outer layer of an adrenal gland is the adrenal cortex.

It produces three kinds of steroid hormones. These are ***glucocorticoids***, ***mineralocorticoids***, and small amounts of sex hormones. The major glucocorticoid is ***cortisol*** and the major mineralocorticoid is ***aldosterone***.

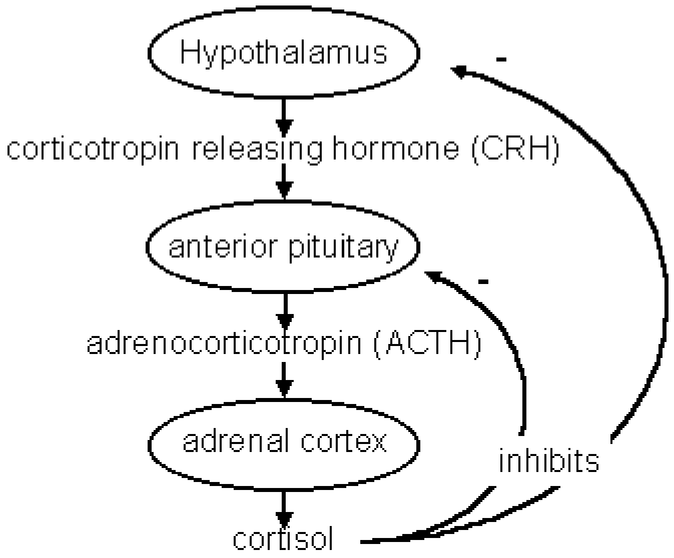
Cortisol (A Glucocorticoid)

Glucocorticoids are produced in response to stress.

Cortisol raises the level of glucose in the blood by stimulating the liver to produce glucose from stored non-carbohydrate sources such as proteins and lipids and to release it into the blood.

Cortisol reduces swelling by inhibiting the immune system. Swelling of tissues due to injury or infection is discussed in the chapter on the immune system. The drug prednisone, derived from cortisol, is used to treat inflammation.

Negative feedback control of cortisol level is diagrammed below.



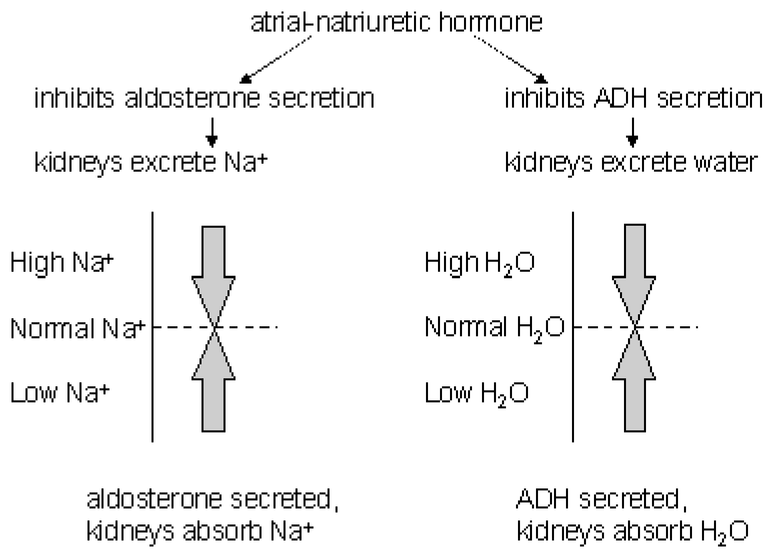
Aldosterone (A Mineralocorticoid)

Aldosterone secretion is not under the control of the anterior pituitary.

It acts primarily on the kidney to promote absorption of sodium and excretion of potassium.

Increased sodium levels contributes to the retention of water and thus increased blood volume. In the absence of aldosterone, sodium is excreted and the lower sodium levels result in decreased blood volume and lower blood pressure.

The presence of too much blood in the circulatory system stimulates the heart to produce ***atrial natriuretic factor***. This hormone inhibits the release of aldosterone by the adrenal cortex and ADH by the posterior pituitary causing the kidneys to excrete excess water. The loss of water and sodium contribute to lowering the blood volume.



Adrenal Medulla

The adrenal medulla is composed of modified neurons that secrete epinephrine and norepinephrine (adrenaline and noradrenaline) under conditions of stress.

These hormones are released in response to a variety of stresses and stimulate the fight- or- flight response of the sympathetic nervous system. It results in a faster heart rate, faster blood flow, and dilated airways to facilitate oxygen flow to the lungs. In addition, the level of glucose in the blood is increased to make energy more available.

Their secretion is controlled by brain centers (including hypothalamus) via sympathetic nerves, not by pituitary hormones.

Gonads

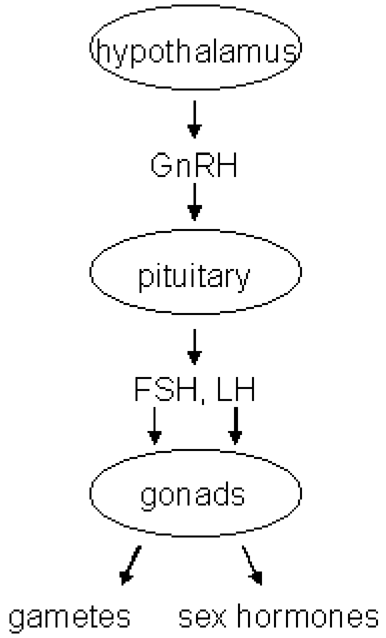
LH and ***FSH*** from the anterior pituitary stimulate the gonads (ovaries and testes).

LH stimulates the testes to produce several kinds of steroid hormones called ***androgens***. One of these androgens is ***testosterone***, the main sex hormone in males.

LH stimulates the ovaries produce ***estrogen*** and ***progesterone***, the female sex hormones.

Sex hormones are responsible for the development of ***secondary sex characteristics***, which develop at puberty. Some examples of secondary sex characteristics in males are deepening of the voice (due to a large larynx), growth of facial hair, and muscle development. Some secondary sex characteristics in females are development of the breasts and broadening of the pelvis. Both sexes show increased activity of sweat glands and sebaceous glands (oil glands in the skin), and growth of pubic and axillary (armpit) hair.

FSH controls gamete (egg or sperm) production.



Pancreas

The pancreas is a digestive gland that secretes digestive enzymes into the duodenum through the pancreatic duct.

The ***islets of Langerhans*** are groups of cells within the pancreas that secrete ***insulin*** and ***glucagon***. The islets are endocrine glands because they are ductless; the circulatory system carries their hormones to target cells.

Insulin

Insulin promotes the removal of glucose from the blood for storage as glycogen (muscle, liver), fats (fat cells), and protein.

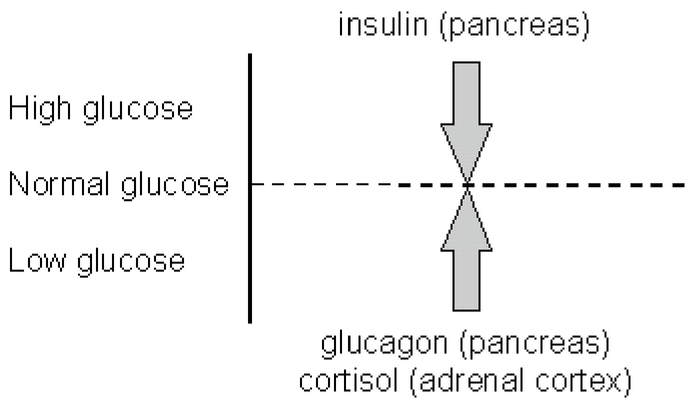
It promotes the buildup of fats and proteins and inhibits their use as an energy source.

Glucagon

Glucagon is produced in the islets of Langerhans but by different cells than those that produce insulin.

The effects of glucagon are opposite those of insulin. It raises the level of glucose in the blood.

It is normally secreted between meals to maintain the concentration of glucose in the blood.



Diabetes Mellitus

Diabetes mellitus is a disease in which glucose is not sufficiently metabolized. This results in high glucose levels in blood and glucose in the urine.

Cells can starve because glucose is not being metabolized.

Type I

Type I diabetes is also called "juvenile-onset diabetes" or "insulin-dependent diabetes" because the symptoms usually appear during childhood and insulin injections are necessary to treat it.

It usually occurs after a viral infection triggers an immune response that results in the body destroying its own insulin-producing cells.

Because the disease is caused by a lack of insulin, it can be treated with insulin injections.

Type II

Type II diabetes is more common than type I.

Type II diabetes is caused by a deficiency in insulin production or by changes in insulin receptors on the target cells. In either case, blood glucose level may be high because cells do not receive the message to metabolize glucose.

This form of diabetes usually becomes noticeable in middle age.

It is treated with a low fat, low sugar diet, regular exercise, weight control. Another treatment is oral medications that make the cells more sensitive to the effects of insulin or that stimulate more insulin production.

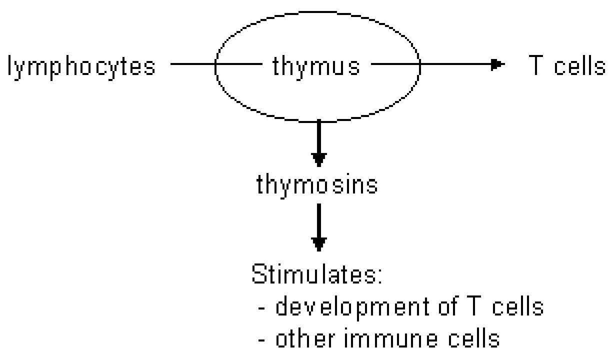
Thymus Gland

The thymus grows during childhood but gradually decreases in size after puberty.

Lymphocytes that have passed through the thymus are transformed into ***T cells***.

Lymphocytes are white blood cells that function to fight infection. There are two kinds of lymphocytes: B cells and T cells. T cells participate in identifying and destroying body cells that are infected.

Thymus hormones called ***thymosins*** stimulate the development and differentiation of T lymphocytes. They play a role in regulating the immune system by stimulating other kinds of immune cells as well.



Pineal Gland

Fish and Amphibians

The pineal gland of fish and amphibians is located near the skin and functions to detect light.

Birds and Mammals

In birds, it is located on the brain but still receives direct light stimulus through the skull.

In mammals, it is located within the brain and therefore cannot receive light stimulation directly. Light from the eyes stimulates the gland via the optic nerve.

Melatonin is produced at night. During the winter, nights are longer and as a result the level of melatonin in the blood is higher. The level of melatonin in the blood therefore varies with season and can be used to help animals time events such as when to breed, nest, migrate, etc.

These annual cycles are called ***circannual rhythms***. Melatonin may also participate in producing 24-hour cycles called ***circadian rhythms***.

In humans, the gland may be involved in sexual development.

References المصادر

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