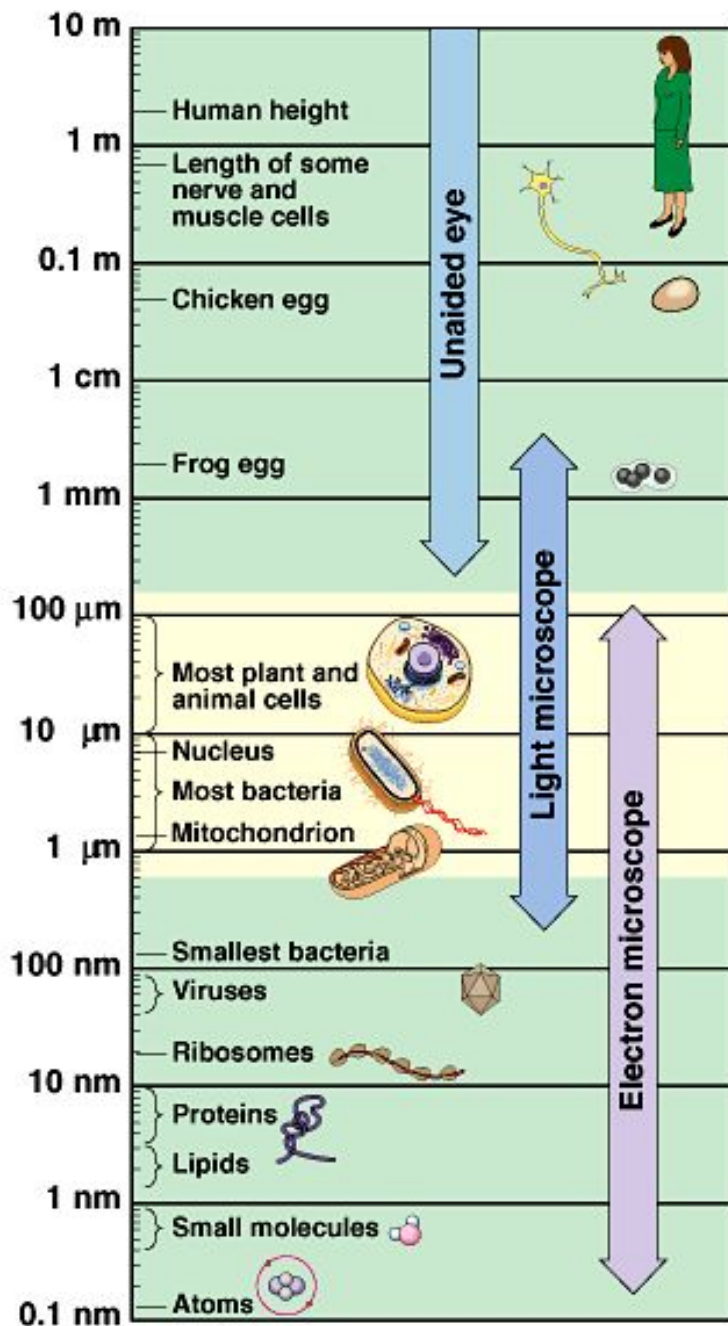


Генно-инженерные и белковые технологии в физиологии растений и сельском хозяйстве

Структурно-функциональная организация генов и белков. Экспрессия генов и биосинтез белка, клеточный контроль этих процессов. Гены продуктивности растений.





Измерения:

1 сантиметр (см) = 10^{-2} метра (м)

1 миллиметр (мм) = 10^{-3} м

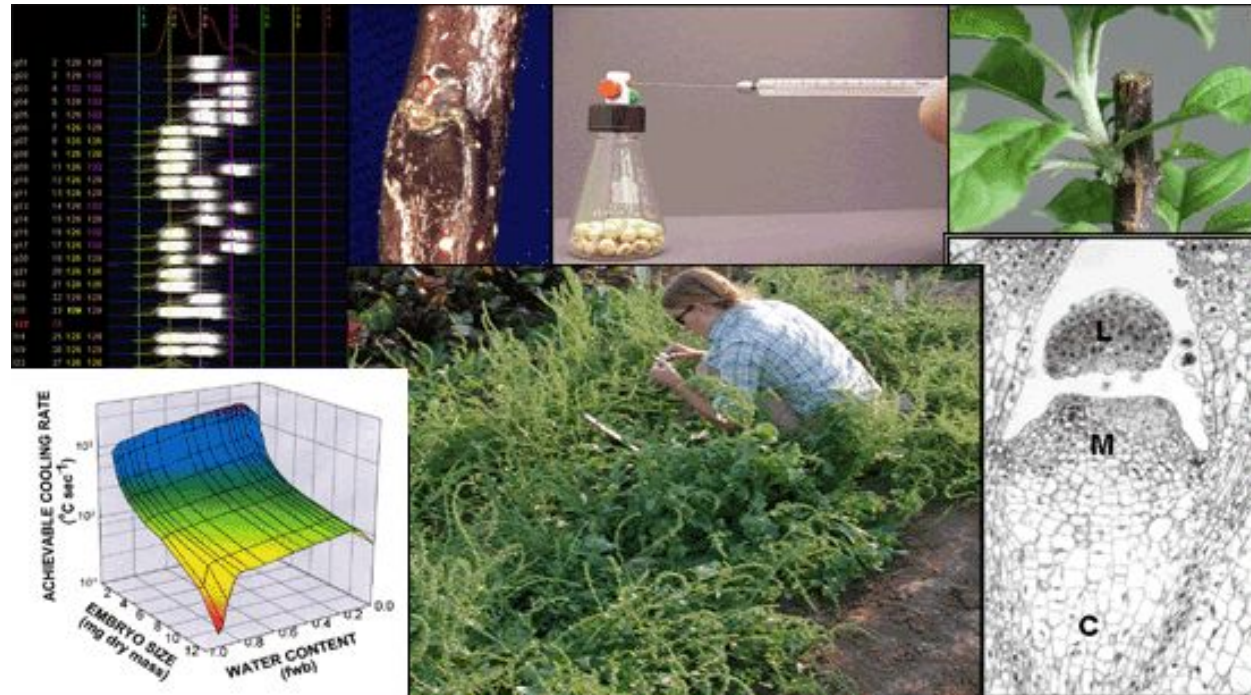
1 микрометр ($\mu\text{м}$) = 10^{-3} мм = 10^{-6} м

1 нанометр (нм) = 10^{-3} $\mu\text{м}$ = 10^{-9} м

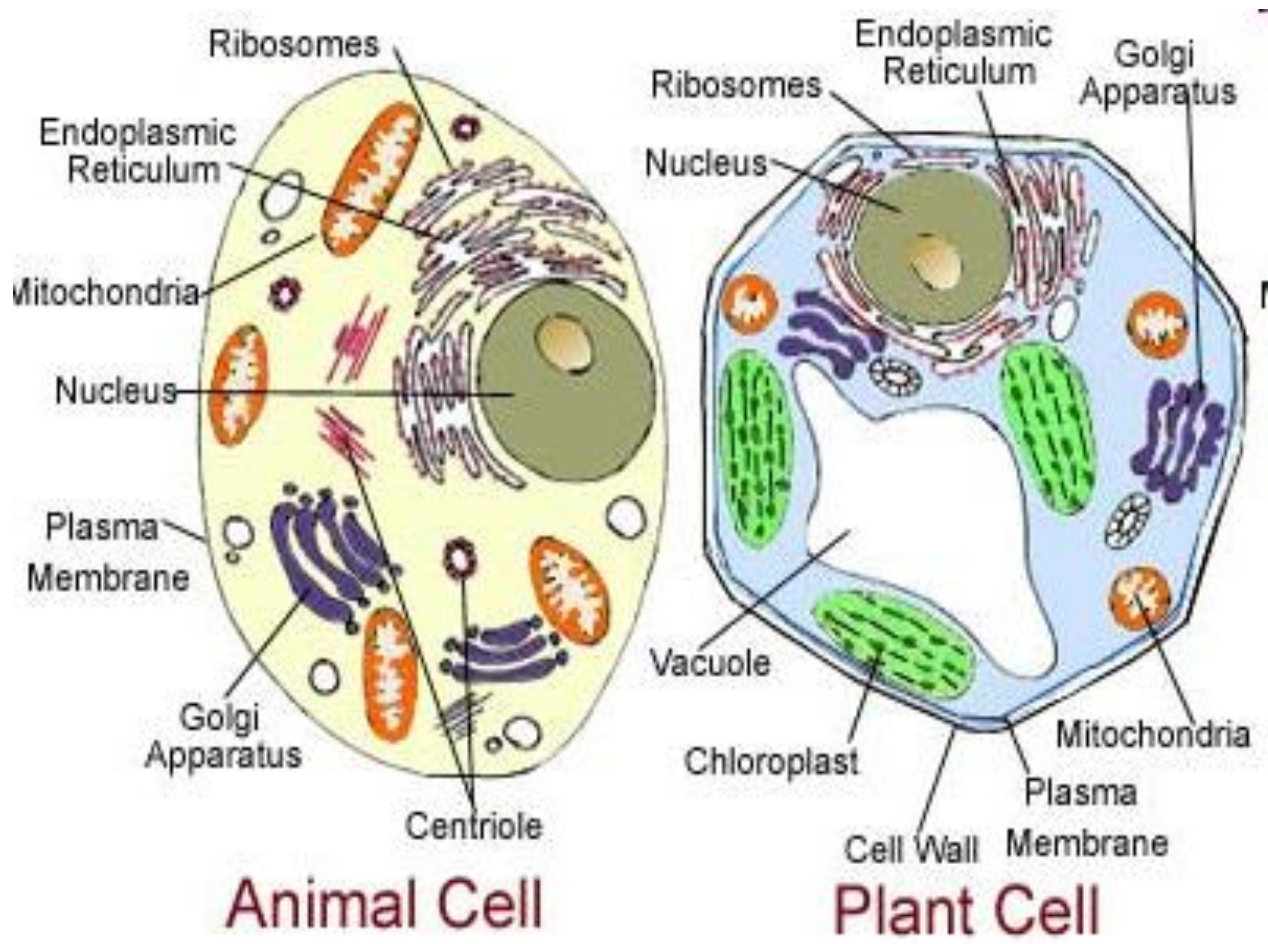


Уровни организации (международная классификация, 2011 год):

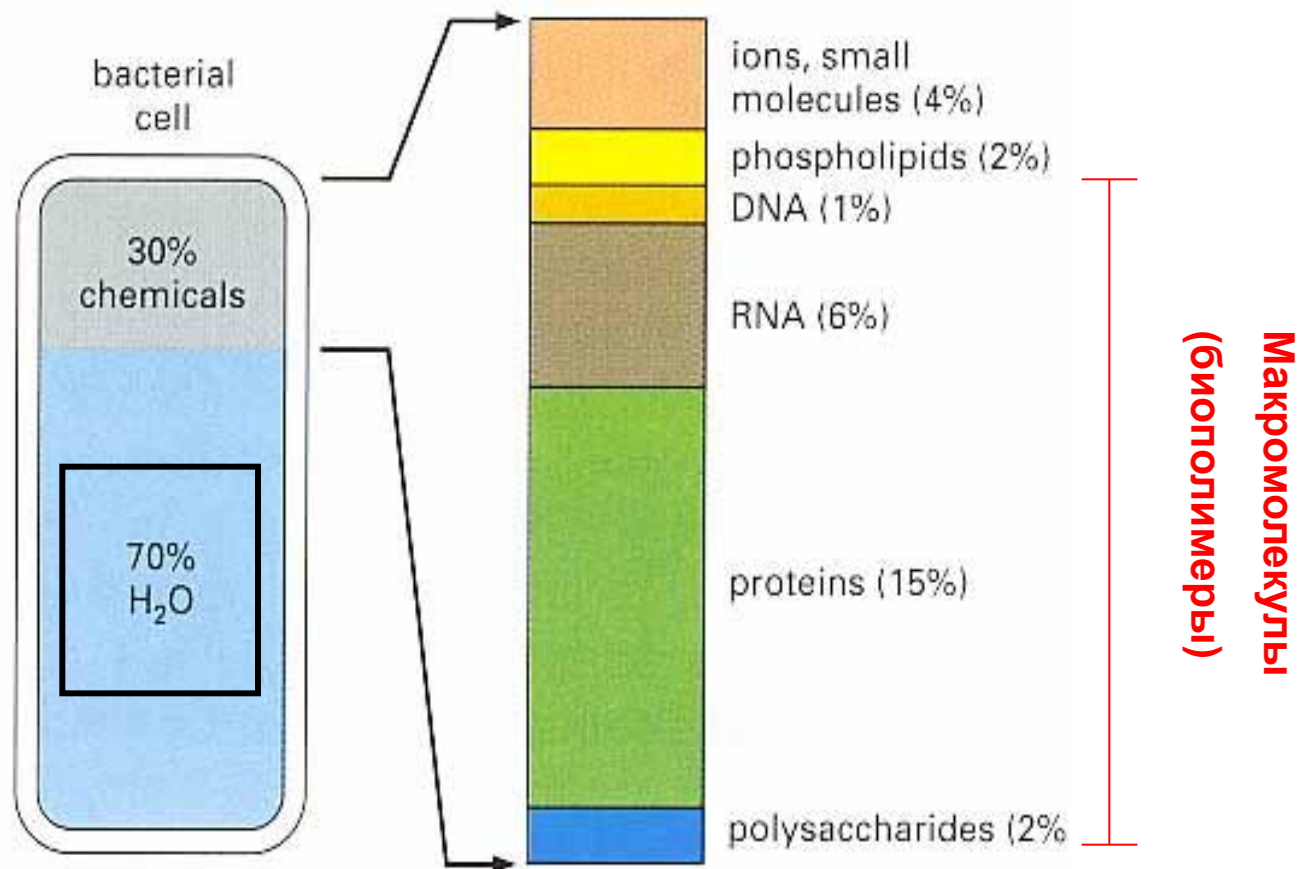
- **Atoms**
- **Molecules**
- **Assemblies**
- **Cells**
- **Tissue**
- **Organ**
- **Organ system**
- **Organism**
- **Population**

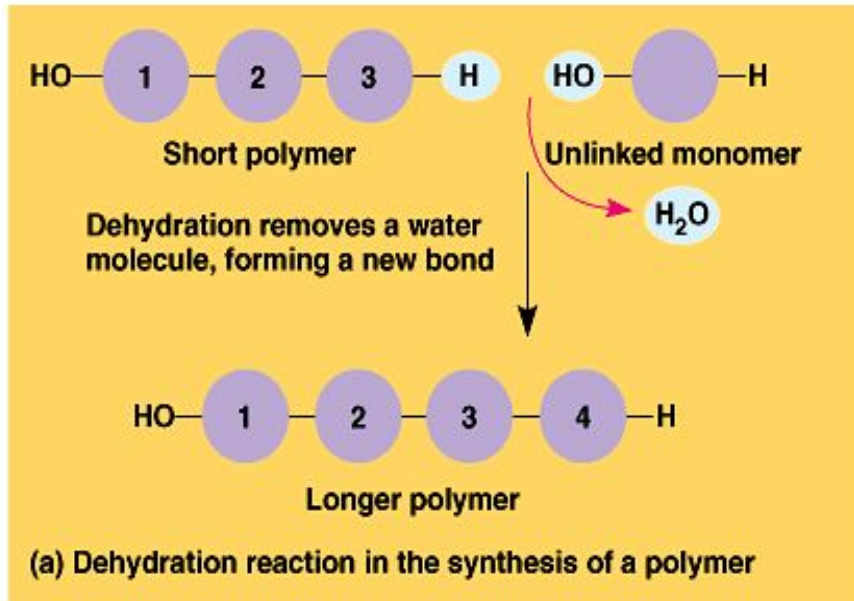


**Растительные клетки (большая часть биомассы на планете)
пища, топливо, материалы, витамины и т.д.**



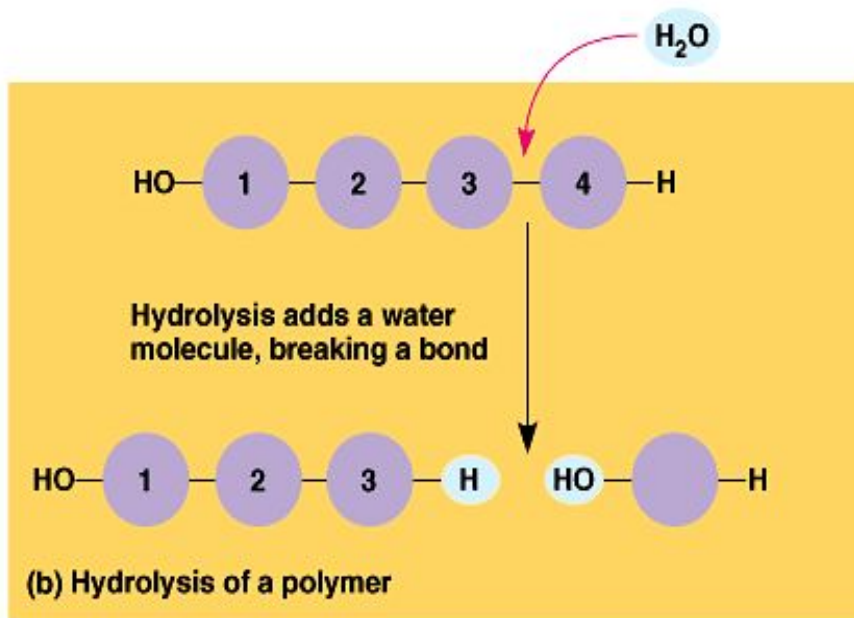
Химический состав типичной клетки





Общий принцип образования и распада биополимеров

СИНТЕЗ.....



распад.....

**Всего 20 аминокислот участвует в образовании белков и других реакциях
(международные названия и классификация):**

AMINO ACID		SIDE CHAIN	
Aspartic acid	Asp	D	negative
Glutamic acid	Glu	E	negative
Arginine	Arg	R	positive
Lysine	Lys	K	positive
Histidine	His	H	positive
Asparagine	Asn	N	uncharged polar
Glutamine	Gln	Q	uncharged polar
Serine	Ser	S	uncharged polar
Threonine	Thr	T	uncharged polar
Tyrosine	Tyr	Y	uncharged polar

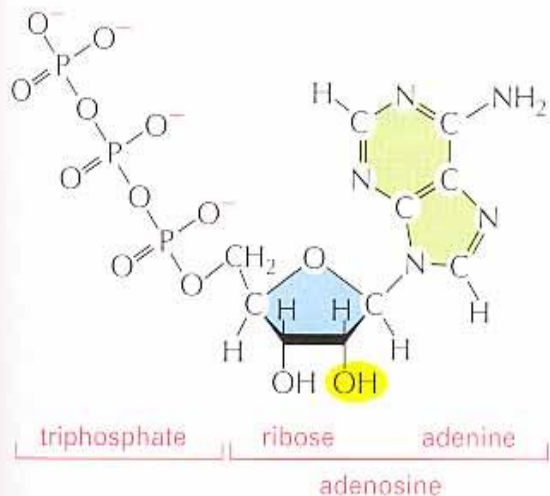
┌────────── POLAR AMINO ACIDS ─────────┐

AMINO ACID		SIDE CHAIN	
Alanine	Ala	A	nonpolar
Glycine	Gly	G	nonpolar
Valine	Val	V	nonpolar
Leucine	Leu	L	nonpolar
Isoleucine	Ile	I	nonpolar
Proline	Pro	P	nonpolar
Phenylalanine	Phe	F	nonpolar
Methionine	Met	M	nonpolar
Tryptophan	Trp	W	nonpolar
Cysteine	Cys	C	nonpolar

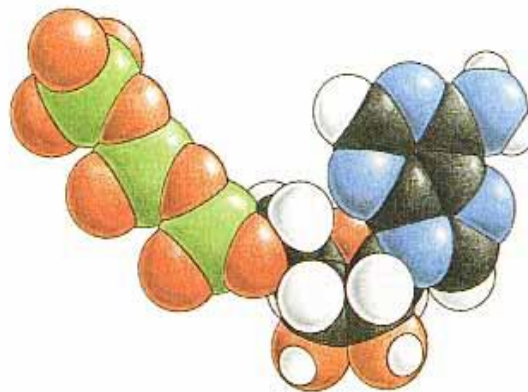
┌────────── NONPOLAR AMINO ACIDS ─────────┐

Figure 4-3 Twenty different amino acids are found in proteins. Both three-letter and one-letter abbreviations are presented. As shown, there are an equal number of polar and nonpolar side chains. For atomic structures, see Panel 2-5 (pp. 74-75).

Аденозинтрифосфат - АТФ



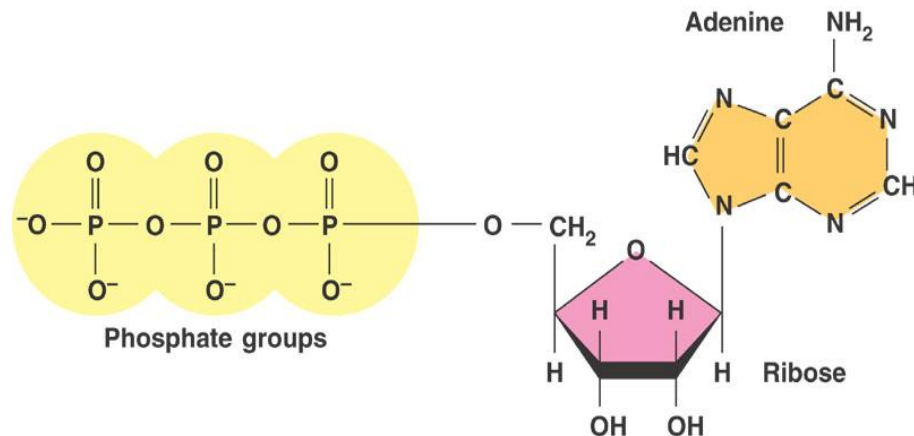
(A)



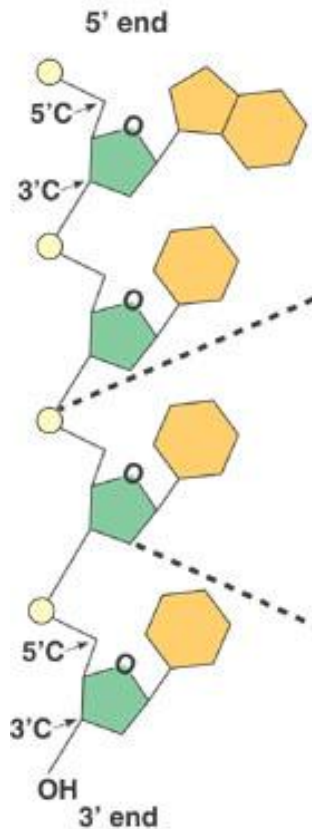
(B)

Figure 2–23 Adenosine triphosphate (ATP) is a nucleotide whose reactivity resides in its terminal phosphate groups. (A) Structural formula. (B) Space-filling model. In (B) the colors of the atoms are C, black; H, white; N, blue; O, red; and P, green. The deoxyribonucleotide version of adenosine triphosphate (dATP) differs only in that a hydrogen atom replaces the hydroxyl group shaded in yellow in (A).

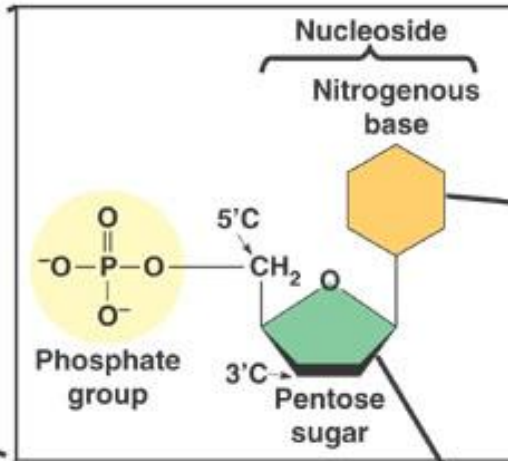
- АТФ – нуклеотид
- предшественник биосинтеза нуклеиновых кислот
- источник энергии
- медиатор, нейротрансмиттер, регулятор



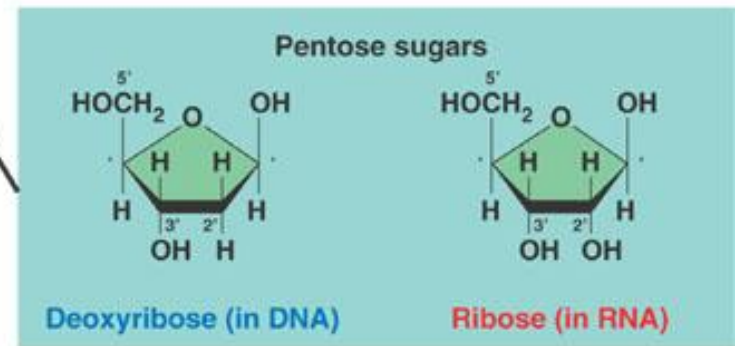
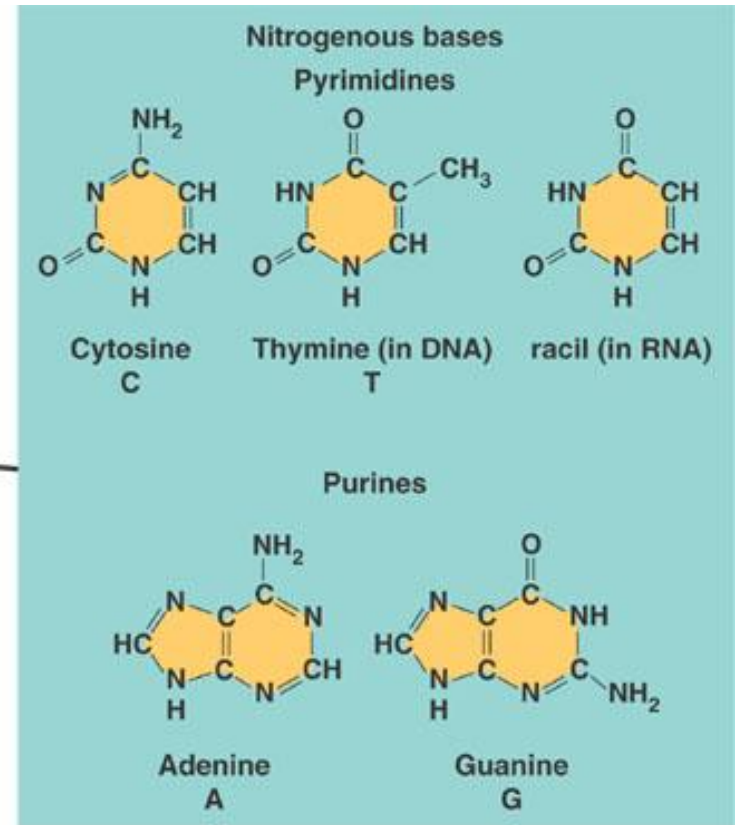
Строение нуклеиновых кислот:



(a) Polynucleotide, or nucleic acid



(b) Nucleotide



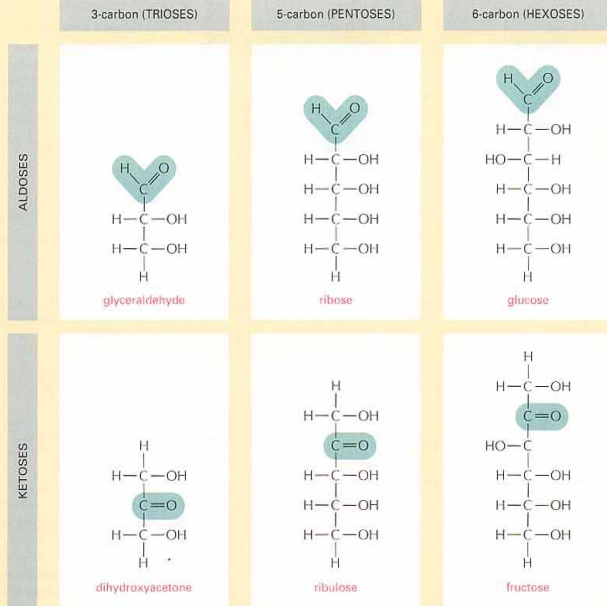
(c) Nucleoside components

Строение липидов:

Panel 2-3 An outline of some of the types of sugars

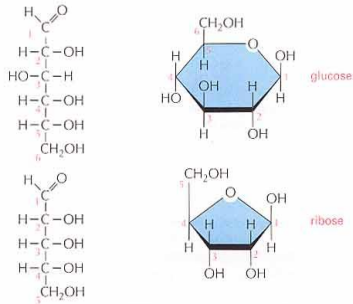
MONOSACCHARIDES

Monosaccharides usually have the general formula $(CH_2O)_n$, where n can be 3, 4, 5, or 6, and have two or more hydroxyl groups. They either contain an aldehyde group ($-C=O$) and are called aldoses or a ketone group ($>C=O$) and are called ketoses.



RING FORMATION

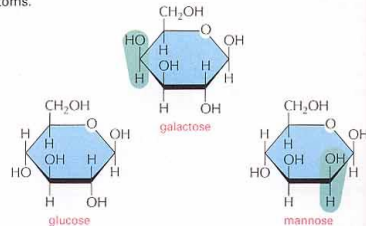
In aqueous solution, the aldehyde or ketone group of a sugar molecule tends to react with a hydroxyl group of the same molecule, thereby closing the molecule into a ring.



Note that each carbon atom has a number.

ISOMERS

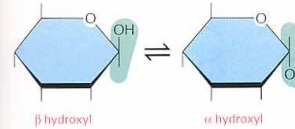
Many monosaccharides differ only in the spatial arrangement of atoms—that is, they are **isomers**. For example, glucose, galactose, and mannose have the same formula ($C_6H_{12}O_6$) but differ in the arrangement of groups around one or two carbon atoms.



These small differences make only minor changes in the chemical properties of the sugars. But they are recognized by enzymes and other proteins and therefore can have important biological effects.

α AND β LINKS

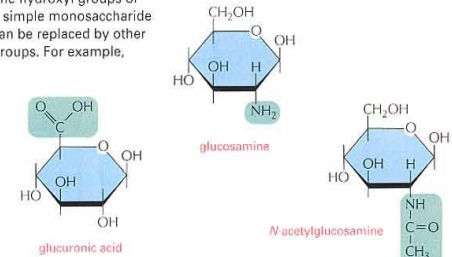
The hydroxyl group on the carbon that carries the aldehyde or ketone can rapidly change from one position to the other. These two positions are called α and β .



As soon as one sugar is linked to another, the α or β form is frozen.

SUGAR DERIVATIVES

The hydroxyl groups of a simple monosaccharide can be replaced by other groups. For example,

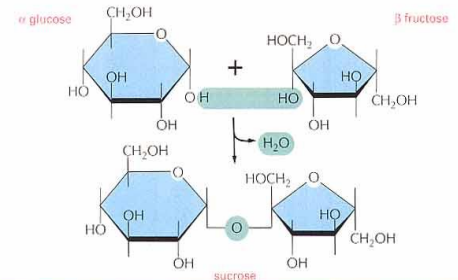


DISACCHARIDES

The carbon that carries the aldehyde or the ketone can react with any hydroxyl group on a second sugar molecule to form a **disaccharide**. Three common disaccharides are

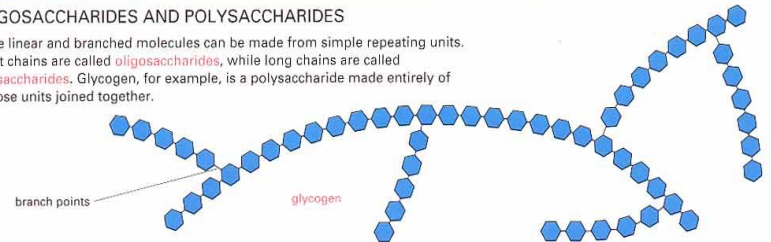
- maltose (glucose + glucose)
- lactose (galactose + glucose)
- sucrose (glucose + fructose)

The reaction forming sucrose is shown here.



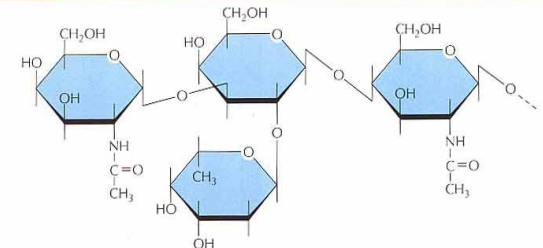
OLIGOSACCHARIDES AND POLYSACCHARIDES

Large linear and branched molecules can be made from simple repeating units. Short chains are called **oligosaccharides**, while long chains are called **polysaccharides**. Glycogen, for example, is a polysaccharide made entirely of glucose units joined together.



COMPLEX OLIGOSACCHARIDES

In many cases a sugar sequence is nonrepetitive. Many different molecules are possible. Such complex oligosaccharides are usually linked to proteins or to lipids, as is this oligosaccharide, which is part of a cell-surface molecule that defines a particular blood group.



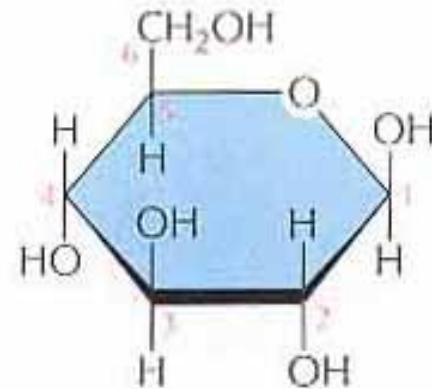
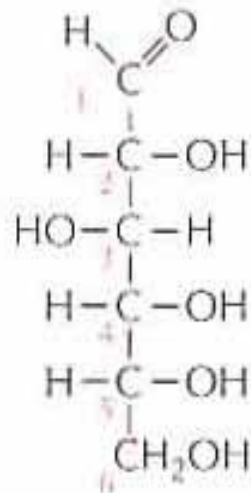
MONOSACCHARIDES

Monosaccharides usually have the general formula $(\text{CH}_2\text{O})_n$, where n can be 3, 4, 5, or 6, and have two or more hydroxyl groups. They either contain an aldehyde group ($-\text{C} \begin{smallmatrix} \text{O} \\ // \\ \text{H} \end{smallmatrix}$) and are called aldoses or a ketone group ($>\text{C}=\text{O}$) and are called ketoses.

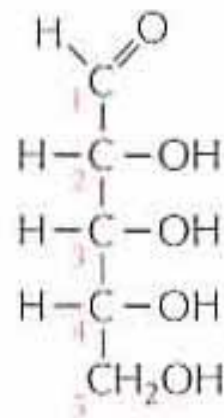
	3-carbon (TRIOSES)	5-carbon (PENTOSES)	6-carbon (HEXOSES)
ALDOSES	<p>glyceraldehyde</p>	<p>ribose</p>	<p>glucose</p>
KETOSES	<p>dihydroxyacetone</p>	<p>ribulose</p>	<p>fructose</p>

RING FORMATION

In aqueous solution, the aldehyde or ketone group of a sugar molecule tends to react with a hydroxyl group of the same molecule, thereby closing the molecule into a ring.



glucose

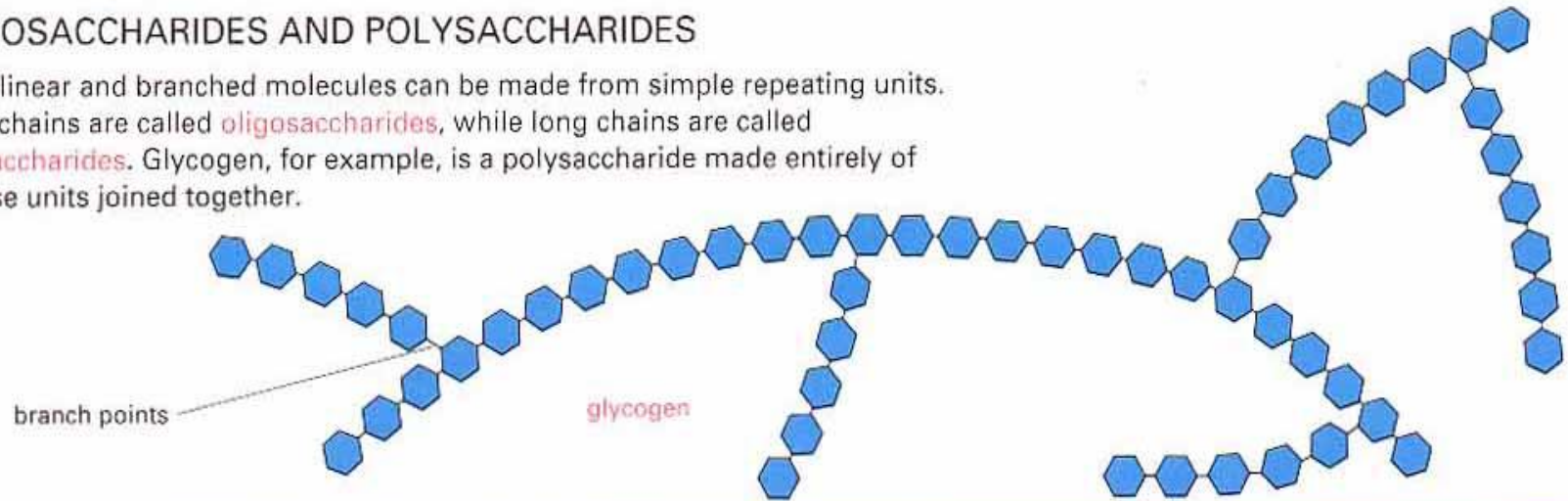


ribose

Note that each carbon atom has a number.

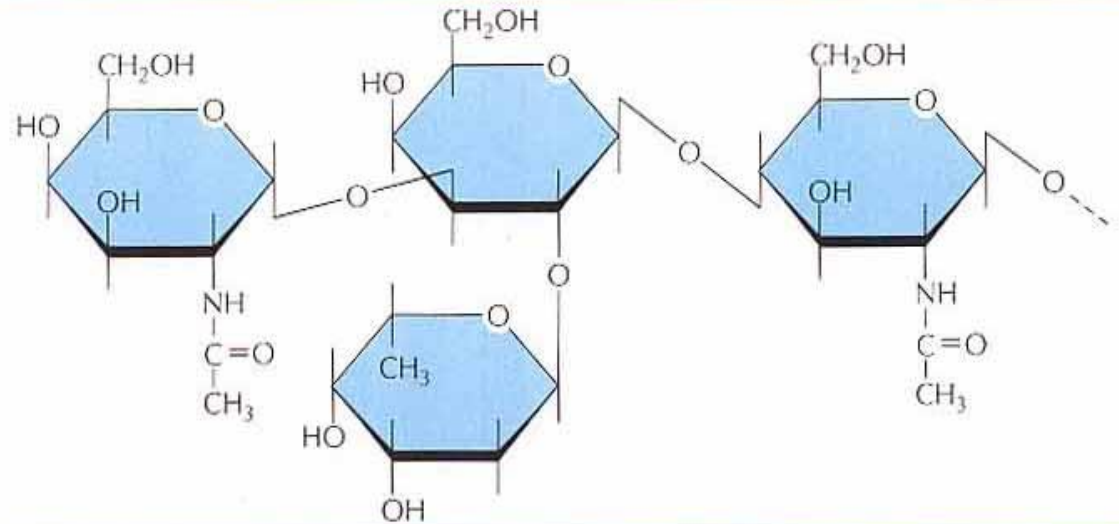
OLIGOSACCHARIDES AND POLYSACCHARIDES

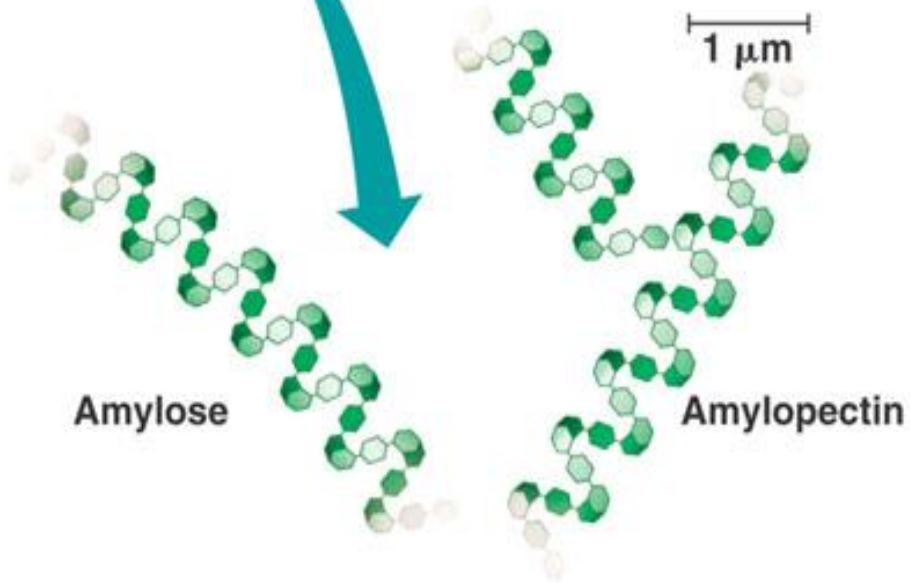
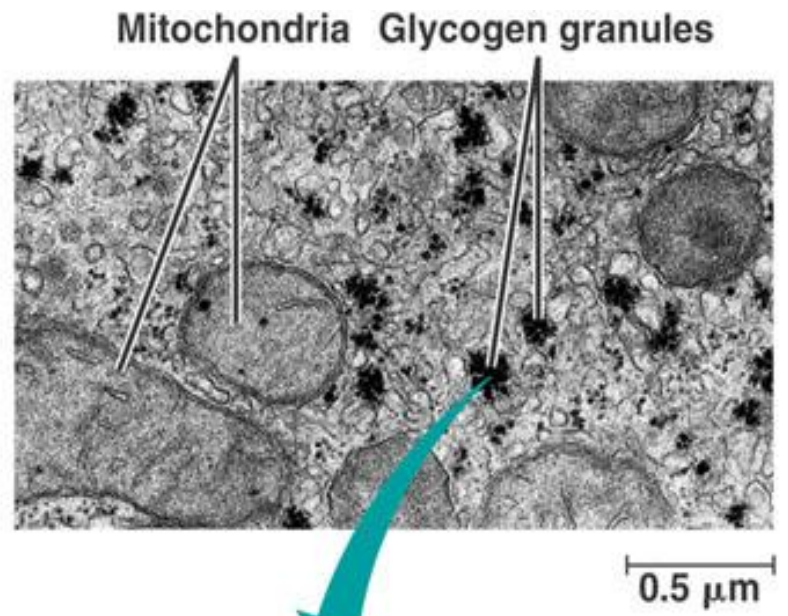
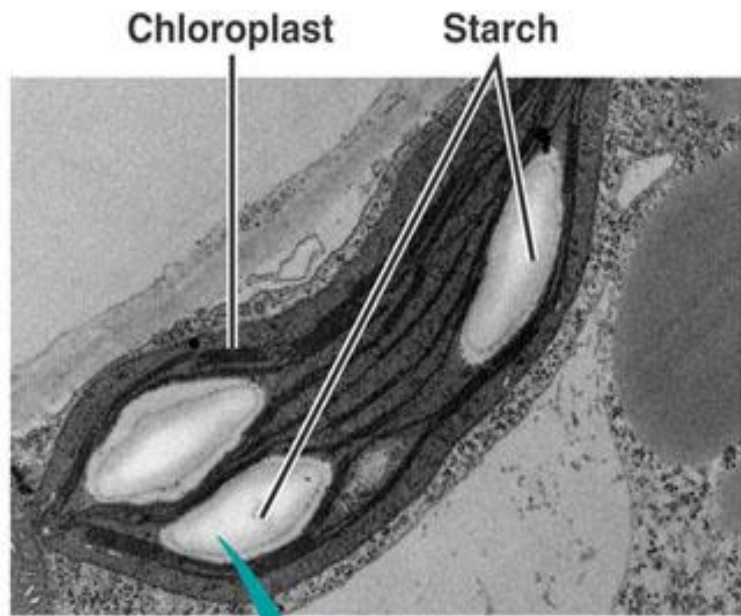
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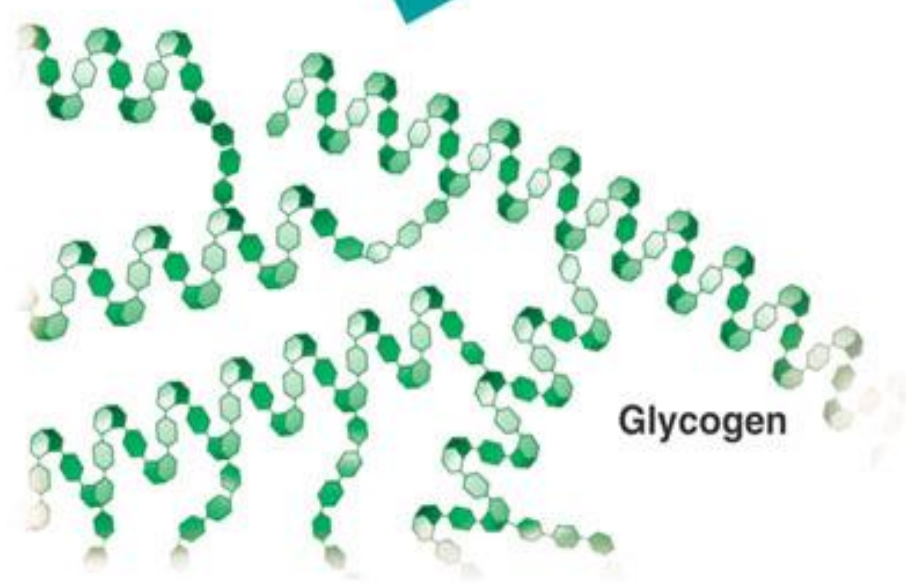
COMPLEX OLIGOSACCHARIDES

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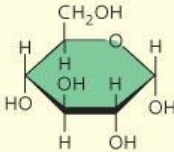
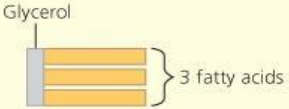

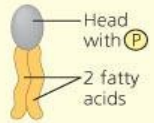
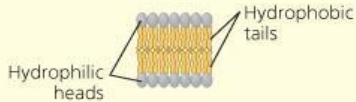
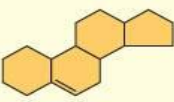
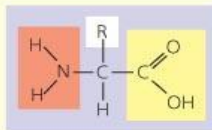
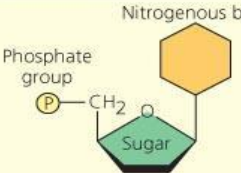




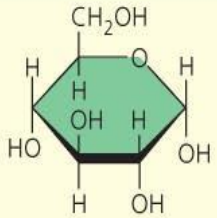
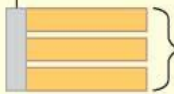

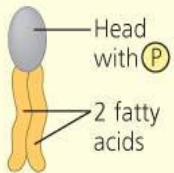
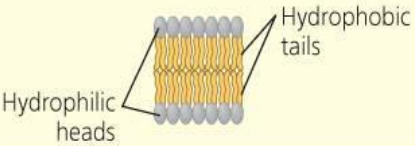
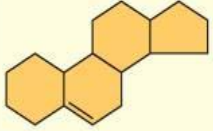


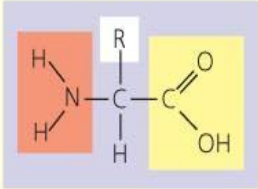
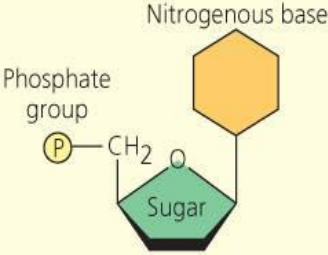


(a) Starch: a plant polysaccharide



(b) Glycogen: an animal polysaccharide

Large Biological Molecules	Components	Examples	Functions	
Concept 5.2 Carbohydrates serve as fuel and building material	 <p>Monosaccharide monomer</p>	Monosaccharides: glucose, fructose Disaccharides: lactose, sucrose Polysaccharides: <ul style="list-style-type: none"> • Cellulose (plants) • Starch (plants) • Glycogen (animals) • Chitin (animals and fungi) 	Fuel; carbon sources that can be converted to other molecules or combined into polymers <ul style="list-style-type: none"> • Strengthens plant cell walls • Stores glucose for energy • Stores glucose for energy • Strengthens exoskeletons and fungal cell walls 	
	Concept 5.3 Lipids are a diverse group of hydrophobic molecules and are not macromolecules	Glycerol  <p>3 fatty acids</p>	Triacylglycerols (fats or oils): glycerol + 3 fatty acids	Important energy source 
	 <p>Head with P 2 fatty acids</p>	Phospholipids: phosphate group + 2 fatty acids	Lipid bilayers of membranes  <p>Hydrophilic heads Hydrophobic tails</p>	
 <p>Steroid backbone</p>	Steroids: four fused rings with attached chemical groups	<ul style="list-style-type: none"> • Component of cell membranes (cholesterol) • Signals that travel through the body (hormones) 		
Concept 5.4 Proteins have many structures, resulting in a wide range of functions	 <p>Amino acid monomer (20 types)</p>	<ul style="list-style-type: none"> • Enzymes • Structural proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Defensive proteins 	<ul style="list-style-type: none"> • Catalyze chemical reactions • Provide structural support • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Protect against disease 	
Concept 5.5 Nucleic acids store and transmit hereditary information	 <p>Nitrogenous base Phosphate group Sugar</p> <p>Nucleotide monomer</p>	DNA:  <ul style="list-style-type: none"> • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded RNA:  <ul style="list-style-type: none"> • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded 	Stores all hereditary information Carries protein-coding instructions from DNA to protein-synthesizing machinery	

Large Biological Molecules	Components	Examples	Functions	
<p>Concept 5.2 Carbohydrates serve as fuel and building material</p>	 <p>Monosaccharide monomer</p>	<p>Monosaccharides: glucose, fructose</p> <p>Disaccharides: lactose, sucrose</p> <p>Polysaccharides:</p> <ul style="list-style-type: none"> • Cellulose (plants) • Starch (plants) • Glycogen (animals) • Chitin (animals and fungi) 	<p>Fuel; carbon sources that can be converted to other molecules or combined into polymers</p>	
	<p>Concept 5.3 Lipids are a diverse group of hydrophobic molecules and are not macromolecules</p>	<p>Glycerol</p>  <p>3 fatty acids</p>	<p>Triacylglycerols (fats or oils): glycerol + 3 fatty acids</p>	<p>Important energy source</p> 
		 <p>Head with (P)</p> <p>2 fatty acids</p>	<p>Phospholipids: phosphate group + 2 fatty acids</p>	<p>Lipid bilayers of membranes</p>  <p>Hydrophilic heads</p> <p>Hydrophobic tails</p>
 <p>Steroid backbone</p>		<p>Steroids: four fused rings with attached chemical groups</p>	<ul style="list-style-type: none"> • Component of cell membranes (cholesterol) • Signals that travel through the body (hormones) 	

Large Biological Molecules	Components	Examples	Functions
<p>Concept 5.4 Proteins have many structures, resulting in a wide range of functions</p>	 <p>Amino acid monomer (20 types)</p>	<ul style="list-style-type: none"> • Enzymes • Structural proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Defensive proteins 	<ul style="list-style-type: none"> • Catalyze chemical reactions • Provide structural support • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Protect against disease
<p>Concept 5.5 Nucleic acids store and transmit hereditary information</p>	 <p>Nucleotide monomer</p>	<p>DNA: </p> <ul style="list-style-type: none"> • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded <p>RNA: </p> <ul style="list-style-type: none"> • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded 	<p>Stores all hereditary information</p> <p>Carries protein-coding instructions from DNA to protein-synthesizing machinery</p>

- Разнообразие комбинаций трех полимеров определяет разнообразие живого на планете. Растения, животные и грибы имеют одинаковые «мономеры» и принципы их соединения в макромолекулы, но благодаря отличиям в молекулярной структуре и организации, они могут сильно отличаться на клеточной и организменном уровне.

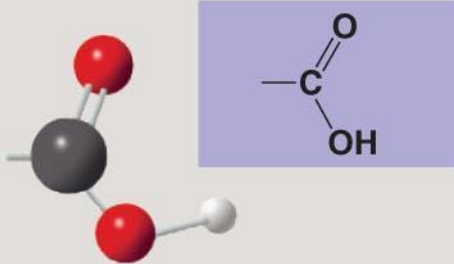


Семь функциональных групп, которые наиболее важны в биохимических процессах:

- Гидроксильная**
- Карбонильная**
- Карбоксильная**
- Амино**
- Сульфгидрильная**
- Фосфатная**
- Метильная**

Carboxyl

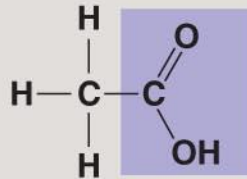
STRUCTURE



Carboxylic acids, or organic acids

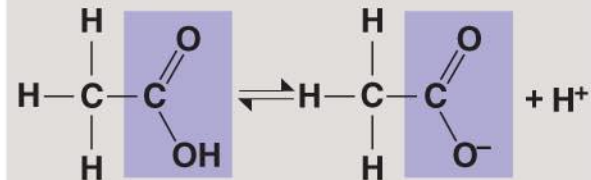
**NAME OF
COMPOUND**

EXAMPLE



Acetic acid, which gives vinegar its sour taste

- Has acidic properties because the covalent bond between oxygen and hydrogen is so polar; for example,



Acetic acid

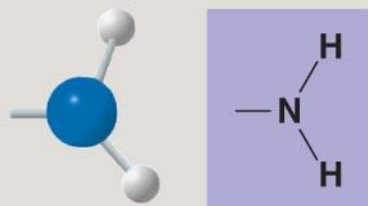
Acetate ion

- Found in cells in the ionized form with a charge of 1- and called a carboxylate ion (here, specifically, the acetate ion).

**FUNCTIONAL
PROPERTIES**

Amino

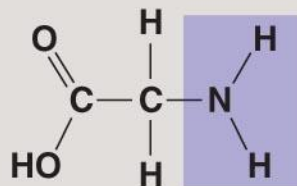
STRUCTURE



Amines

NAME OF
COMPOUND

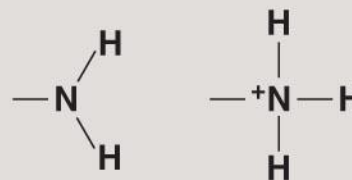
EXAMPLE



Glycine

Because it also has a carboxyl group, glycine is both an amine and a carboxylic acid; compounds with both groups are called amino acids.

- Acts as a base; can pick up an H^+ from the surrounding solution (water, in living organisms).



(nonionized)

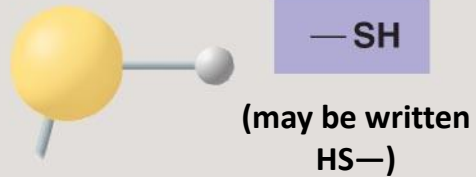
(ionized)

- Ionized, with a charge of $1+$, under cellular conditions.

FUNCTIONAL
PROPERTIES

Sulfhydryl

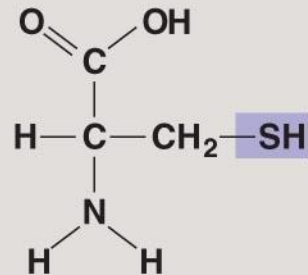
STRUCTURE



Thiols

**NAME OF
COMPOUND**

EXAMPLE



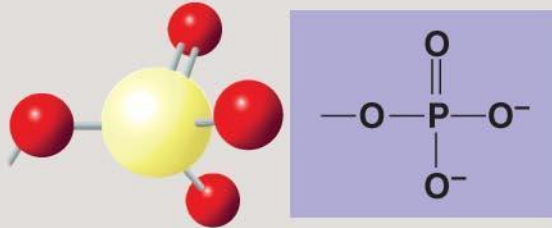
Cysteine

Cysteine is an important sulfur-containing amino acid.

- FUNCTIONAL PROPERTIES**
- Two sulfhydryl groups can react, forming a covalent bond. This “cross-linking” helps stabilize protein structure.
 - Cross-linking of cysteines in hair proteins maintains the curliness or straightness of hair. Straight hair can be “permanently” curled by shaping it around curlers, then breaking and re-forming the cross-linking bonds.

Phosphate

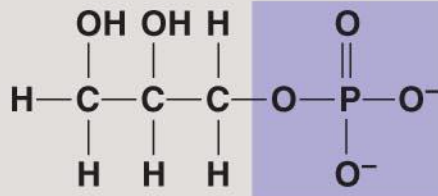
STRUCTURE



Organic phosphates

NAME OF COMPOUND

EXAMPLE



Glycerol phosphate

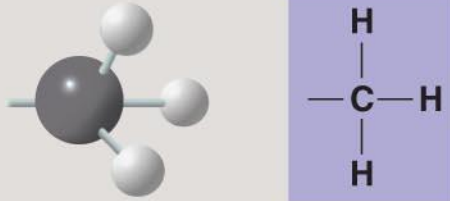
In addition to taking part in many important chemical reactions in cells, glycerol phosphate provides the backbone for phospholipids, the most prevalent molecules in cell membranes.

- **Contributes negative charge to the molecule of which it is a part (2- when at the end of a molecule; 1- when located internally in a chain of phosphates).**
- **Has the potential to react with water, releasing energy.**

FUNCTIONAL PROPERTIES

Methyl

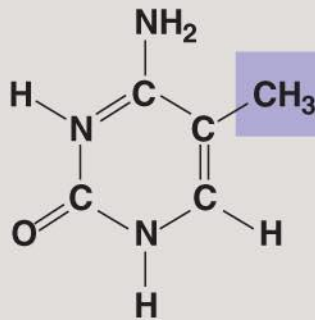
STRUCTURE



Methylated compounds

NAME OF
COMPOUND

EXAMPLE



5-Methyl cytidine

5-Methyl cytidine is a component of DNA that has been modified by addition of the methyl group.

- Addition of a methyl group to DNA, or to molecules bound to DNA, affects expression of genes.
- Arrangement of methyl groups in male and female sex hormones affects their shape and function.

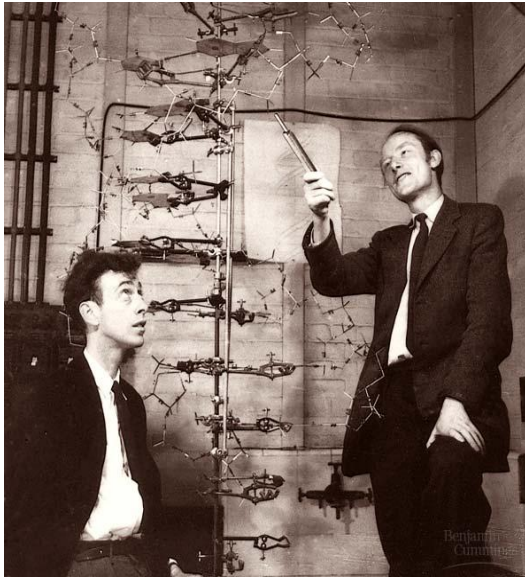
FUNCTIONAL
PROPERTIES

DNA: Franklin, Crick & Watson

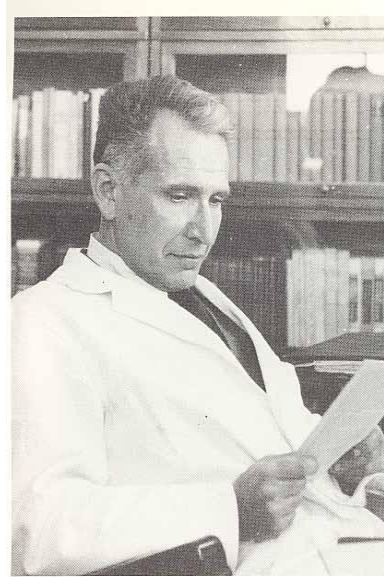
1953



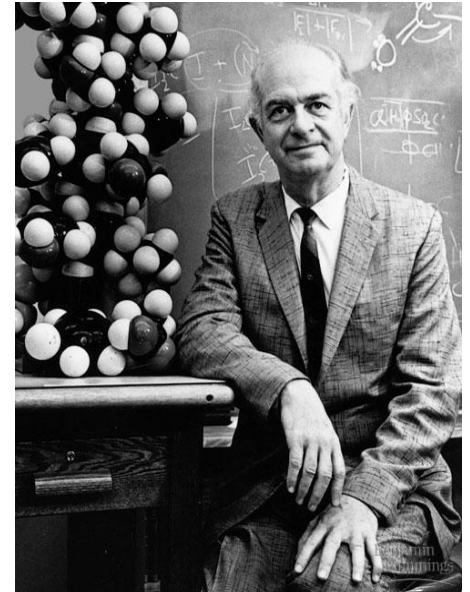
Ученые, которые участвовали в открытии структуры ДНК



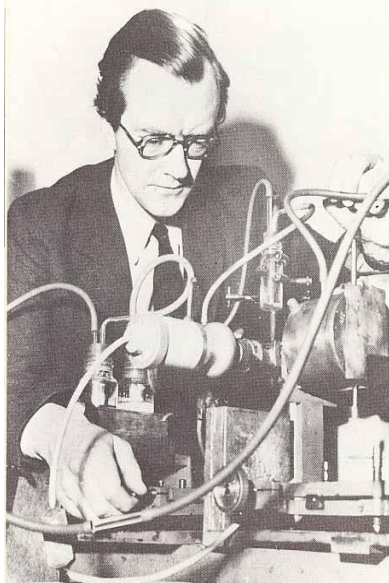
James Watson and Francis Crick, UK



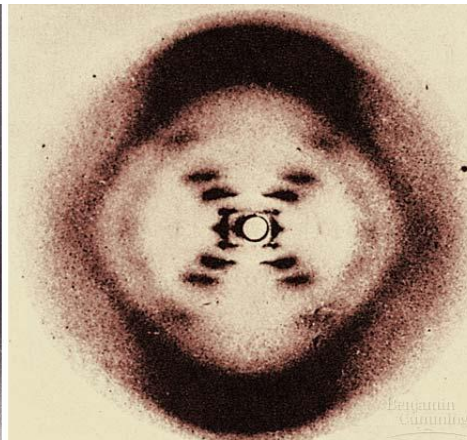
Erwin Chargaff, Ukraine



Linus Pauling, USA



Maurice Wilkins, NZ

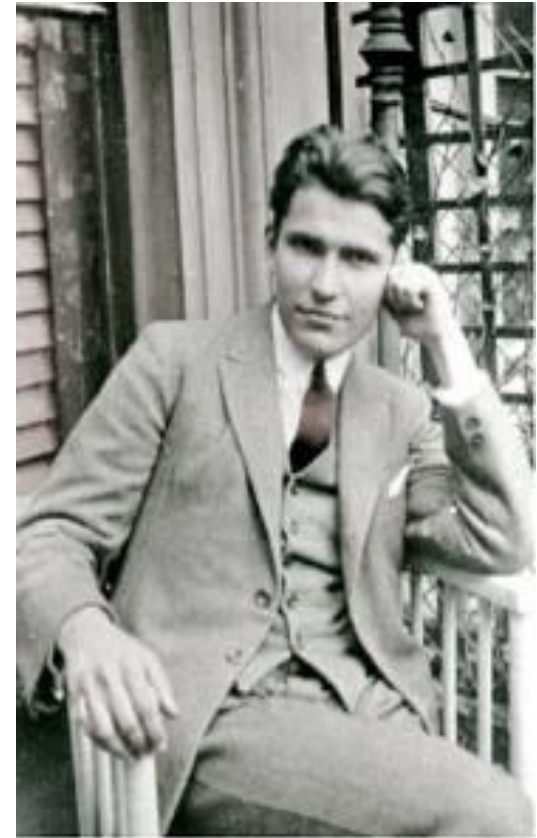


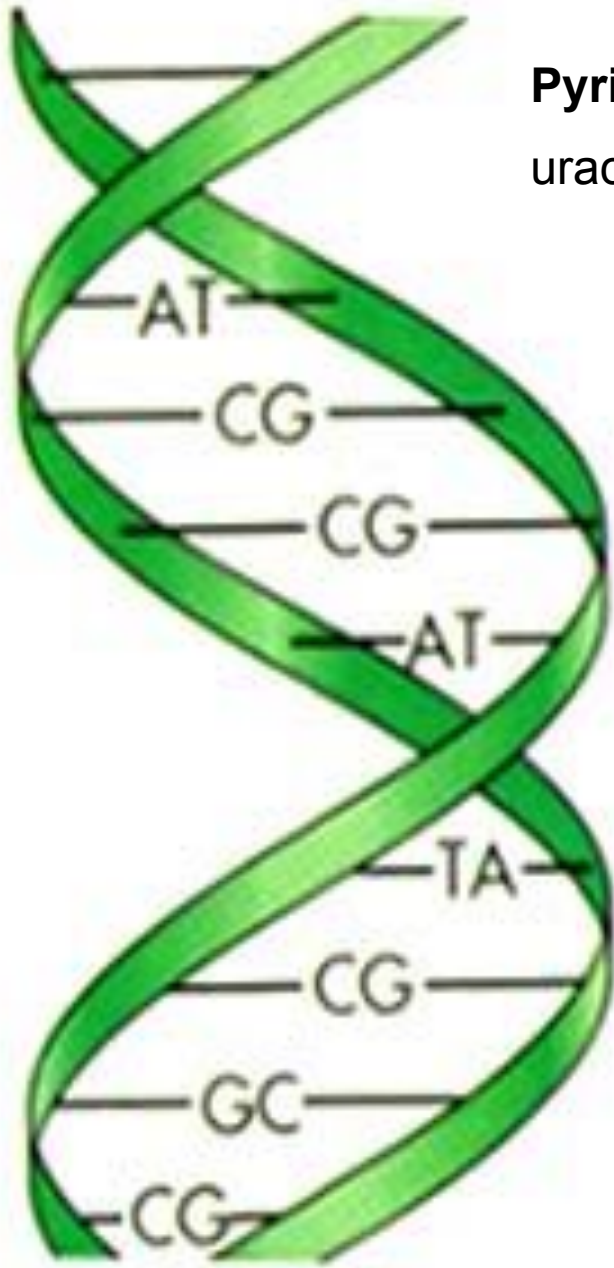
Rosalind Franklin, UK

Первое правило Чаргафа:

В природной ДНК количество единиц гуанина равно количеству единиц цитозина, тогда как количество единиц аденина равно количеству единиц тимина.

**В типичной ДНК эукариот (пример: ДНК человека):
A=30.9%, T=29.4%;
Г=19.9% Ц=19.8%.**





Pyrimidines:

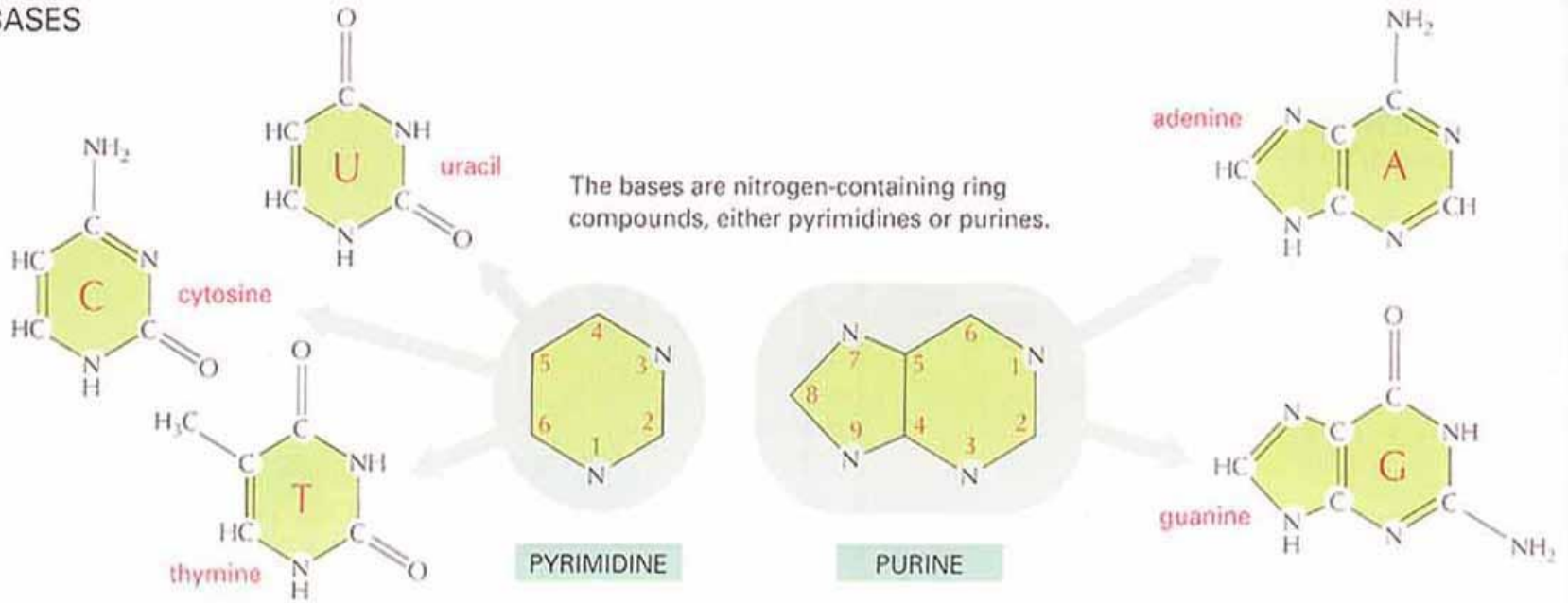
uracil, cytosine, thiamine

Purines :

Adenine, guanosine



BASES



Структура оснований в ДНК и РНК:

пиримидины:

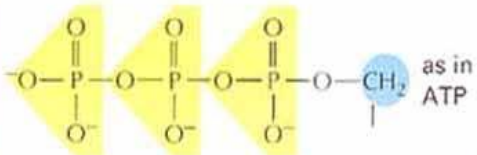
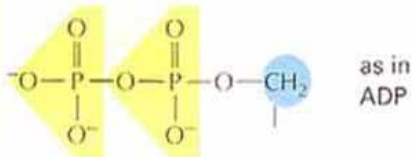
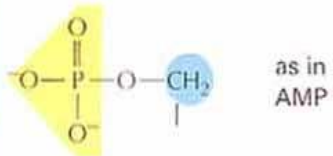
урацил, цитозин, тиамин

пурины:

аденин, гуанозин

PHOSPHATES

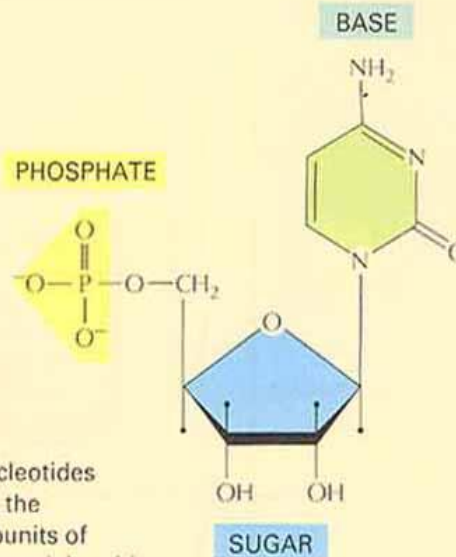
The phosphates are normally joined to the C5 hydroxyl of the ribose or deoxyribose sugar (designated 5'). Mono-, di-, and triphosphates are common.



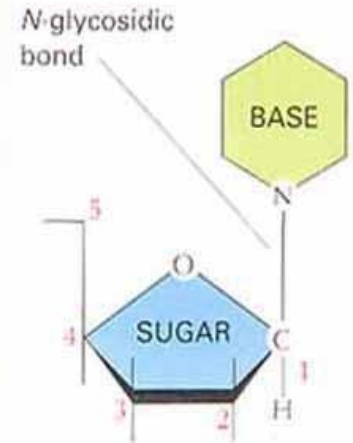
The phosphate makes a nucleotide negatively charged.

NUCLEOTIDES

A nucleotide consists of a nitrogen-containing base, a five-carbon sugar, and one or more phosphate groups.



BASIC SUGAR LINKAGE



The base is linked to the same carbon (C1) used in sugar-sugar bonds.

Nucleotide

нуклеотид

Nucleoside

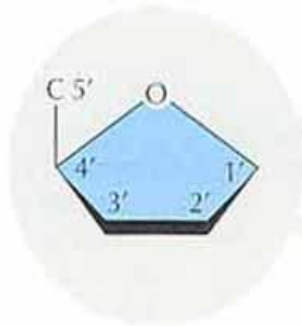
нуклеозид

Разница в сахаре в нуклеиновых кислотах:

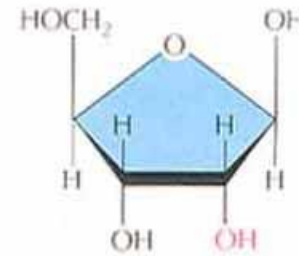
SUGARS

PENTOSE

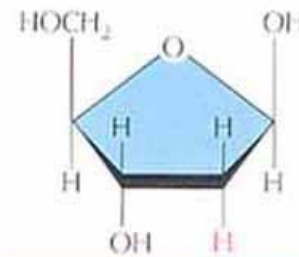
a five-carbon sugar



two kinds are used



β -D-ribose
used in ribonucleic acid



β -D-2-deoxyribose
used in deoxyribonucleic acid

Each numbered carbon on the sugar of a nucleotide is followed by a prime mark; therefore, one speaks of the "5-prime carbon," etc.

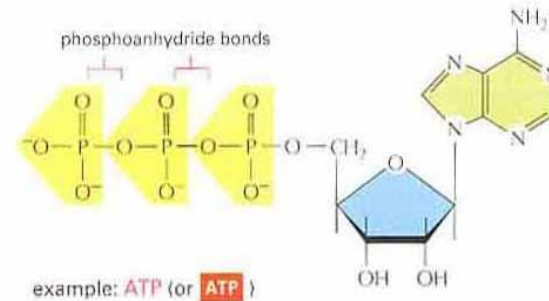
Другие функции

нуклеотидов

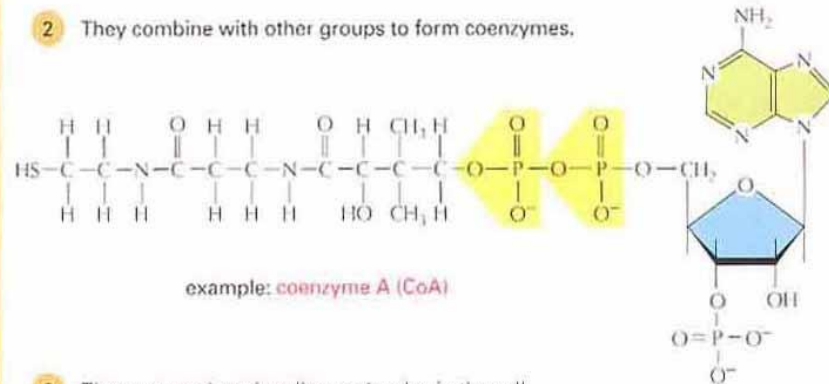
(помимо генетической):

NUCLEOTIDES HAVE MANY OTHER FUNCTIONS

- 1 They carry chemical energy in their easily hydrolyzed phosphoanhydride bonds.

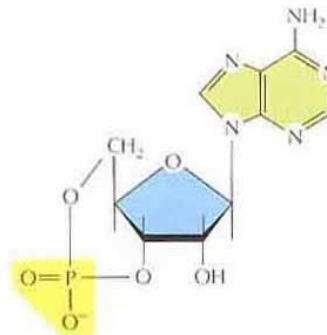


- 2 They combine with other groups to form coenzymes.



- 3 They are used as signaling molecules in the cell.

example: cyclic AMP



Study this carefully to memorize general structure and nomenclature.

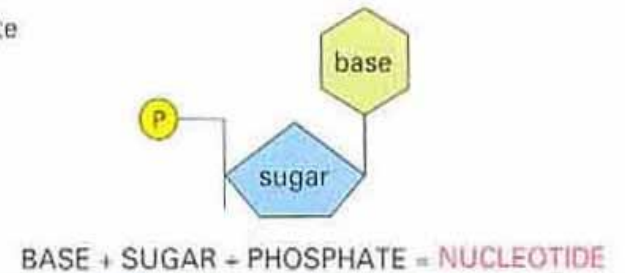
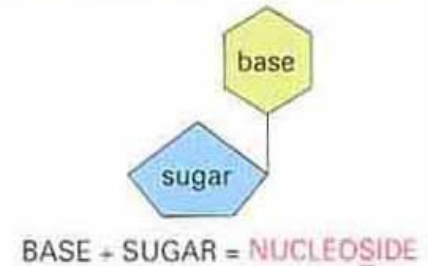
NOMENCLATURE

The names can be confusing, but the abbreviations are clear.

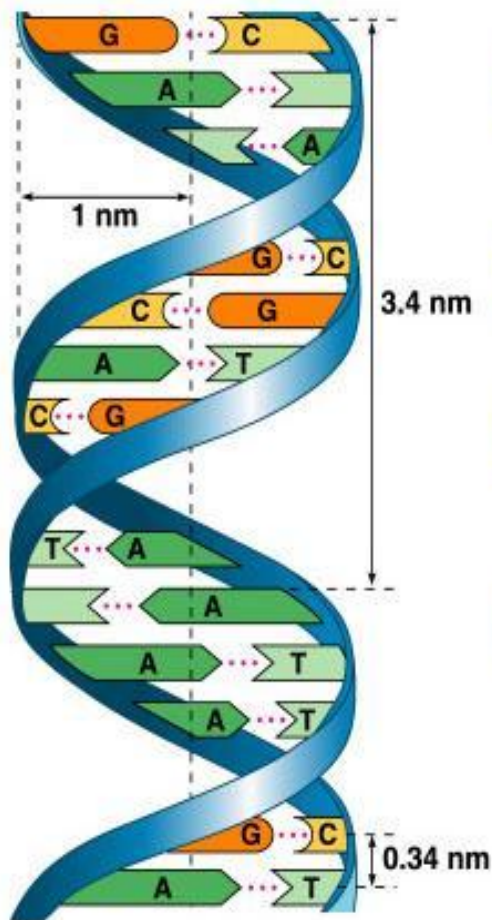
BASE	NUCLEOSIDE	ABBR.
adenine	adenosine	A
guanine	guanosine	G
cytosine	cytidine	C
uracil	uridine	U
thymine	thymidine	T

Nucleotides are abbreviated by three capital letters. Some examples follow:

AMP = adenosine monophosphate
dAMP = deoxyadenosine monophosphate
UDP = uridine diphosphate
ATP = adenosine triphosphate

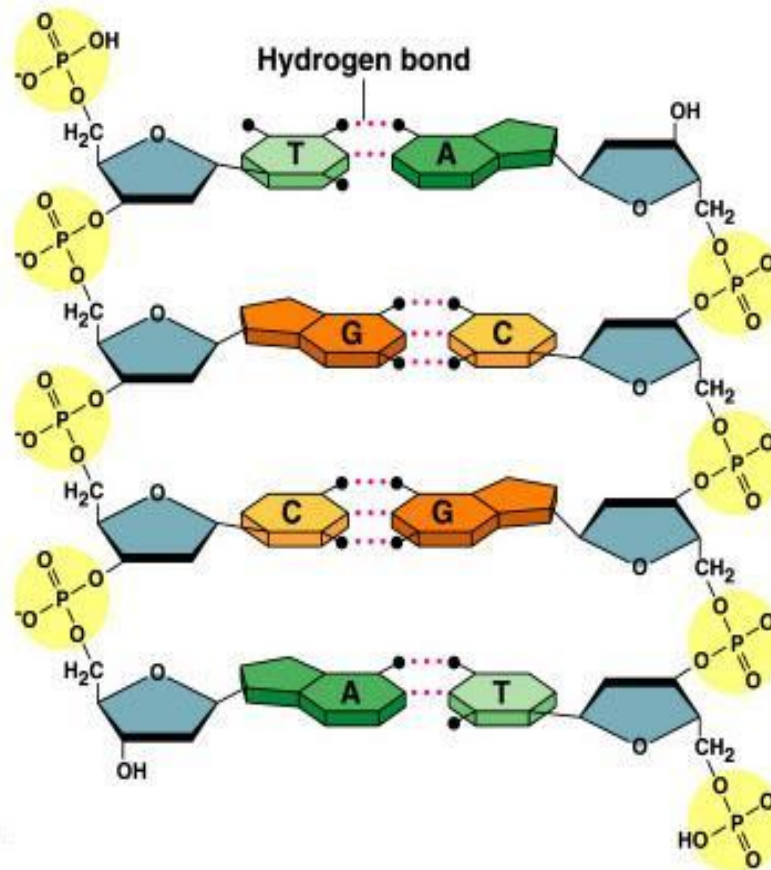


Размеры спирали:



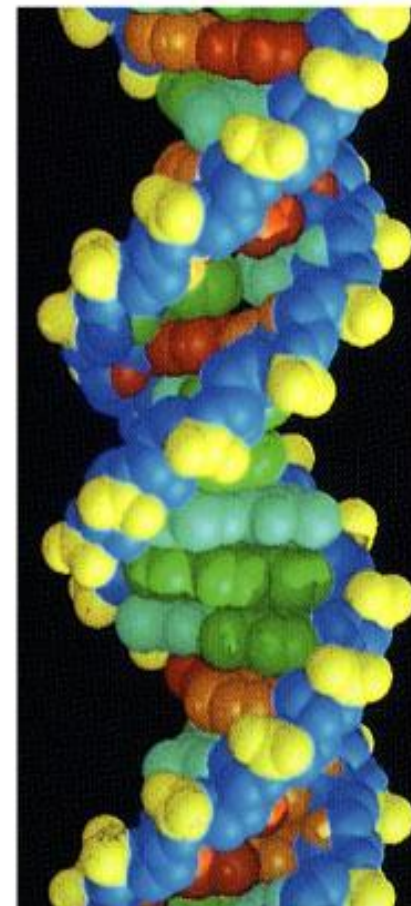
(a) Key features of DNA structure

Водородные связи:

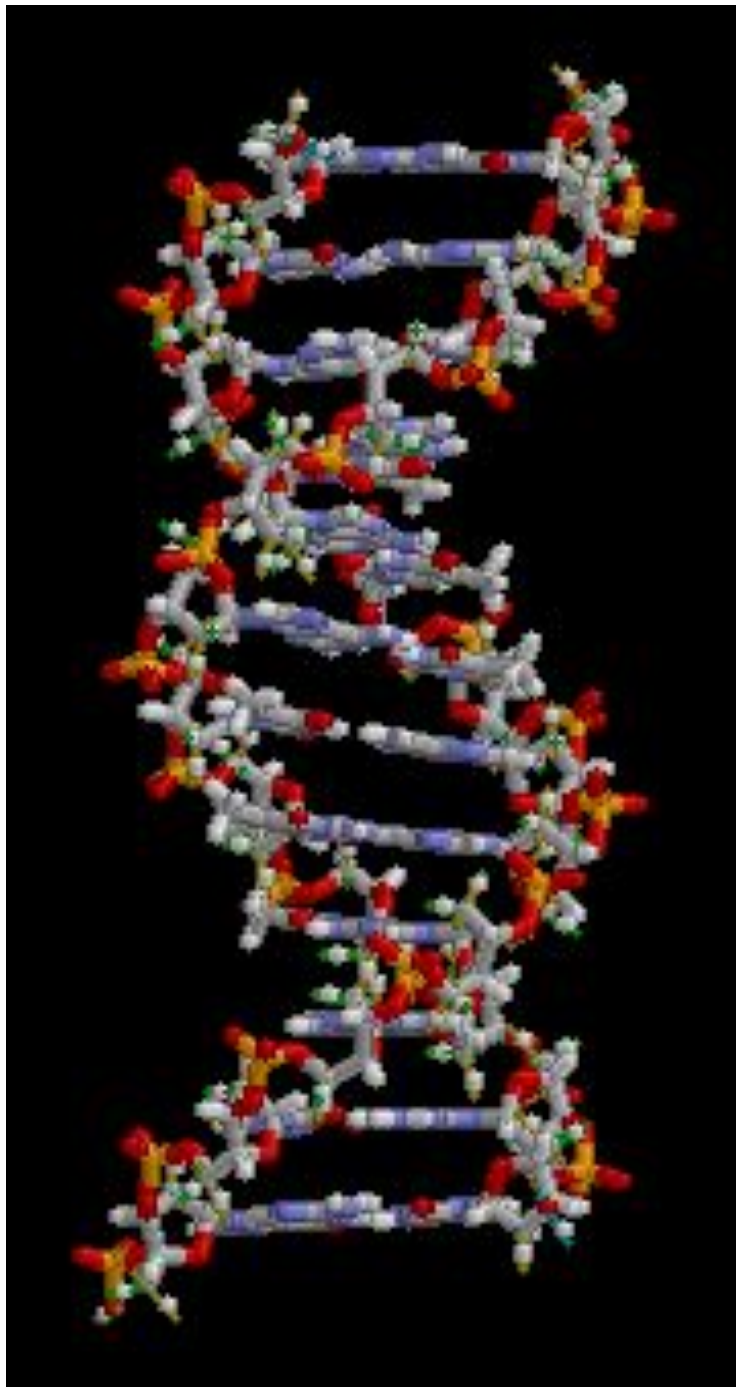


(b) Partial chemical structure

Пространственное расположение частей (по цветам):



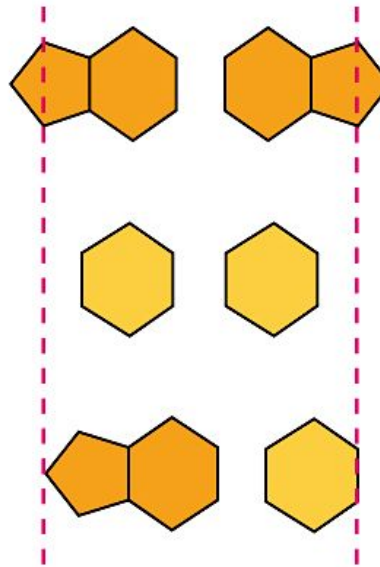
(c) Space-filling model



Purine + purine: too wide

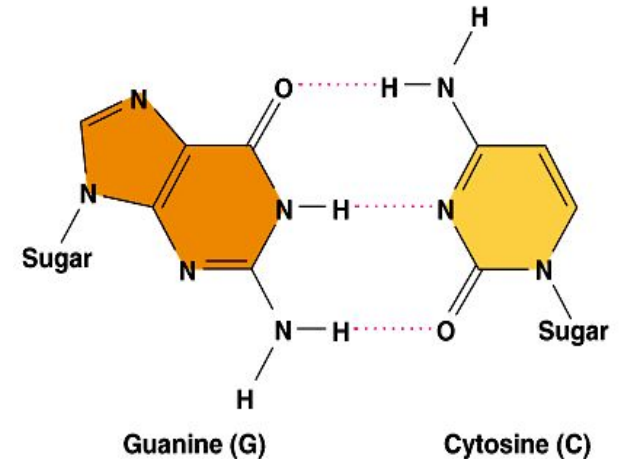
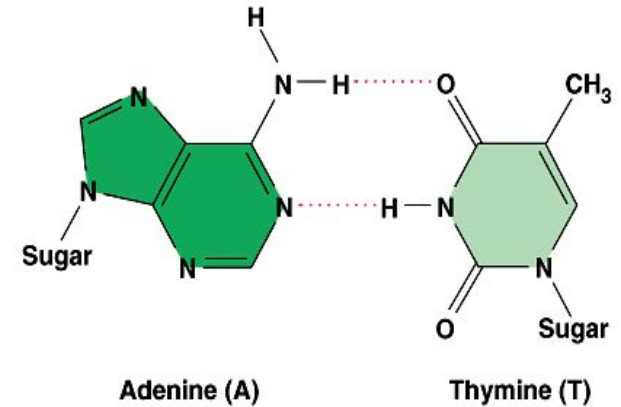
Pyrimidine + pyrimidine: too narrow

Purine + pyrimidine: width consistent with X-ray data

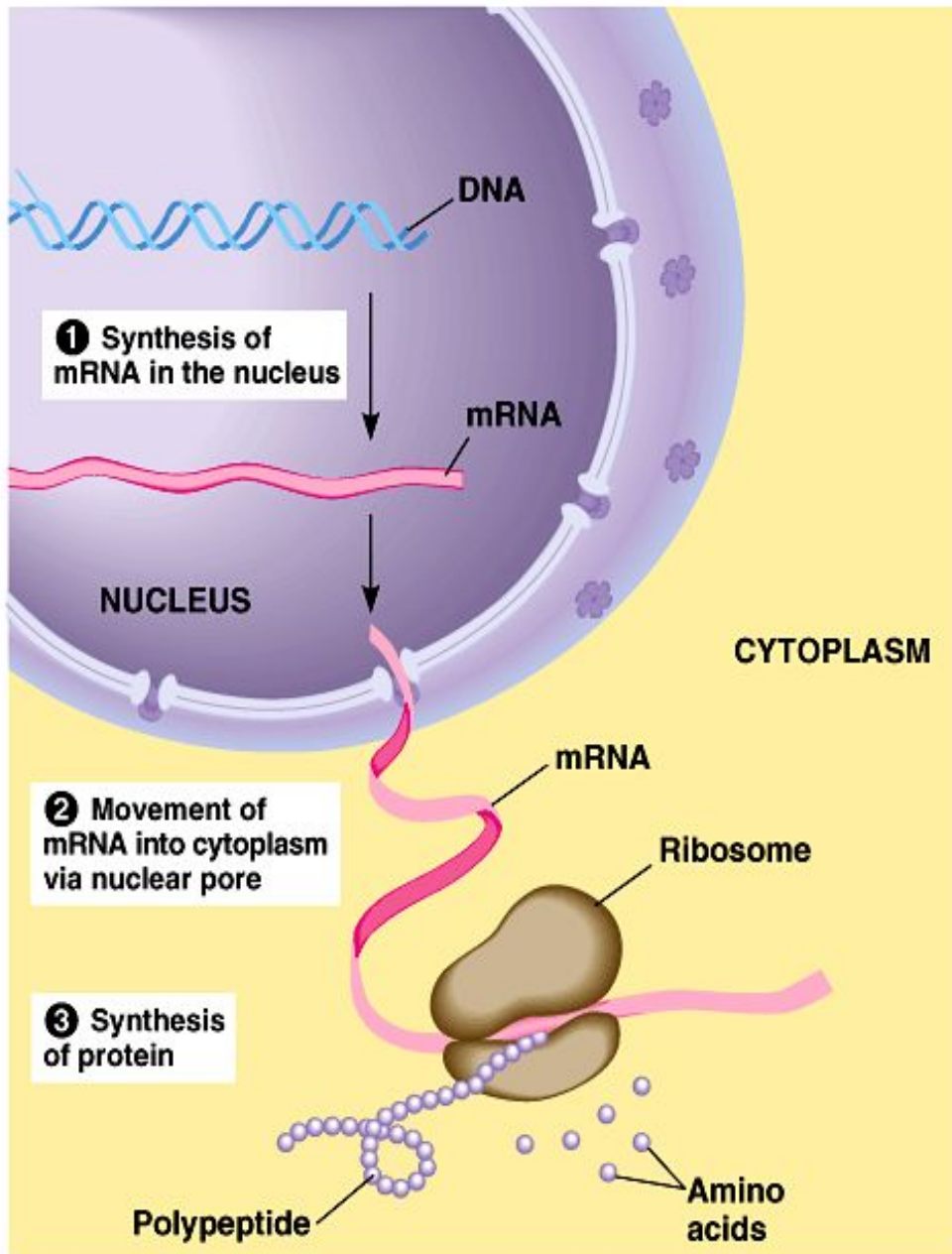


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Hydrogen bonding between bases important in double helix. Two between A and T; three between G and C.



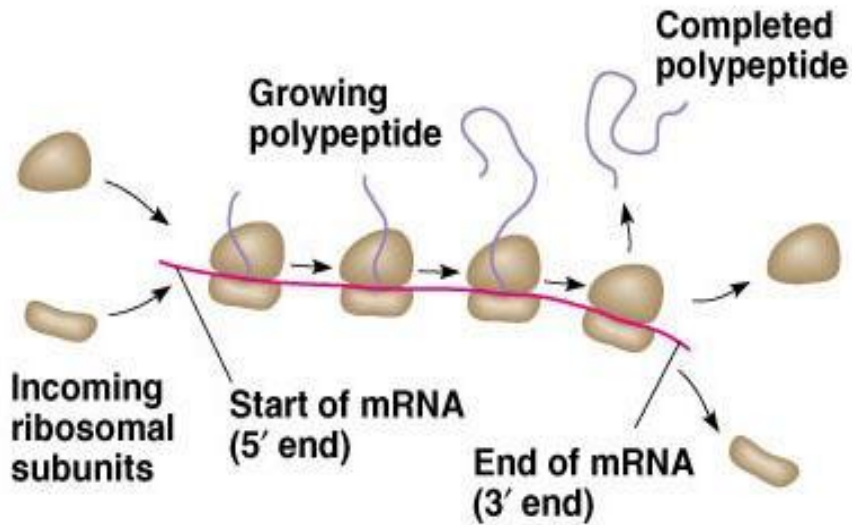
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DNA to RNA to protein:

a diagrammatic overview of information flow in a cell.

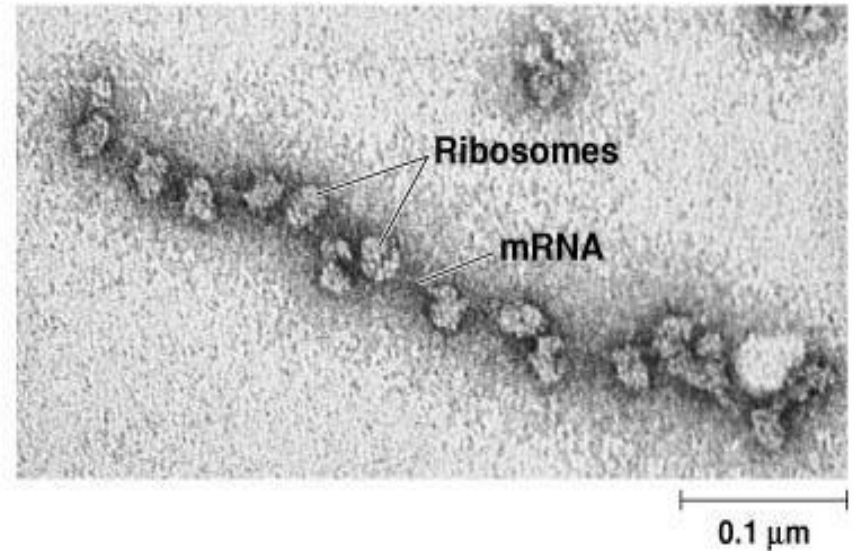
Both DNA and RNA are nucleic acids



(a) An mRNA molecule is generally translated simultaneously by several ribosomes in clusters called polyribosomes.

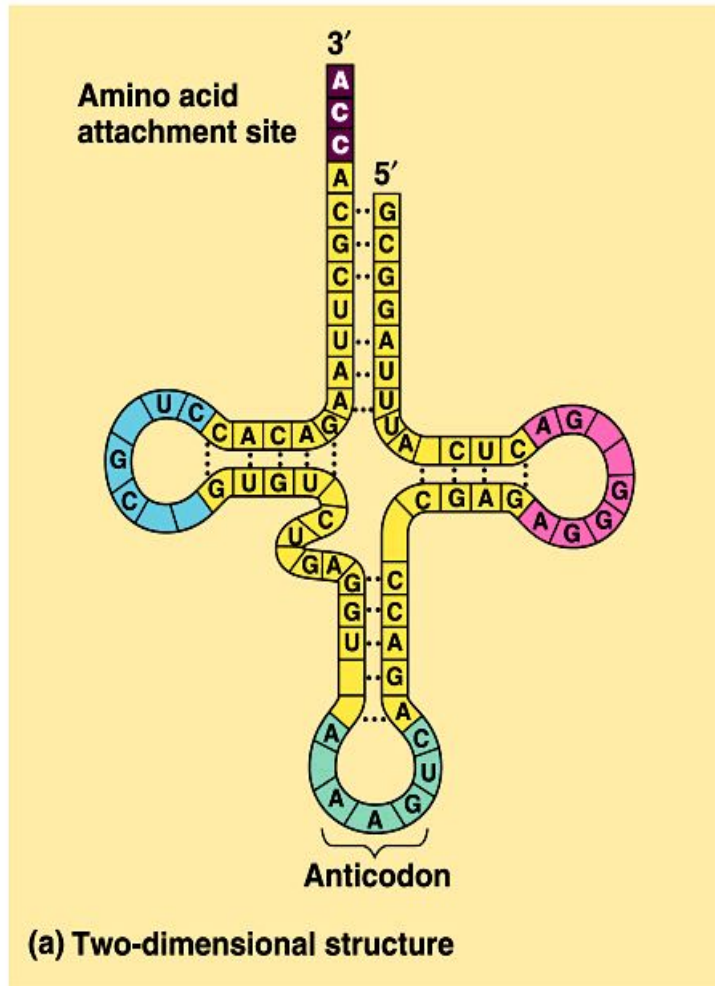
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mRNA is translated into a polypeptide/protein in the cytoplasm.

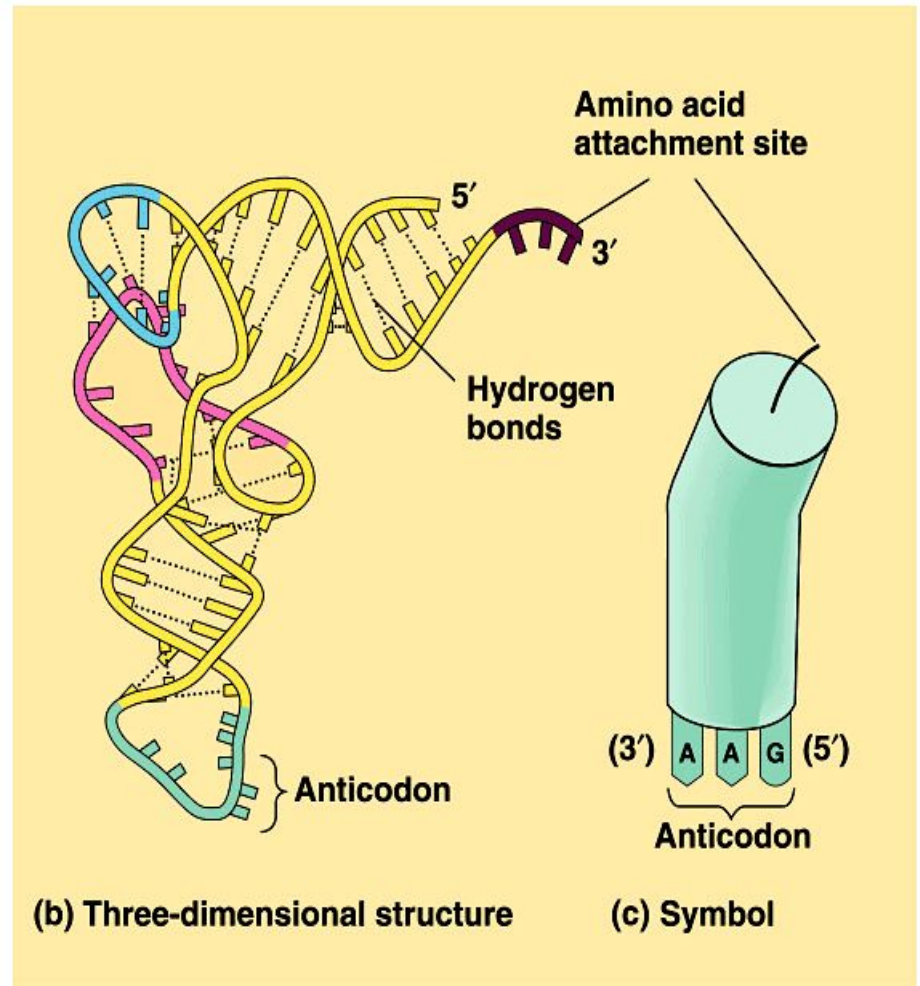


(b) This micrograph shows a large polyribosome in a prokaryotic cell (TEM).

Ribosomes are composed of RNA and protein



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Transfer RNA is an adaptor molecule bringing in amino acids in the synthesis of protein.

Campbell and Reece **Figure 17.14** The structure of transfer RNA (tRNA).

Table 17.1 Types of RNA in a Eukaryotic Cell

Type of RNA	Functions
Messenger RNA (mRNA)	Carries information specifying amino acid sequences of proteins from DNA to ribosomes.
Transfer RNA (tRNA)	Serves as adapter molecule in protein synthesis; translates mRNA codons into amino acids.
Ribosomal RNA (rRNA)	Plays catalytic (ribozyme) roles and structural roles in ribosomes.
Primary transcript	Serves as a precursor to mRNA, rRNA, or tRNA, before being processed by splicing or cleavage. Some intron RNA acts as a ribozyme, catalyzing its own splicing.
Small nuclear RNA (snRNA)	Plays structural and catalytic roles in spliceosomes, the complexes of protein and RNA that splice pre-mRNA.
SRP RNA	Is a component of the signal-recognition particle (SRP), the protein-RNA complex that recognizes the signal peptides of polypeptides targeted to the ER.
Small nucleolar RNA (snoRNA)	Aids in processing of pre-rRNA transcripts for ribosome subunit formation in the nucleolus.
Small interfering RNA (siRNA) and microRNA (miRNA)	Are involved in regulation of gene expression.

These first three are the types of RNA that you need to know about:

mRNA

tRNA

rRNA

Table 17.1 Types of RNA in a Eukaryotic Cell

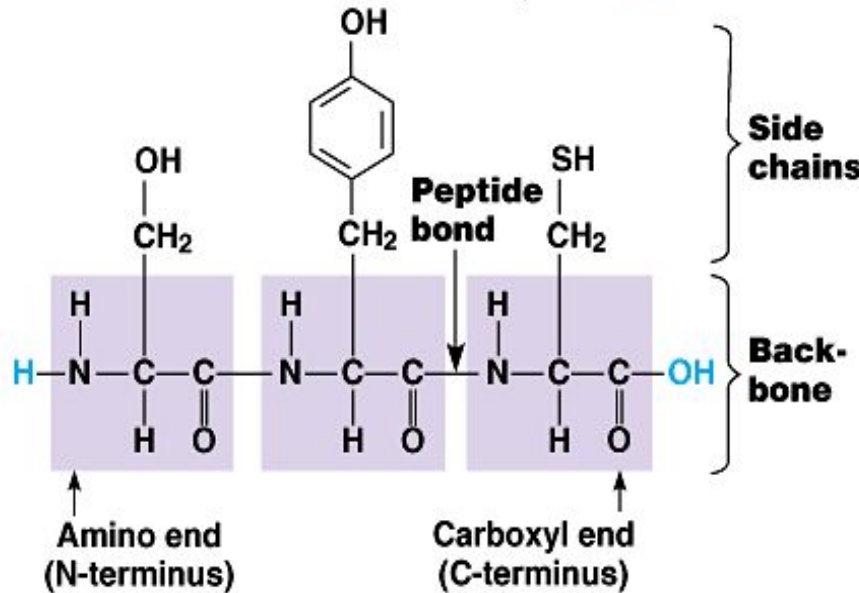
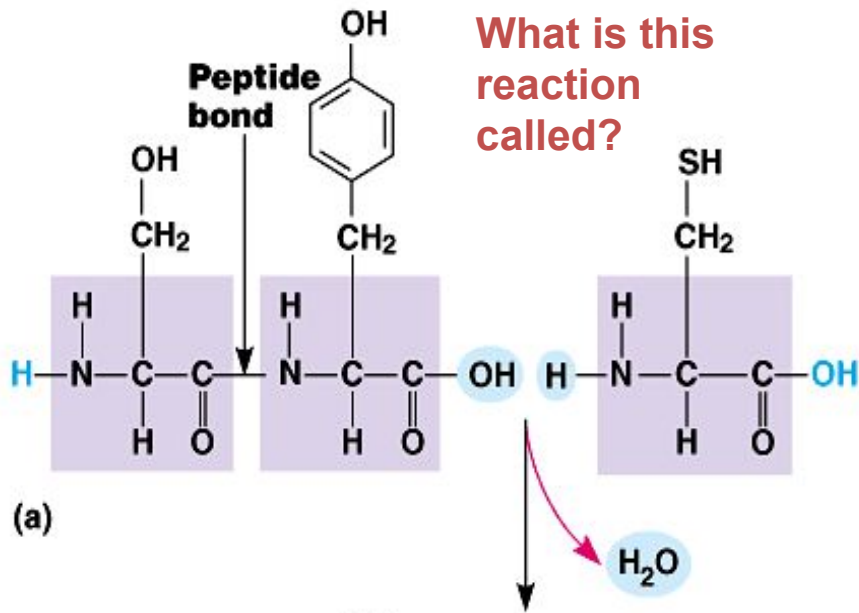
Type of RNA	Functions
Messenger RNA (mRNA)	Carries information specifying amino acid sequences of proteins from DNA to ribosomes.
Transfer RNA (tRNA)	Serves as adapter molecule in protein synthesis; translates mRNA codons into amino acids.
Ribosomal RNA (rRNA)	Plays catalytic (ribozyme) roles and structural roles in ribosomes.

Proteins

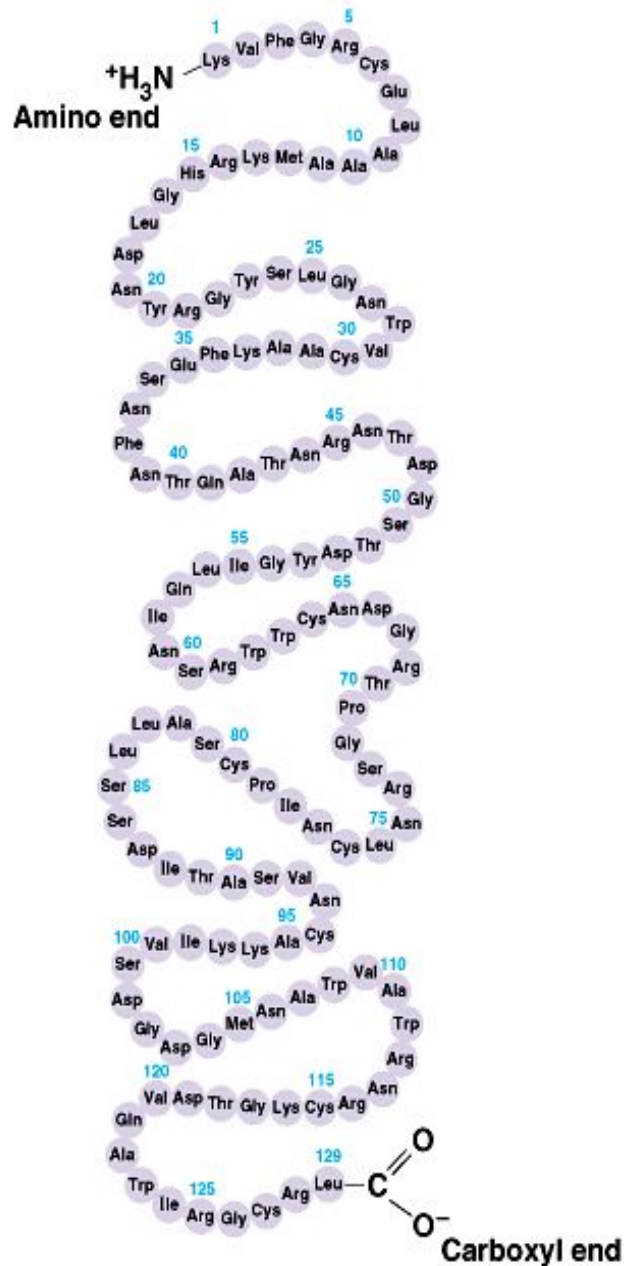
Making a polypeptide chain

Amino acids are linked by the formation of a **peptide bond**

Note the different side chains of the amino acids



(b)



The primary structure of a protein is the sequence of amino acids

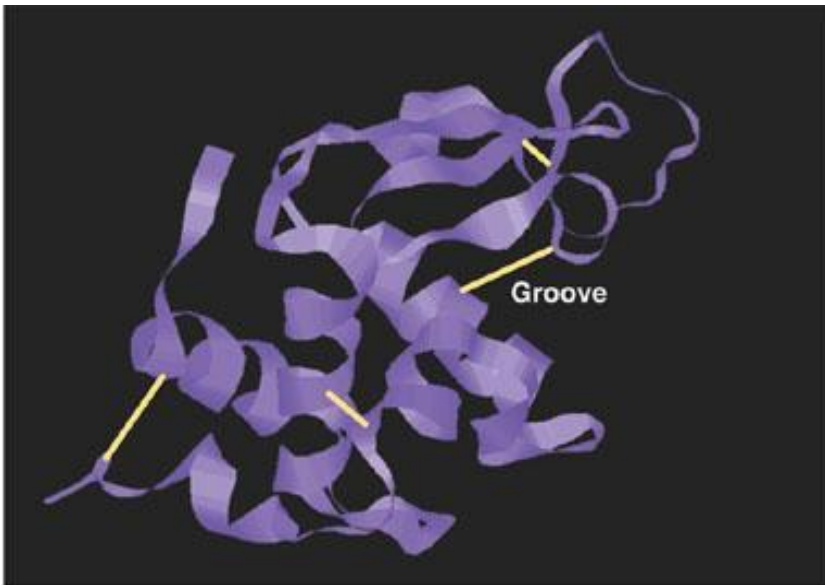
This is the enzyme lysozyme

There is an amino terminal to the protein, which has an amino group.

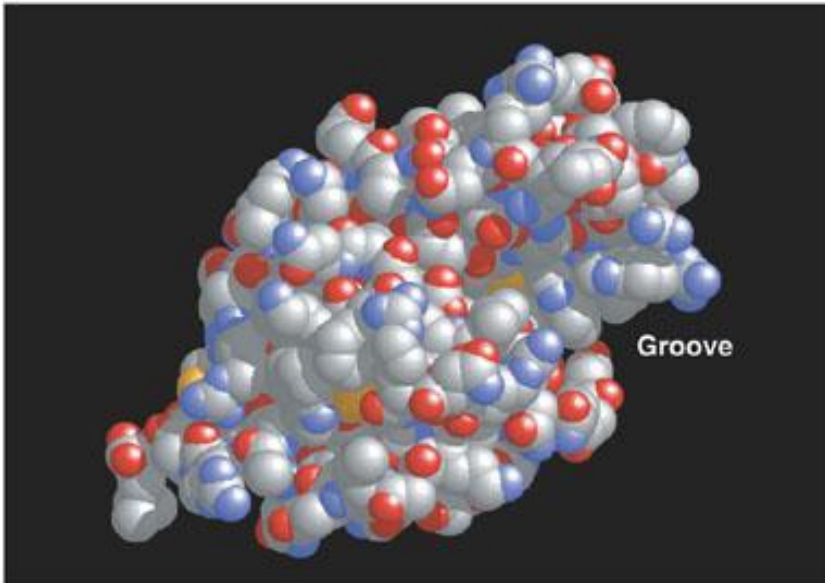
The end of the protein has a carboxyl group.

**Campbell and Reece
Figure 5.19**

Conformation of the enzyme lysozyme. Two types of model, the ribbon model and the space filling model

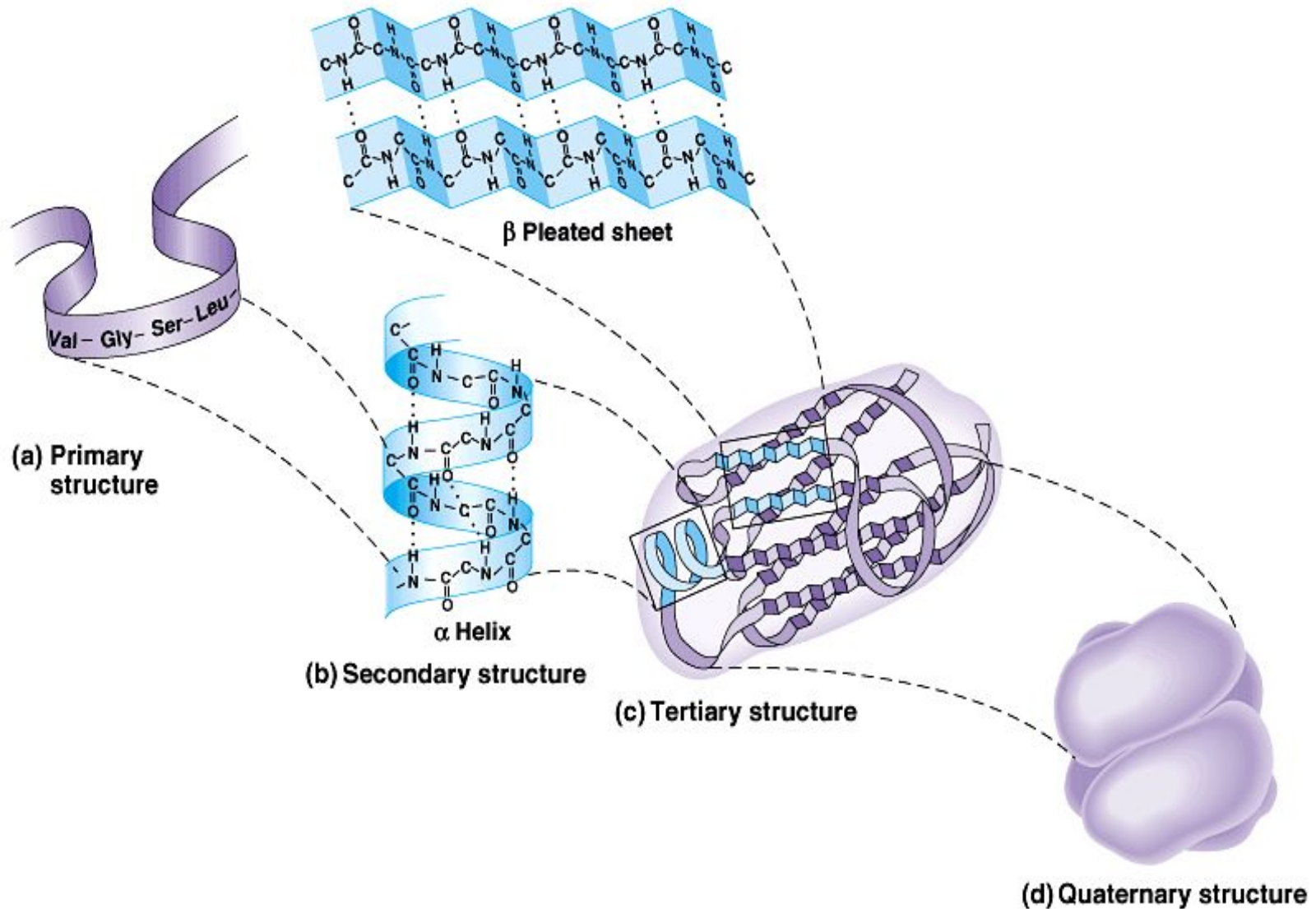


(a) A ribbon model



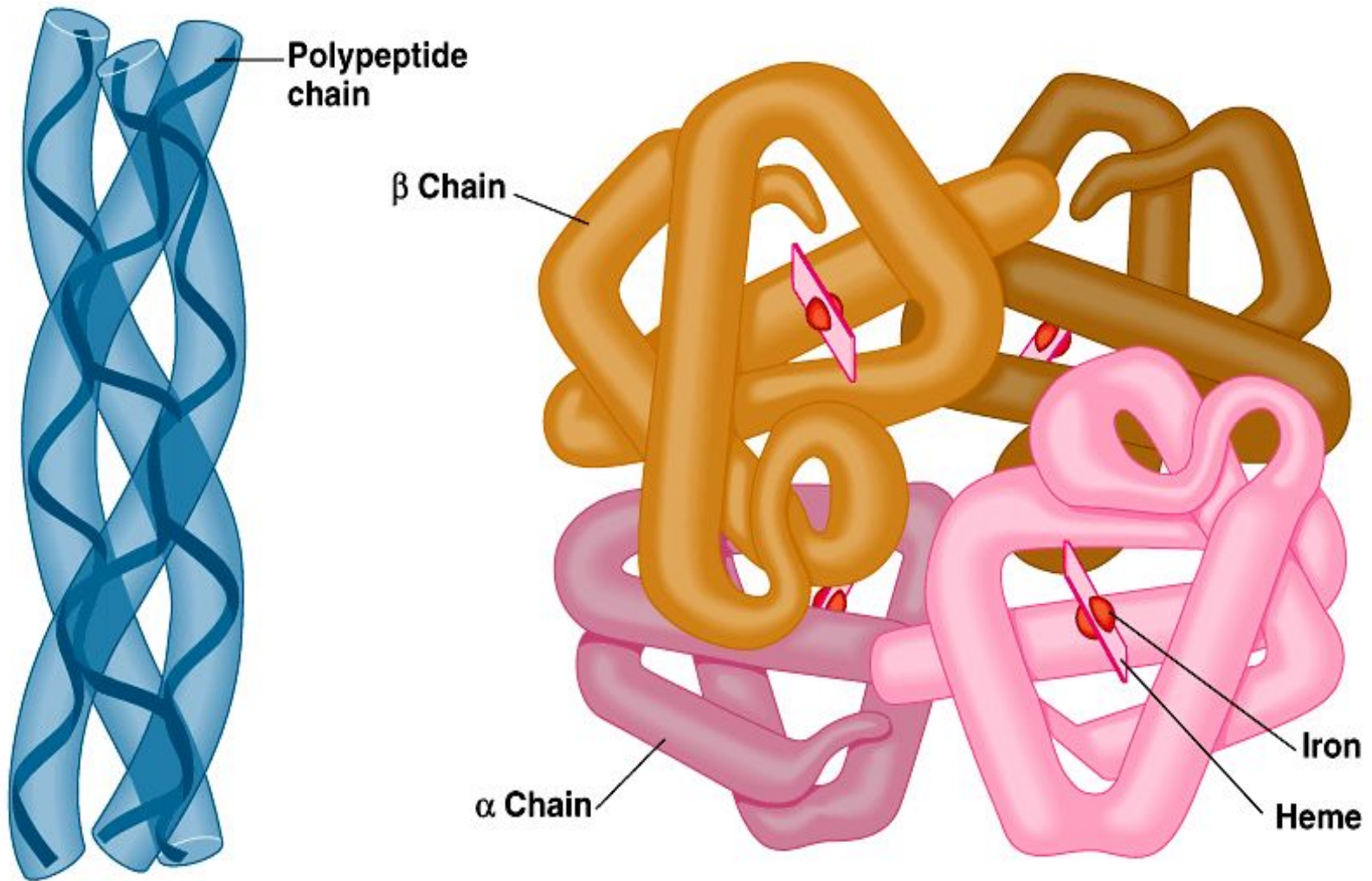
(b) A space-filling model

The substrate molecule in bacterial cell walls binds in the groove



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Campbell and Reece 8 **Figure 5.21** Exploring levels of protein structure.



(a) Collagen

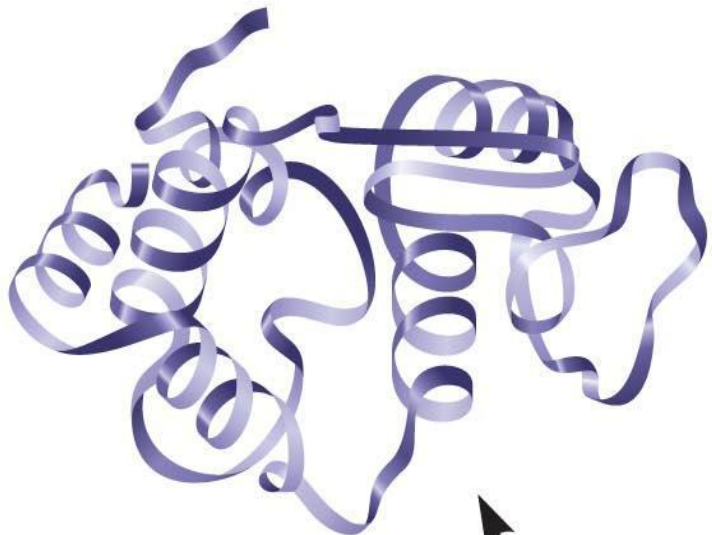
(b) Hemoglobin

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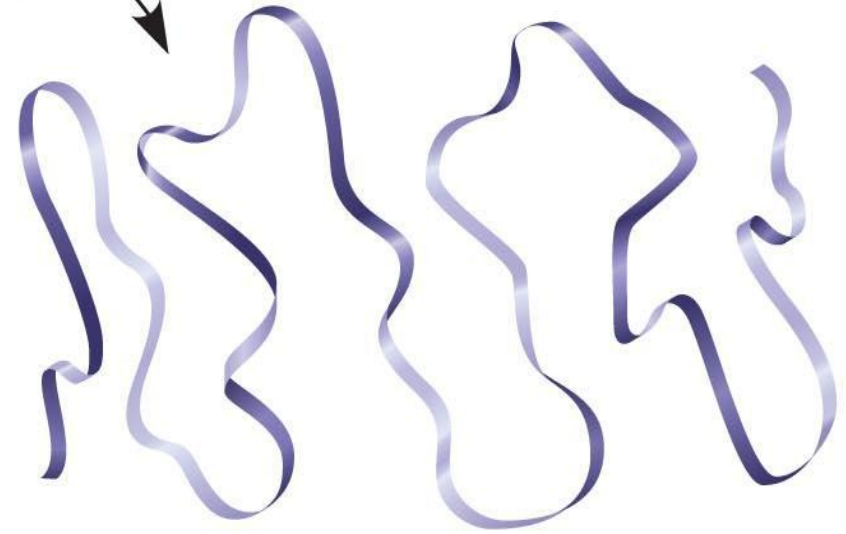
Campbell and Reece 8 **Figure 5.21** The quaternary structure of proteins.

Heat, low/high pH

Denaturation



Normal protein



Denatured protein

Renaturation

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Campbell and Reece 8 Fig 5.23 Denaturation and renaturation of a protein

Protein structure and protein-protein interactions are important in viral particle structure

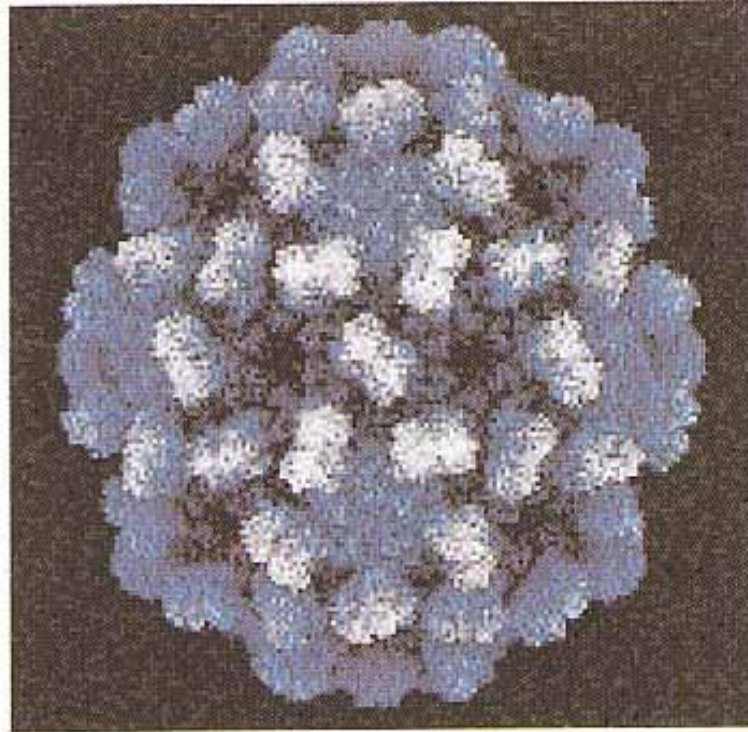
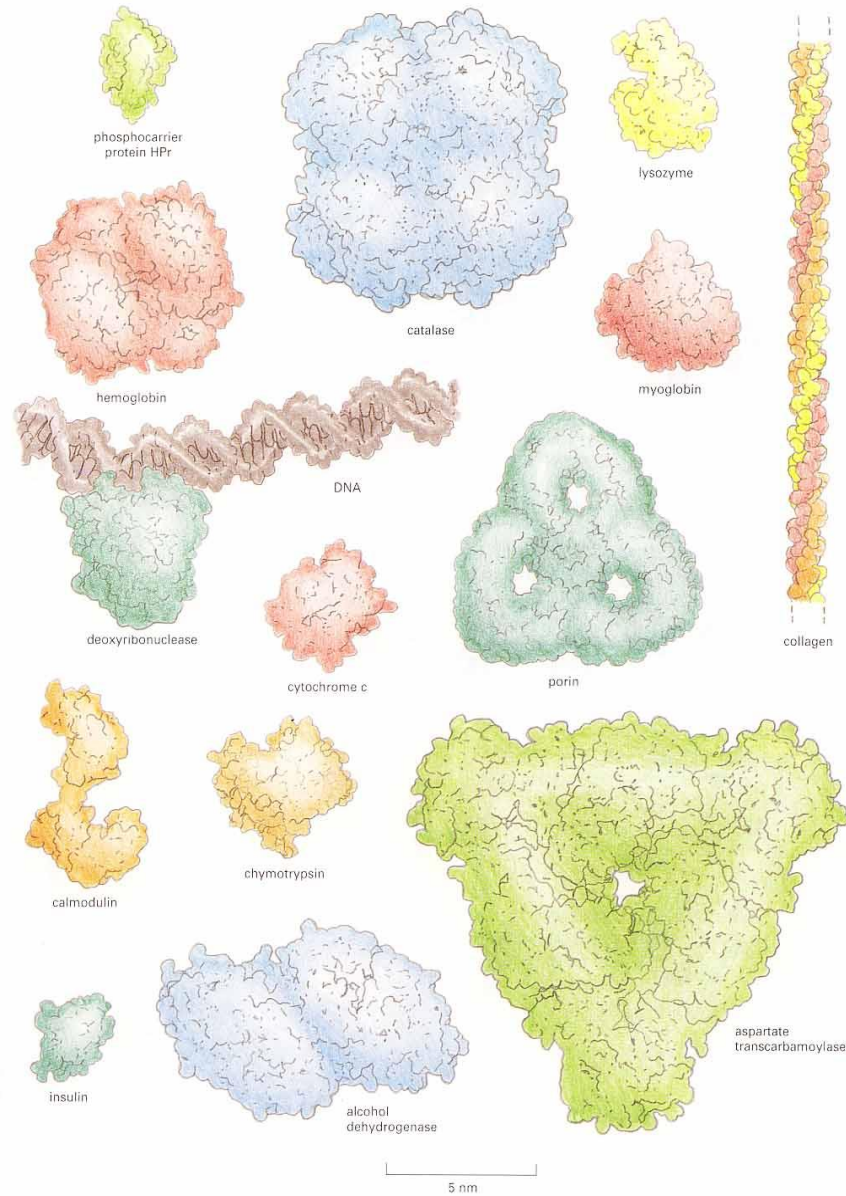


Figure 4–27 Viral capsids are made of spherical protein assemblies. The structure of tomato bushy stunt virus, shown here, was determined by X-ray crystallography and is known in atomic detail. (Courtesy of Robert Grant, Stephan Crainic, and James M. Hogle.)

Examples of relative sizes and shapes of different proteins



Compare the size and general shape of:
collagen,
catalase and
chymotrypsin

Figure 4-9 Proteins come in a variety of shapes and sizes. Each protein is shown as a space-filling model, represented at the same scale. In the top left corner is the phosphocarrier protein HPr, which is featured in greater detail in Panel 4-2 (pp. 132-133). Part of a molecule of DNA (gray) is shown for comparison. (After David S. Goodsell, *Our Molecular Nature*. New York: Springer-Verlag, 1996.)