24.1 Structure and Classification of Lipids

- ***Lipids*** are naturally occurring molecules from plants or animals that are soluble in nonpolar organic solvents.
- Lipid molecules contain large hydrocarbon portion and not many polar functional group, which accounts for their solubility behavior.

Classification of Lipids

Lipids that are ester or amides of fatty acids:

- *Waxes* – are carboxylic acid esters where both R groups are long straight hydrocarbon chain. Performs external protective functions.
- *Triacylglycerol* – are carboxylic acid triesters of glycerols. They are a major source of biochemical energy.
- *Glycerophopholipids* - triesters of glycerols that contain charged phosphate diesters. They help to control the flow of molecules into and out of cells.

- *Sphingomyelins* – amides derived from an amino alcohol, also contain charged phosphate diester groups. They are essential to the structure of cell membranes.
- *Glycolipids* – amides derived from sphingosine, contain polar carbohydrate groups. On the cell surface, they connect with by intracellular messengers.

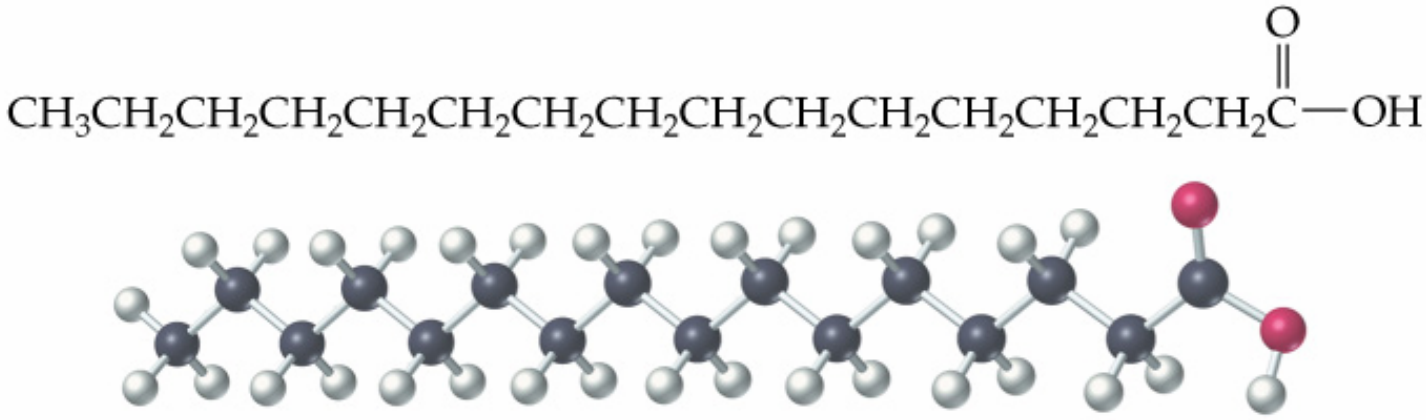
Lipids that are not esters or amides:

- *Steroids* – They performs various functions such as hormones and contributes to the structure of cell membranes.
- *Eicosanoids* – They are carboxylic acids that are a special type of intracellular chemical messengers.

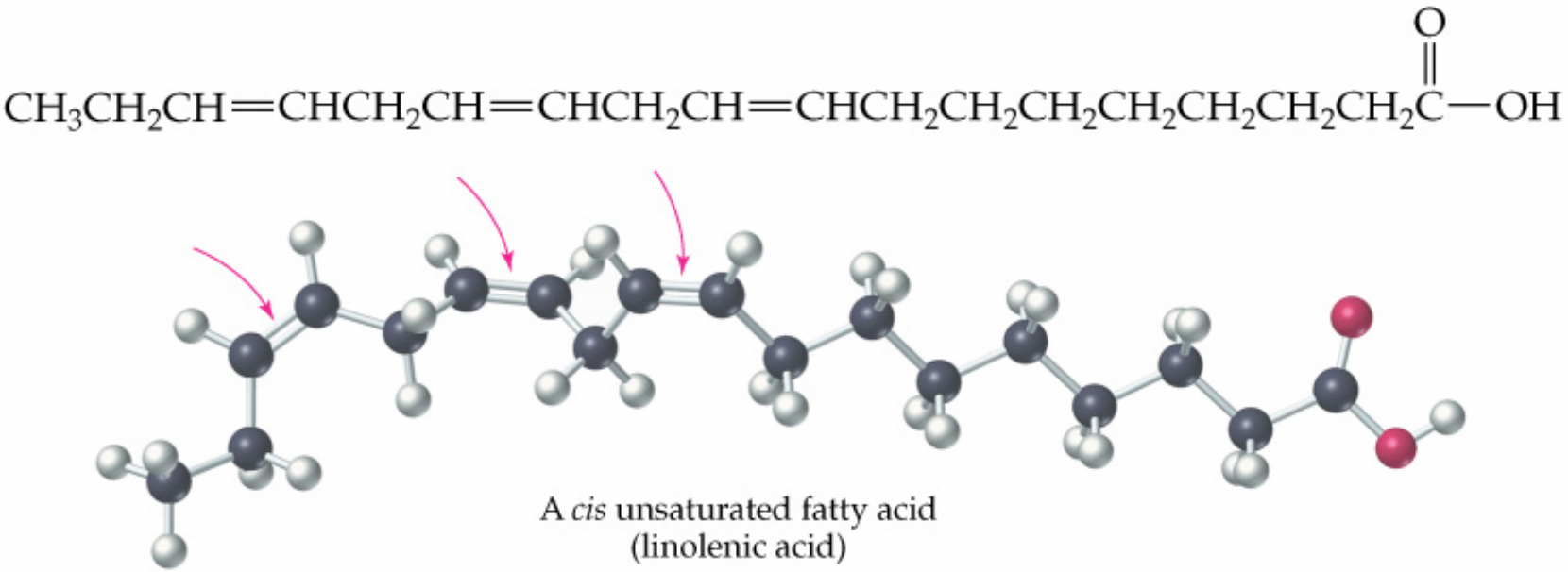
24.3 Properties of Fats and Oils

Oils: A mixture of triglycerols that is liquid because it contains a high proportions of unsaturated fatty acids.

Fats: A mixture of triglycerols that is solid because it contains a high proportions of saturated fatty acids.



A saturated fatty acid
(palmitic acid)



A *cis* unsaturated fatty acid
(linolenic acid)

Properties of triglycerols in natural fats and oils:

- Nonpolar and hydrophobic
- No ionic charges
- Solid triglycerols (Fats) - high proportions of saturated fatty acids.
- Liquid triglycerols (Oils) - high proportions of unsaturated fatty acids.

24.4 Chemical Reactions of Triglycerols

Hydrogenation: The carbon-carbon double bonds in unsaturated fatty acids can be hydrogenated by reacting with hydrogen to produce saturated fatty acids. For example, margarine is produced when two thirds of the double bonds present in vegetable oil is hydrogenated.

Hydrolysis of triglycerols: Triglycerols like any other esters react with water to form their carboxylic acid and alcohol – a process known as hydrolysis.

- In body, this hydrolysis is catalyzed by the enzyme hydrolase and is the first step in the digestion of dietary fats and oils.
- In the laboratory and commercial production of soap, hydrolysis of fats and oils is usually carried out by strong aqueous bases such as NaOH and KOH and is called saponification.

24.5 Cell Membrane Lipids: Phosphilipids and Glycolipids

- Cell membranes establish a hydrophobic barrier between the watery environment in the cell and outside the cell. Lipids are ideal for this function.
- The three major kinds of cell membrane lipids in animals are *phospholipids*, *glycolipids*, and *cholesterol*.

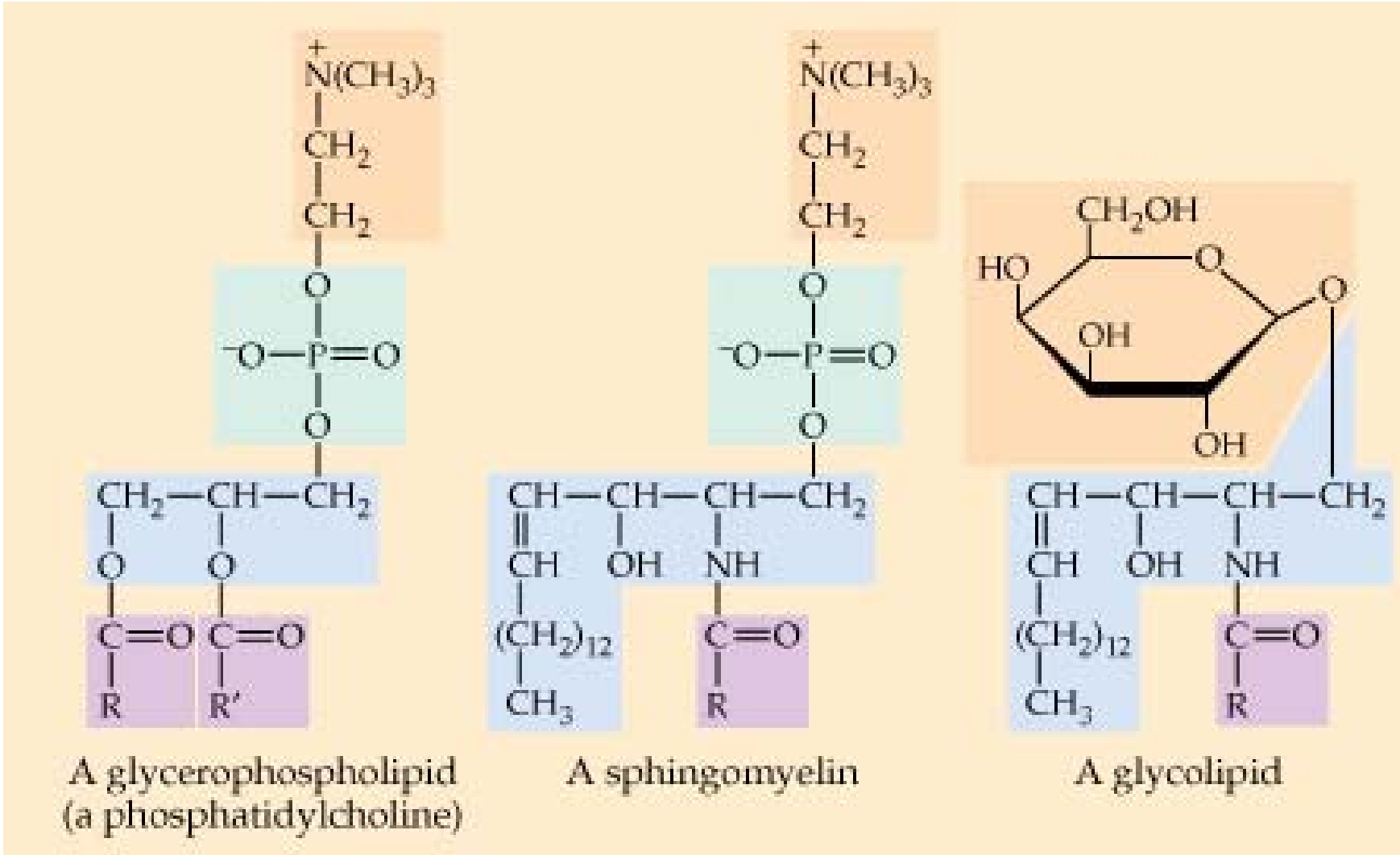
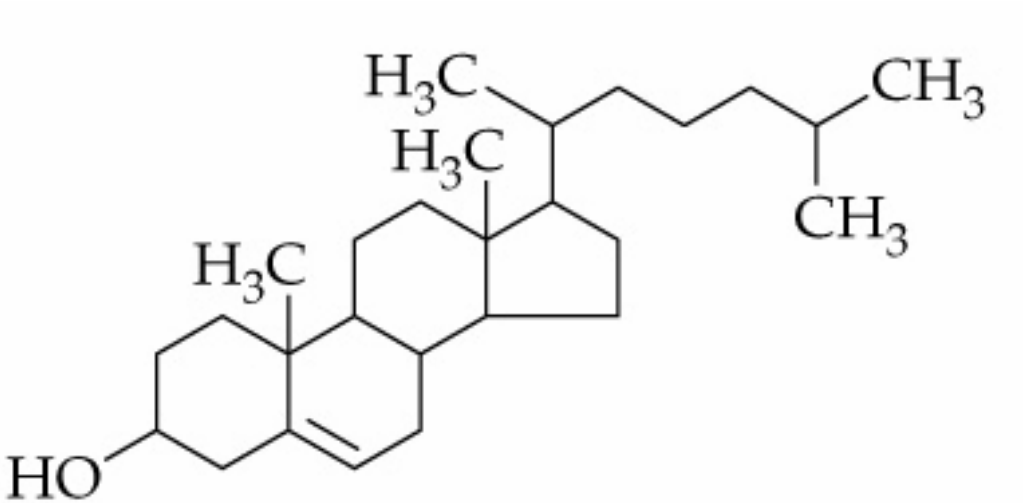


Fig 24.4 Membrane lipids

- Phosphoilipids contain an ester link between a phosphoric acid and an alcohol. The alcohol is either a glycerol to give a glycerophopholipid or a sphingosine to give sphingomyelins.
- Glycolipids: Glycolipids are derived from sphingosine. They differ from sphingomyelins by having a carbohydrate group at C1 instead of a phosphate bonded to a choline.

24.5 Cell Membrane Lipids: Cholesterol

- Animal cell membranes contain significant amount of cholesterol.

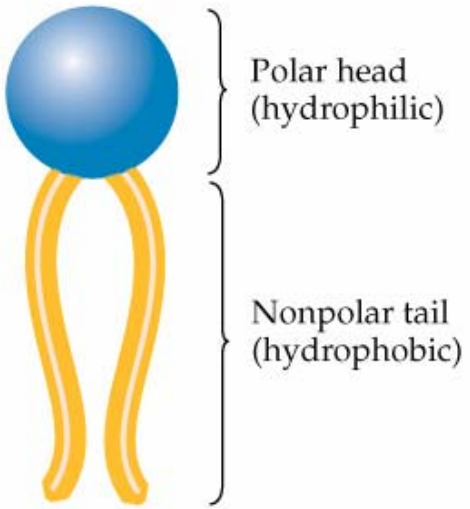


Cholesterol

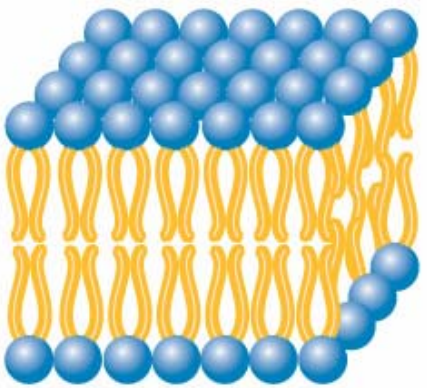
- Cholesterol is a steroid, a member of the class of lipids that all contain the same four ring system.
- Cholesterol serves two important purposes: as a component of cell membranes and as a starting materials for the synthesis of all other steroids.

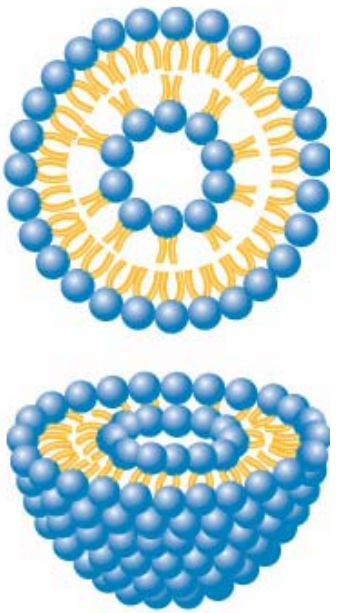
24.7 Structure of Cell Membranes

The basic structural unit of cell membrane is lipid bilayer which is composed of two parallel sheets of membrane lipid molecules arranged tail to tail. Bilayers are highly ordered and stable, but still flexible.



Membrane lipid


Lipid bilayer


Liposome

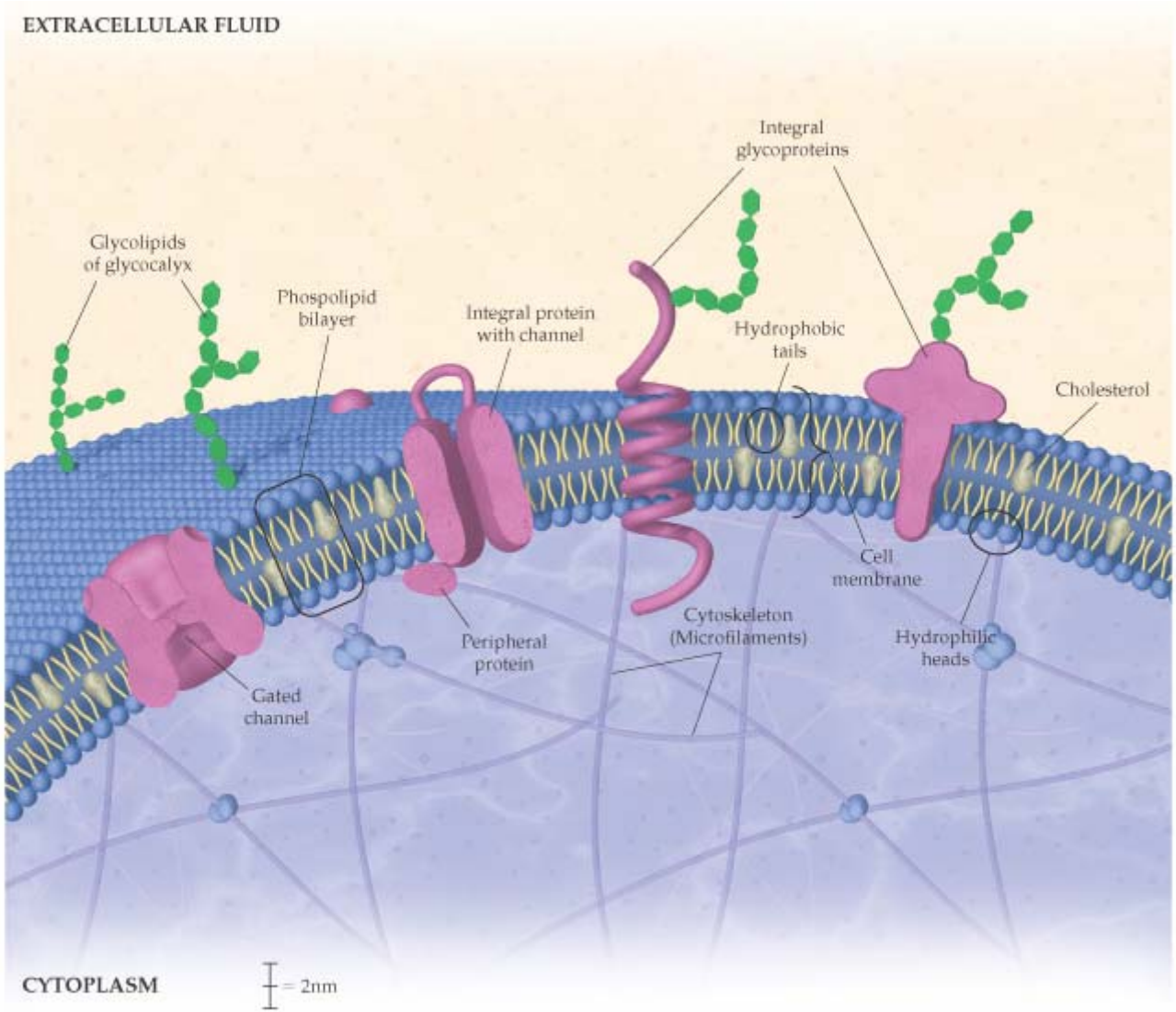


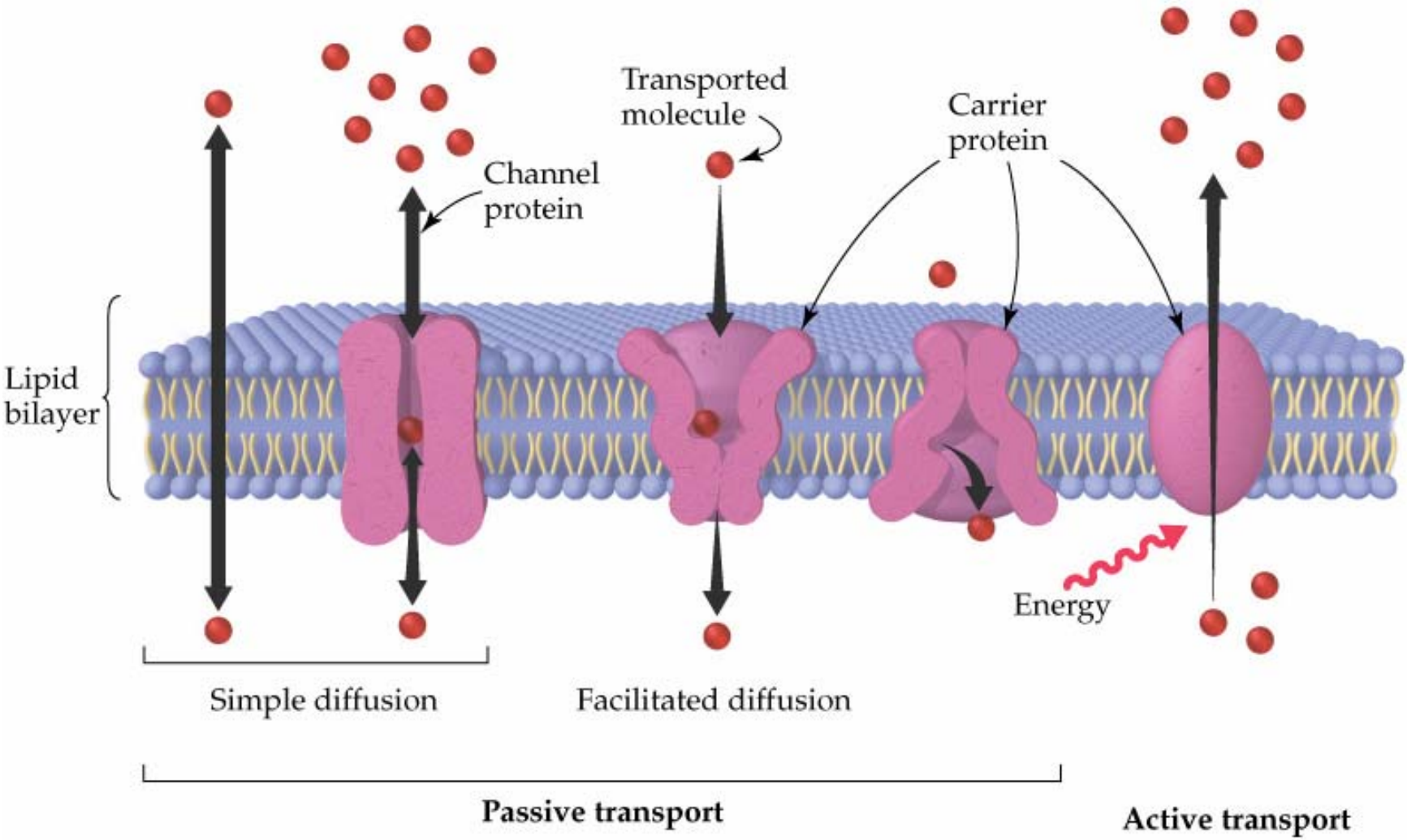
Fig 24.7 The cell membrane

When phospholipids are shaken vigorously with water, they spontaneously form liposome – small spherical vesicle with lipid bilayer surrounding an aqueous center. Water soluble substances can be trapped in the center of the liposome, and lipid-soluble substances can be incorporated into the bilayer.

24.8 Transport Across Cell Membranes

The cell membranes allow the passage of molecules and ions into and out of a cell by two modes; passive transportation and active transportation.

- *Passive transport* – substances move across the cell membrane freely by diffusion from regions of higher concentration to regions of lower concentration. Glucose is transported into many cells in this way.


Transported molecule
Carrier protein
Channel protein
Lipid bilayer
Energy
Simple diffusion
Facilitated diffusion
Passive transport
Active transport

- *Active transport* - substances move across the cell membrane only when energy is supplied because they must go in the reverse direction from regions of lower to regions of higher concentration. Only by this method, cells maintain lower Na^+ concentration within cells and higher Na^+ concentration in extracellular fluids, with the opposite concentration ratio for K^+.

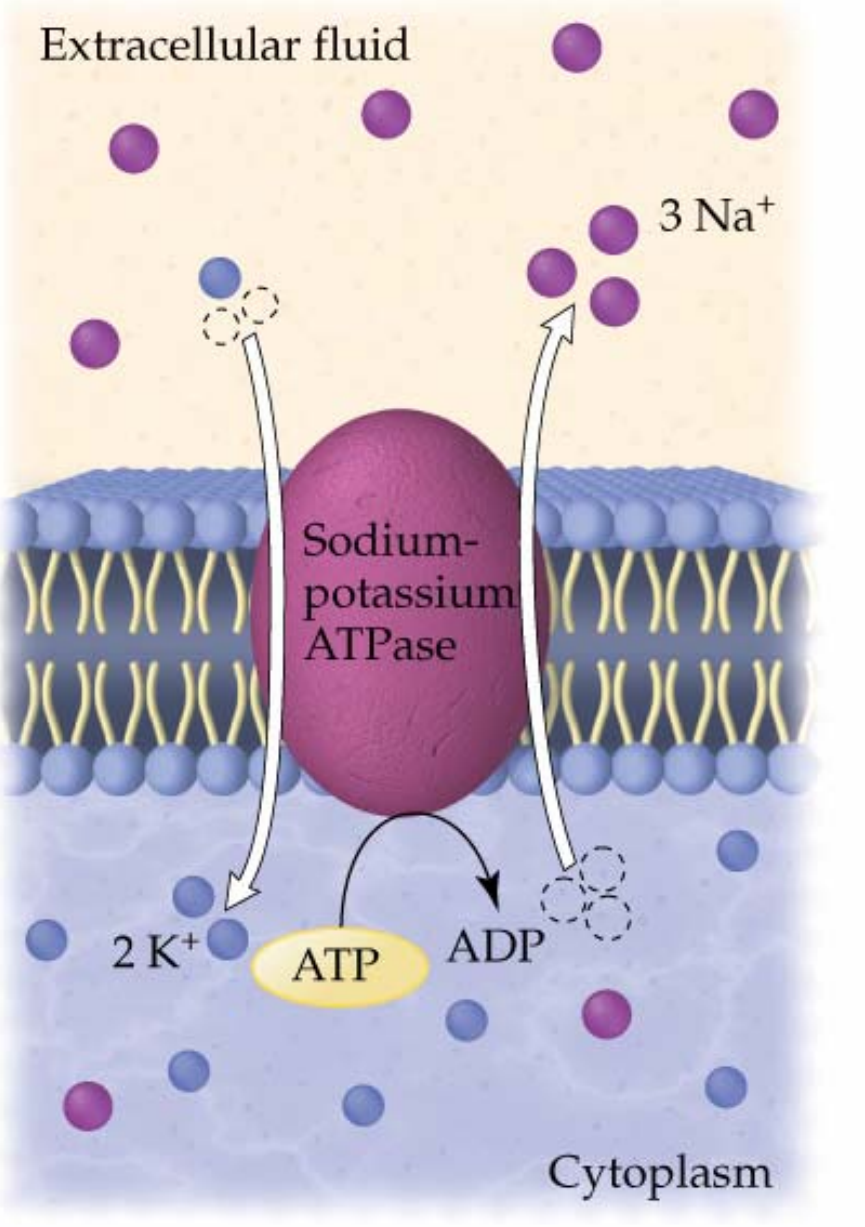


Fig 24.9 An example of active transport

Properties of cell membranes:

- Cell membranes are composed of a fluid like phospholipid bilayer.
- The bilayer incorporates cholesterol, proteins, and glycolipids.
- Small nonpolar molecules cross by diffusion through the lipid bilayer.

- Small ions and polar molecules diffuse through the aqueous media in protein pores.
- Glucose and certain other substances cross with the aid of proteins without energy input.
- Na^+, K^+, and other substances that maintain concentration gradients inside and outside the cell cross with expenditure of energy and the aid of proteins.

25.1 Digestion of Triacylglycerols

Lipid metabolism is the second most important source of energy in our body. Majority of the lipids in our diet are triacyglycerols (TAG), therefore, metabolism of triacylglycerols, which stored in our fatty tissue, constitute our chief energy source.

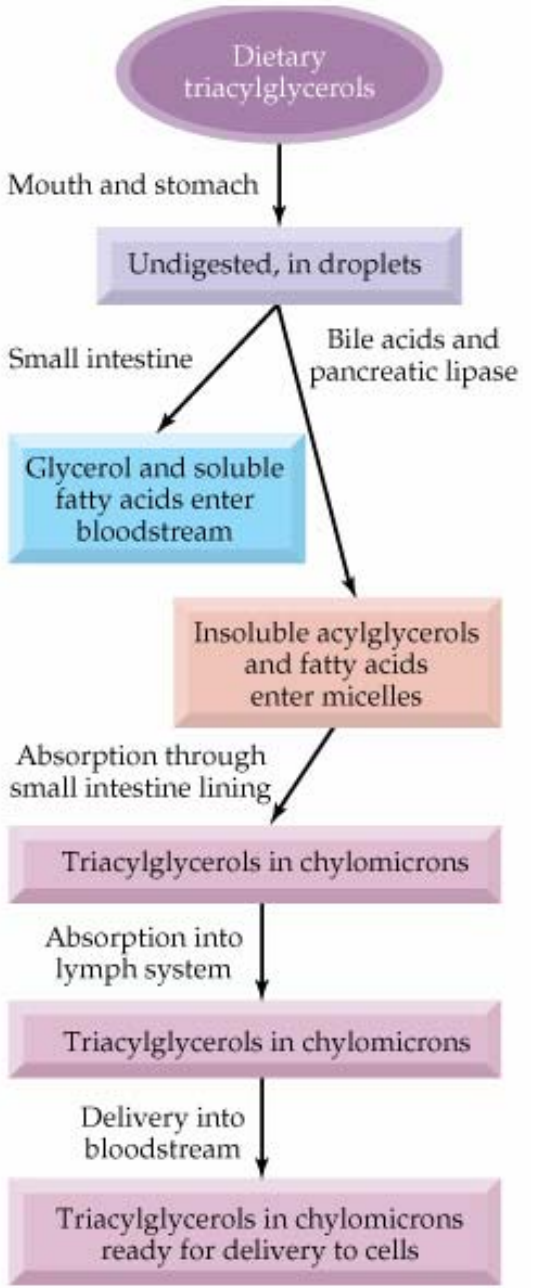


Fig 25.1 Digestion of triacylglycerols

- When eaten, triacylglycerols pass through the mouth unchanged and enters into the stomach where the heat and churning action of the stomach breaks lipids into smaller droplets.
- The hydrophobic lipid droplets are packaged in various kinds of lipoproteins. This is necessary in order for the hydrophobic lipids to move about in aqueous environments.

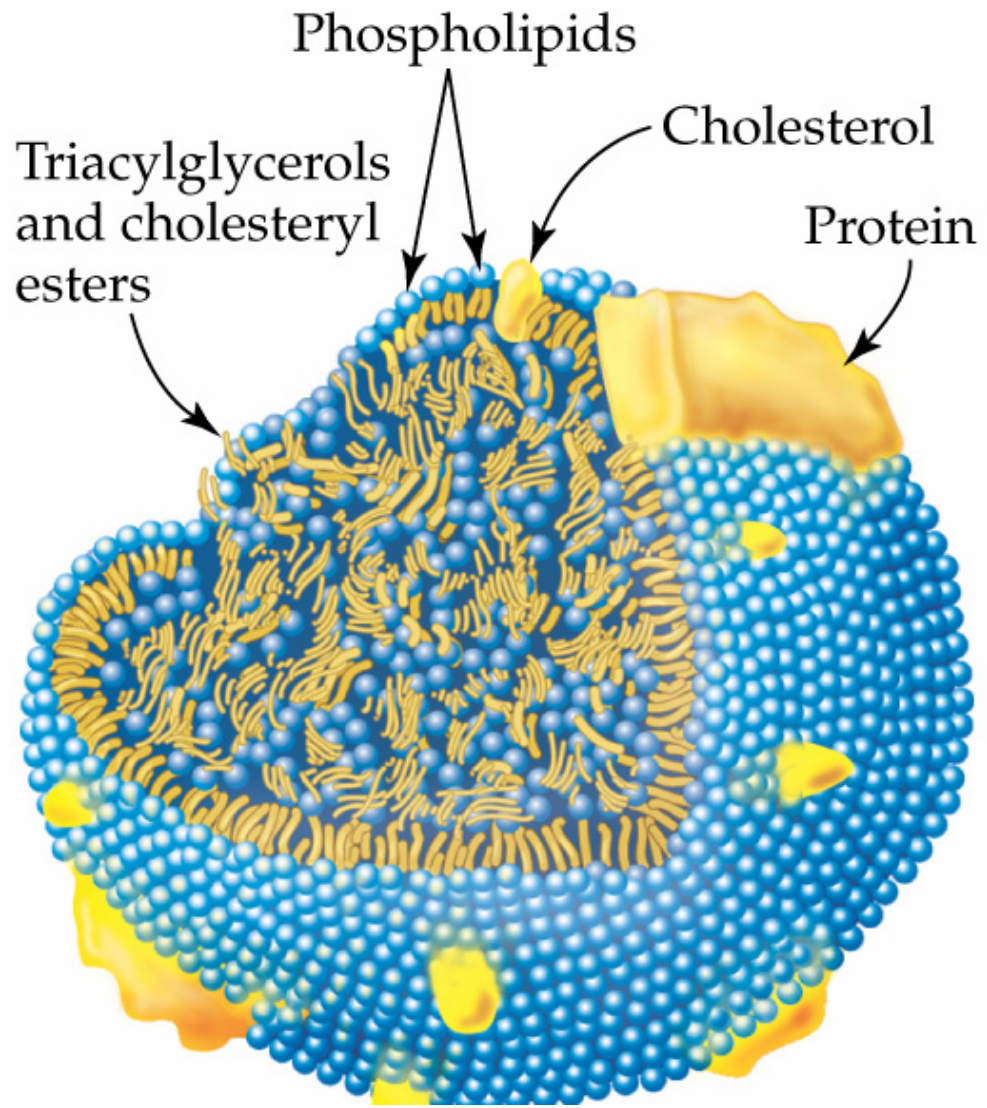
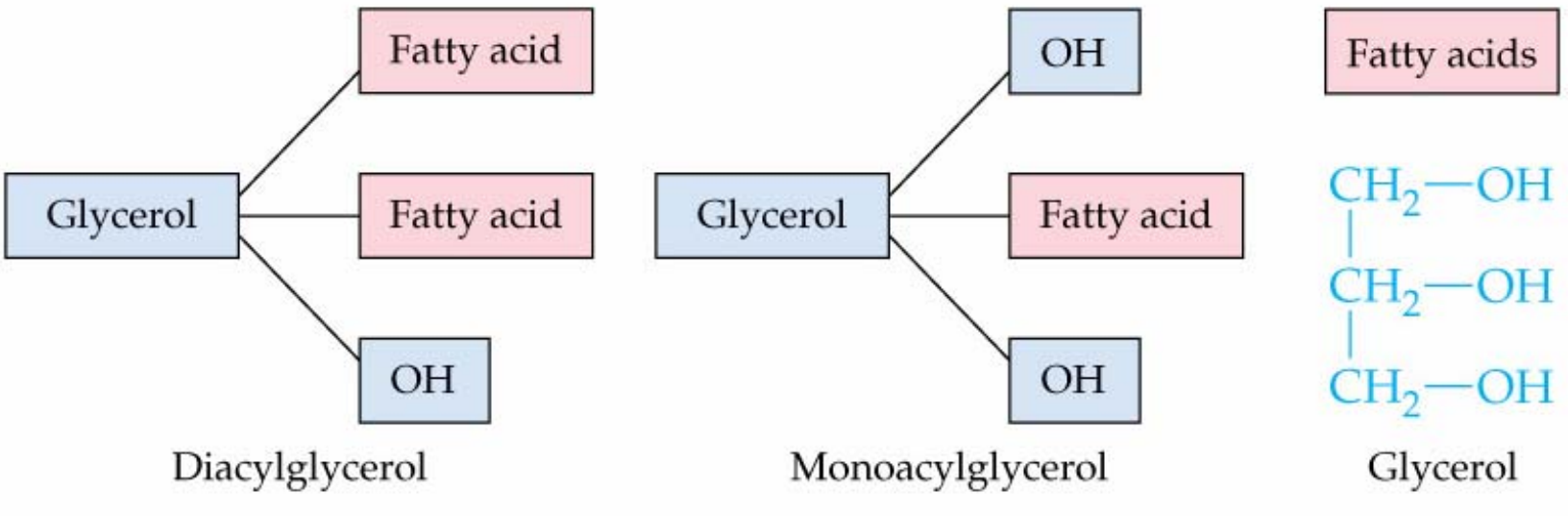


Fig 25.2 A lipoprotein

- Partially digested lipids are partially hydrolyzed in the upper intestine with the help of bile released by the gallbladder and the enzyme pancreatic lipases to mono and diacylglycerols, fatty acids and a small amount of glycerol.



- Water soluble small fatty acids and glycerols enters into the blood stream and carried to the liver.
- The still-insoluble acylglycerols and larger fatty acids are emulsified once again. They are then packaged into water soluble lypoproteins known as chylomicrons.

- Chylomicrons are too large to enter blood stream through capillary walls. Instead, they are absorbed by the lymphatic system and carried to the thoracic duct, where the lymphatic system is emptied into the blood stream.

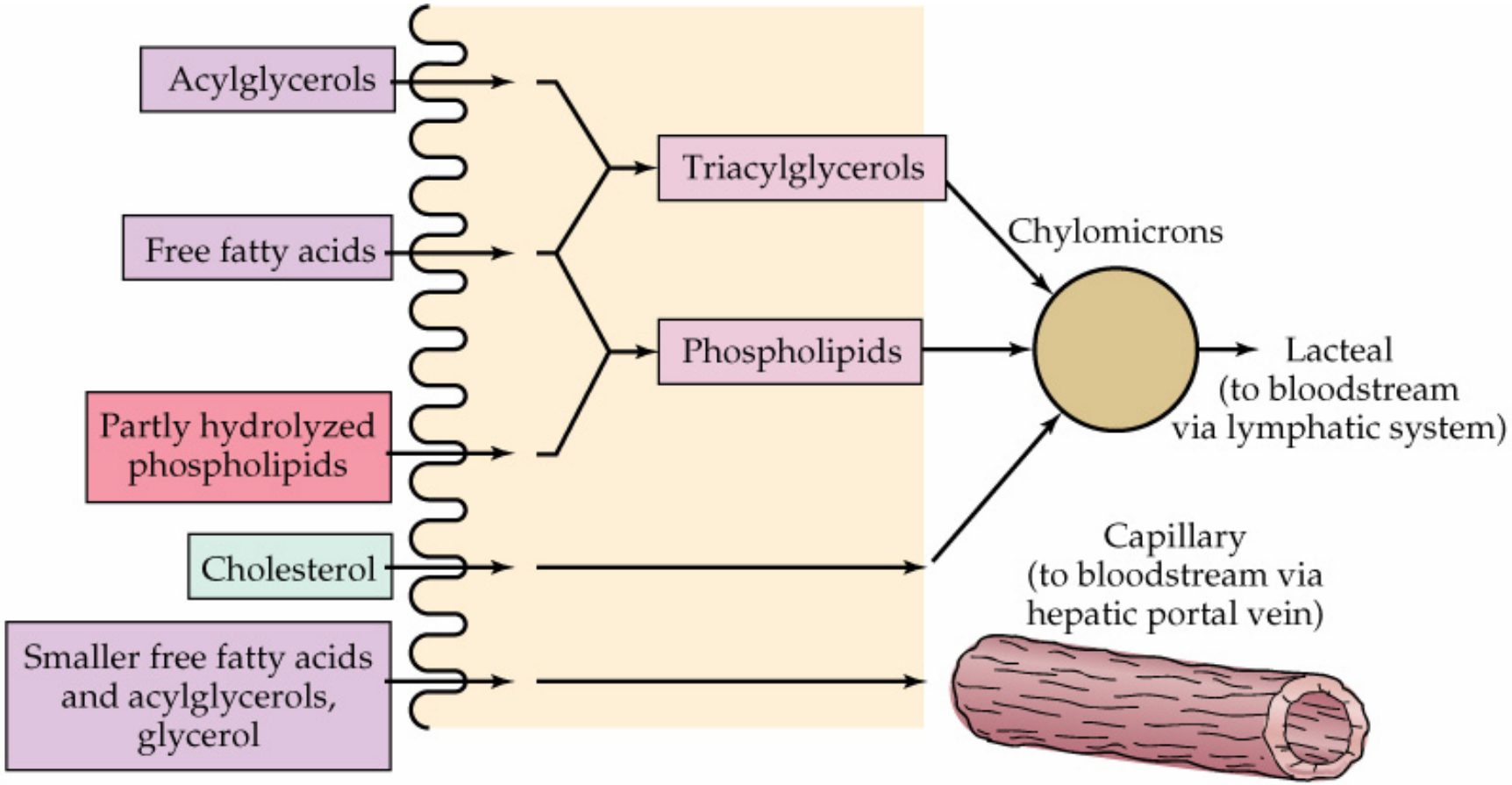


Fig 25.4 Pathways of lipids through the villi

25.2 Lipoproteins for Lipid Transport

- Lipids enter metabolism from three different sources: (1) the diet, (2) storage in adipose tissue, and (3) synthesis in the liver.
- Whatever their source these lipids must eventually be transported in blood, an aqueous media.
- To become water soluble, fatty acid release from adipose tissue associate with albumin. All other lipids are carried by lipoproteins.

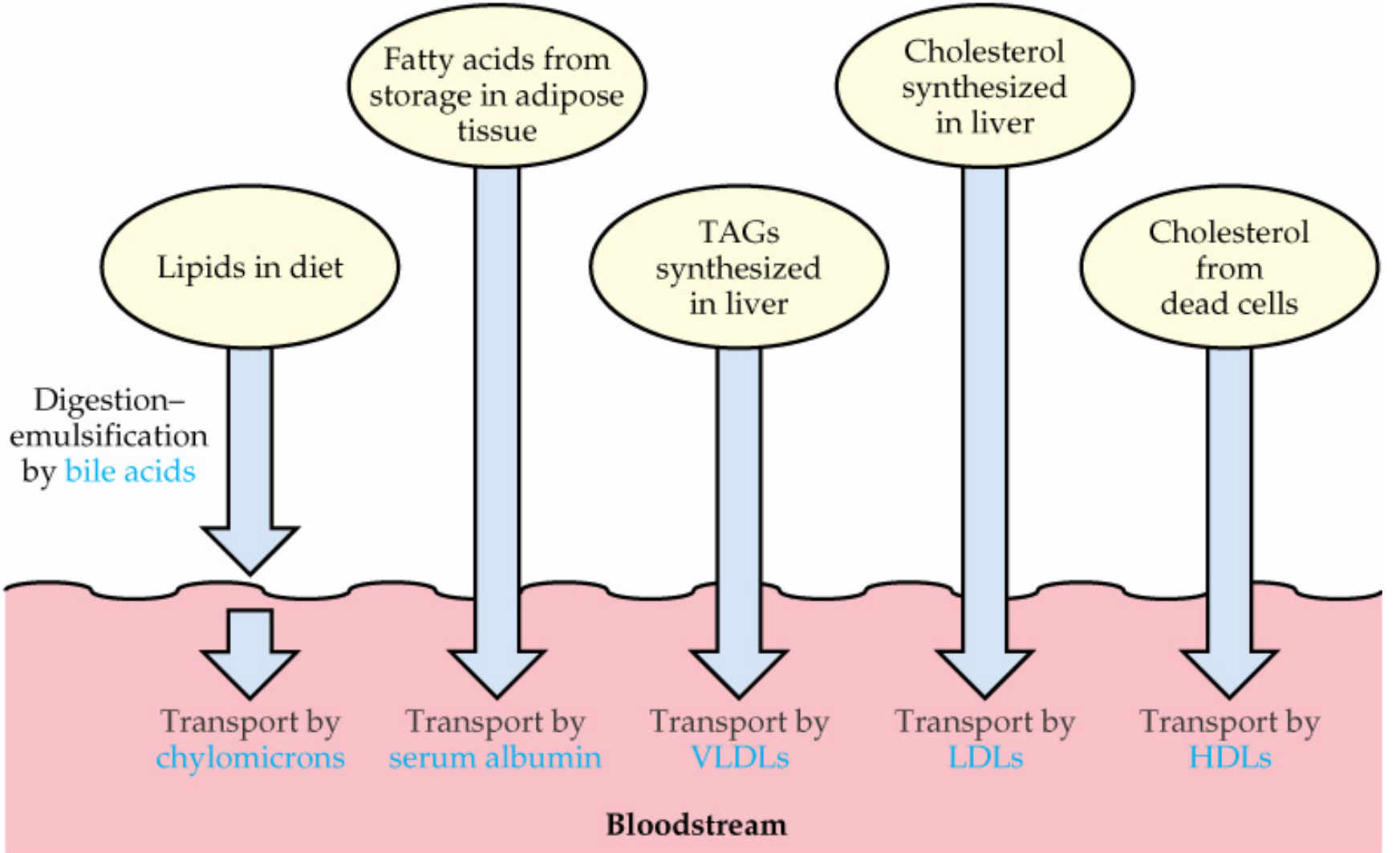
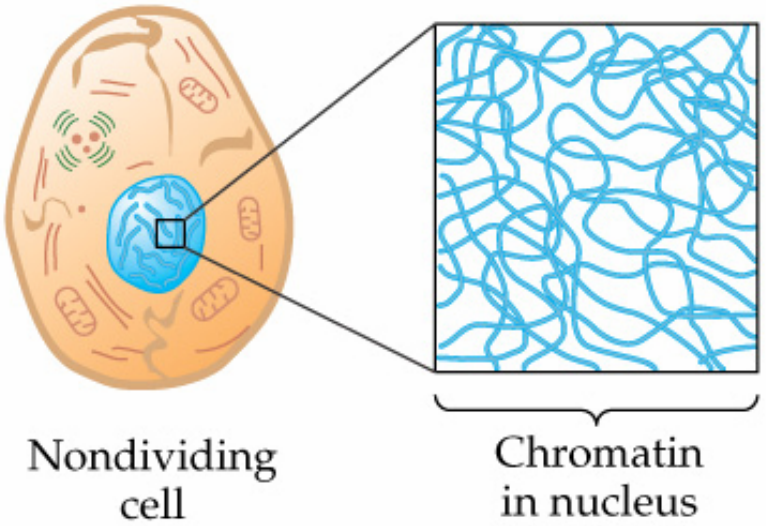
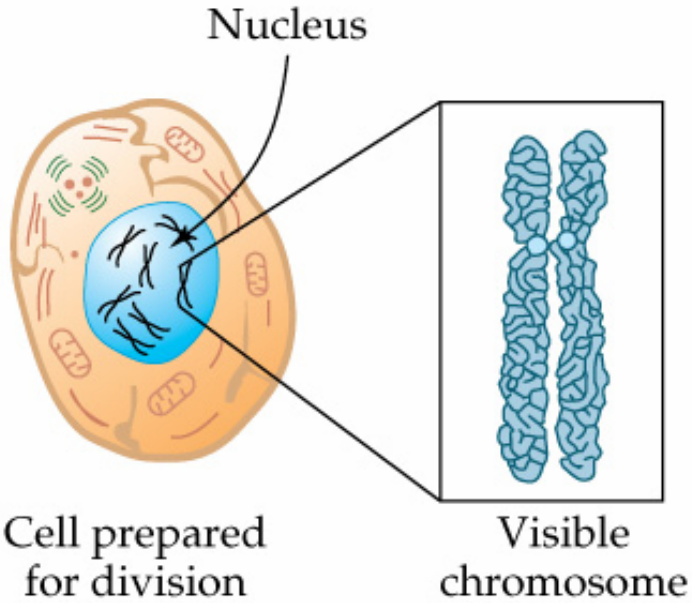


Fig 25.5 Transport of lipids

26.1 DNA, Chromosome, and Genes

- ***DNA*** (deoxyribonucleic acid): The nucleic acid that stores genetic information.
- ***Chromosome***: A complex of proteins and DNA molecule: visible during cell division.
- When a cell is not actively dividing, its nucleus is occupied by chromatin, which is a compact tangle of DNA twisted around proteins known as histones.
- During cell division, chromatin organizes itself into *chromosome*.


Nondividing cell
Chromatin in nucleus


Nucleus
Cell prepared for division
Visible chromosome

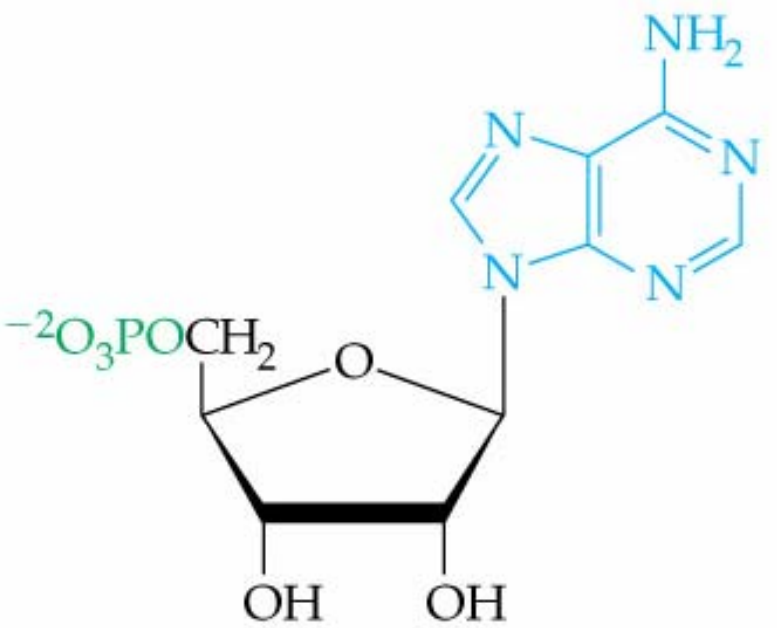
- Each chromosome contains a different DNA molecule, and the DNA is duplicated so that each new cell receives a complete copy.
- Each DNA molecule is made up of many genes – individual segments of DNA that contain the instructions that directs the synthesis of a single polypeptide.
- Number of chromosome varies from organism to organism. For example, a horse has 64 chromosome (32 pairs), a cat has 38 or 19 pairs of chromosomes, a mosquito has 3, a human has 46 or 23 pairs of chromosomes.

26.2 Composition of Nucleic Acids

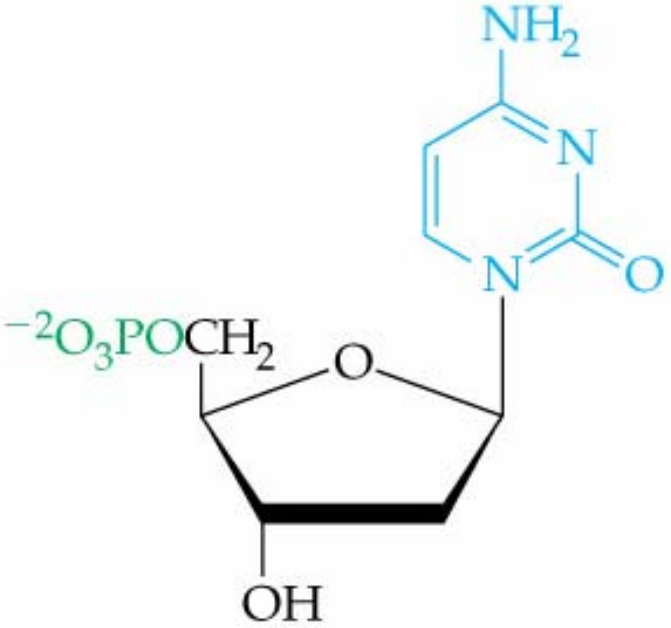
- Nucleic acids are polymer of nucleotides.
- Each nucleotides has three parts: a five-membered ring monosaccharide, a nitrogen-containing cyclic compound that is a base, and a phosphate group.
- There are two kinds of nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The function of RNA is to put the information stored in DNA to use.

In RNA, the sugar is ribose.

In DNA, the sugar is deoxyribose.



Adenosine 5′-monophosphate (AMP)
(a ribonucleotide)



Deoxycytidine 5′-monophosphate (dCMP)
(a deoxyribonucleotide)

Base componenet

- Thymine is present only in DNA molecules. Uracil is present only in RNA. Adenine, guanine, and cytosine bases are present in both DNA and RNA.
- The combination of ribose or deoxyribose and one of the bases listed in Table 261 produces a **nucleoside**.
- Nucleotides are building blocks of nucleic acids. Each nucleotide is a 5'-monophosphate ester of a nucleoside.

26.3 The Structure of Nucleic Acid Chains

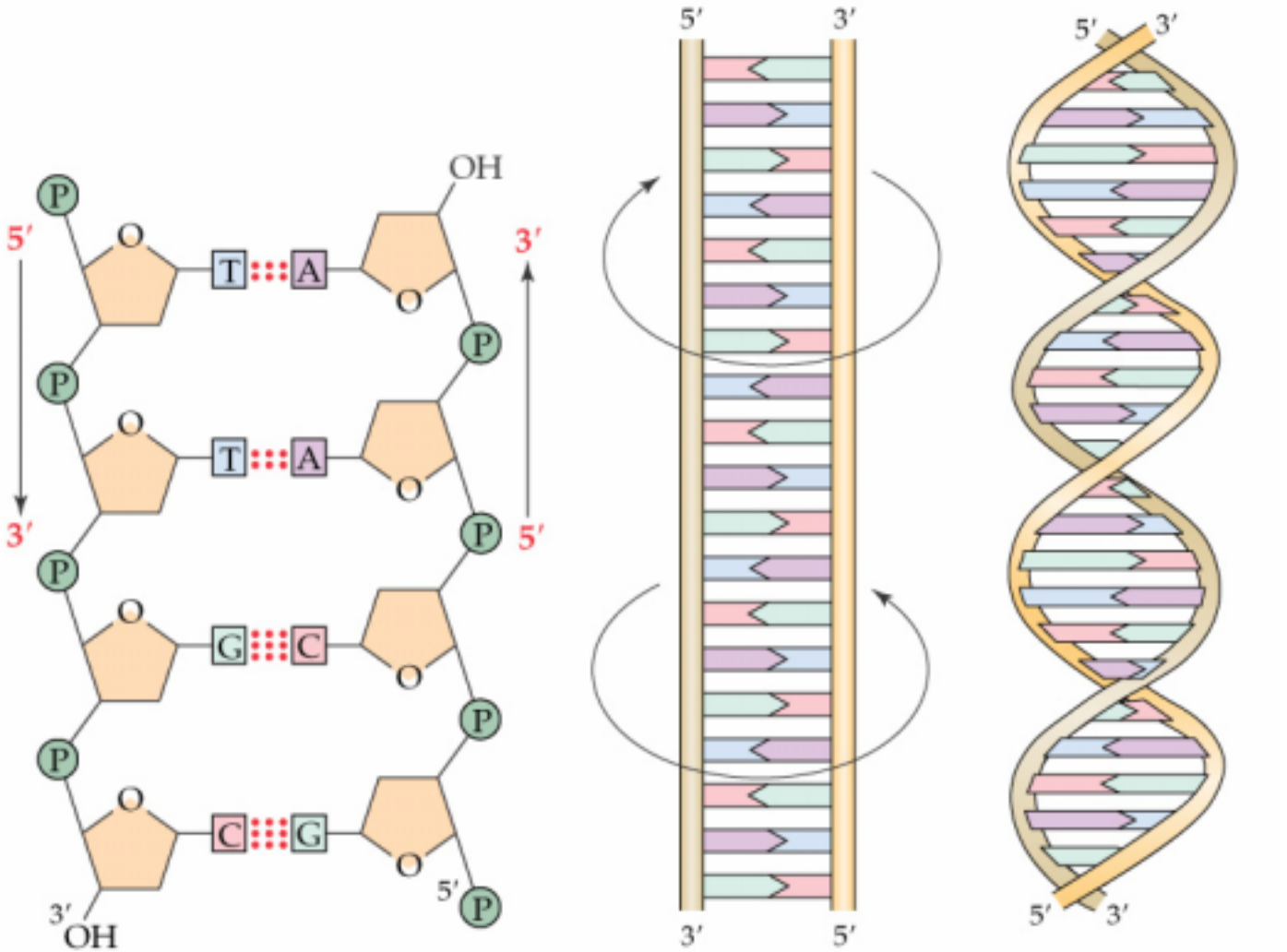
- The nucleotides are connected in DNA and RNA by phosphate diester linkages between the –OH group on C3’ of the sugar ring of one nucleotide and the phosphate group on C5’ of the next nucleotide.
- The structure and function of a nucleic acid depends on the sequence in which its individual nucleotides are connected.
- The differences between different nucleic acids are provided by the order of the groups bonded to the backbone and bases.

26.4 Base Pairing in DNA: The Watson-Crick Model

DNA samples from different cells of the same species have the same proportions of the four heterocyclic bases, but samples from different species have different proportions of bases. For example, human DNA contain 30% each of adenine and thymine, and 20% each of guanine and cytosine.

The bacterium *Escherichia Coli* contains 24% each of adenine and thymine, 26% each of guanine and cytosine. In both cases, A and T are present in equal amounts, are as G and C. The bases occur in pairs.

- In 1953, James Watson and Francis Crick proposed double helix structure for DNA that accounts for base pairing also accounts for the storage and transfer of genetic information.

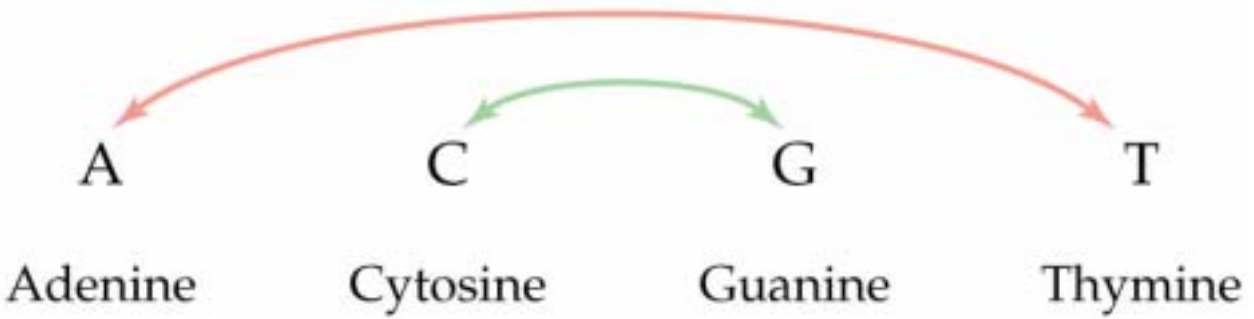


Double helix The two strands coiled around each other in A screwlike fasion.

- Two strands of DNA coiled around each other in a right-handed screwlike fashion. In most organisms the two polynucleotides of DNA form a double helix.
- The two strands of DNA double helix run in opposite directions-one in the 5’ to 3’ direction, the other in the 3’ to 5’ direction.
- The sugar-phosphate back-bone is on the outside of the right handed double helix, and the heterocyclic bases are on the inside.

Fig 26.3 A segment of DNA

- A base on one strand points directly toward a base on the second strand.
- The double helix looks like a twisted ladder, with the sugar-phosphate backbone making up the sides and the hydrogen-bonded base pairs, the rungs.
- Wherever a T base occurs in one strand, an A base falls opposite it in the other strand; Wherever a C base occurs in one strand, an G base falls opposite it in the other strand. This ***base pairing*** explains why A and T and why C and G occur in equal amounts in double-stranded DNA.



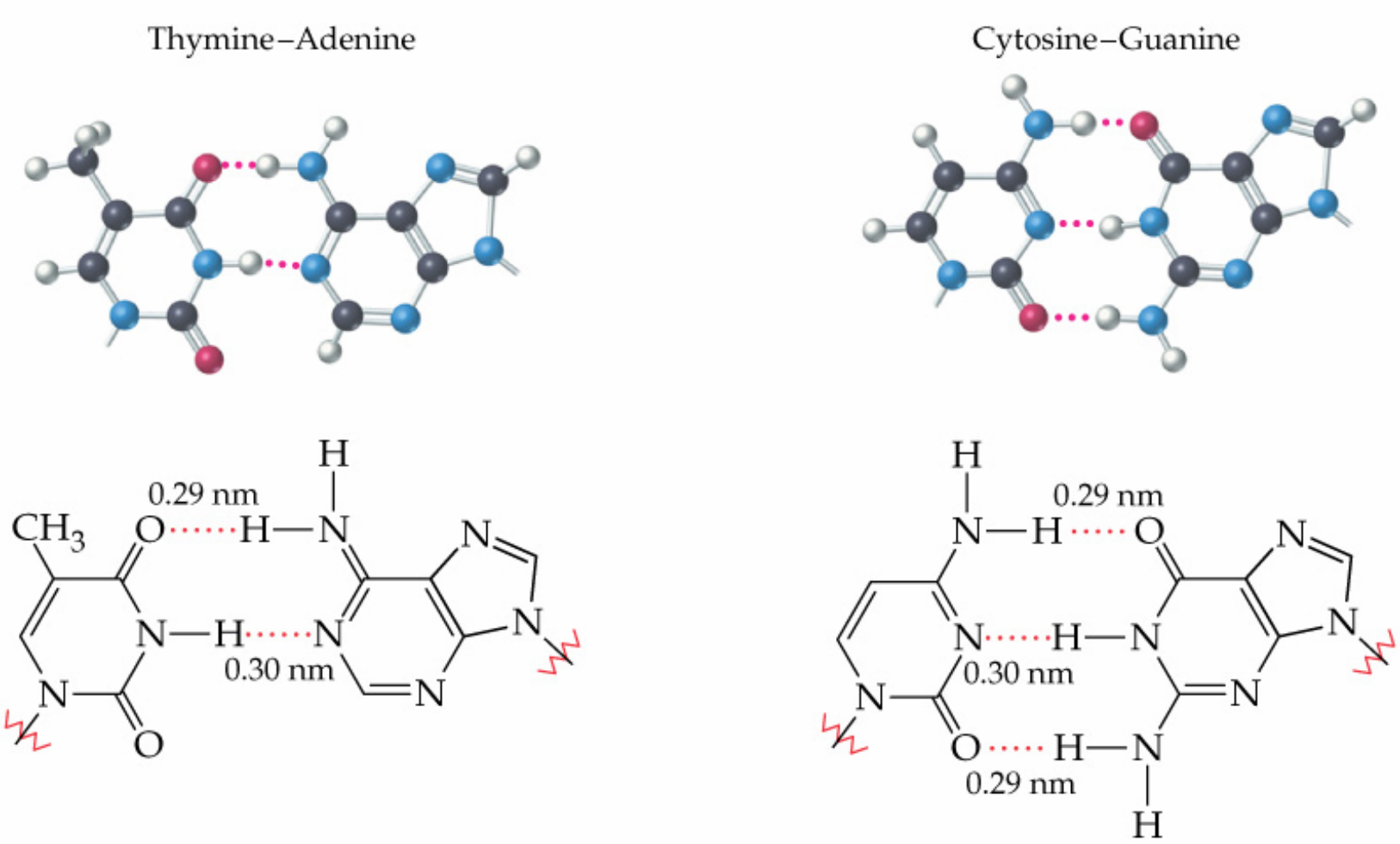


Fig 26.2 Base pairing in DNA

26.5 Nucleic Acids and Heredity

- Each of our 23 pairs of chromosomes contain one DNA copied from that of our father and one DNA copied from that of our mother.
- Most cells in our body contain copies of these originals.
- Our genetic information is carried in the sequence of bases along the DNA strands. Every time a cell divides, the information is passed along to the daughter cells.

- The following three processes are involved in duplication, transfer, and use of genetic information:

  Replication: The process by which a replica, or identical copy, of DNA is made when a cell divides.

  Transcription: The process by which the genetic messages contained in DNA are read and copied.

  Translation: The process by which the genetic messages carried by RNA are decoded and used to build proteins.

26.6 Replication of DNA

- DNA replication involves unwinding of the double helix at several places.
- As the DNA strands separates and the bases are exposed, DNA polymerase enzymes begins their function as a facilitator for replication of DNA.
- Nucleoside triphosphates carrying each of the four bases move into place one by one by forming hydrogen bonds between the base they carry and the base exposed on the DNA strand being copied, the template strand.

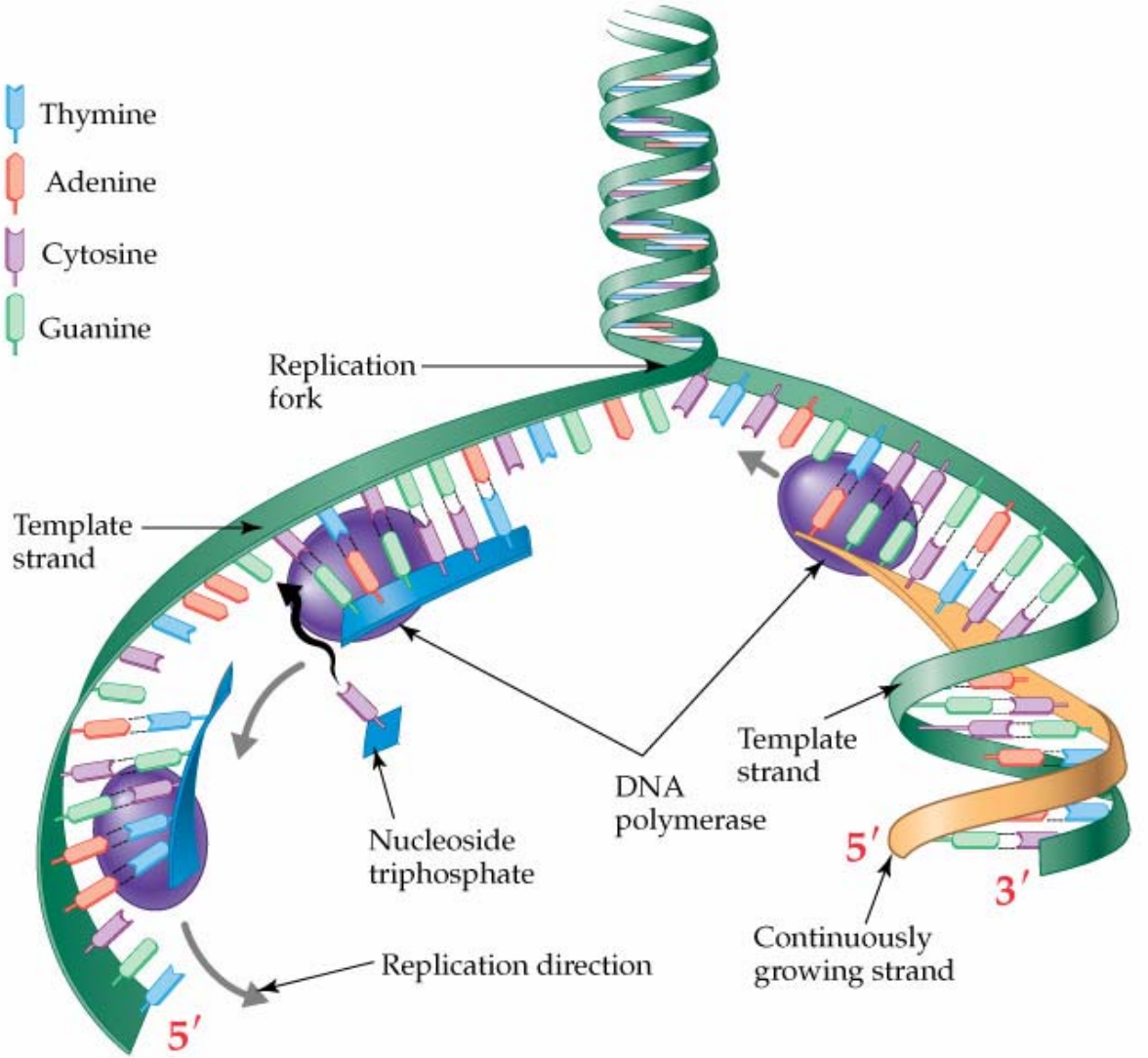
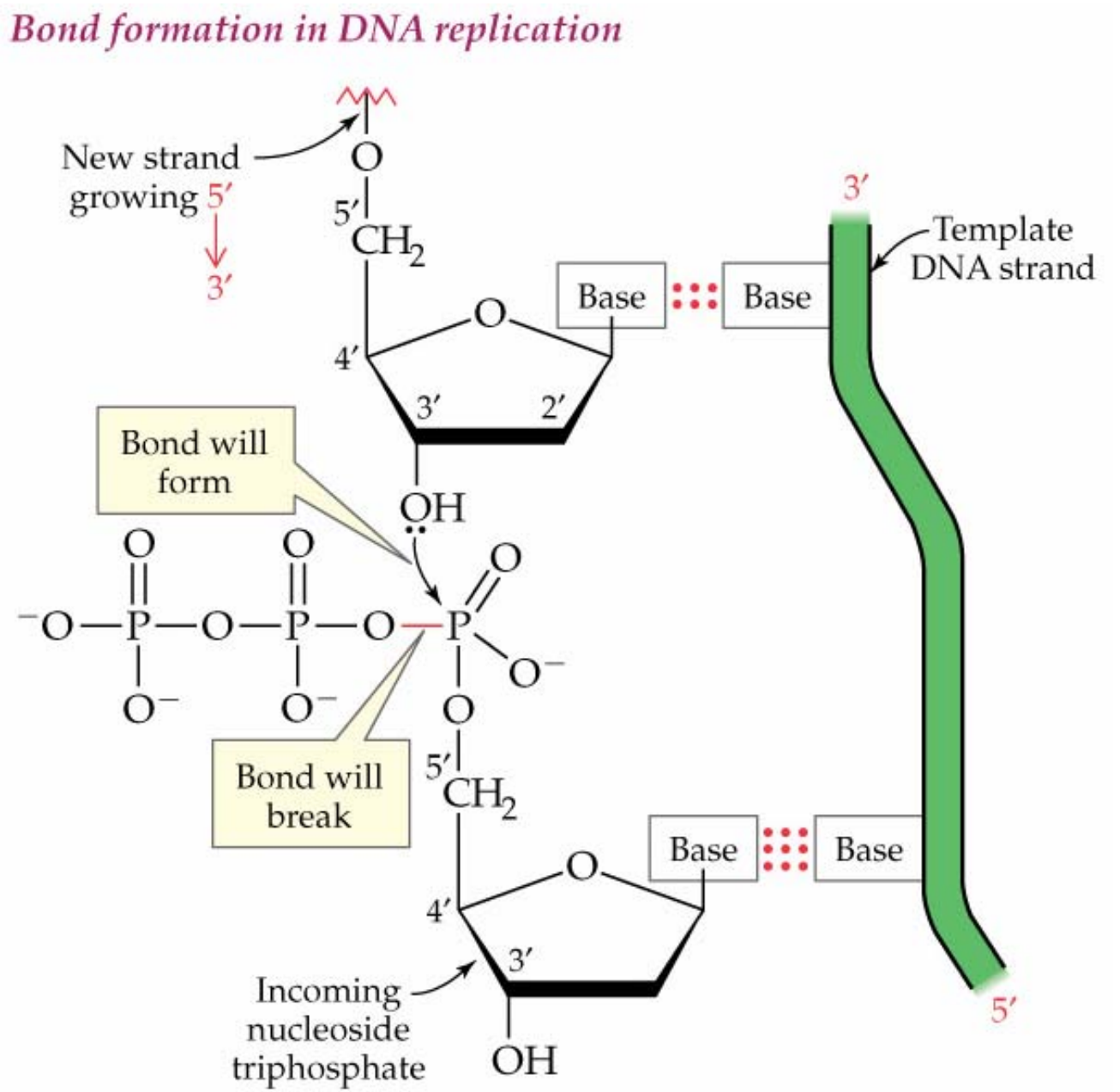


Fig 26.5 DNA replication

- The hydrogen bonding requires that A can pair only with T, and G can pair only with C.
- DNA polymerase then catalyze the bond formation between the 5’ phosphate group of the arriving nucleoside triphosphate and the 3’ –OH group of the growing polynucleotide strand, as the two extra phosphate groups are removed. Therefore, the template strand is copied in the 3’ to 5’ direction.
- Each new strand is complementary to its template strand, two identical copies of the DNA double helix are produced during replication.


Bond formation in DNA replication
New strand growing 5′
3′
5′
CH2
O
4′
3′
2′
OH
Base
Base
3′
Template DNA strand
Bond will form
Bond will break
O
P
O⁻
5′
CH2
Base
Base
4′
3′
Incoming nucleoside triphosphate
OH
5′

26.7 Structure and Function of RNA

RNA is similar to DNA – both are sugar-phosphate polymers and both have nitrogen-containing bases attached – but there are differences between them.

DNA has only one kind of function-storing genetic information. By contrast, the different kinds of RNA perform different functions.

The following three RNA make it possible for the encoded information carried by the DNA to be put to use in the synthesis of proteins.

Ribosome RNA: The granular organelles in the cell where protein synthesis takes place. These organelles are composed of protein and ribosomal RNA (rRNA).

Messenger RNA (mRNA): The RNA that carries the code transcribed from DNA and directs protein synthesis.

Transfer RNA (tRNA): The smaller RNA that delivers amino acids one by one to protein chains growing at ribosomes. Each tRNA recognizes and carries only one amino acid.

26.8 Transcription: RNA Synthesis

- RNA are synthesized in the cell nucleus. Before leaving the nucleus, all types of RNA are modified in the various ways needed for their various functions.
- In transcription, a small section of the DNA double helix unwinds, the bases on the two strands are exposed, and one by one the complementary nucleotides are attached.

- rRNA, tRNA, and mRNA are all synthesized in essentially the same manner. Only one of the two DNA strands is transcribed during RNA synthesis.
- The DNA strand that is transcribed is the template strand; while the its complementary strand is the informational strand.
- The messenger RNA produced is a duplicate of the DNA informational strand, but with U base wherever the DNA has a T base.

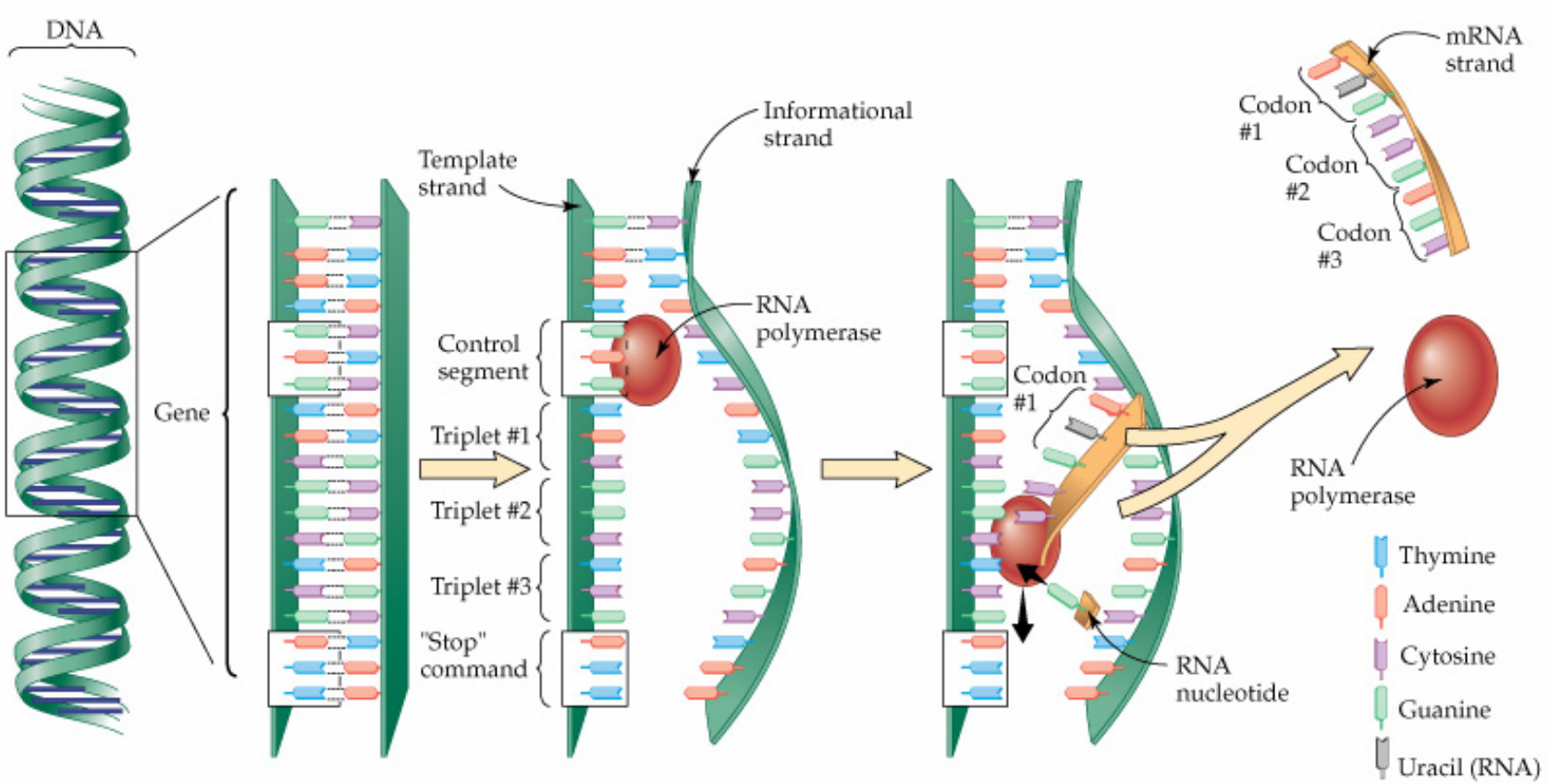


Fig 26.6 Transcription of DNA to produce mRNA

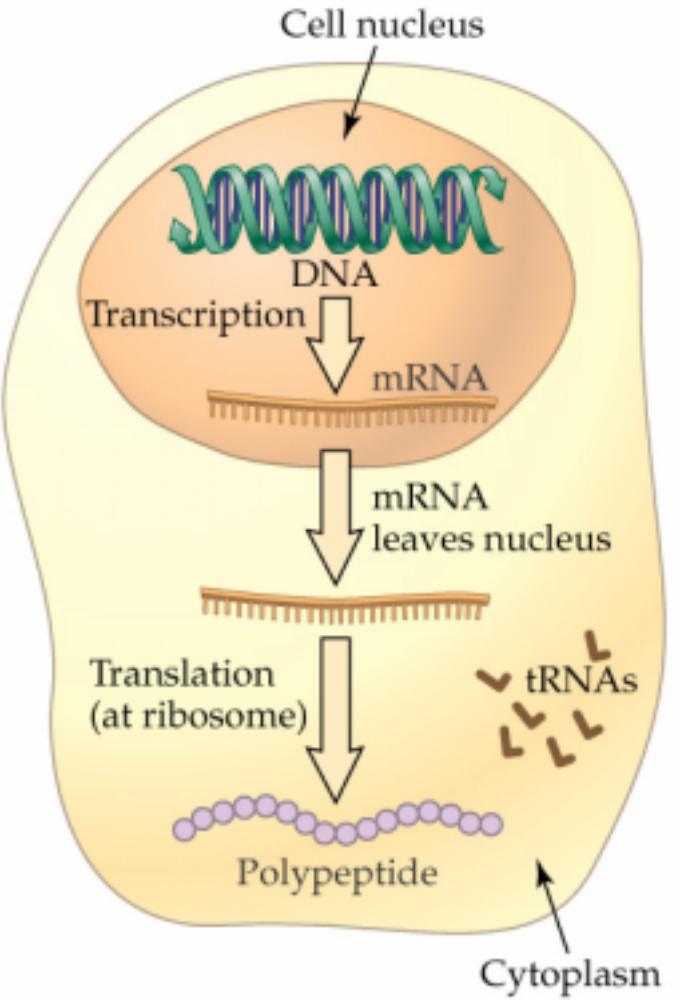
26.9 The Genetic Code

- The ribinucleotide sequence in an mRNA chain is like a coded sentence that species the order in which amino acid residues should be joined to form a protein.
- Each word, or **codon** in the mRNA sentence is a series of three ribonucleotides that code for a specific amino acid.

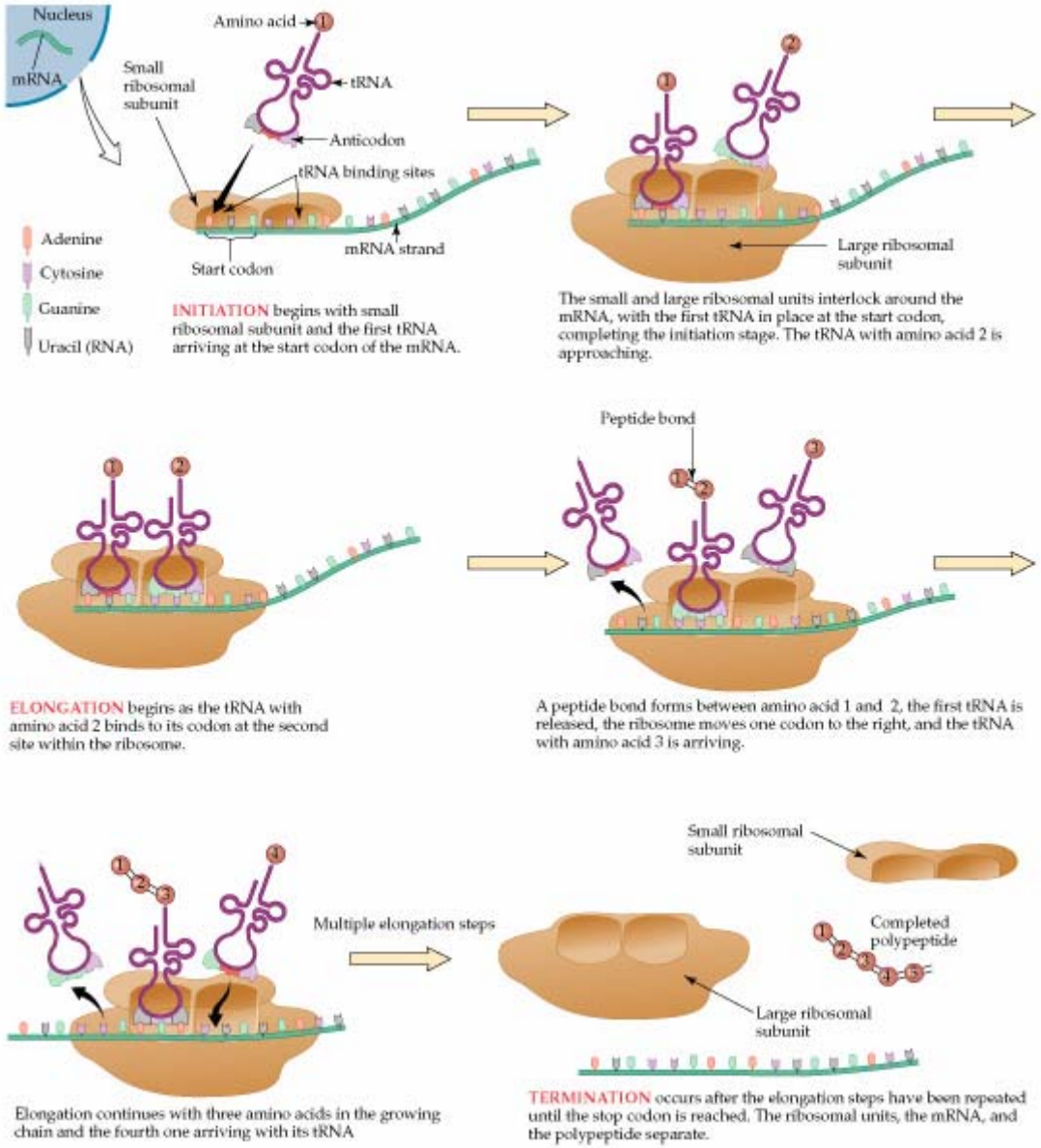
- For example, the series uracil-uracil-guanine (UUG) on an mRNA chain is a codon directing incorporation of the amino acid leucine into a growing protein chain.
- Of the 64 possible three-base combinations in RNA, 61 code for specific amino acids and 3 code for chain termination.

26.10 Translation: Transfer RNA and Protein Synthesis

- The synthesis of proteins occur at ribosomes, which are outside the nucleus and within the cytoplasm of cells.
- The mRNA connects with the ribosome, and the amino acids attached to transfer RNA (tRNA) are delivered one by one.



Three stages in protein Synthesis are initiation, elongation, and termination. A diagram of translation is shown in the Fig 26.8.



27.1 Mapping the Human Genome

- A working draft of human genome was completed in 2000.
- There are about 3 billion base pairs and 30,000-40,000 genes, each able to direct synthesis of more than one protein.
- Roughly 50% of the genome consists of noncoding, repetitive sequences.
- About 200 of the human genes are identical to those in bacteria.
- The strategy Human Genome Project, an international consortium, has adopted for generating the complete map is shown in Fig 27.1.

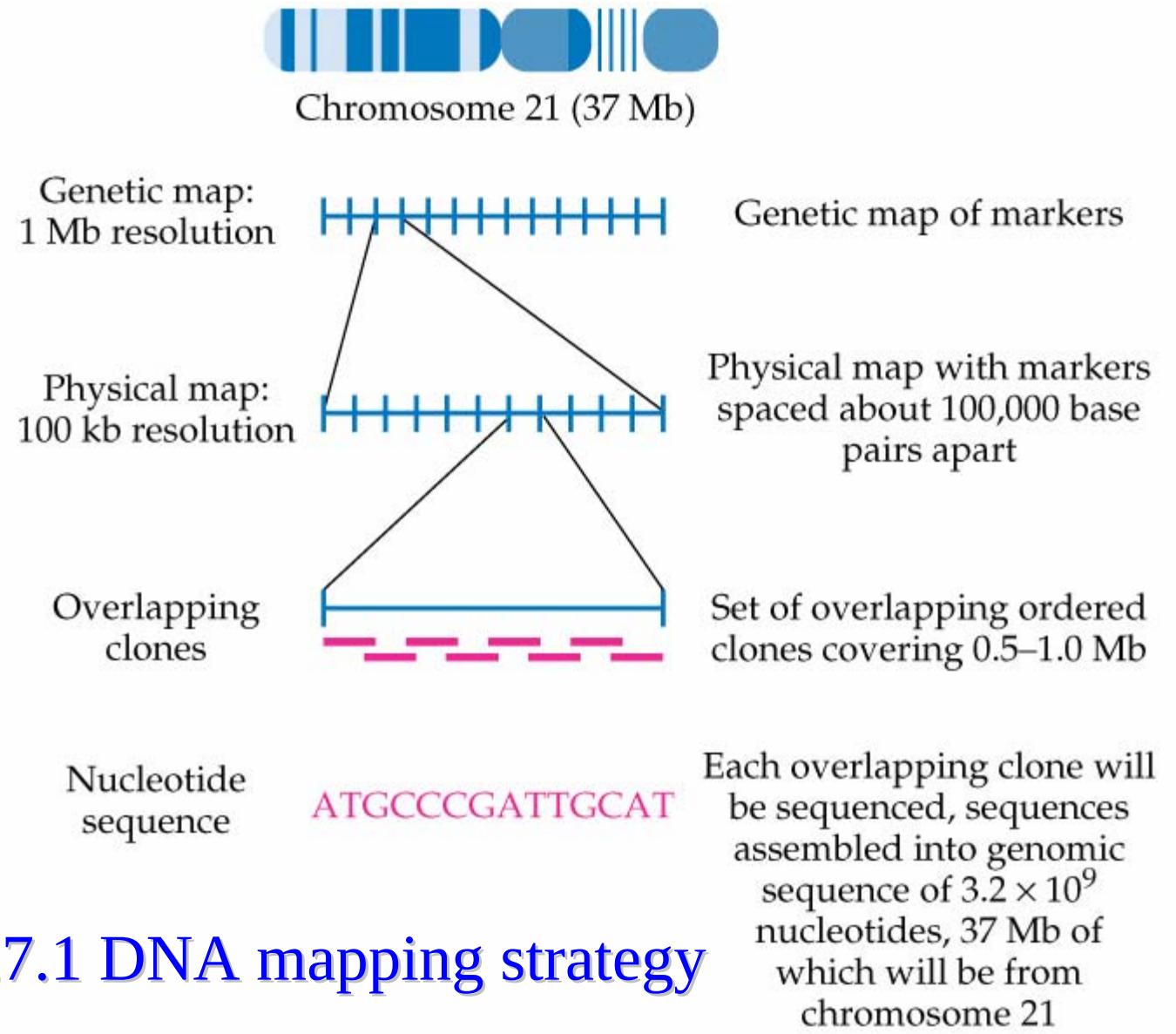


Fig 27.1 DNA mapping strategy

27.2 A Trip Along a Chromosome

- The DNA in a chromosome begins with the telomerase that occur at both ends of every chromosomes.
- Telomeres are long sequence of repeating nucleotides. They do not code for anything.
- Telomeres protect the ends of chromosomes from accidental changes that might alter the DNA's coding sequence. At each cell division, the telomeres are shortened and significant shortening occurs with the death of the cell.
- Centromers, which are the constrictions that determine the shape of chromosomes during cell divisions, are also large repetitive base sequence that do not code for proteins.

- Telomerase is the enzyme responsible for adding telomeres to DNA.
- It is speculated that the telomere shortening plays a role in aging.
- The genome map identified 34 million bases that are attributed to 545 genes in one of the smaller chomosome 22.
- This chromosome carries genes known to be associated with the immune system, congenital heart disease, schizophrenia, leukemia, various cancer, and many other genetically related conditions.

27.3 Mutations and Polymorphisms

- An occasional error during the transcription of a messenger RNA molecule may not create a serious problem, however, if an error occurs during the replication of a DNA molecule, the consequence may be far more damaging.
- An error in base sequence that is carried along during DNA replication is called ***mutation***.
- Mutation can results from spontaneous or random events or can be induced by external agents called ***mutagen***.

- Viruses, chemicals, and ionizing radiations can all be mutagenic.
- The biological; effects of incorporating an incorrect amino acid into a protein range from negligible to catastrophic.
- The effect of mutation may be a hereditary disease or a birth defect.
- Polymorphism are also variations in the nucleotide sequence of DNA within a given population. The location of polymorphisms responsible for some inherited human diseases are shown in Fig 27.2.

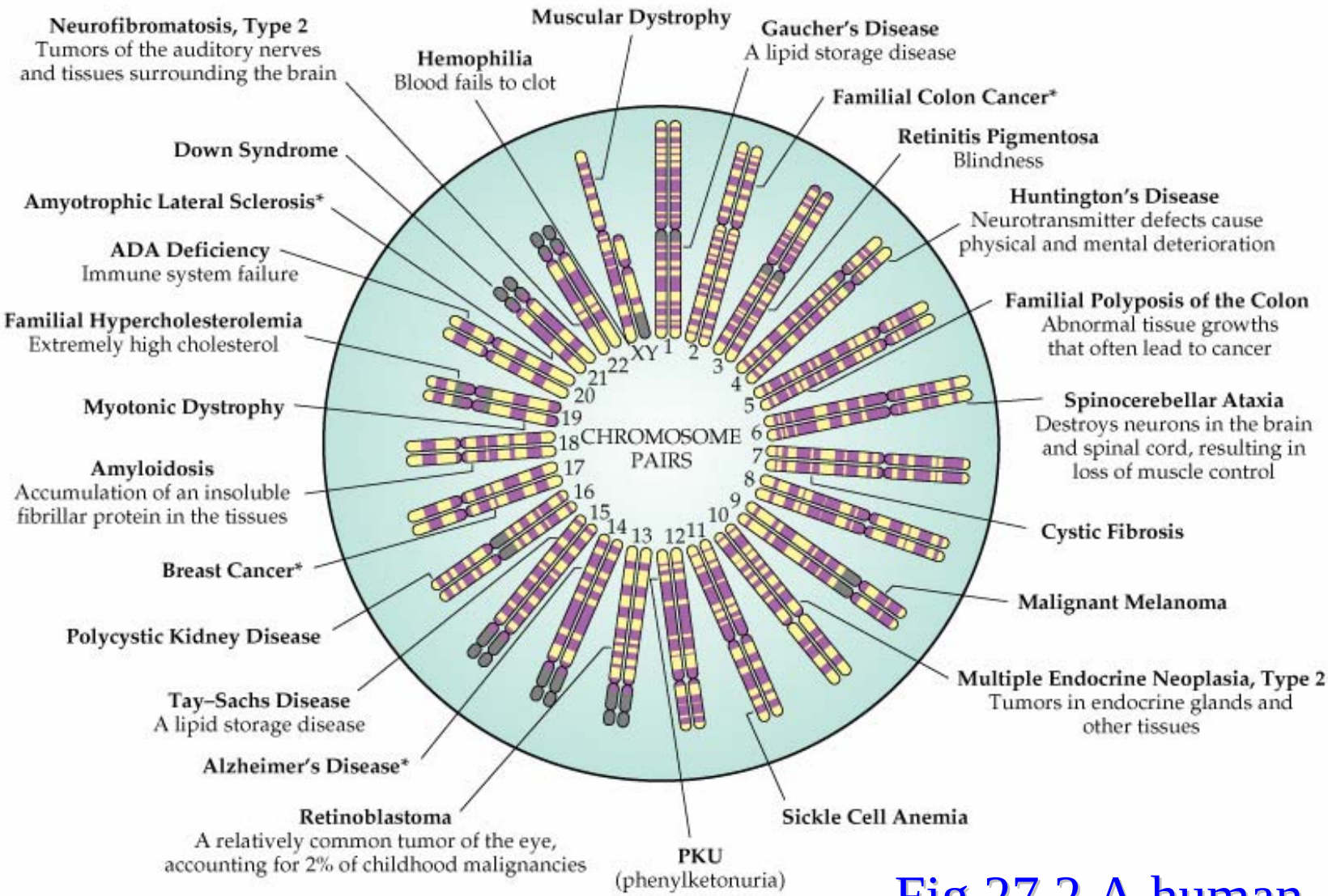


Fig 27.2 A human Chromosome map

27.4 Recombinant DNA

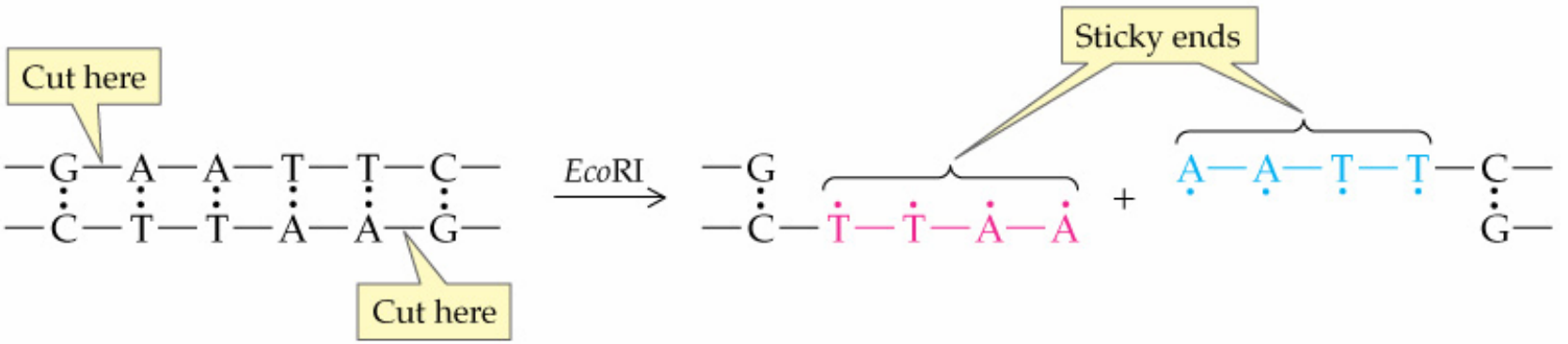
- Recombinant DNA: DNA that contains two or more DNA segments not found together in nature.
- Recombinant DNA technology made it possible to cut a gene out of one organism and recombine it into the genetic machinery of another organism.

- The two other techniques that play important roles in DNA studies are:

  - Polymerase chain reaction (PCR): PCR allows the synthesis of large quantities of identical piece of DNA.

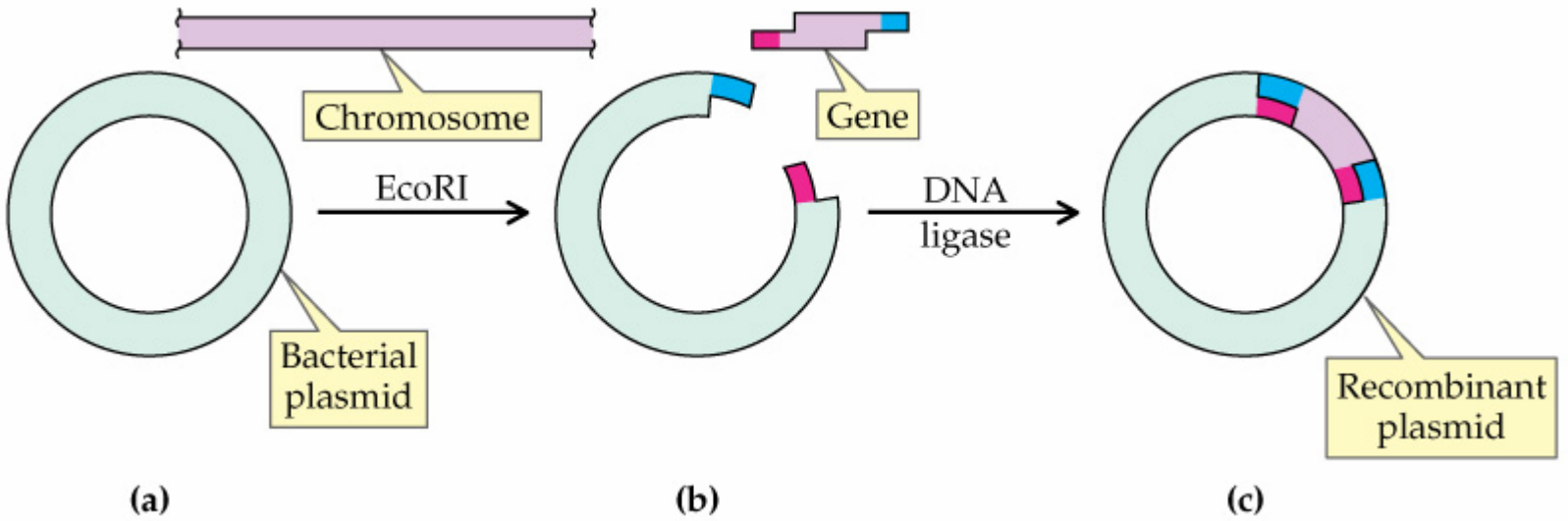
  - Electrophoresis: A technique that allows separation of proteins or DNA fragments according to their size.

Consider a gene fragment that has been cut from human DNA is to be inserted into a bacterial plasmid. The gene and the plasmid are both cut with the same enzyme that produces sticky ends.



The sticky ends on the gene fragment are complementary to the sticky ends on the opened plasmid.

The two are mixed together in the presence of a DNA ligase enzyme that joins them together by forming their phosphodiester bonds and reconstitutes the now-altered plasmid. The altered plasmid is then inserted into a bacteria cell where the normal transcription and translation take place to synthesize the protein encoded by the recombinant DNA.



27.5 Genomics: Using What We Know

Genomics: The study of genes and their functions.

Genetically modified plants and animals

A number of genetically modified plants have already been planted in large quantities in the United States. Genetically modified corn produces a toxin that kills caterpillar and soybeans genetically modified to withstand herbicides are two genetically modified crops that are grown in large quantities in the United States.

Tests are underway with genetically modified tomatoes that have longer shelf life, cofee beans that are caffein free, potatoes that absorb less fat when fried, and most notably a yellow rice that provides vitamin A desperately needed in poor populations.

Gene Therapy

Gene therapy is based on the promise that replacement of a disease causing gene with the healthy gene will cure or prevent disease. The focus has been on using viruses as vector, the agents that will deliver therapeutic quantities of DNA directly into cell nuclei. Expectations remain greater than achievements thus far.

A Personal Genomic Survey

If the personal genomic survey is available to the physician during examination, drugs could be prescribed that will be most effective. Another application might be in the screening of infants for possible defects in genes that may cause disease.

Snips and Chips

A DNA chip may be used to screen for the polymorphism that wipes out the effect of a drug or have several polymorphisms codes for an enzyme that metabolizes a particular drug. The results could aid in choosing the right drug and dosage. A DNA chip is a solid supported large number of short, single stranded bits of DNA of known composition.

A sample to be screened is labeled with a fluorescent tag and applied to the chip. During an incubation period, the sample will bond to the DNA segments with complementary nucleic acid sequences. Then the fluorescence is read to discover where the bonding has occurred and what DNA variations are present.

Bioethics

Ethical, legal, and social implications of human genetic research is the greatest concern every one has. These concerns deals with the following questions:

- Who should have access to personal genetic information and how will it be used?
- Who should own ans control genetic information?
- Should genetic testing should be performed when no treatment is available?
- Should we re-engineer the genes we pass on to our children?

29.3 Blood

Blood flows through the body in the circulatory system, which in the absence of trauma or disease is essentially a closed system. Major components of blood are:

Whole Blood

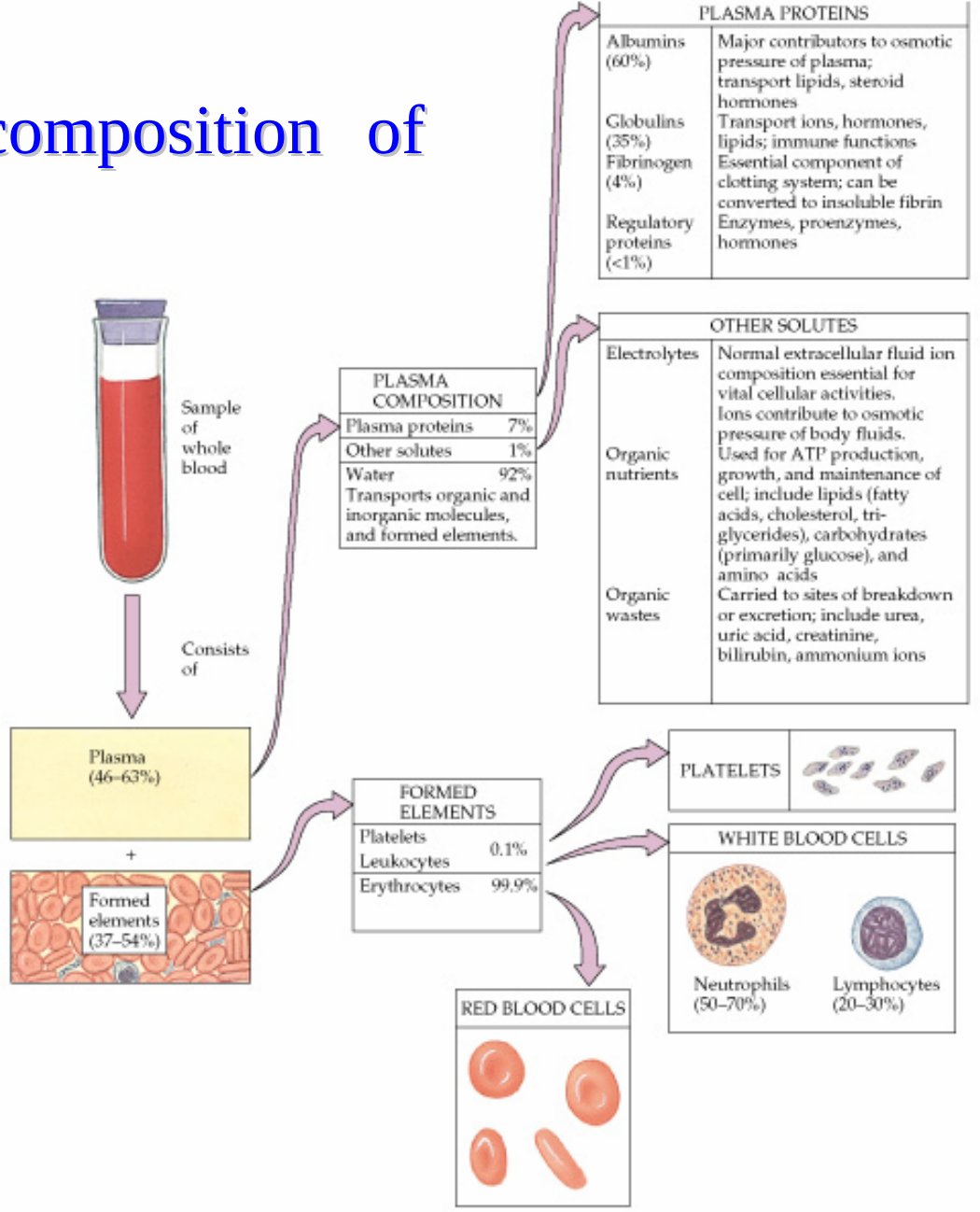
Blood plasma – fluid part of blood containing water soluble solutes. About 55% of blood is plasma. *Blood cells* – red blood cells carry gases and white blood cells are part of the immune system.

Blood serum

Fluid portion of plasma left after blood has clotted.

The functions of the major protein and cellular component of blood are *transport*, *regulation*, *and* defense.

Fig 29.6 The composition of whole blood



29.4 Plasma Proteins, White Blood Cells, and Immunity

Antigen: A substance foreign to the body that triggers the immune response.

Antigen can be any molecule or part of a molecule recognized by the body as not a part of itself or they can be small molecules known as haptens that are recognized as antigens only when they have bonded to carrier proteins.

The recognition of an antigen can initiate three different responses.

- *Inflammatory response:* A general localized response that is not specific to any given antigen.
- *Cell-mediated immune response*: Unlike inflammatory response, immune response depends on recognition of the invader antigen. The invading antigen is detected by the defender white blood cells known as T cells by an interaction similar to between enzyme and substrate.

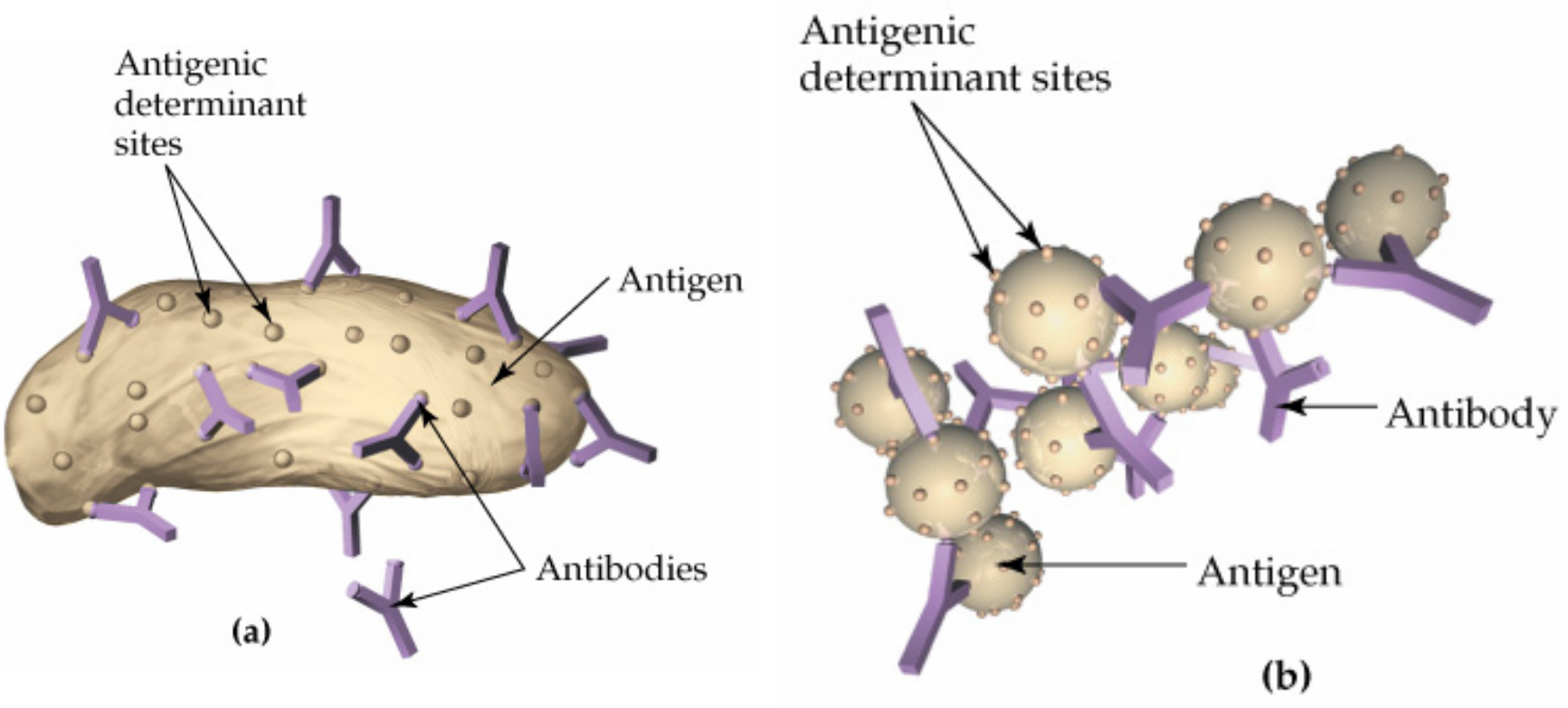


Fig 29.9 (a) Antigen bonds to antigenic-determinant sites on the surface of, for example, a bacterium. (b) The interaction of many antigens and antibodies (each antibody has two binding sites) creates a large immune complex.

- *Antibody-mediated immune response*: Utilizes antibodies produced by the white blood cells known as B cells.

Inflammation and the immune responses require normal numbers of white blood cells to be effective. If the white blood cell count falls below *1000 per milliliter of blood*, any infection can be life-threatening. Devastating results of white blood cell destruction in AIDS is an example of this condition.

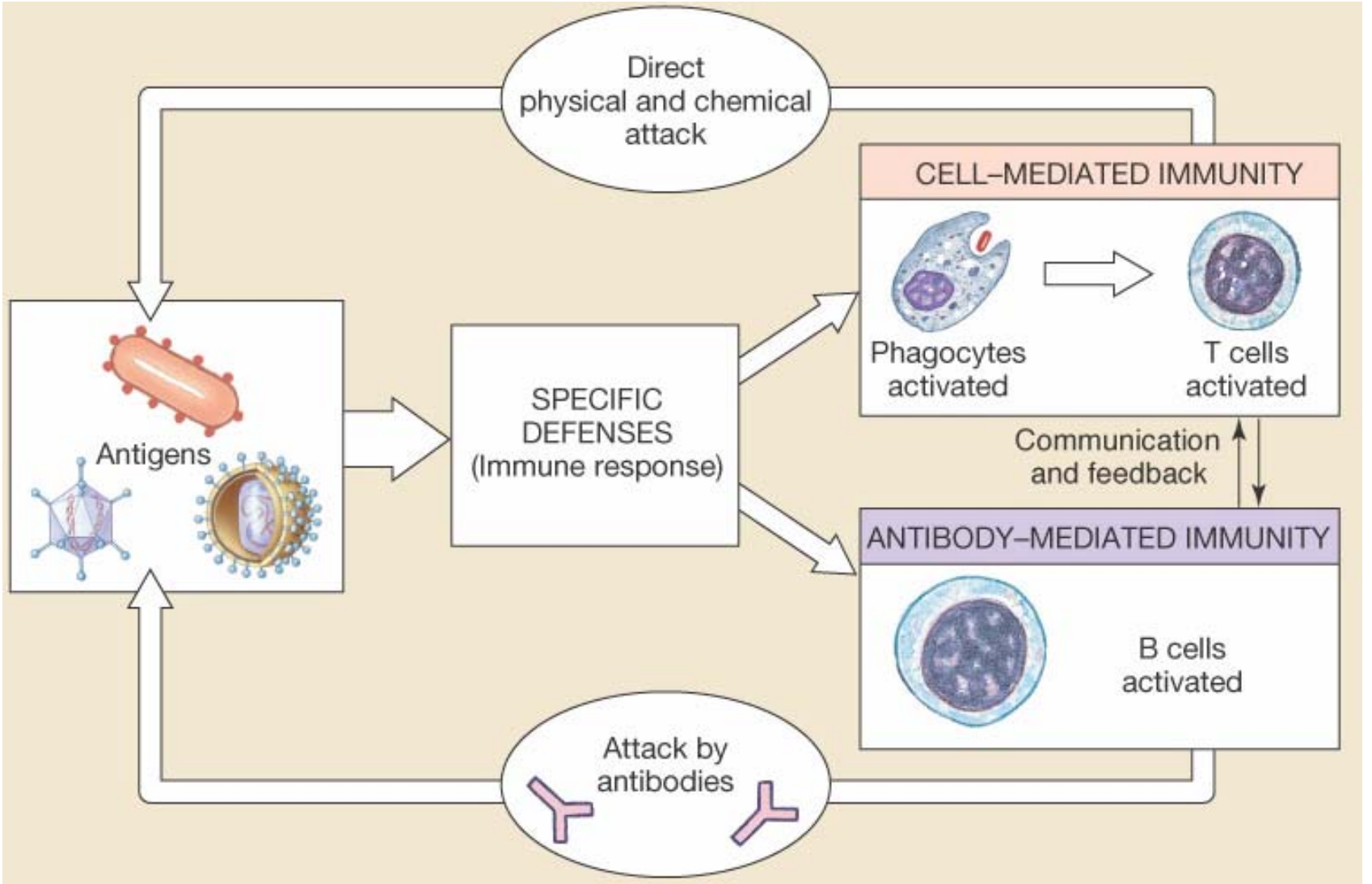


Fig 29.7 The immune response.

Inflammatory Response

Cell damage due to infection or injury initiates inflammation, a non-specific defense mechanism that produces swelling, redness, warmth, and pain. Chemical messengers released at the site of the injury direct the inflammatory response. One such messenger is histamine which is stored in cells throughout the body. Histamine release is also triggered by an allergic response.

Cell-mediated Immune Response

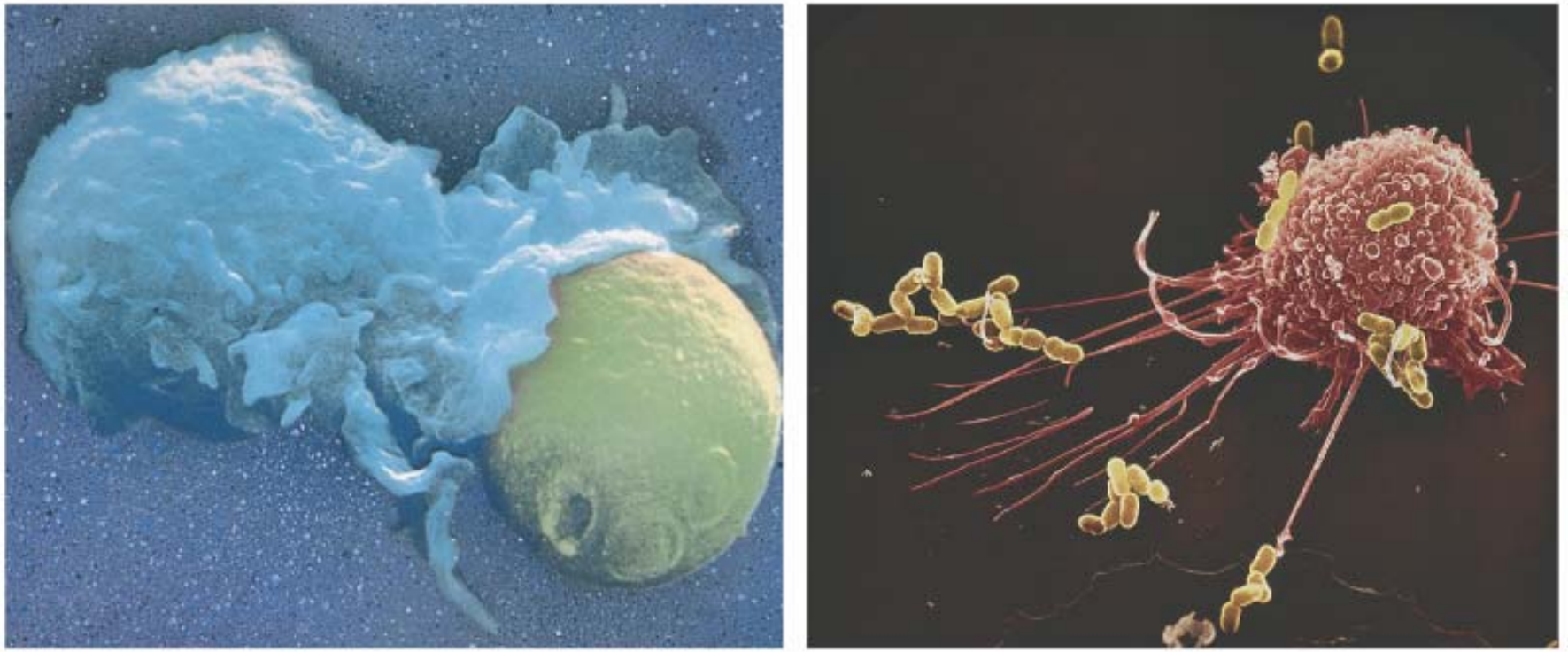
The cell-mediated immune response is under control of several kinds of T-lymphocytes, or T-cells. It guards principally against abnormal cells and bacteria or viruses that have invaded normal cells.

Cell-mediated immune also guards against some cancer cells and causes the rejection of transplanted organs.

A complex series of events results into production of cytotoxic, or killer, T cells that destroy the invaders and helper T cells that enhance defense against the invaders in a variety of ways. Thousands of memory T cells are also produced that will remain on guard and will immediately generate the appropriate killer T cells if the same pathogen reappears.

Antibody-mediated Immune Response

The white blood cells known as B lymphocytes or B cells, with the assists of T cells are responsible for antibody-mediated immune response. Unlike T cells, B cells identify antigens adrift in body fluids. A B cell is activated when it first bonds to an antigen and then encounters a helper T cell that recognizes the same antigen. This activation can take place any where in the body but often occurs in lymph nodes, tonsils, or the spleen, which have large concentration of lymphocytes. Once activated, B cells secrete antibodies specific to the antigen.



White blood cells: (a) A lymphocyte phagocytizing a yeast cell. (b) A lymphocyte reaches out to snare several *E. Coli* bacteria.

29.5 Blood Clotting

A blood clot consists of blood cells trapped in a mesh of the insoluble fibrous protein known as *fibrin*.

The body's mechanism for stopping blood loss is referred as hemostasis. The following events results into hemostasis.

- Constriction of blood vessels.
- Formation of a plug composed of the blood cells known as platelets at the site of the tissue damage.

- Blood clotting triggers when blood makes contact with the negatively charged surface of the fibrous protein collagen exposed at the site of the tissue damage (known as the intrinsic pathway) and/or when the damaged tissue releases a glycoprotein known as tissue factor. The results of either events is activation of zymogens that catalyzes a series of reactions that promotes blood clotting.

29.6 Red Blood Cells and Blood Gases

- Red blood cells, or erythrocytes, transport blood gases -oxygen and carbon dioxide.
- Erythrocytes in mammals have no nuclei or ribosomes and can not replicate themselves. They don't have mitochondria or glycogen and therefore they must obtain glucose from the surrounding plasma.
- 95% of the proteins in erythrocyte is hemoglobin, a carrier of oxygen and carbon dioxide.

Oxygen Transport

- The Iron (II) ion, Fe^{2+}, in the center of each heme molecule plays the center role in oxygen transport.
- Oxygen is held by the Fe^{2+} by boding through oxygen's lone pair of electrons.
- Hemoglobin carrying four oxygen is bright red.
- At normal physiological conditions, the percentage of heme molecules that carry oxygen, known as percent saturation, depends on the partial pressure of oxygen in the surrounding tissues as shown in Fig 29.11.

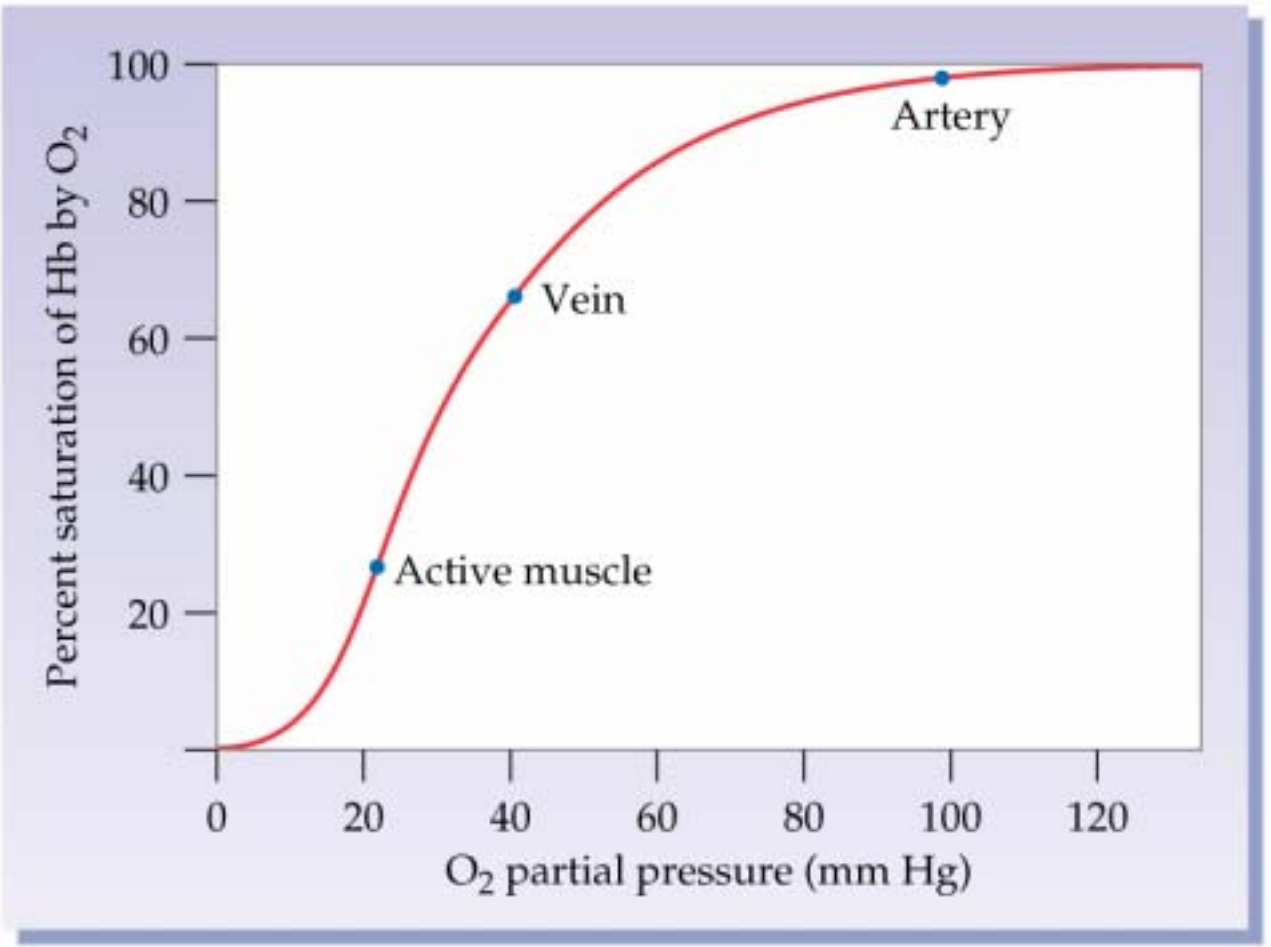
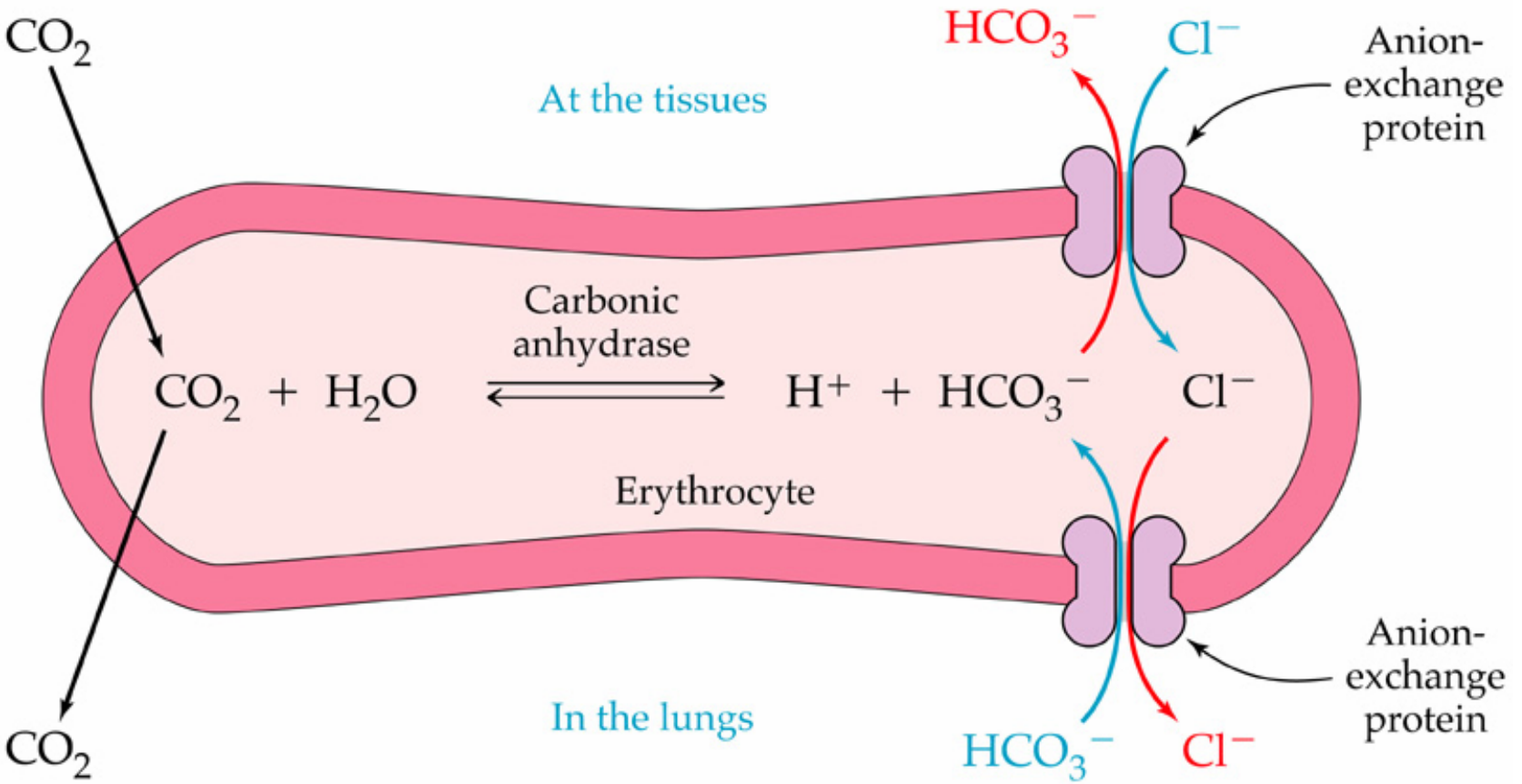


Fig 29.11 Oxygen saturation of hemoglobin at normal physiological conditions

Carbon Dioxide Transport, Acidosis, and Alkalosis

- Carbon dioxide from metabolism in the peripheral cells diffuses into interstitial fluid and then into capillaries where it is transported in blood three ways: (1) dissolved, CO_2 (aq), (2) bonded to hemoglobins, or (3) as HCO_3^-.
- Most of the CO_2 is rapidly converted to HCO_3^- ion within erythrocytes, which contain a large concentration of carbonic anhydrase. Water soluble HCO_3^- ion leave the erythrocyte and travel in the blood to the lungs where it is converted back to the CO_2 for exhalation.


CO_2
At the tissues
HCO_3^-
Cl^-
Anion-exchange protein
Carbonic anhydrase
$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$
Cl^-
Erythrocyte
CO_2
In the lungs
HCO_3^-
Cl^-
Anion-exchange protein

- To maintain electrolyte balance, a Cl^- ion enters the erythrocyte for every HCO_3^- ion that leaves, and the process is reversed when the blood reaches the lungs. A cell-membrane protein controls the ion exchange.
- To counter the increase in acidity due to hemoglobin binding of CO_2 and the action of carbonic anhydrase, hemoglobin reversibly bind hydrogen ions.
- The change in the oxygen saturation curve with CO_2 and H^+ concentration and with temperature are shown in Fig 29.12.

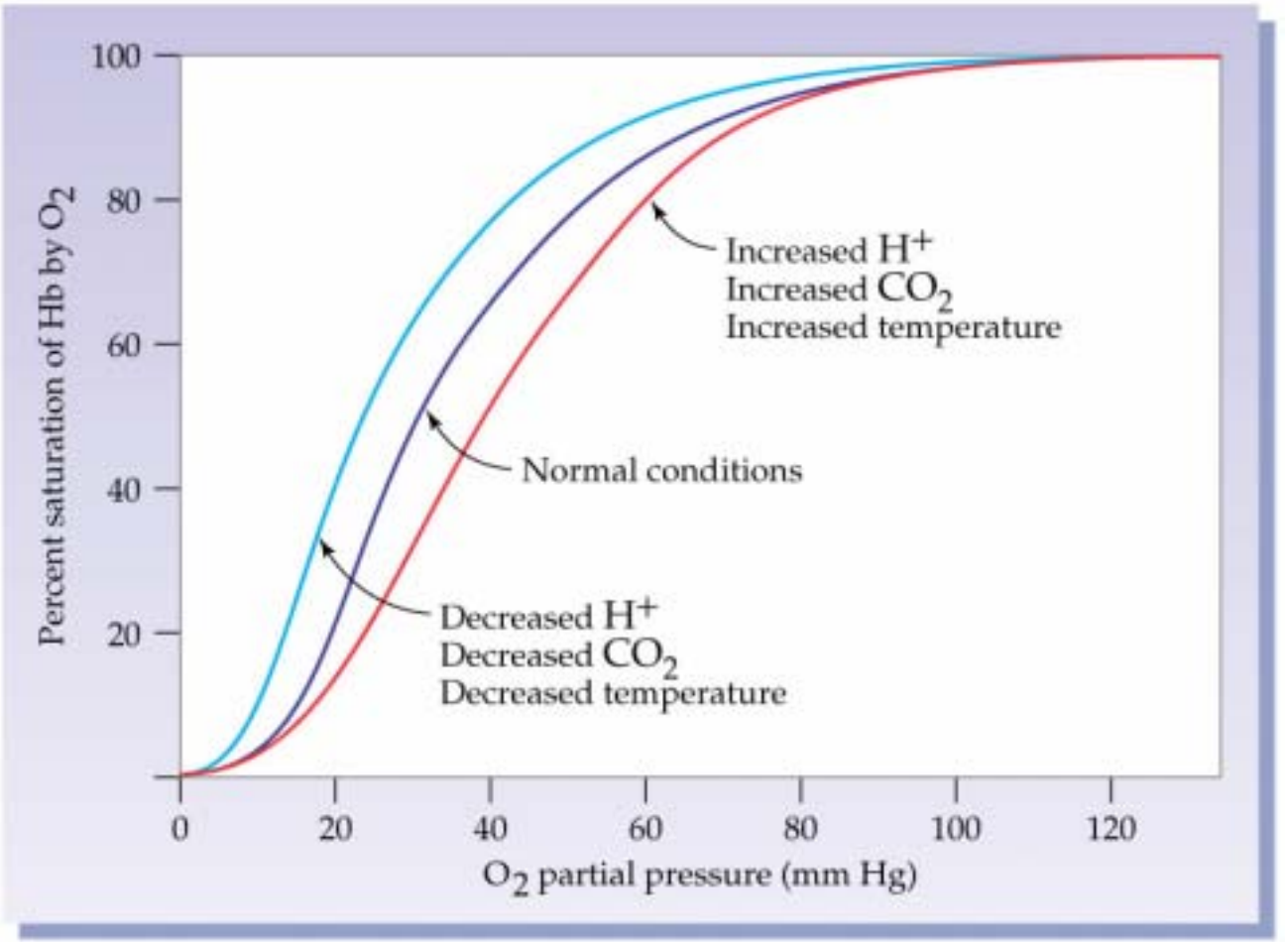


Fig 29.12 Changes in oxygen affinity of hemoglobin with changing conditions

Acidosis	Normal	Alkalosis
Below 7.35	7.35–7.45	Above 7.45

Acidosis: The abnormal condition associated with a blood plasma pH below 7.35.

Alkalosis: The abnormal condition associated with a blood plasma pH above 7.35.