

University of Baghdad
College of Science – Department of Chemistry

BIOCHEMISTRY (1)

2nd Class - Students of Biology
Department – College of Science

1st Semester

By

Ass. Prof. Dr. Saba Zuhair Hussein

BOOKS

- **Principals of Biochemistry, 4th ed. by Horton *et.al*, 2006.**
- **Biochemistry, 2^{ed} by P. Naik 2007 (JAYPEE).**



CONTENTS:

- **Amino Acid**
- **Peptides**
- **Nucleic acid**



Lecture 1

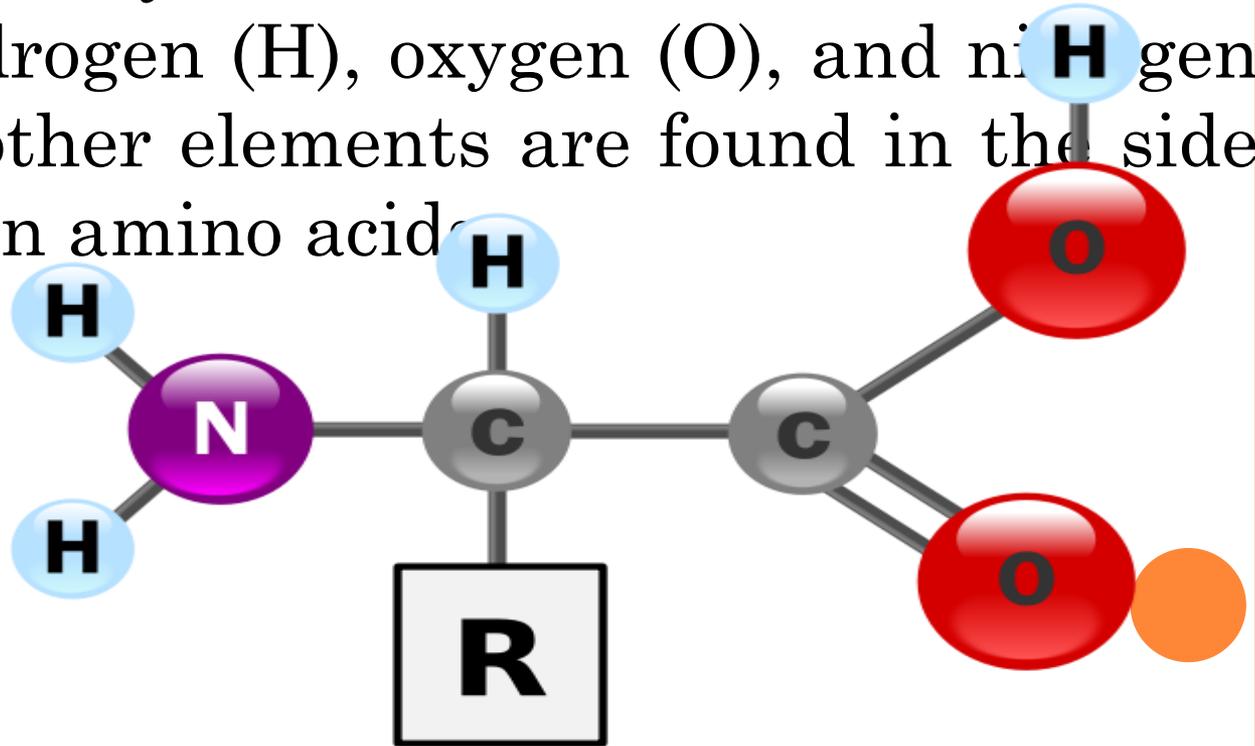


Amino Acid

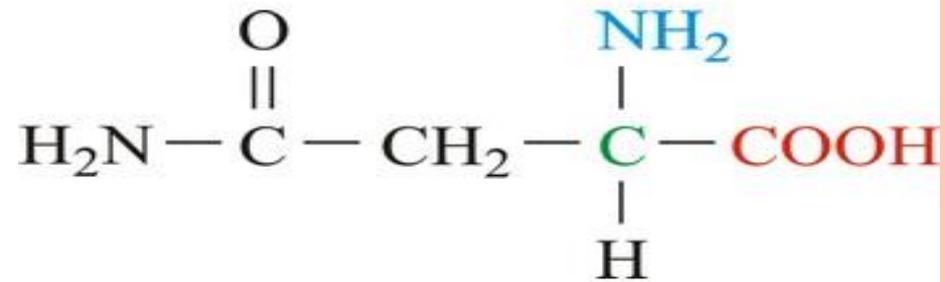


Amino acids are building blocks of **peptides** and **proteins**

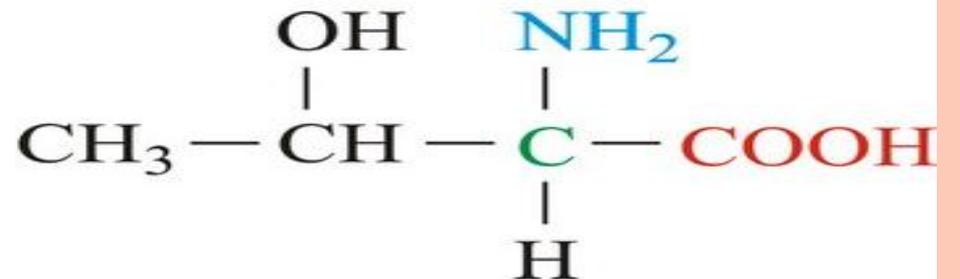
They are organic compounds containing amine (-NH₂) and carboxyl (-COOH) functional groups, along with a side chain (**R group**) specific to each amino acid. The key elements of an amino acid are carbon (C), hydrogen (H), oxygen (O), and nitrogen (N), although other elements are found in the side chains of certain amino acids.



-The first to be discovered was **Asparagine (Asn)**, in 1806, French chemists Louis-Nicolas Vauquelin and Pierre Jean Robiquet isolated a compound from asparagi (named **asparagine**)



-The last of the 20 common amino acids to be discovered was **Threonine (Thr)** in 1938 by William Cumming Rose.

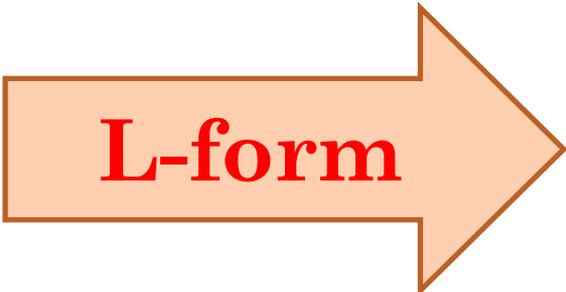


Structure of the Amino Acids

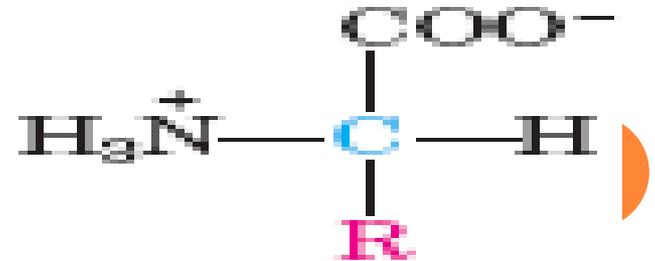
Although over 200 amino acids have been shown to be present in the various plants and animals, only **20** of them (**L- isomers**) are commonly found in proteins, these 20 amino acids of proteins are often referred to as **standard, primary** or **normal amino acids**, to distinguish them from others.

They are called **proteogenic** amino acids.

The others which never occur in proteins are known as **non- proteogenic** amino acids.



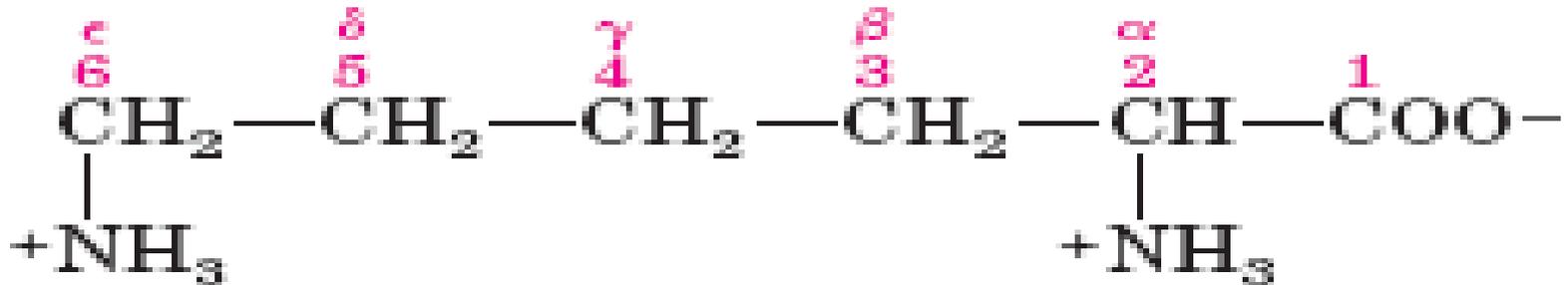
L-form



Classification of Amino Acids

1. Classification based on the position of amino group

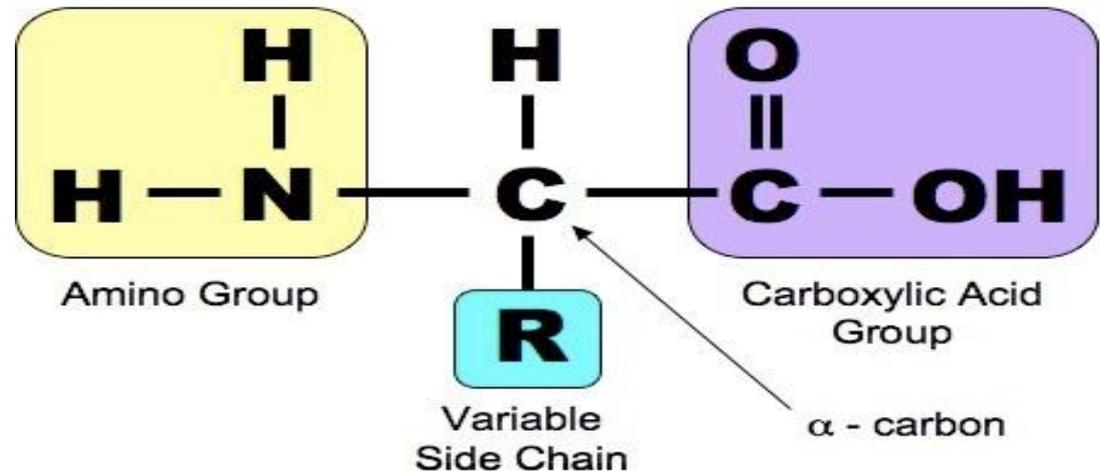
Amino acids may be classified as α , β or γ - amino acids according to the position of the amino group in the carbon chain



Lysine

- All 20 of the common amino acids are

α -amino acids



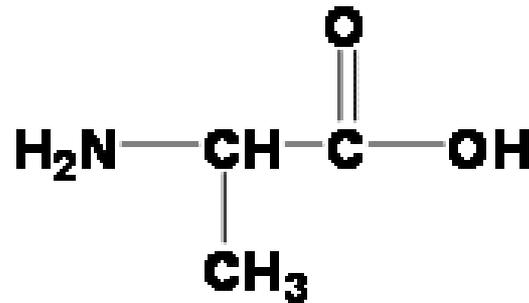
Classification of Amino Acids

2. Classification based on their acid-base properties

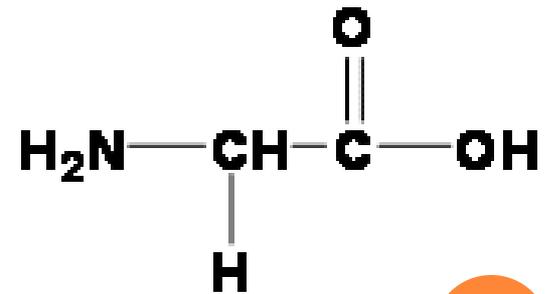
On the basis of the acid-base properties in solution, amino acids are classified into three types

i) Neutral amino acids : Most α -amino acids contain an amino group at one end and a carboxyl group at the other end. They do not contain any amino group or carboxyl group in the side chain (R). These are called neutral amino acids

Examples



alanine



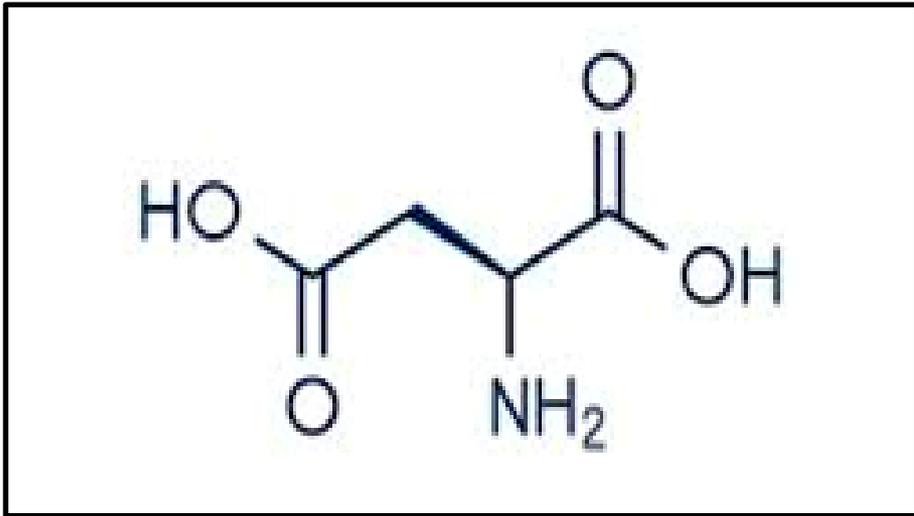
glycine



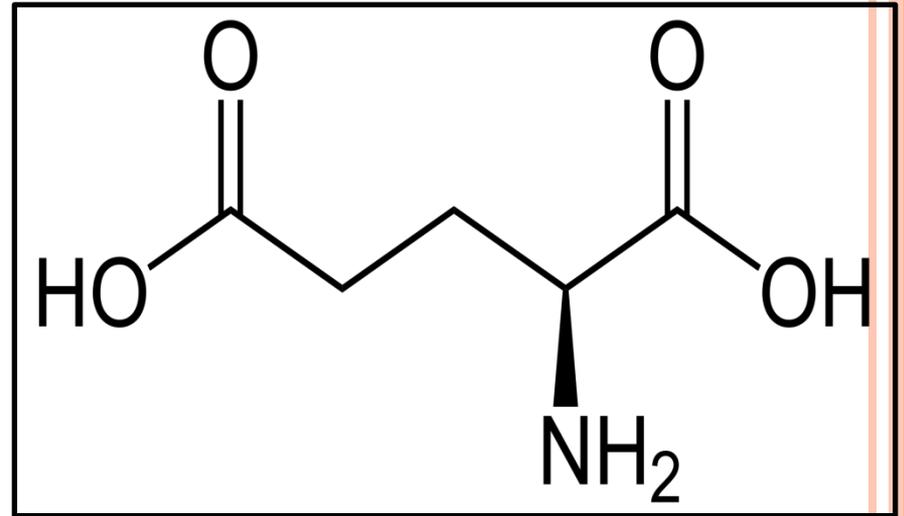
Classification of Amino Acids

ii) Acidic amino acids : The amino acids containing an extra carboxyl group in the side chain are referred to as acidic acids

Examples



Aspartic acid



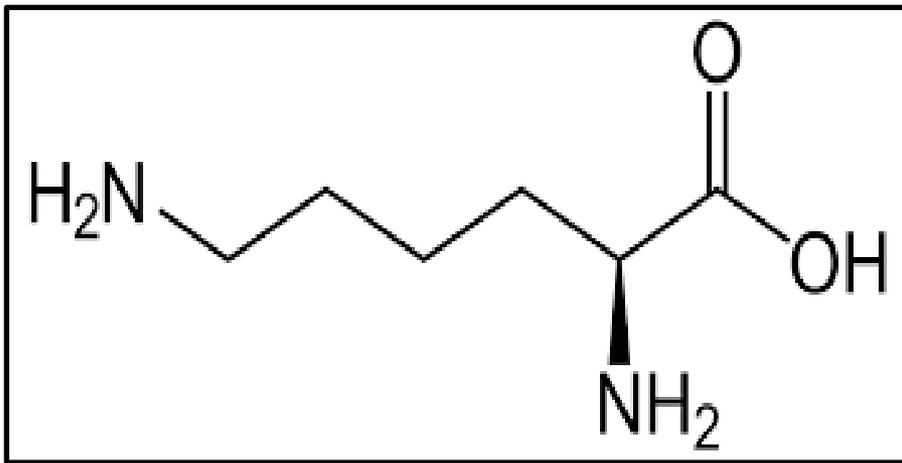
Glutamic acid



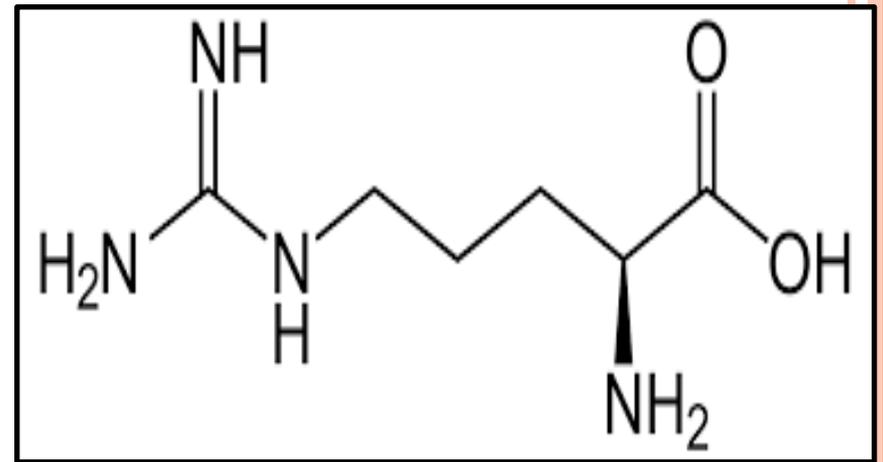
Classification of Amino Acids

iii) Basic amino acids : The amino acids containing an extra amino group in the side chain are termed basic amino acids

Examples



Lysine



Arginine



Nutritional Classification of Amino Acids

3. Classification based on their biological importance

i) Essential or indispensable:

Amino acids are essential for the growth of body and its protection from diseases. Certain amino acids which are essential for the growth of body, **cannot** be synthesized by the body. Therefore, they must be included in the human diet.

Such amino acids are referred to as essential amino acids. They are also called indispensable amino acids.

Val	Phe	Met
Leu	Trp	Lys
Ile	His	
Thr	Arg	

These are rich in cereals, soyabeans, egg, milk, cheese, meat, carrot leaves and tender coconut



Nutritional Classification of Amino Acids

ii) Non-Essential or dispensable:

They **can** be produced from endogenous metabolites. Hence, they need not be included in the diet. These amino acids are termed nonessential amino acids

Gly

Ala

Ser

Cys

Glu

Gln

Asp

Asn

Tyr

Pro

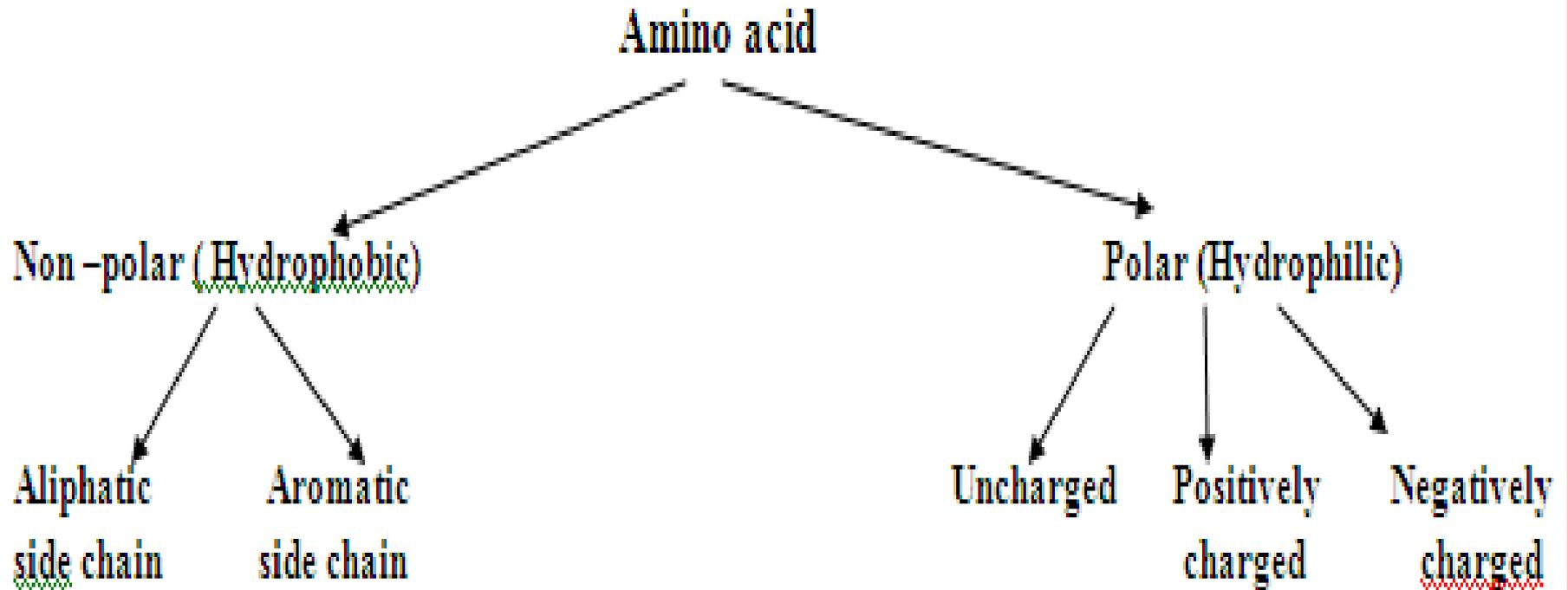


Lecture 2



Classification of Amino Acids

3. Classification based on their structure



Classification of Amino Acids

Nonpolar, Aliphatic R Groups (7 a.a)

They include amino acids with aliphatic side chains

Name	Abr.	Sym.
Glycine	Gly	G
Alanine	Ala	A
Proline	Pro	P
Valine	Val	V
Leucine	Leu	L
Isoleucine	Ile	I
Methionine	Met	M



Classification of Amino Acids

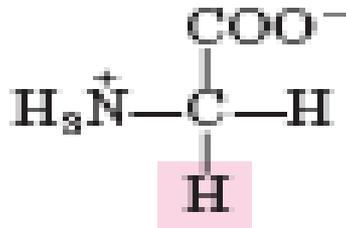
Nonpolar, Aliphatic R Groups (7 a.a)

Name	Abr.	Sym.
Glycine	Gly	G
Alanine	Ala	A
Proline	Pro	P
Valine	Val	V
Leucine	Leu	L
Isoleucine	Ile	I
Methionine	Met	M

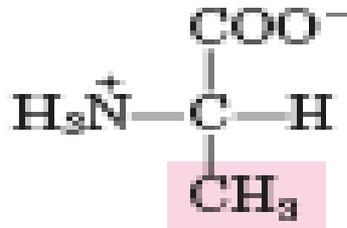


Classification of Amino Acids

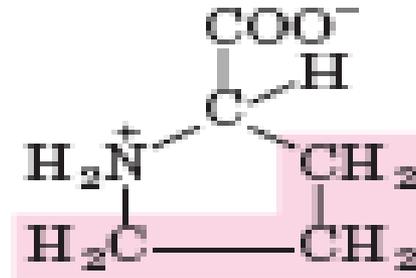
Nonpolar, aliphatic R groups



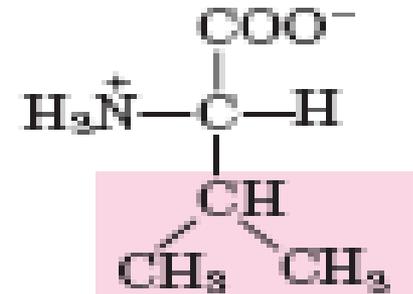
Glycine



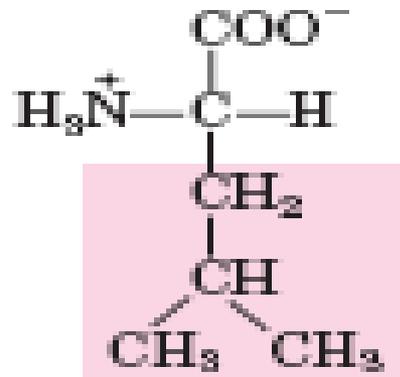
Alanine



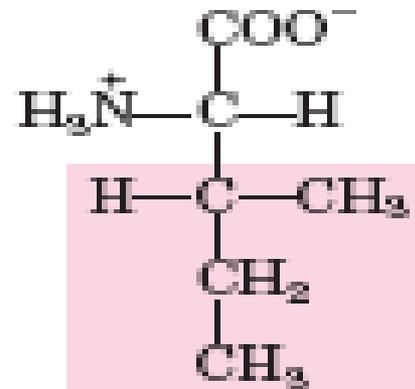
Proline



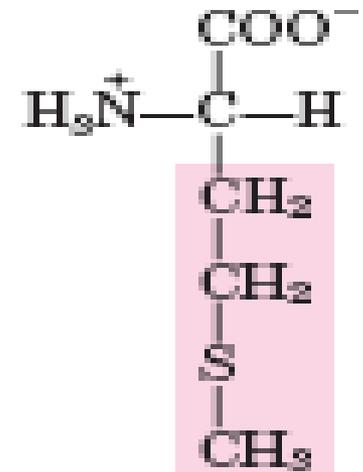
Valine



Leucine



Isoleucine



Methionine

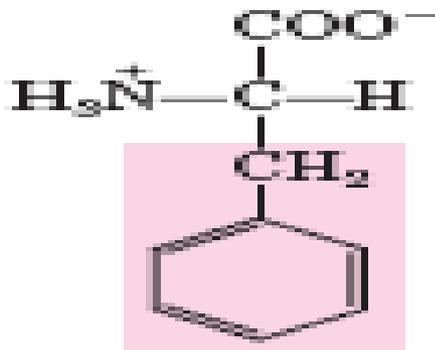
❖ Met (Thioether group) → $-\text{CH}_2-\text{S}-\text{CH}_3$

Aromatic R Groups (3a.a)

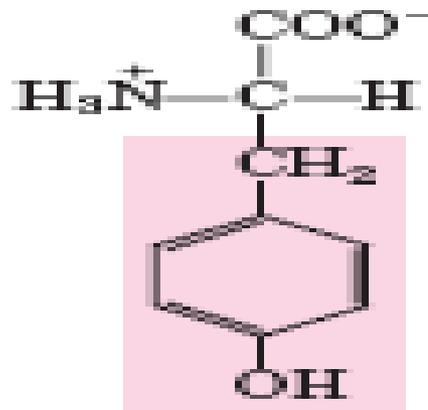
These are amino acids containing aromatic rings in the side chain

Name	Abr.	Sym.
Phenylalanine	Phe	F
Tyrosine	Tyr	Y
Tryptophan	Trp	W

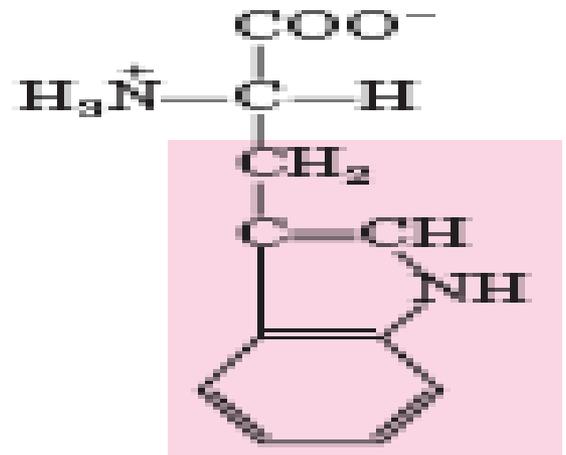
Aromatic R groups



Phenylalanine

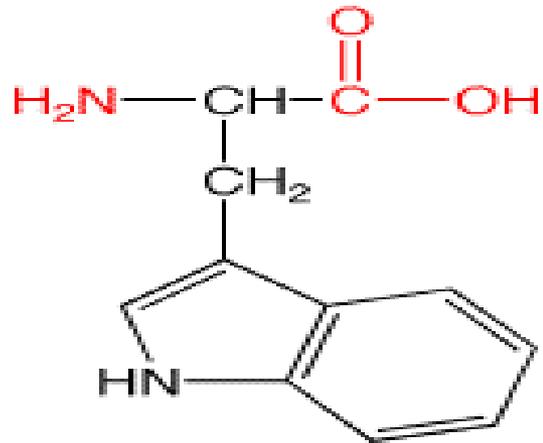


Tyrosine



Tryptophan

❖ Trp (Indole Ring)

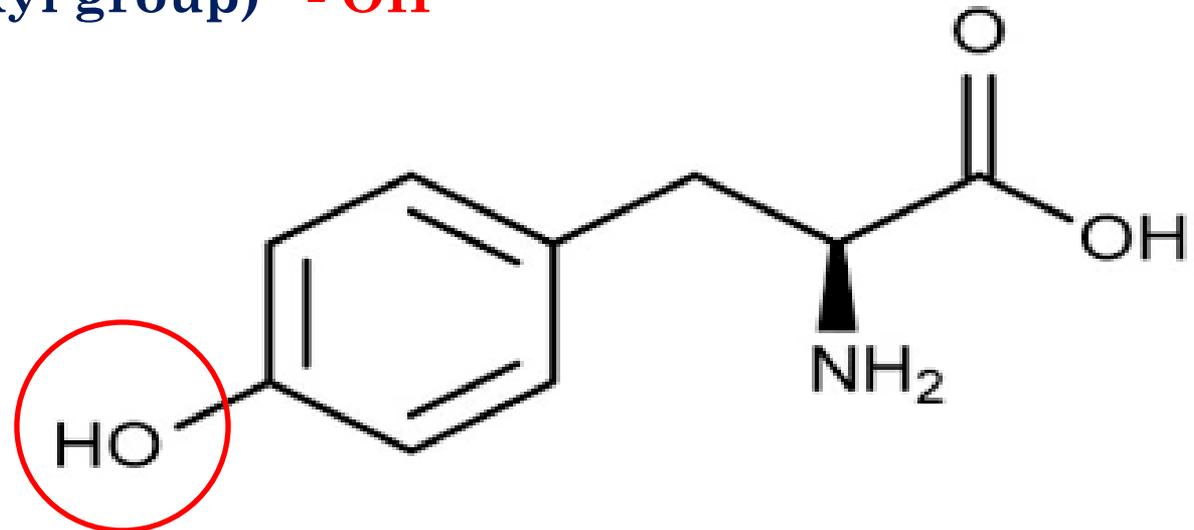


Tryptophan



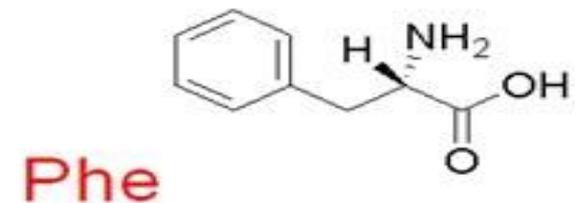
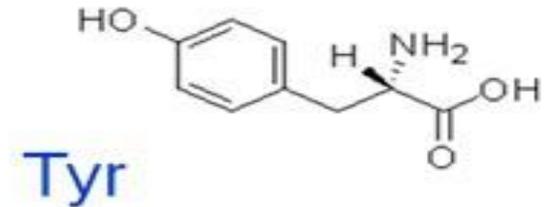
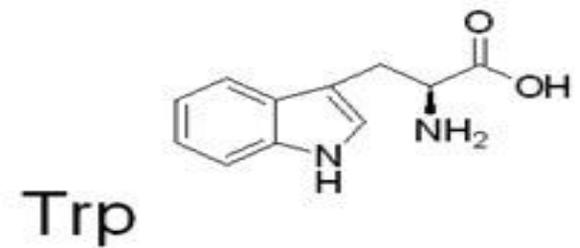
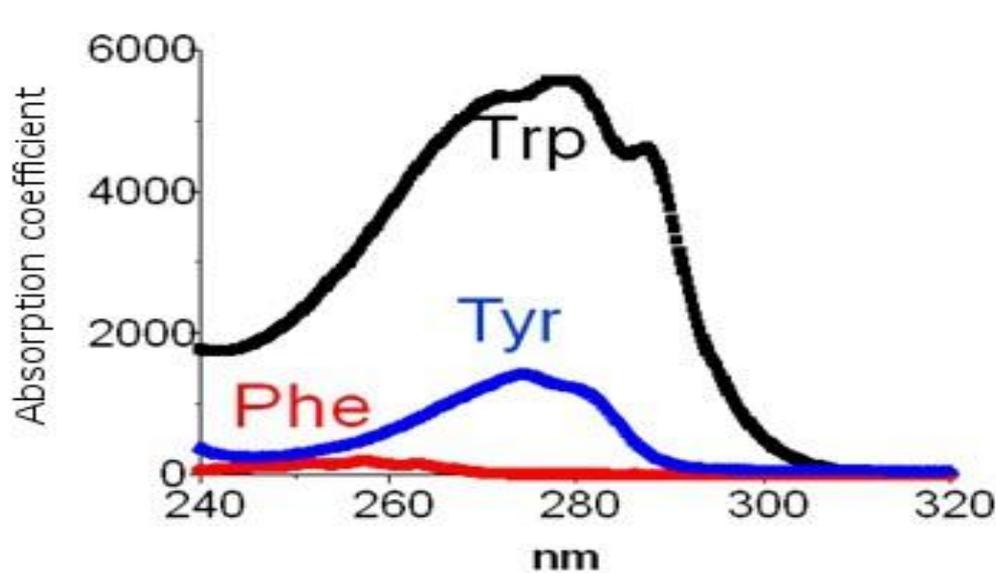
Indole

❖ Tyr (Hydroxyl group) - OH



-**Tryptophan** and **Tyrosine**, and to a much lesser extent **Phenylalanine**, absorb ultraviolet light.

-This accounts for the characteristic strong absorbance of light by most proteins at a wavelength of 280 nm, a property exploited by researchers in the characterization of proteins.

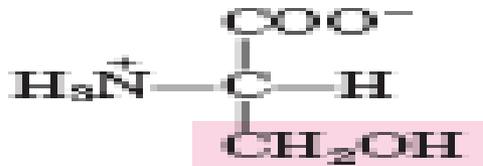


Polar Uncharged R Groups (5 a.a)

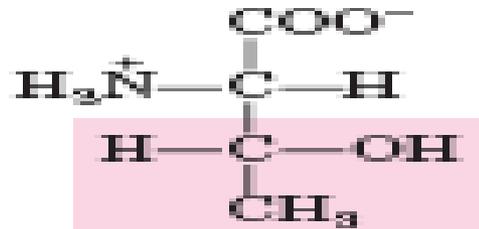
Name	Abr.	Sym.
Serine	Ser	S
Threonine	Thr	T
Cysteine	Cys	C
Asparagine	Asn	N
Glutamine	Gln	Q



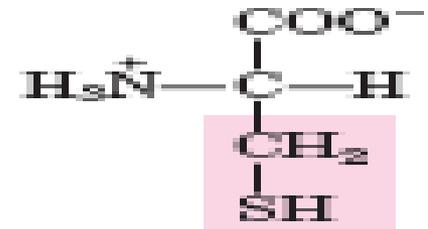
Polar, uncharged R groups



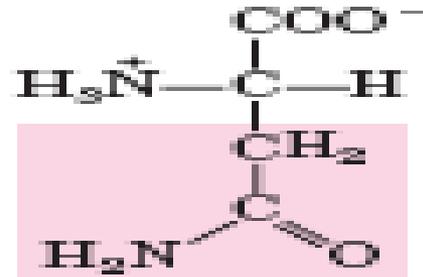
Serine



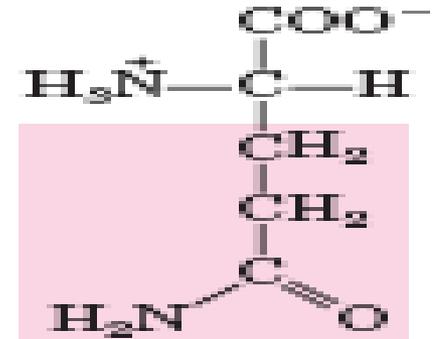
Threonine



Cysteine



Asparagine

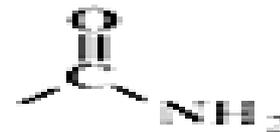


Glutamine

❖ Ser & Thr (Hydroxyl group) -

OH

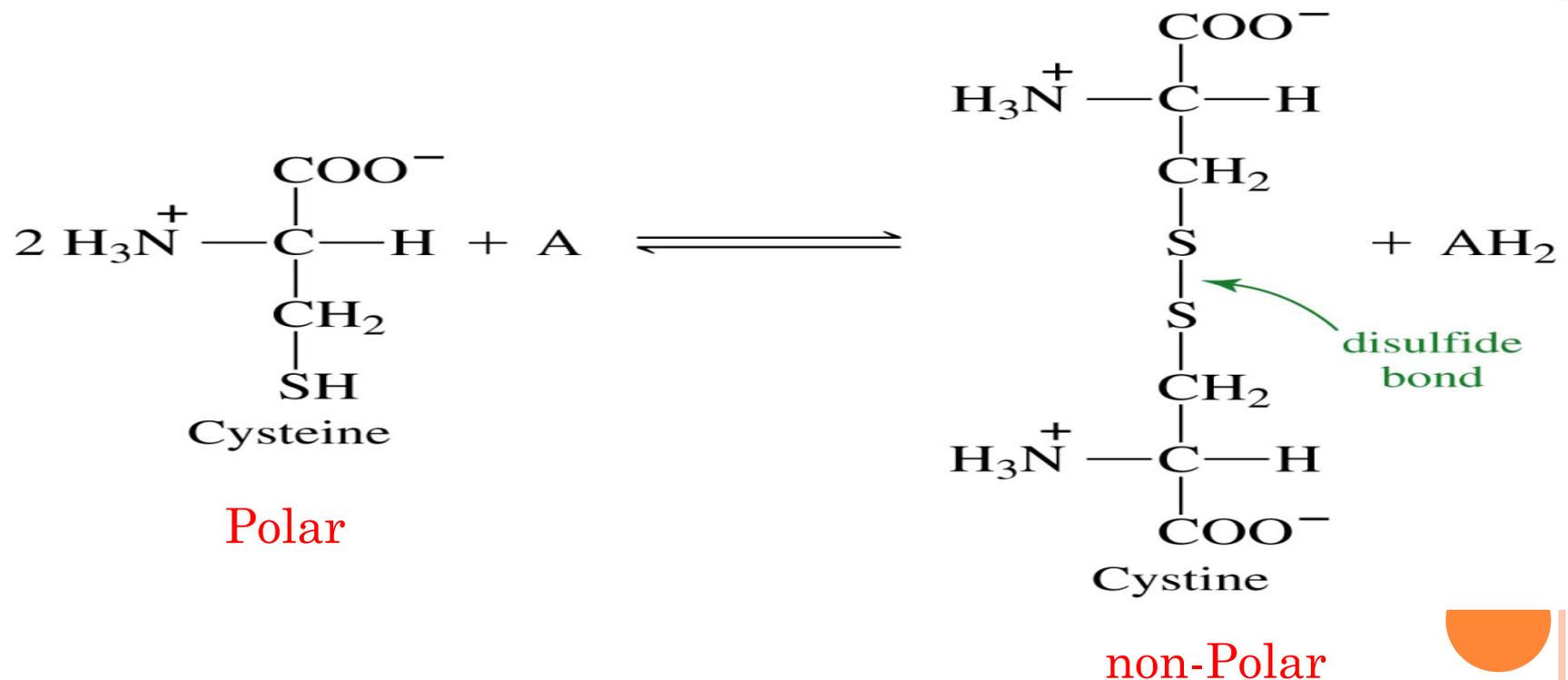
❖ Cys (Thiol group) -SH



❖ Asp & Glu (Amide group)

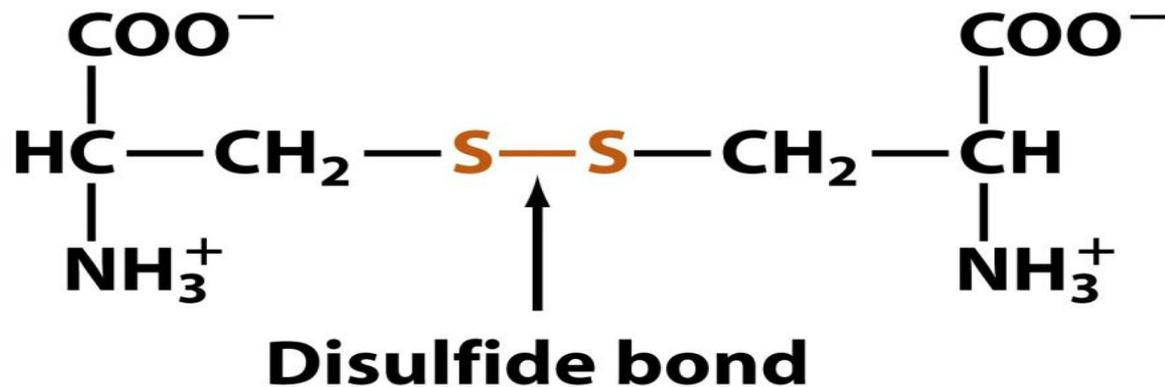


Cysteine is readily oxidized to form a covalently linked dimeric amino acid called **Cystine**, in which two cysteine molecules or residues are joined by a **disulfide bond**. The disulfide-linked residues are strongly hydrophobic (nonpolar).



Disulfide bonds

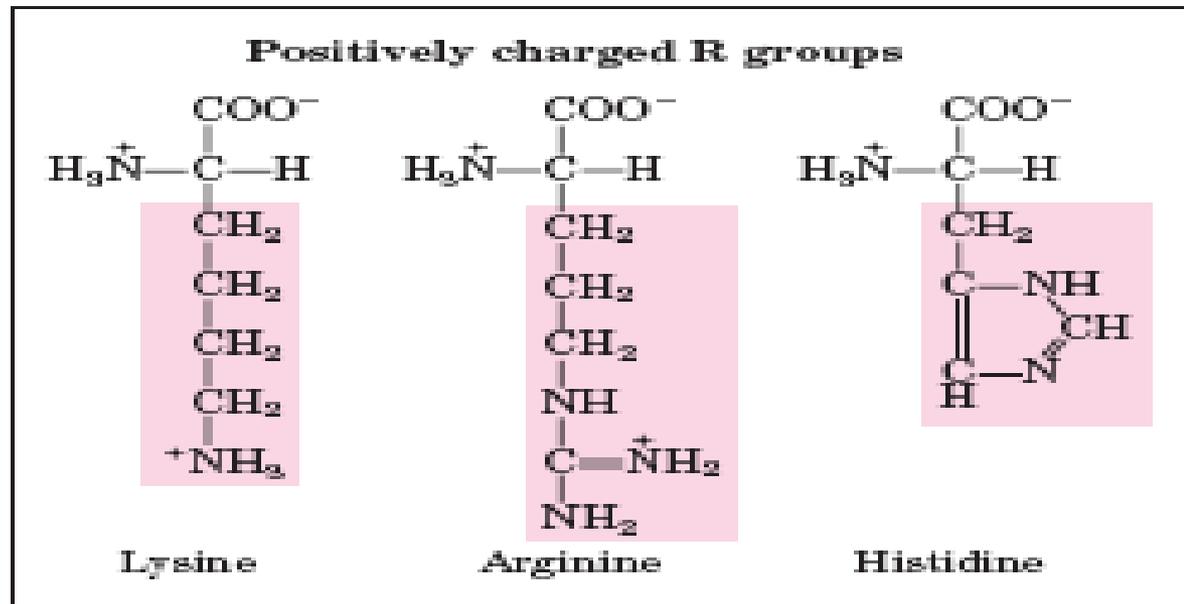
Disulfide bonds play a special role in the structures of many proteins by forming covalent links between parts of a protein molecule or between two different polypeptide chains



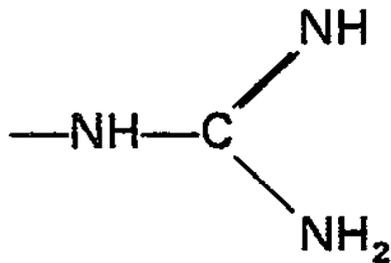
Positively charged R Groups (Basic) (3 a.a)

Diamino acids (Basic amino acids) : These amino acids contain two amino groups, one in the main an the other in the side chain

Name	Abr.	Sym.
Lysine	Lys	K
Arginine	Arg	R
Histidin e	His	H

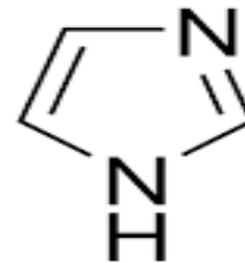


❖ Arg (Guanidino group)

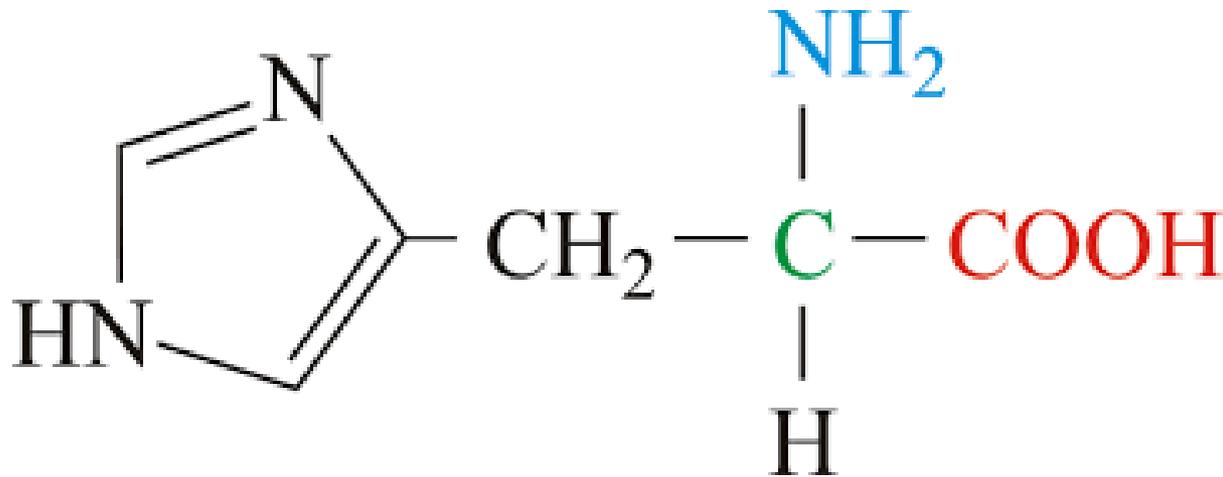


❖ His (Imidazole

group)



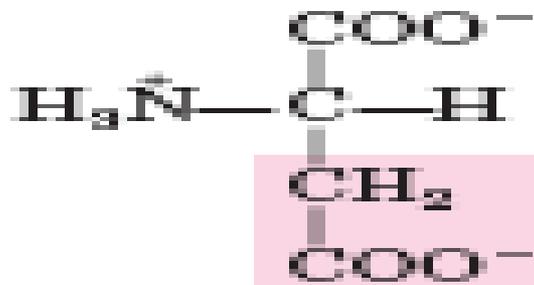
Histidine is the only common amino acid having an ionizable side chain with a pK_a near neutrality. In many enzyme-catalyzed reactions, a His residue facilitates the reaction by serving as a proton donor/acceptor



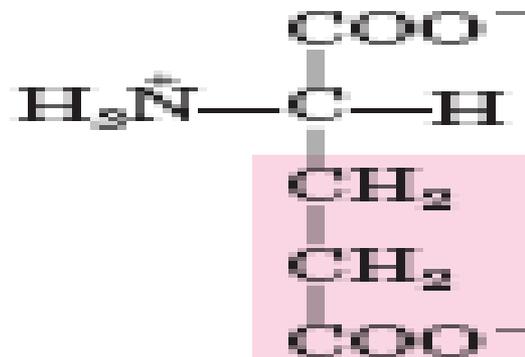
Negatively charged R Groups (Acidic) (2 a.a)

Name	Abr.	Sym.
Aspartate Aspartic acid	Asp	D
Glutamate Glutamic acid	Glu	E

Negatively charged R groups



Aspartate



Glutamate

Lecture 3



Importance of Amino Acids

- 1. Formation of proteins:** amino acids are joined to each other by **peptide bonds** to form proteins and peptides.
- 2. Formation of glucose:** glucogenic amino acids are converted to glucose in the body.
- 3. Enzyme activity:** the thiol group (-SH) of cysteine has an important role in certain enzyme activity.
- 4. Transport and storage form of ammonia:** amino acid glutamine play an important role in transport and storage of amino nitrogen in the form of ammonia

Importance of Amino Acids

5. **As a buffer:** both free amino acids and some amino acids present in protein can potentially act as buffer , e.g. histidine can serve as the best buffer at physiological buffer (pH= 7).

6. **Detoxification reactions:** Glycine , cysteine and methionine are involved in the detoxification of toxic substances.

7. **Formation of biologically important compounds:** specific amino acids can give rise to specific biologically important compounds in the body

Importance of Amino Acids

Biologically important compounds formed by amino acid

Amino acid	Biologically important compound
Tyrosine	Hormone, e.g. adrenaline and thyroxine , Skin pigment,e.g. melanin
Tryptophane	Vitamin , e.g. niacin
Glycine ,arginine and methionine	Creatine
Glycine and , cysteine	Bile salts
Glycine	Haem
Aspartic and glutamic acids	Pyrimidine bases
Glycine, aspartic acid and glutamic acid	Purine bases
β -Alanine	Coenzyme-A



Physical Properties of Amino Acids

➤ They are :

Colorless

Crystalline substances with different taste,

Generally soluble in water.

They have high melting points (above 200°C) and often result in decomposition.

Optical activity

➤ The α -carbon of amino acids is bonded to four different groups:

a carboxyl group,

an amino group,

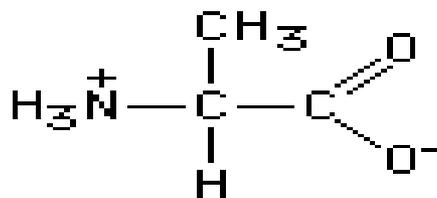
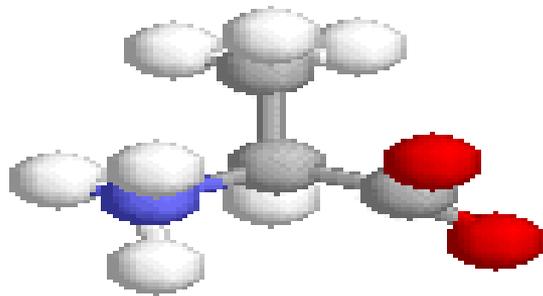
an R group, and

a hydrogen atom (except in Glycine, the R group is another hydrogen atom).

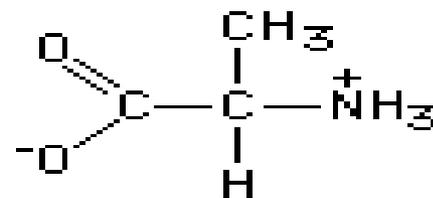
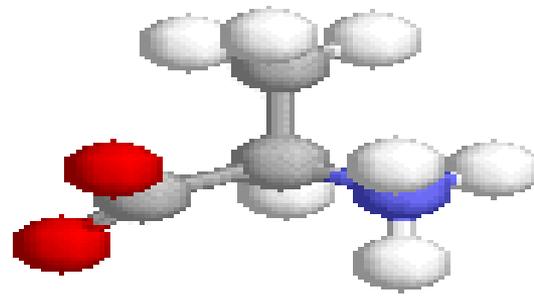
➤ That led the α -carbon atom to be a **asymmetric - chiral center**.

Because of this asymmetry, all naturally occurring amino acids (of course except **Glycine**- is optically inactive-) exist in **two optically active forms** : those having $-\text{NH}_2$ group to the **right** are designed as **D-form** and those having $-\text{NH}_2$ group to the **left** are designed as **L-form**

L-alanine



D-alanine



Physical Properties of Amino Acids

- However the **two** amino acids, **Threonine** and **Isoleucine** have **two asymmetric carbon atoms** each and thus have ($2^n = 2^2 = 4$) optical isomers.
- At pH=7 both carboxyl and amino groups are ionized.
- All the amino acids found in proteins are exclusively of the **L-configuration** (L Stereoisomers).
- However, D- amino acids are found in some antibiotics produced by microorganisms and in bacterial cell walls

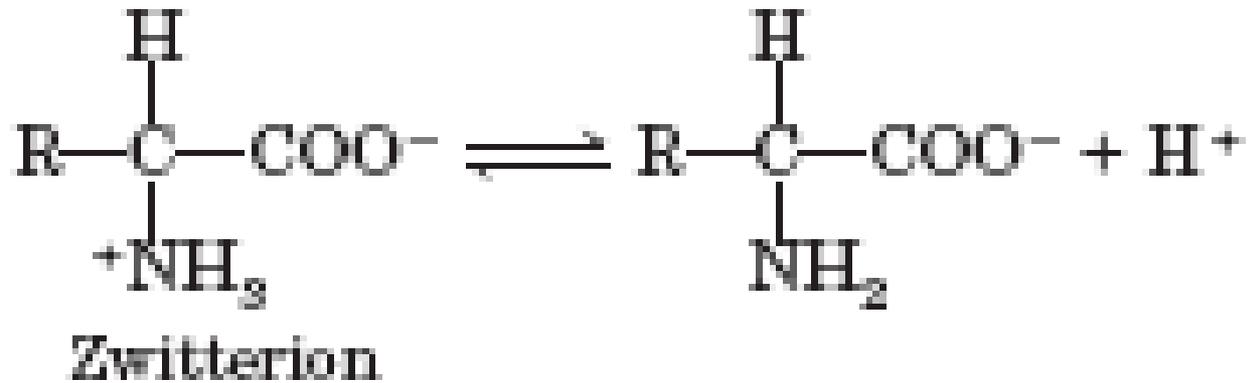
Amino Acids Can Act as Acids and Bases

When an amino acid (monoamino monocarboxylic acid) is dissolved in water, it exists in solution as the **dipolar ion**, or **Zwitterion**, which means that they have both positive and negative charges on the same amino acids

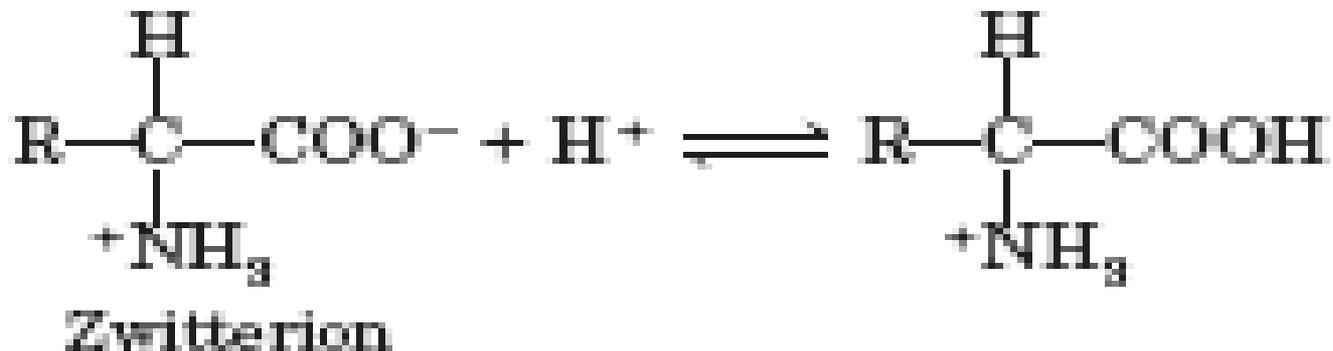
(the acidic α -COOH group is ionized and becomes **negatively** charged anion $-\text{COO}^-$ & the basic α -NH₂ group is protonated to form **positively** charged cation $-\text{NH}_3^+$)

Thus, the overall molecule is **electrically neutral**. Substances having this dual nature are **Amphoteric** and are often called **Ampholytes**.

A zwitter ion can act as either



an acid (proton donor)

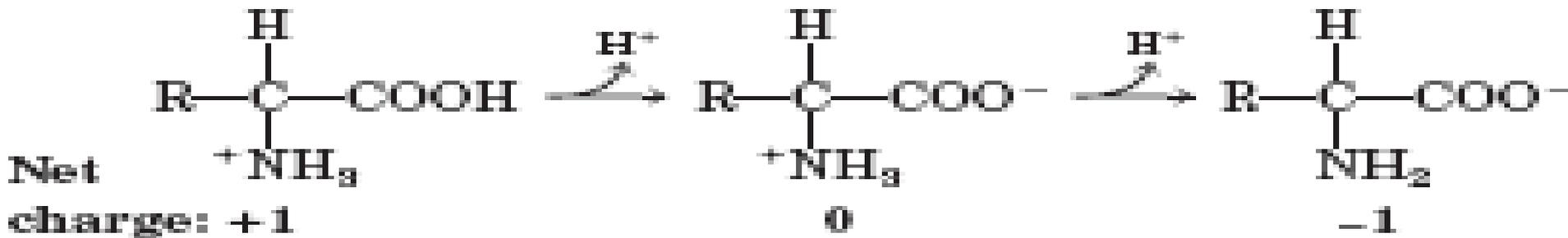


or a base (proton acceptor)



Amino Acids May Have Positive, Negative or Zero Net Charge.

The **net charge** of an amino acid depends upon the **pH of the medium**, therefore by changing the pH we can alter the charge on amino acids or proteins, which facilitates the physical separation of amino acids or proteins:



Acidic pH (pH < PI)
Cation

Amino acid is
soluble

Isoelectric pH (pH = PI)
Zwitter ion (neutral)

Amino acid is
precipitate

Basic pH (pH > PI)
Anion

Amino acid is
soluble

□ At **acidic pH** (high concentration of H^+ ions), ionized $-COO^-$ group loses its proton and becomes uncharged ($-COOH$), so the overall charge on molecule is **positive** (the net charge = +ve).

□ At **alkaline pH** (low concentration of H^+ ions), the $-NH_3^+$ group accepts a proton and becomes uncharged ($-NH_2$), so the overall charge on molecule is **negative** (the net charge = -ve).

□ The pH at which amino acid bears no net charge (the net charge = 0) and therefore does not move in an electric field is called **isoelectric pH (pI**, i.e. **pH = pI**), an amino acid precipitates out of the solution in its pI.

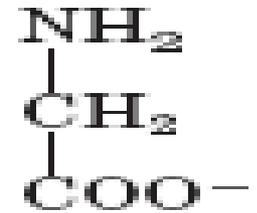
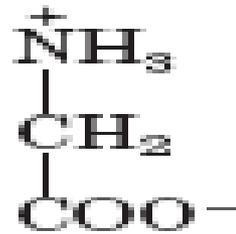
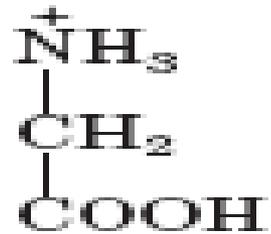
□ The pH at which amino acid bears the maximum total number of charge (the charge = the maximum total number) is known as (**pH**)

Lecture 4



Amino Acids Have Characteristic Titration Curves

Gly



Acidic pH
(pH < PI)
Cation

Neutral
(pH = PI)
Zwitter ion

Basic pH
(pH > PI)
Anion

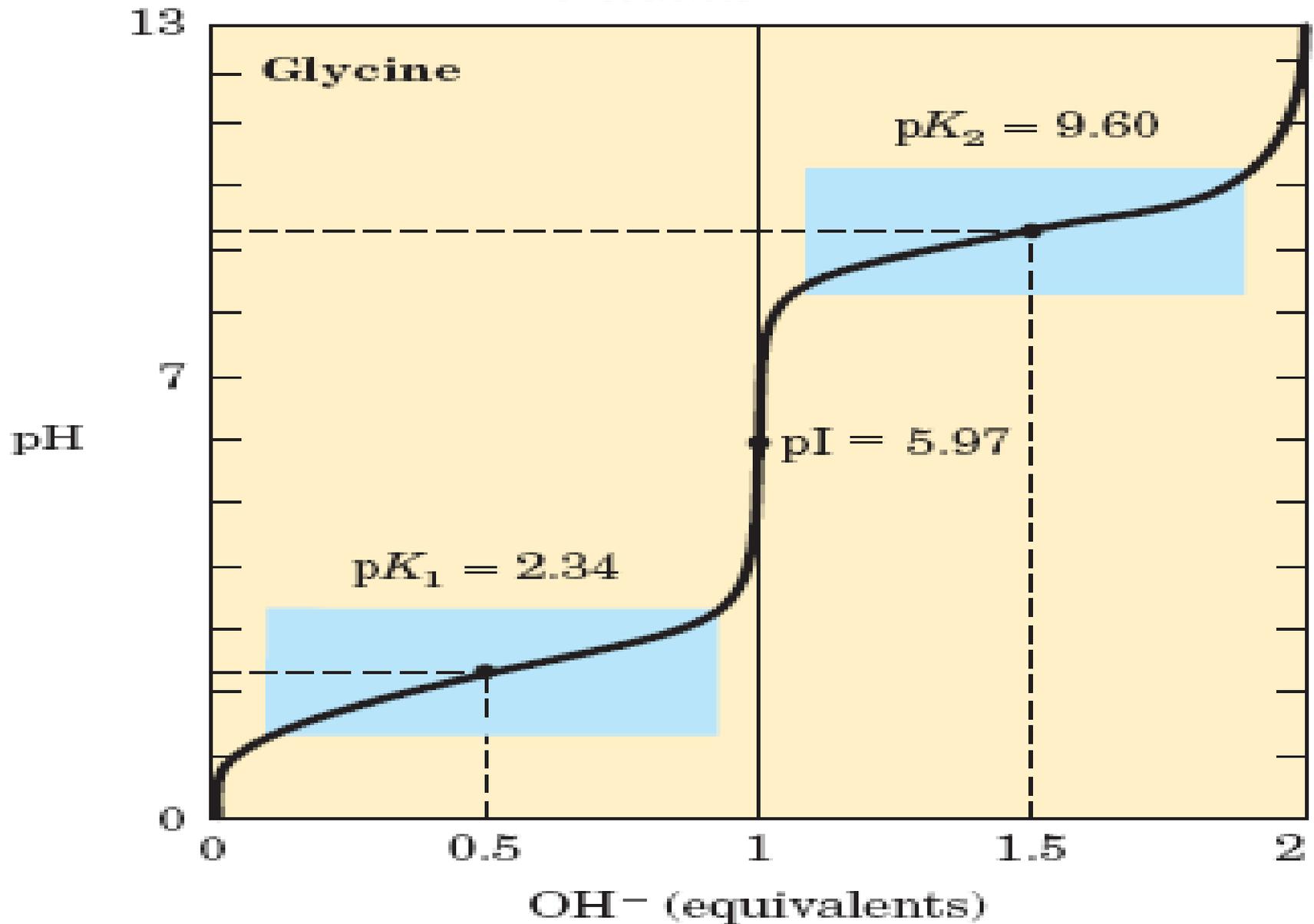
$$\text{PI} = \frac{\text{p}K_1 + \text{p}K_2}{2}$$

2

Gly	Leu	Phe
Ala	Ile	Trp
Val	Ser	Asn
Pro	Thr	Gln
	Met	

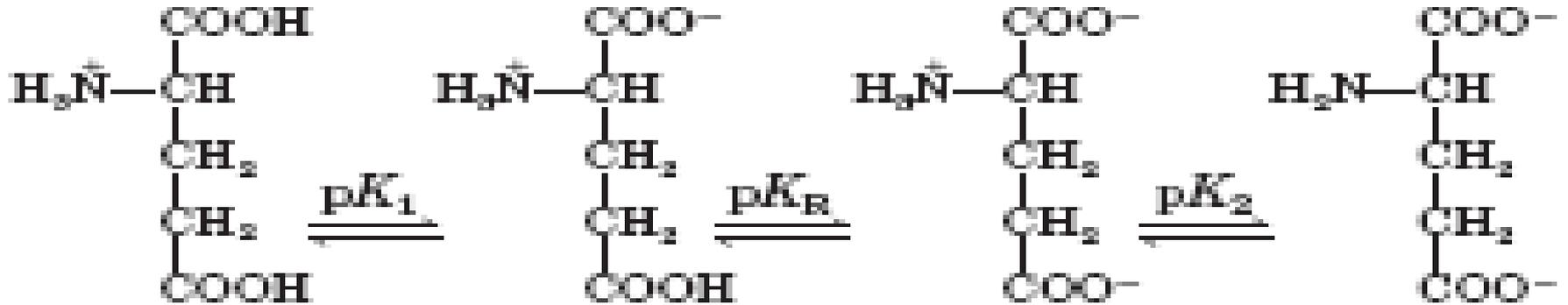
Amino Acids Have Characteristic Titration

Curves



Amino Acids Have Characteristic Titration Curves

Glu



Acidic pH
(pH < PI)
Cation (+1)

Neutral
(pH = PI)
Zwitter ion (0)

Basic pH
(pH > PI)
Anion (-1)

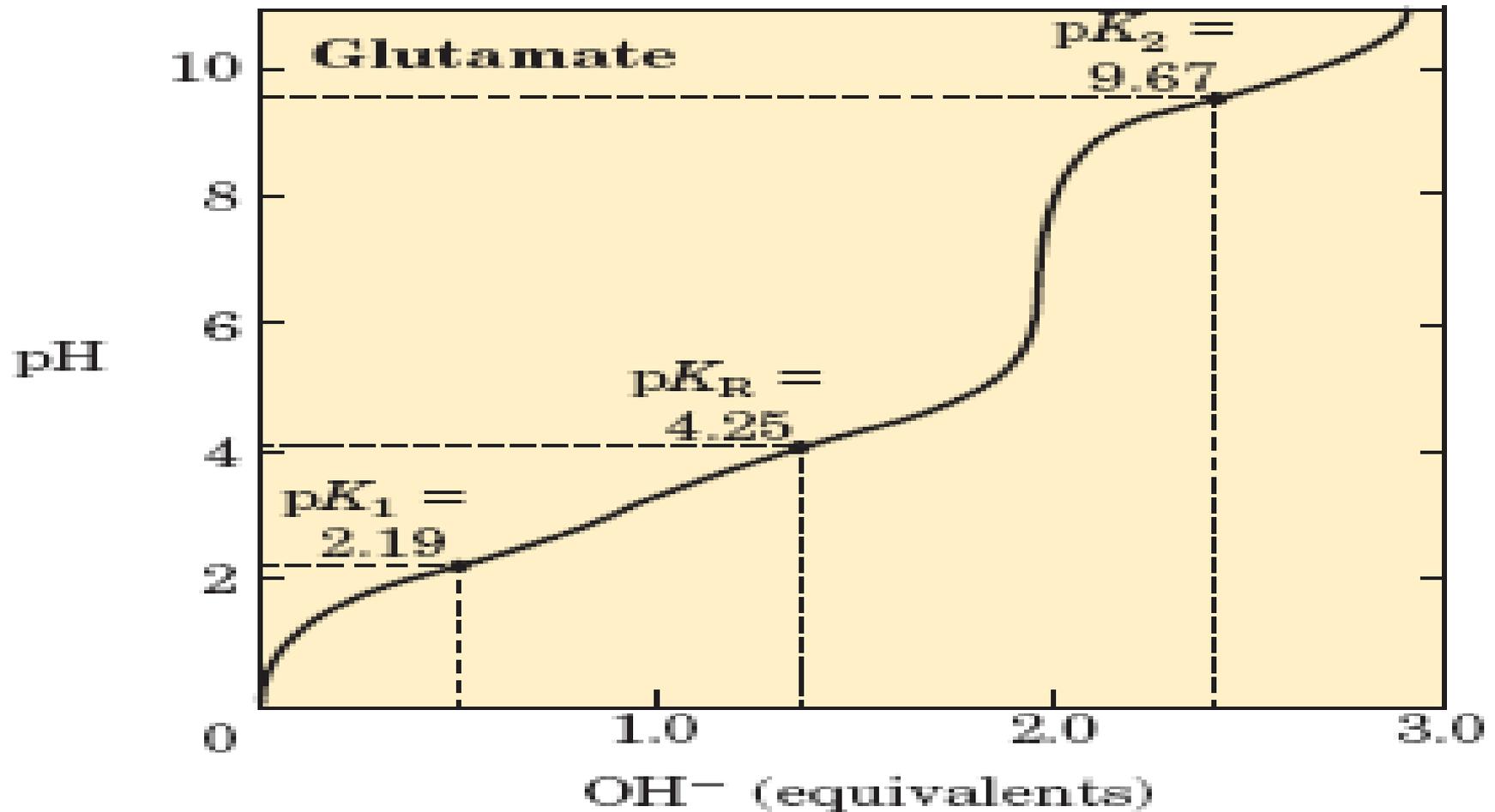
Basic pH
(pH > PI)
Anion (-2)

$$PI = \text{p}K_1 + \text{p}K_2 / 2$$

Asp
Glu

Cys
Tyr

Amino Acids Have Characteristic Titration Curves



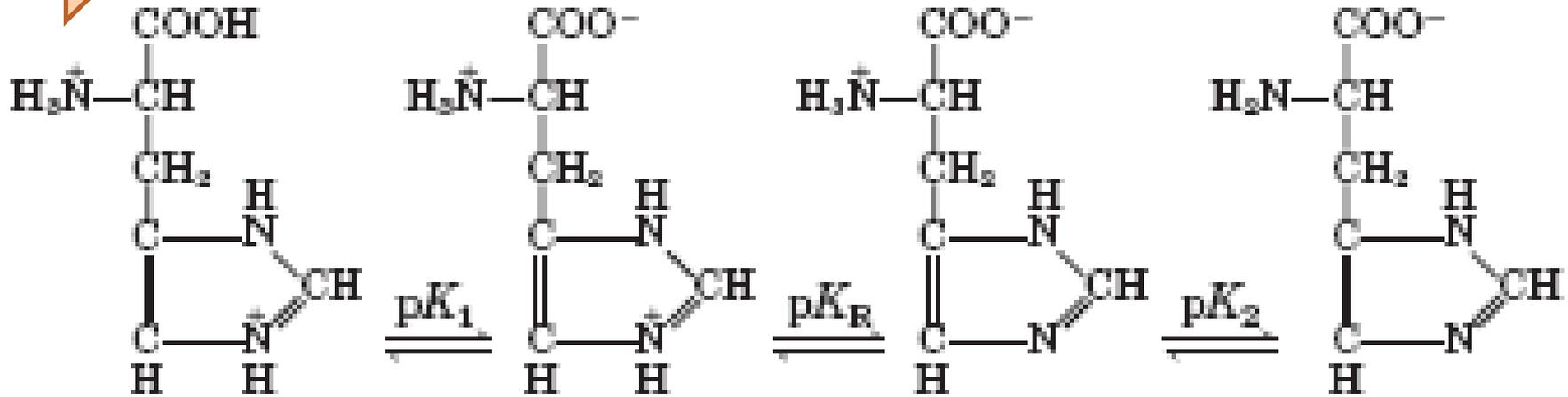
Asp , Glu , Cys

[$pK_R = pK_2$]



Amino Acids Have Characteristic Titration Curves

His



Acidic pH
(pH < PI)
Cation (+2)

Acidic pH
(pH < PI)
Cation (+1)

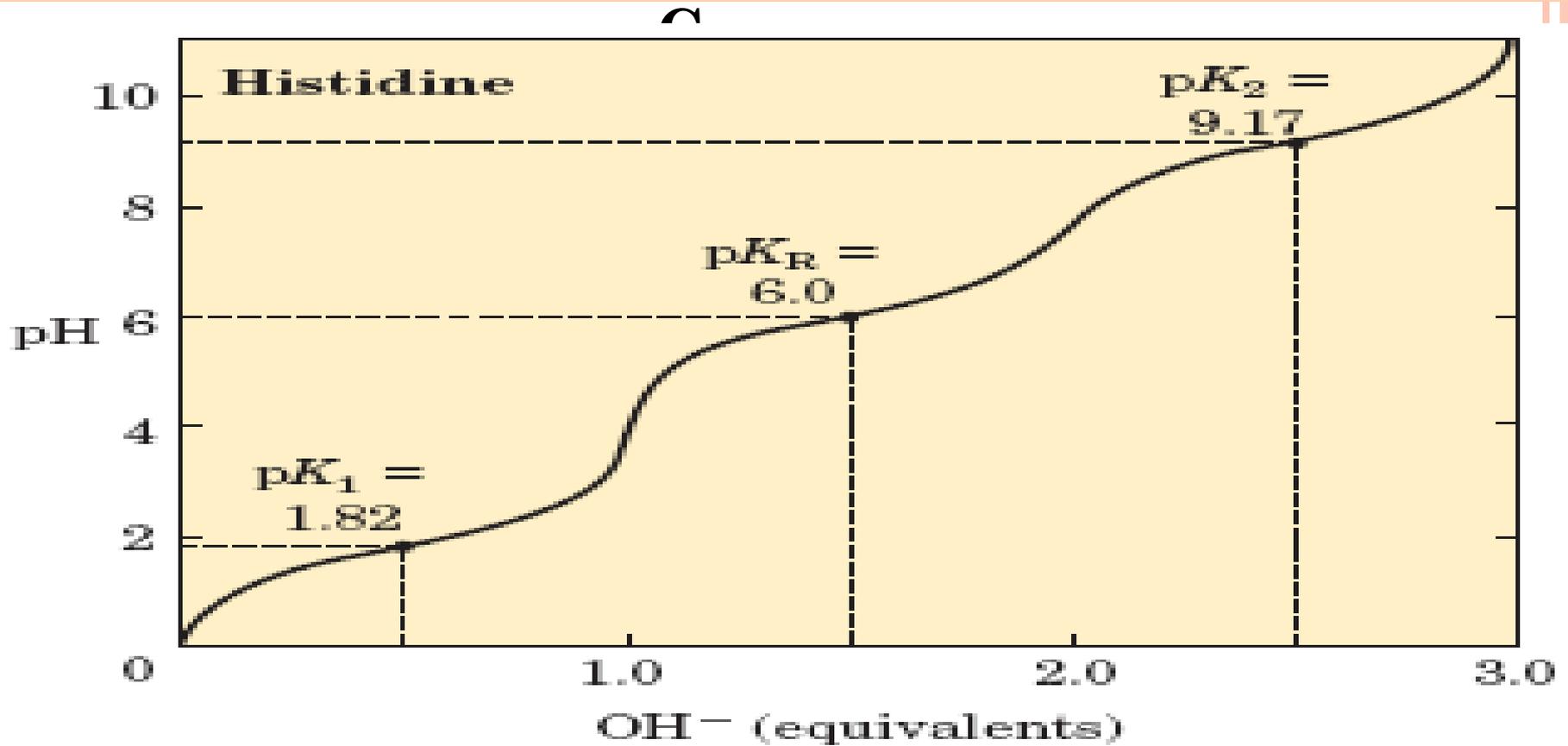
Neutral
(pH = PI)
Zwitter ion (0)

Basic pH
(pH > PI)
Anion (-1)

$$PI = PK_2 + PK_3 / 2$$

Lys
Arg
His

Amino Acids Have Characteristic Titration



Lys , Arg
[$\text{p}K_R = \text{p}K_3$]

His
[$\text{p}K_R = \text{p}K_2$]



Lecture 5



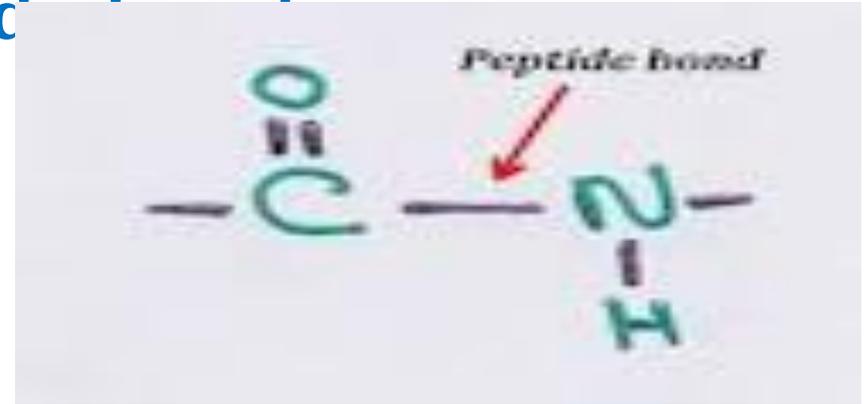
Peptides



Peptides

Peptides Are Chains of Amino Acids

The amino acid units can be covalently joined through a substituted amide linkage, termed a **peptide bond**, **acid amide**

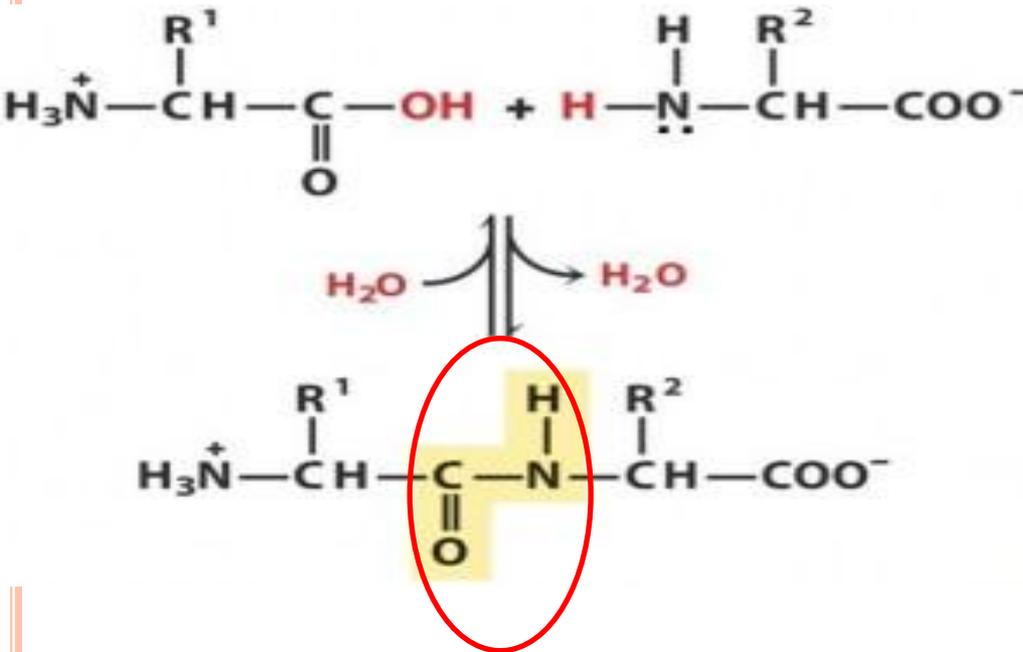


Each two amino acids can be joined by one peptide bonds to form;

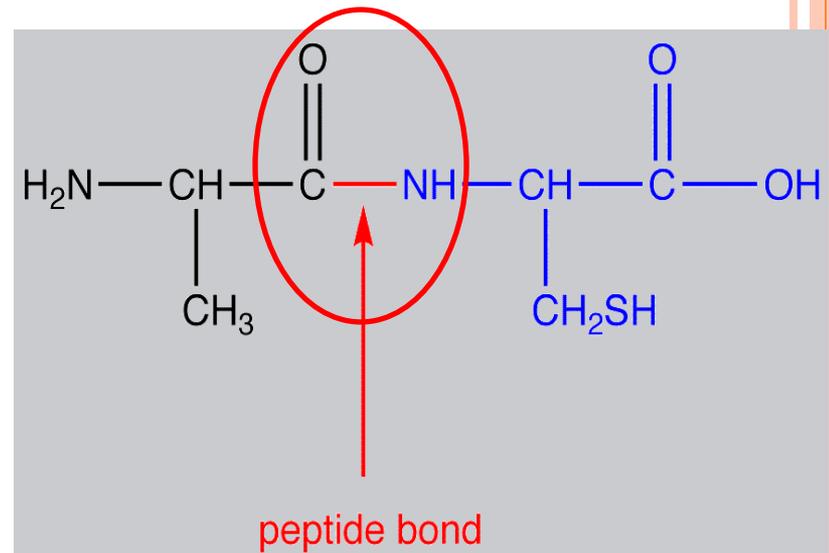
The part left over after losing a hydrogen atom from its amino group and the hydroxyl moiety from its carboxyl group

Peptides

Peptide bonds can be hydrolyzed by **proteolytic enzymes** called **proteases** or **peptidases**. Proteolytic enzymes are found in all cells and tissues



Ala-Cys



Depending on the number of amino acids molecules composing a chain, the peptide may be termed as a:

Dipeptide (containing 2 amino acids units),

Gly-Phe

Tripeptide (containing 3 amino acids units),

Pro-Met-Asp and so on

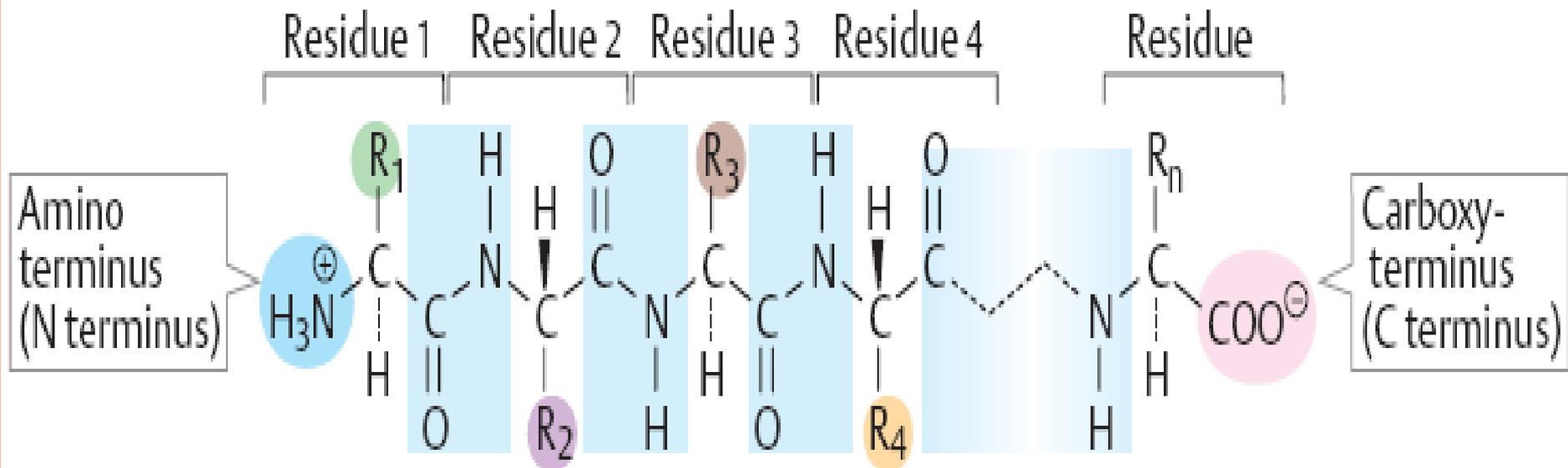
Tetrapeptides (4 a.a),

pentapeptides (5 a.a),



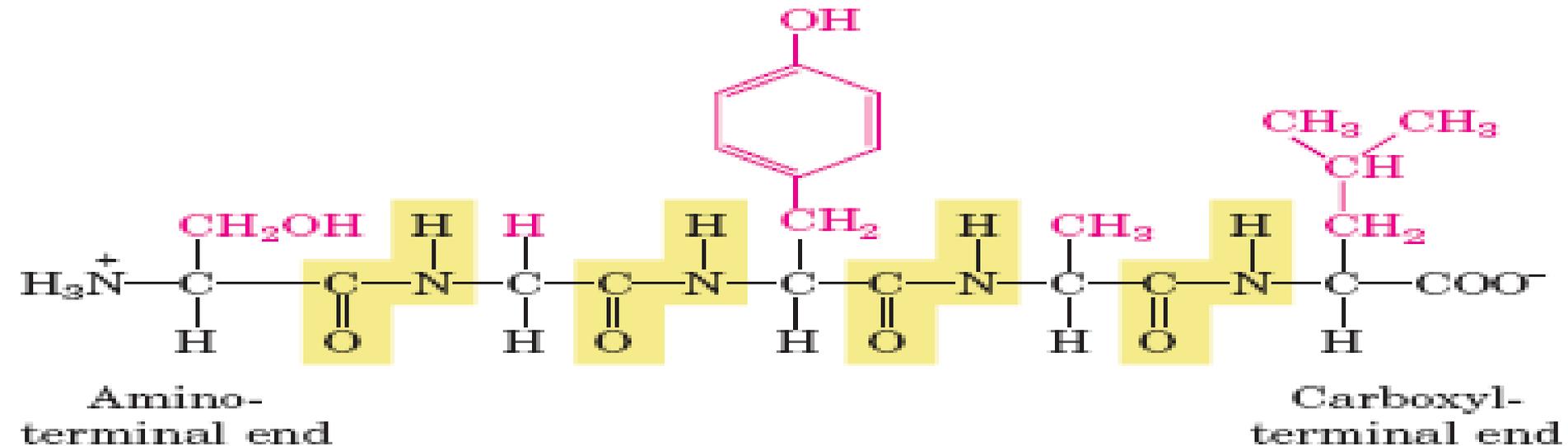
In a peptide, the amino acid residue at the end with a free α -amino group is the **amino-terminal** (or **N-terminal**) residue;

The residue at the other end, which has a free carboxyl group, is the **carboxyl-terminal** (or **C-terminal**) residue.



Peptides are named beginning with the *N*-terminal residue (at the left of the structure), then moving from left to right, the names of all amino acid residues (**except** the last one, i.e. the C-terminal residue) are written by adding the suffix *-yl* because

all these are the **acyl groups**



Ser-Gly-Tyr-Ala-Leu \rightarrow

pentapeptide

[serylglycyltyrosylalanylleucine]

Peptides

Oligopeptide

not more than 10
amino acids units

Polypeptide

more than 10 amino
acids units

polypeptides generally
have molecular
weights below 10,000



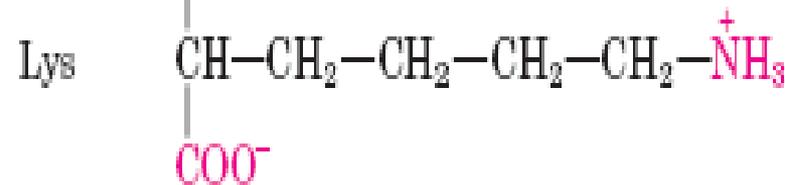
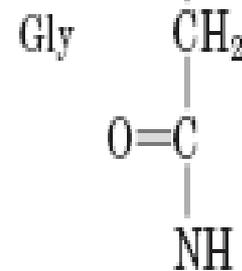
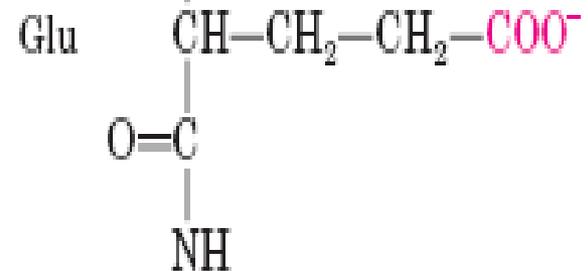
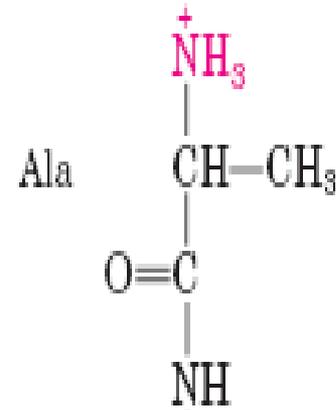
Protein

have higher molecular
weights

Ionization Behavior of Peptides

Peptides contain only **one** free α -amino group and **one** free α -carboxyl group, at opposite ends of the chain. These groups ionize as they do in free amino acids, although the ionization constants are different because an oppositely charged group is no longer linked to the α -carbon.

The α -amino and α -carboxyl groups of all non-terminal amino acids are covalently joined in the peptide bonds, which do not ionize and thus do not contribute to the total acid-base behavior of peptides. However the R groups of some amino acids can ionize, and in a peptide these contribute to the overall acid-base

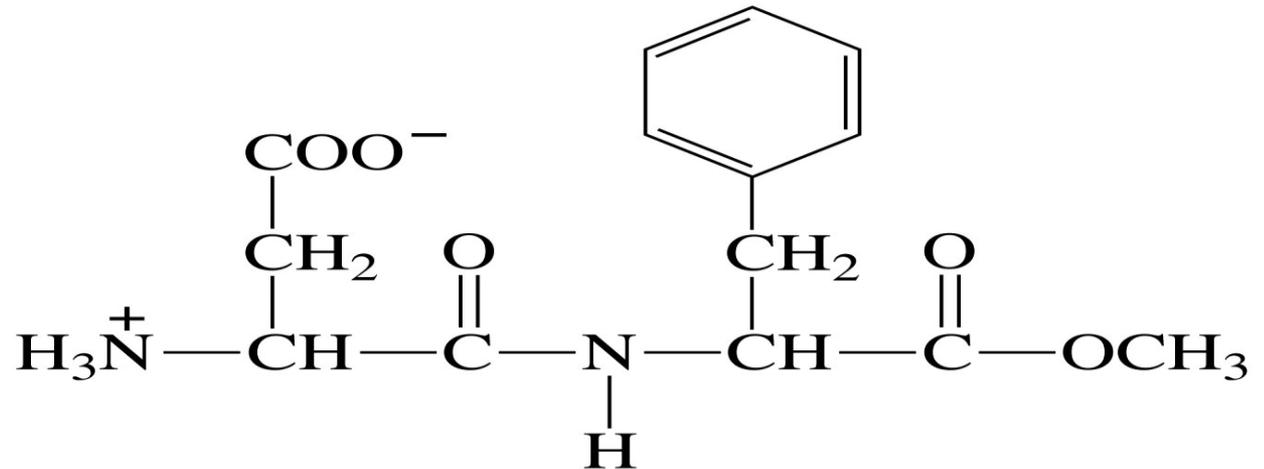


Biologically Active Peptides

Naturally occurring peptides range in length from two to many thousands of amino acid residues.

Even the smallest peptides can have biologically important effects. One of the smallest sized **Dipeptide**

L-aspartyl-L-phenylalanine methyl ester, the artificial sweetener better known as **Aspartame** or **NutraSweet**.



L-Aspartyl-L-phenylalanine methyl ester
(aspartame)

Biologically Active Peptides

❖ **Gastrin:** it is a local peptide hormone produced by stomach (the gastric mucosa), its secretion is stimulated by entry of dietary protein into the stomach, it stimulates the gastric juice.

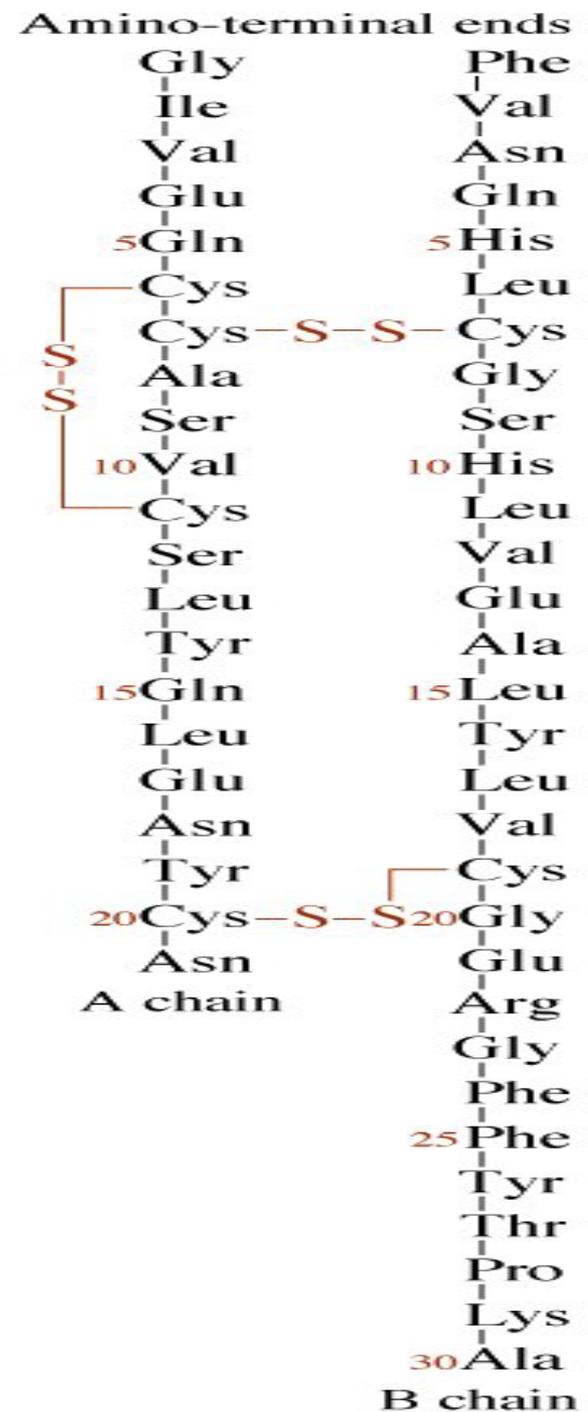
❖ **Enkephalins:** is a pentapeptide (5 amino acid residues)

Tyr—Gly—Gly—Phe—Leu
Leucine enkephalin

Tyr—Gly—Gly—Phe—Met
Methionine enkephalin

Biologically Active Peptides

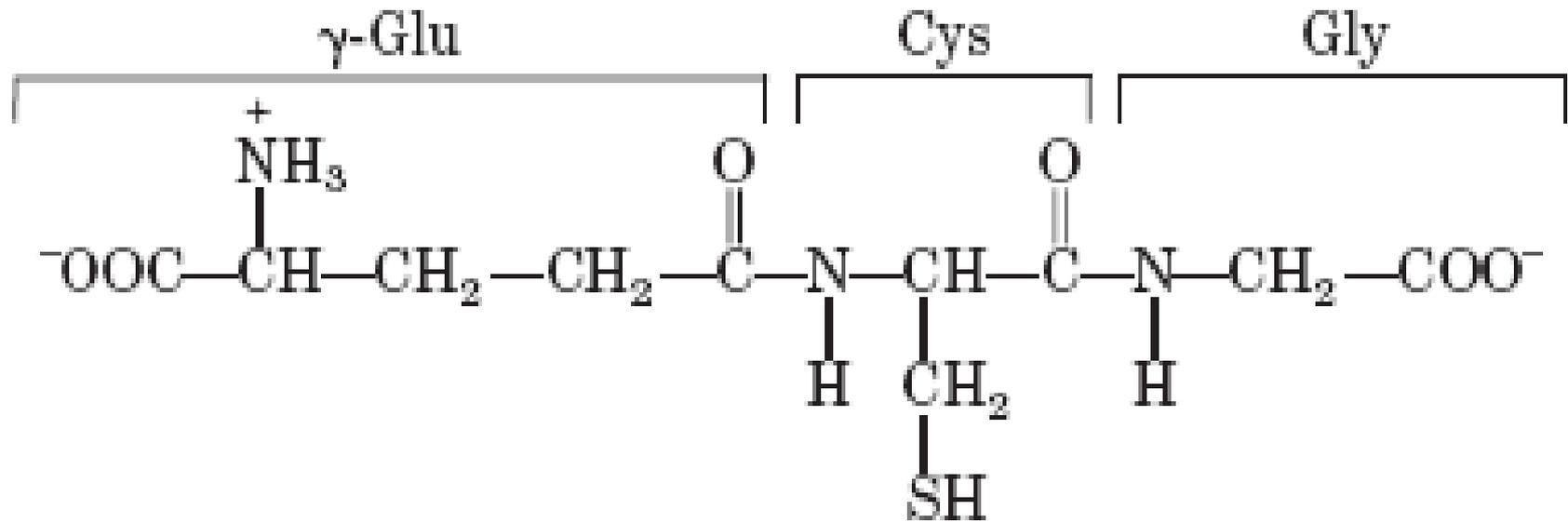
❖ **Insulin:** the pancreatic peptide hormone, which contains **two polypeptide** chains, one having 30 amino acid residues and the other 21, which are linked together by disulfide bonds.



Biologically Active Peptides

Glutathione (GSH): It is a tripeptide (3 amino acid residues), which derived from **glycine**, **glutamate**, and **cysteine**.

GSH characterized by its **γ-peptide** bond (between glutamate, and cysteine), which is not attacked by peptidase), present in plants, animals, and some bacteria, often at high levels, it is found in all mammalian cell except the neurons.



Glutathione (GSH)
(reduced)

Biologically Active Peptides

The oxidized form of glutathione (**GSSG**), produced in the course of its redox activities, contains two glutathione molecules linked by a disulfide bond

γ -Glu—Cys—Gly



γ -Glu—Cys—Gly

Glutathione (GSSG)
(oxidized)



Lecture 6



Nucleic Acid



Nucleic Acid



Nucleic acids are macromolecules that store, transmit and express the genetic information of a cell, which present in all living cells in combination with proteins to form **nucleoproteins**.

Nucleic acids are polymers of a specific sequence of subunits or monomers called **nucleotides**. They are therefore called **polynucleotides**

Nucleic Acid

Two types of nucleic acid are found

a- Deoxyribonucleic acid (DNA)

DNA is found in the nuclei with small amounts in mitochondria and chloroplasts

b- Ribonucleic acid (RNA)

RNA is found in cell cytoplasm (90%) and the nucleolus (10%)



Nucleic Acid

Components of Nucleic acids

Nucleic acids are made up of three chemical units:

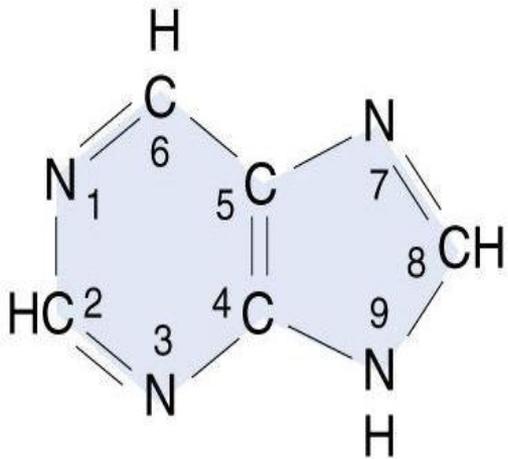
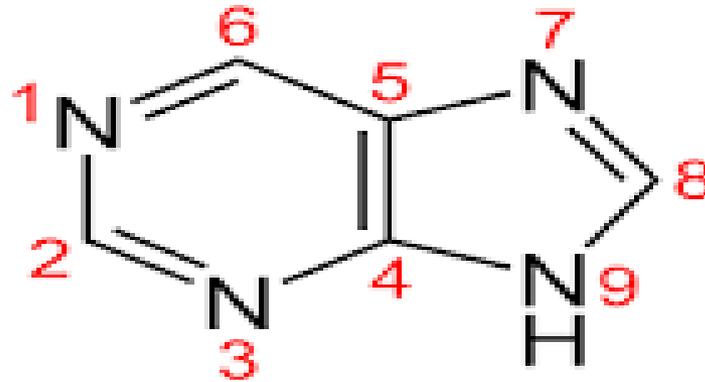
- i) Nitrogenous base [purines or pyrimidines]
- ii) Pentose sugar [ribose or deoxyribose]
- iii) Phosphoric acid



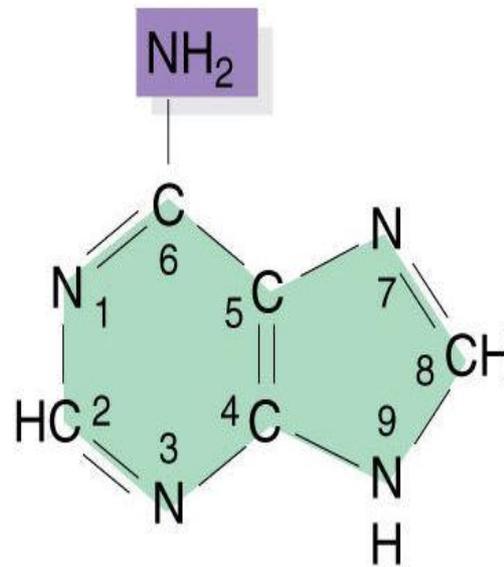
Nitrogenous Bases

PURINES

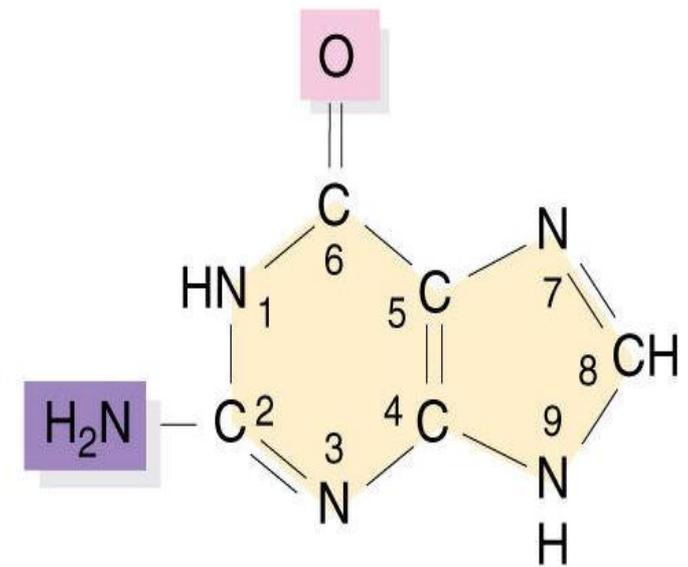
Purine ring



Purine



Adenine (A)

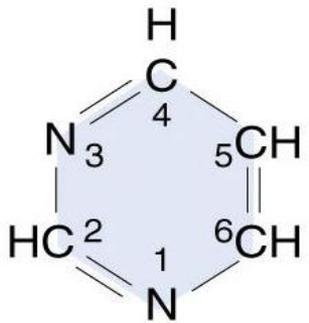
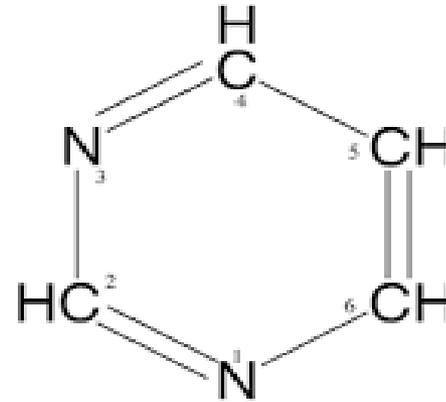


Guanine (G)

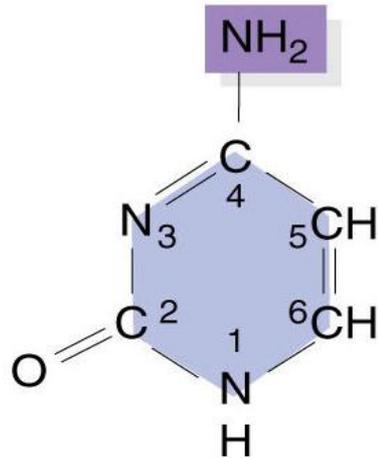
Nitrogen Bases

PYRIMIDINES

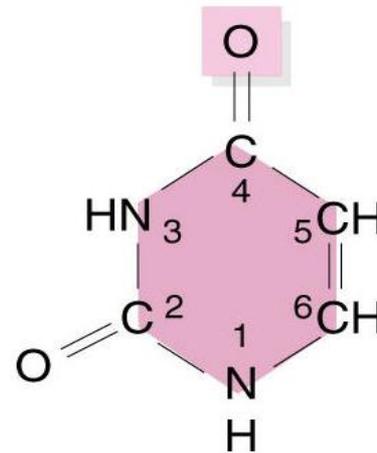
Pyrimidine ring



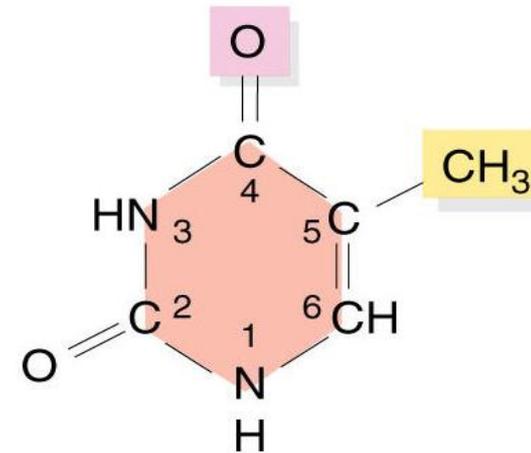
Pyrimidine



Cytosine (C)



Uracil (U)
(found in RNA)

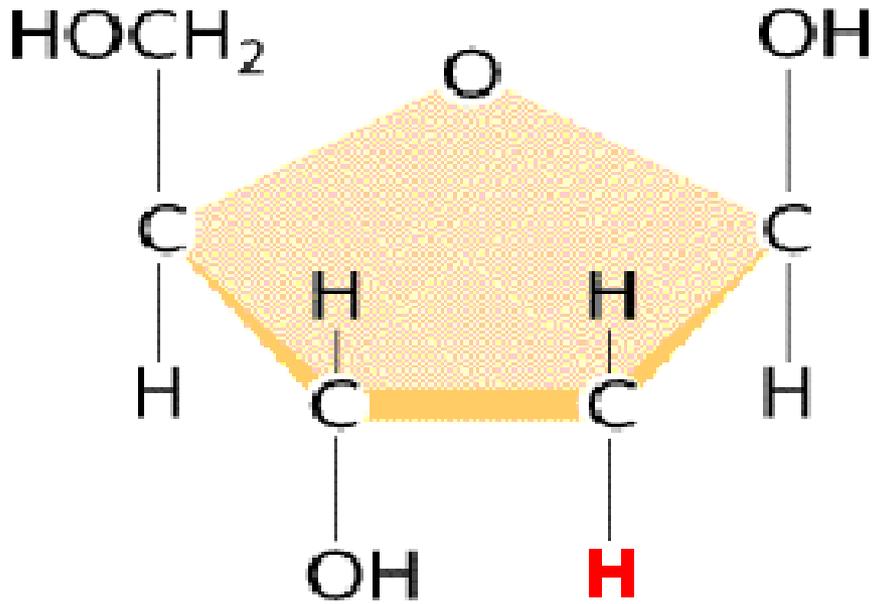


Thymine (T)
(found in DNA)

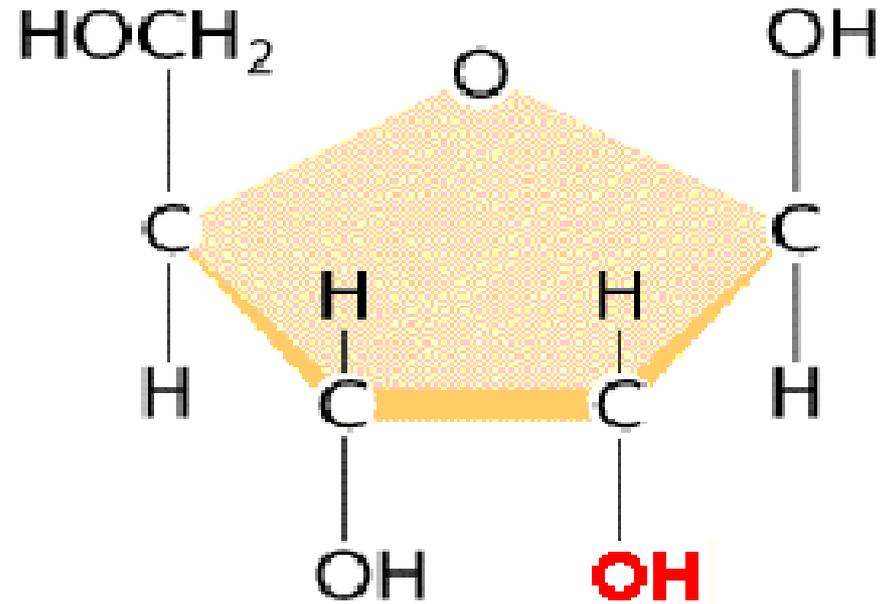
DNA contain
A, G, C, **T**

RNA contain
A, G, C, **U**

SUGARS



2-Deoxyribose



Ribose

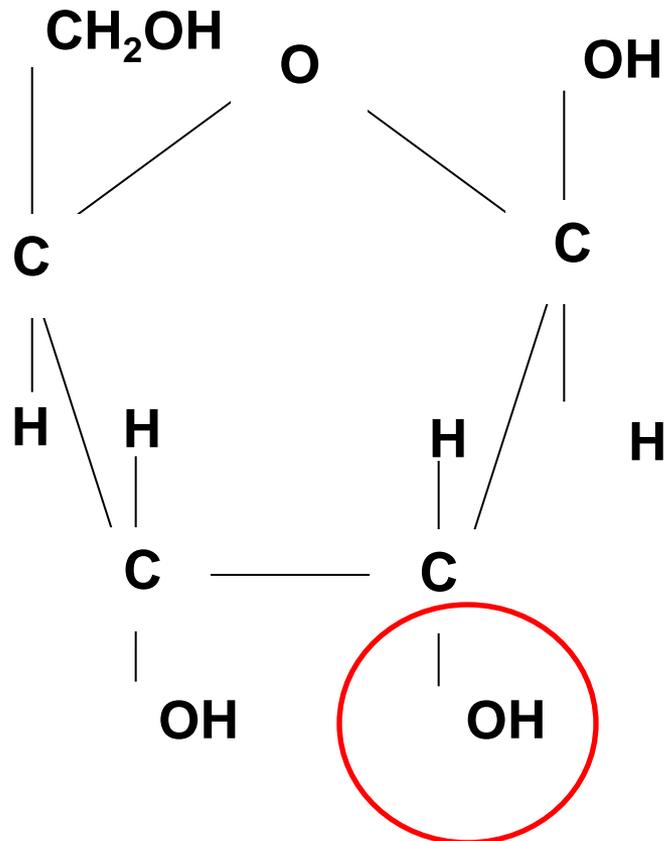
DNA contain
 β -D-2-Deoxyribose

RNA contain
 β -D-Ribose

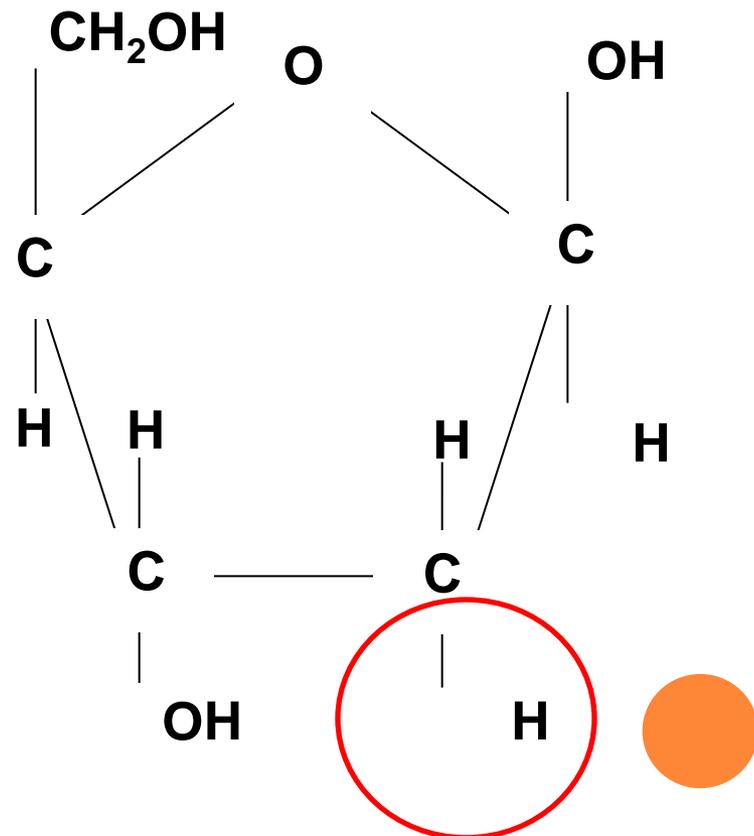
SUGARS

SPOT THE DIFFERENCE

RIBOSE



DEOXYRIBOSE





Nucleosides consist of:

- 1. Nitrogen base purine or pyrimidine**
- 2. Sugar (β -D-Ribose and β -D-2-**

Nucleotides are phosphorylated Nucleosides

- Nucleosides: Nitrogen bases + Sugar**
- Nucleotides: Nitrogen bases + Sugar + Phosphate group**

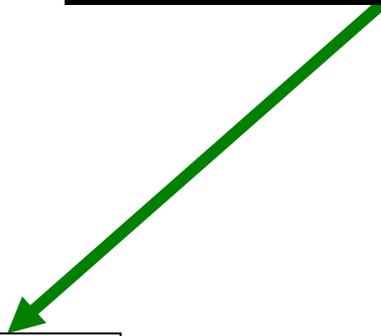
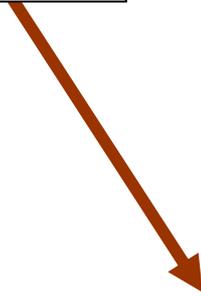
Nucleoside Structure

SUGAR
Ribose or
Deoxyribose

BASE	
PURINES	PYRIMIDINES
Adenine (A) Guanine (G)	Cytocine (C) Thymine (T) Uracil (U)

NUCLEOSIDE

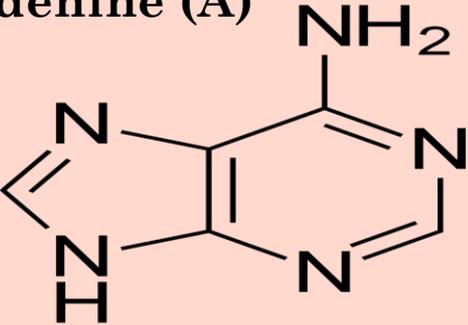
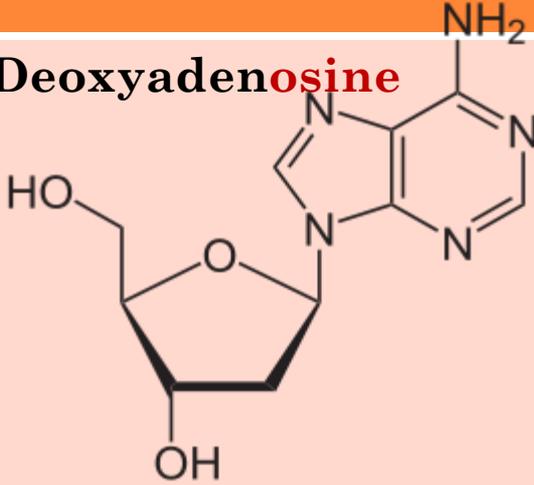
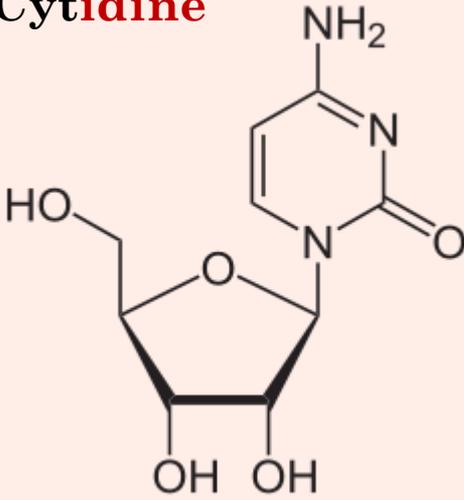
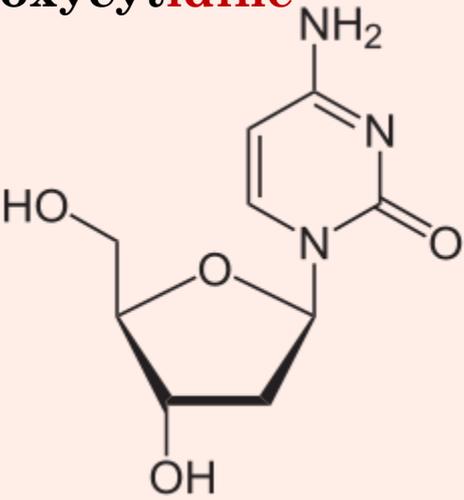
**β -N-glycosidic
bond**



Nucleoside

Base	Ribonucleoside	Deoxyribonucleoside
Adenine (A)	Adenosine	Deoxyadenosine
Guanine (G)	Guanosine	Deoxyguanosine
Uracil (U)	Uridine	Deoxyuridine
Cytosine (C)	Cytidine	Deoxycytidine
Thymine (T)	Thymidine	Deoxythymidine

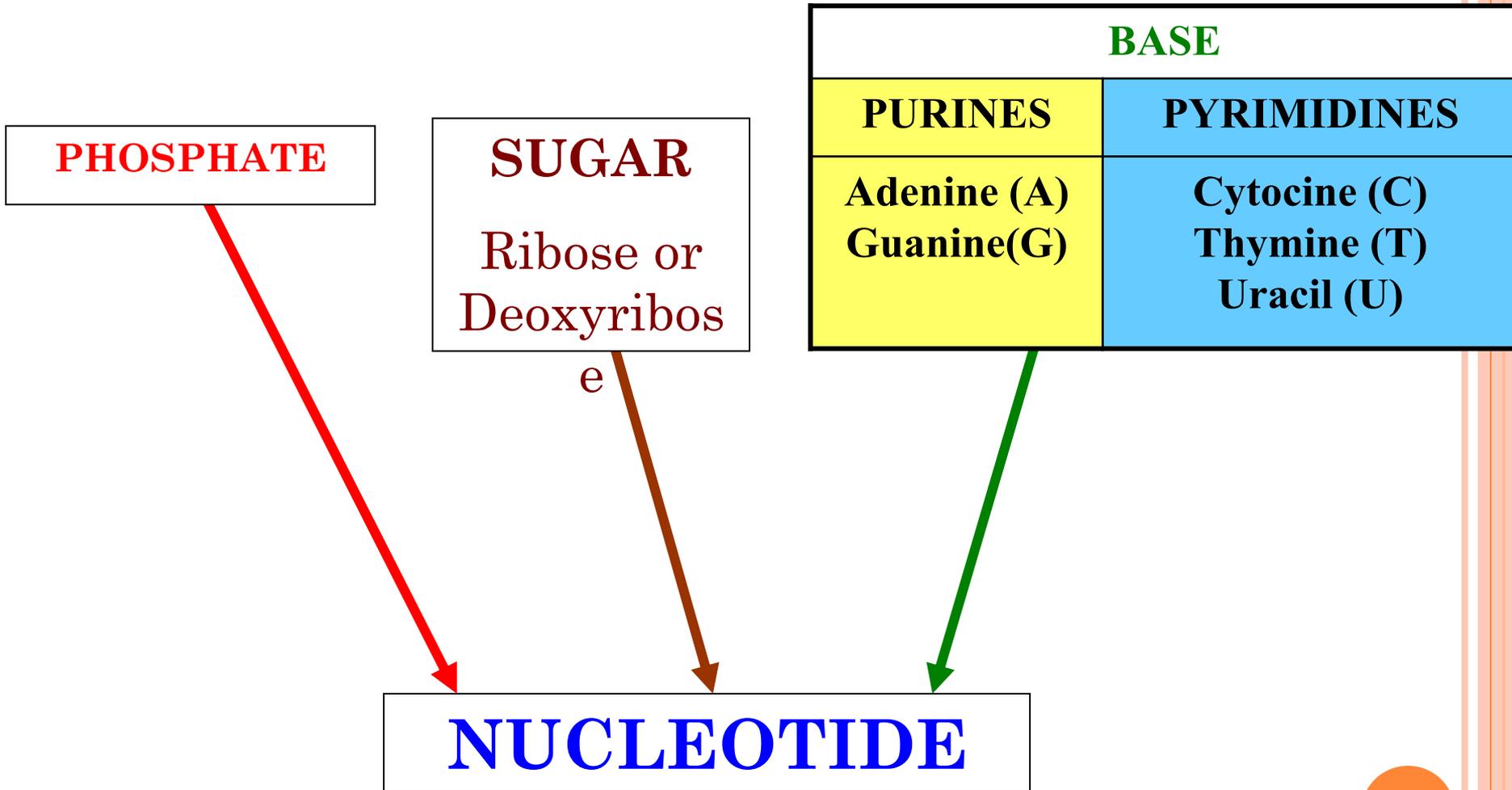
Nucleoside Structure

Nitrogenous base	Ribonucleoside	Deoxyribonucleoside
<p data-bbox="79 362 374 411">Adenine (A)</p>  <chem data-bbox="123 386 591 711">NC1=NC=NC2=C1N=CN2</chem>	<p data-bbox="668 362 935 411">Adenosine</p>  <chem data-bbox="672 297 1205 782">NC1=NC=NC2=C1N=CN2[C@@H]3O[C@H](CO)[C@@H](O)[C@H]3O</chem>	<p data-bbox="1259 362 1680 411">Deoxyadenosine</p>  <chem data-bbox="1278 311 1812 796">NC1=NC=NC2=C1N=CN2[C@@H]3O[C@H](CO)[C@@H](O)[C@H]3O</chem>
<p data-bbox="79 858 388 906">Cytosine (C)</p>  <chem data-bbox="142 953 506 1335">NC1=NC(=O)NC=C1</chem>	<p data-bbox="668 858 890 906">Cytidine</p>  <chem data-bbox="683 878 1147 1378">NC1=NC(=O)NC=C1[C@@H]2O[C@H](CO)[C@@H](O)[C@H]2O</chem>	<p data-bbox="1259 858 1630 906">Deoxycytidine</p>  <chem data-bbox="1336 892 1800 1392">NC1=NC(=O)NC=C1[C@@H]2O[C@H](CO)[C@@H](O)[C@H]2O</chem>

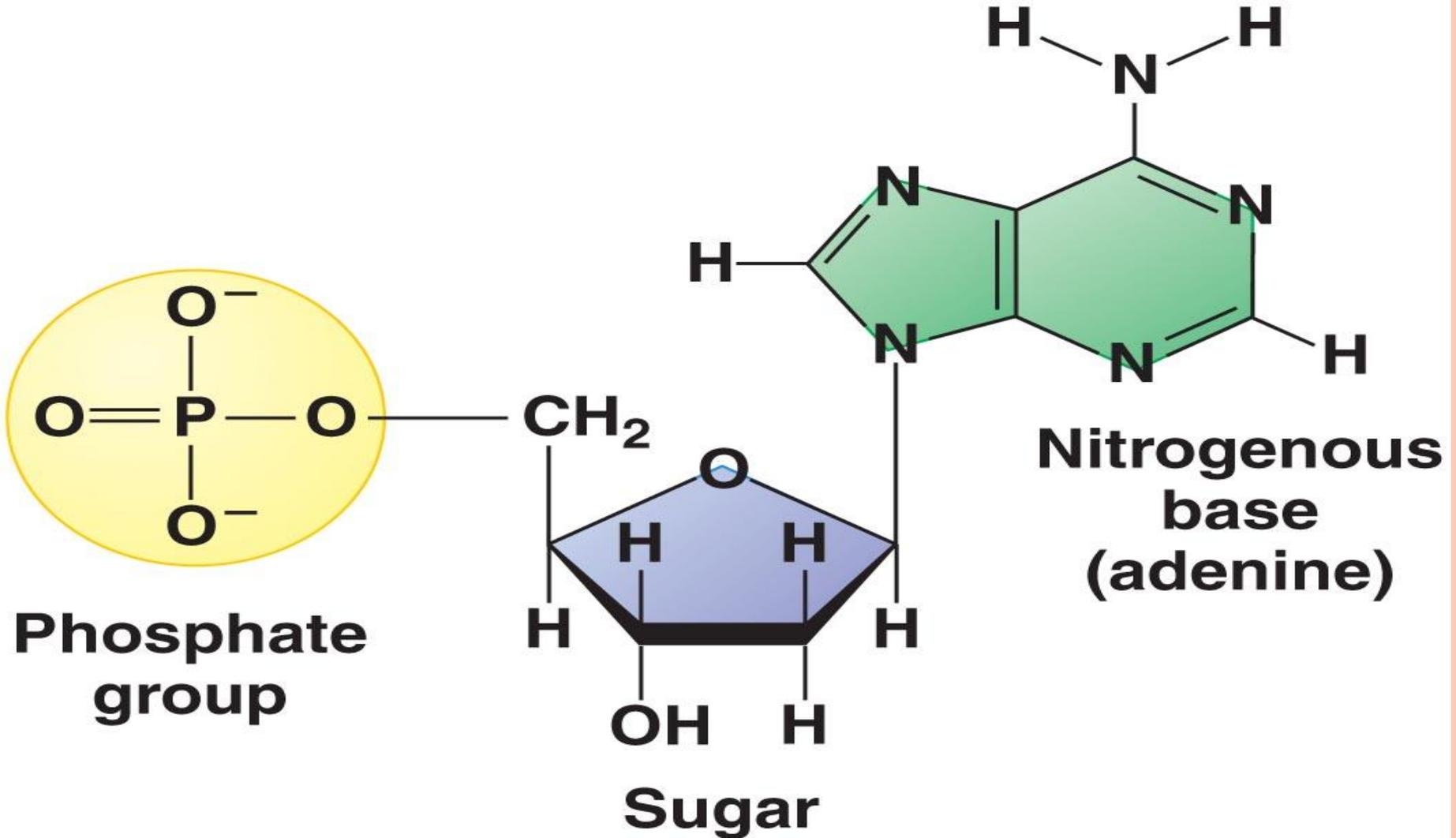
Lecture 7



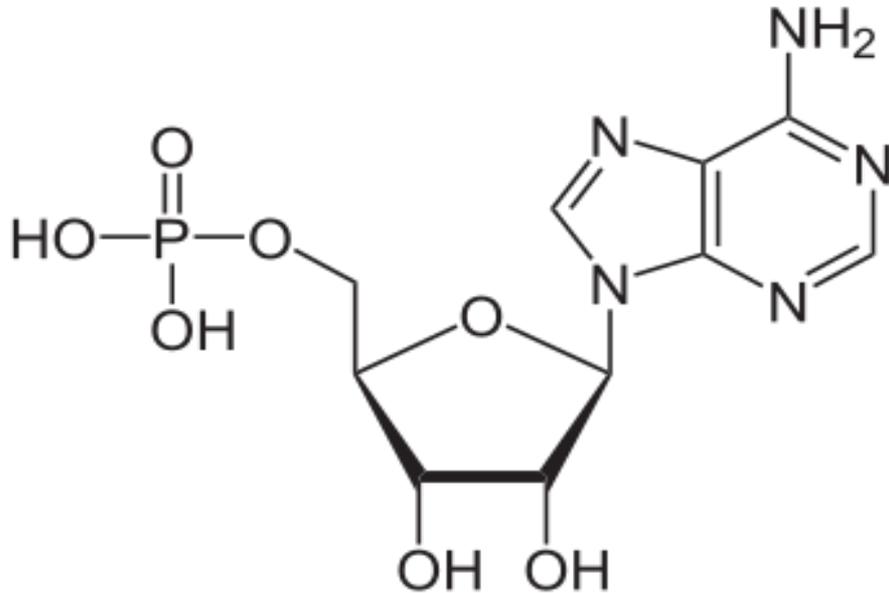
Nucleotide Structure



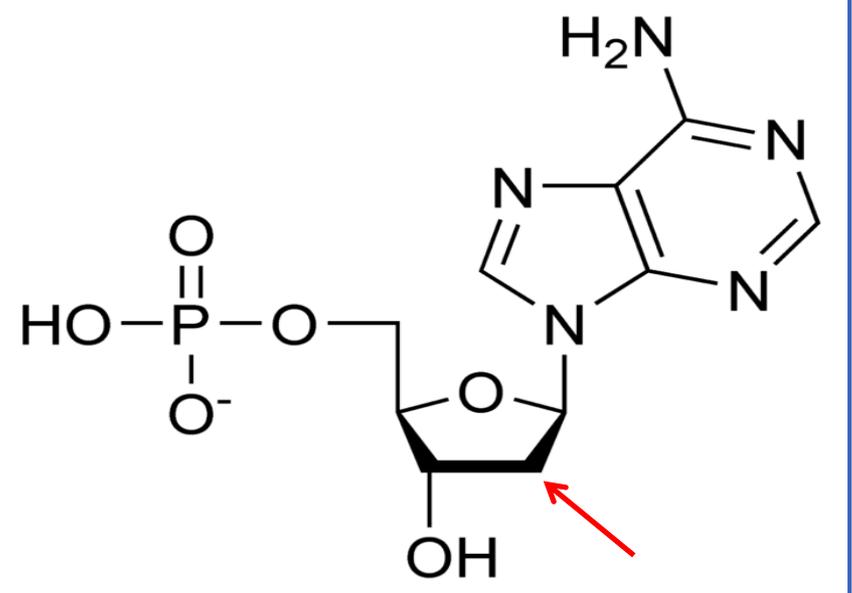
NUCLEOTIDE



Nucleotide Structure



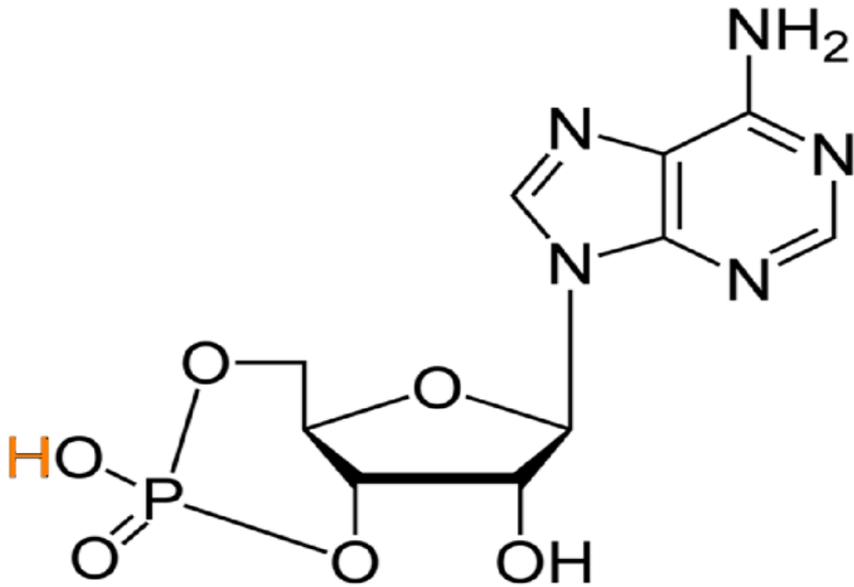
**Adenosine
Monophosphate
(AMP)**



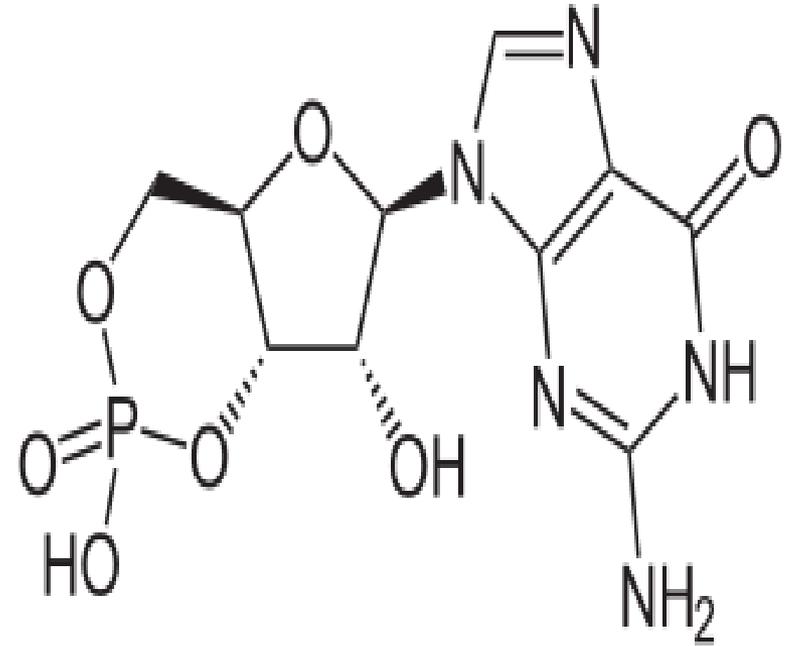
**Deoxyadenosine
Monophosphate
(dAMP)**



Cyclic AMP or GMP



c-AMP

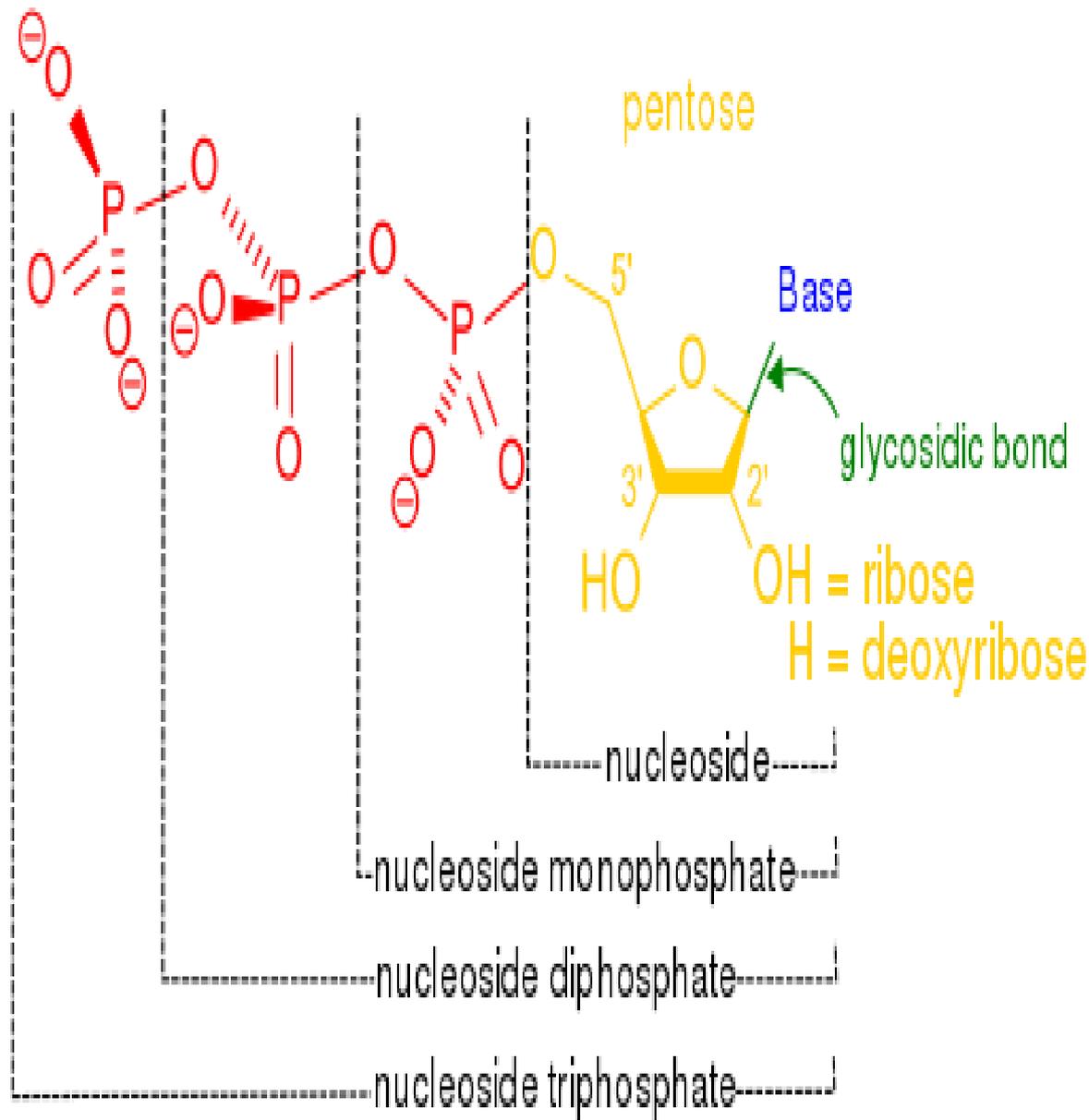


c-GMP

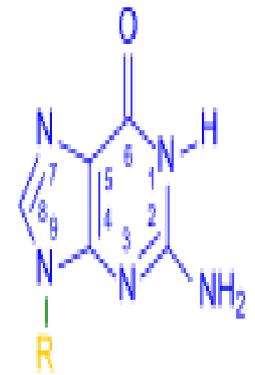
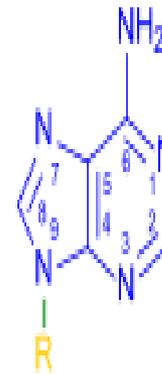
NAD⁺ = Nicotinamide Adenine Dinucleotide

FAD⁺ = Flavin Adenine Dinucleotide





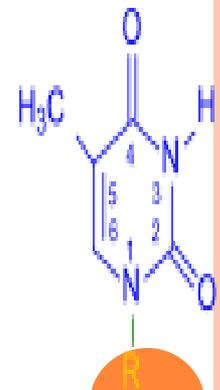
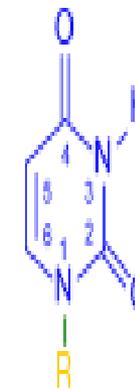
Purines



Adenine

Guanine

Pyrimidines



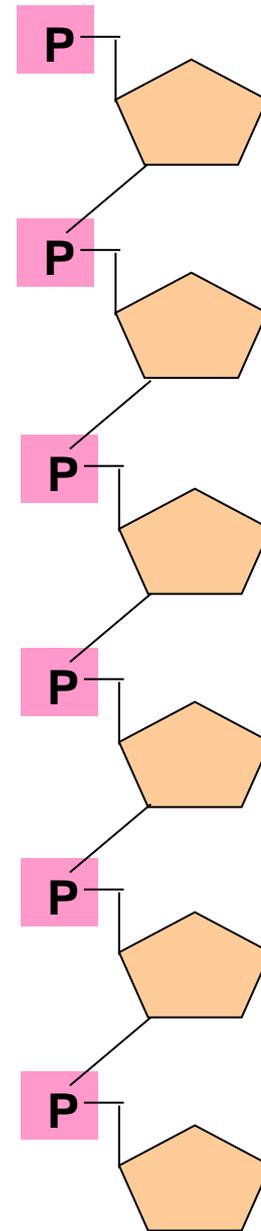
Cytosine

Uracil

Thymine

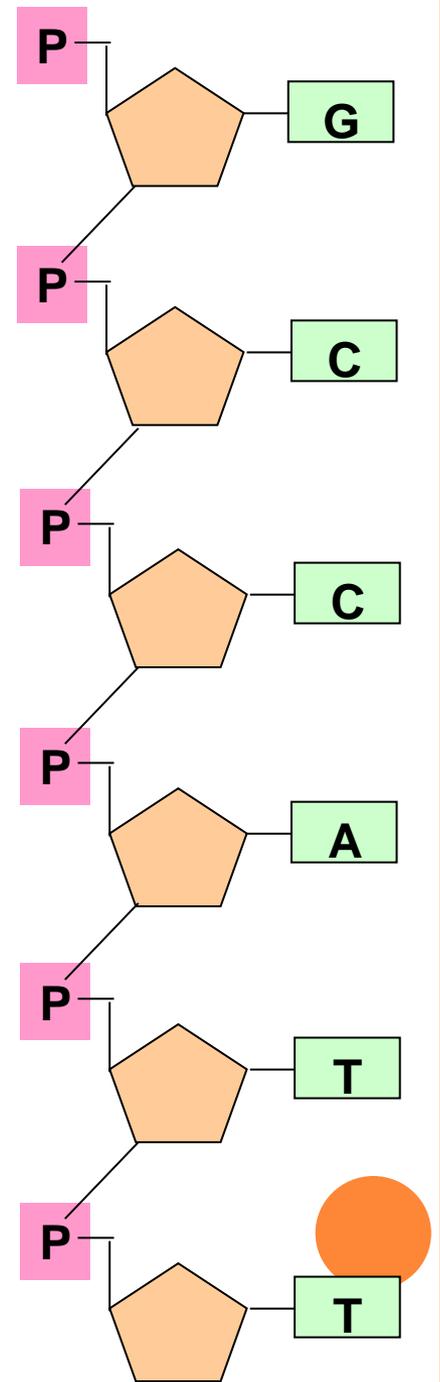
THE SUGAR-PHOSPHATE BACKBONE

- The nucleotides are all orientated in the same direction
- The phosphate group joins the 3rd Carbon of one sugar to the 5th Carbon of the next in line.



ADDING IN THE BASES

- The bases are attached to the 1st Carbon
- Their order is important
It determines the genetic information of the molecule



DNA Structure and Function

DNA, abbreviation of **deoxyribonucleic acid**, organic chemical of complex molecular structure that is found in all prokaryotic and eukaryotic cells and in many viruses.

DNA codes genetic information for the transmission of inherited traits.

DNA serves as the genetic material for cells both prokaryotes and eukaryotes.



DNA Structure and Function

- DNA is located in the nucleus separated from cytoplasm by the nuclear membrane
- DNA present also in mitochondria (less than 0.1% of the total DNA)
- in chloroplasts of plants



Lecture 8



Primary Structure of DNA

Nucleotides are joined together through the phosphate group of one nucleotide connecting in an ester linkage to the OH group on the third carbon atom of the sugar unit of a second nucleotide, linked covalently by **3',5' phosphodiester bond**.

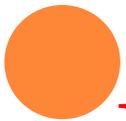
This unit joins to a third nucleotide, and the process is repeated to produce a long nucleic acid chain "Structure of a Segment of DNA".



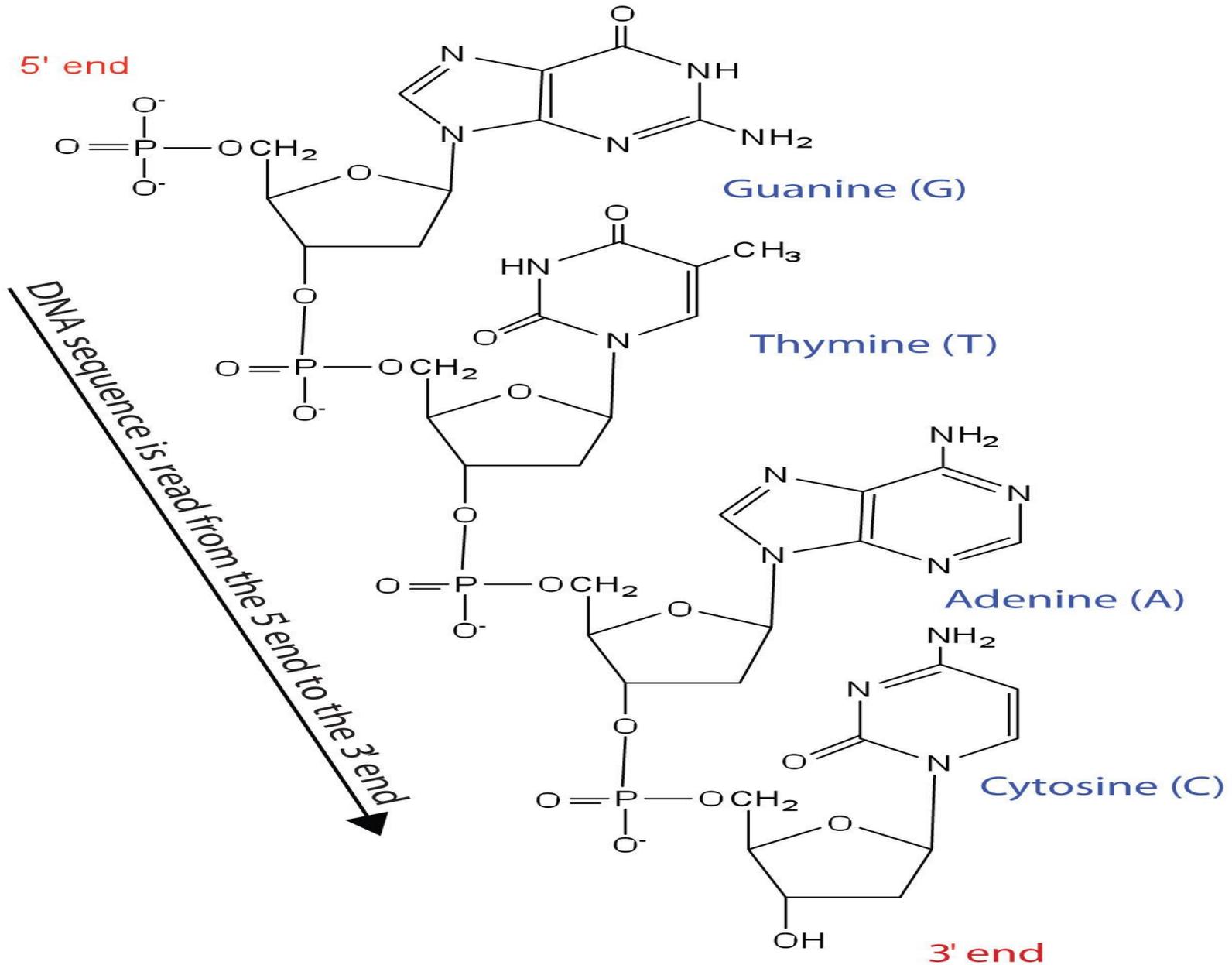
Primary Structure of DNA

The final nucleotide has a free OH group on the 3' carbon atom and is called the *3' end*. The sequence of nucleotides in the DNA segment would be written 5'-dG-dT-dA-dC-3', which is often further abbreviated to dGTAC or just GTAC.

DNA is negatively charged
macromolecule



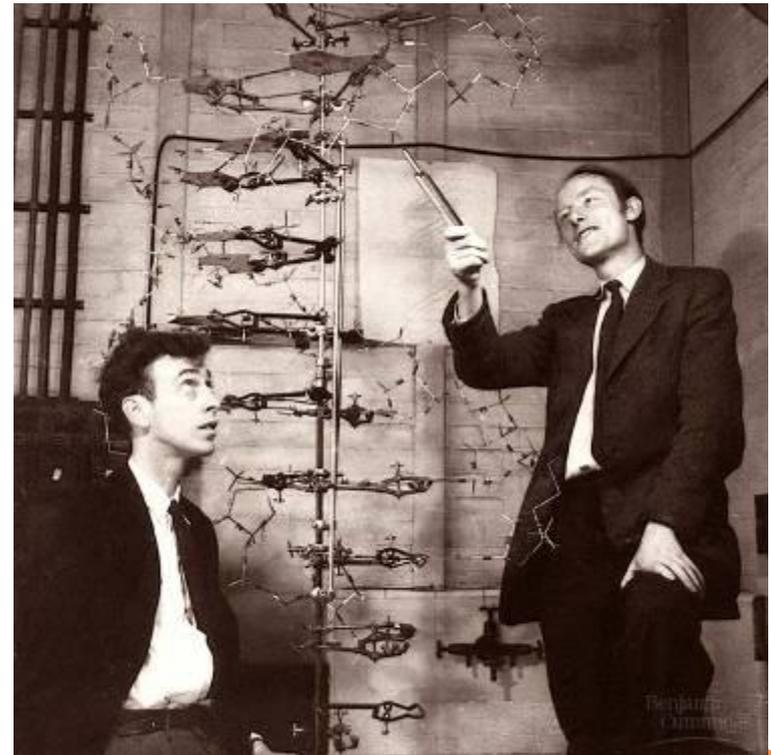
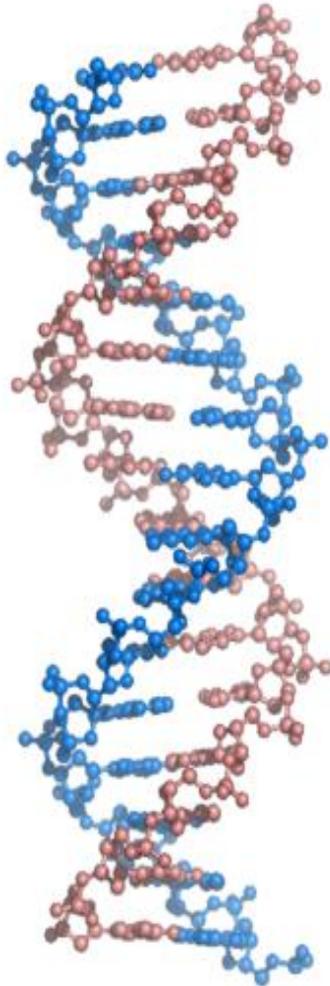
Primary Structure of DNA



Secondary Structure of DNA

THE DOUBLE HELIX (1953)

Watson and Crick model



Secondary Structure of DNA

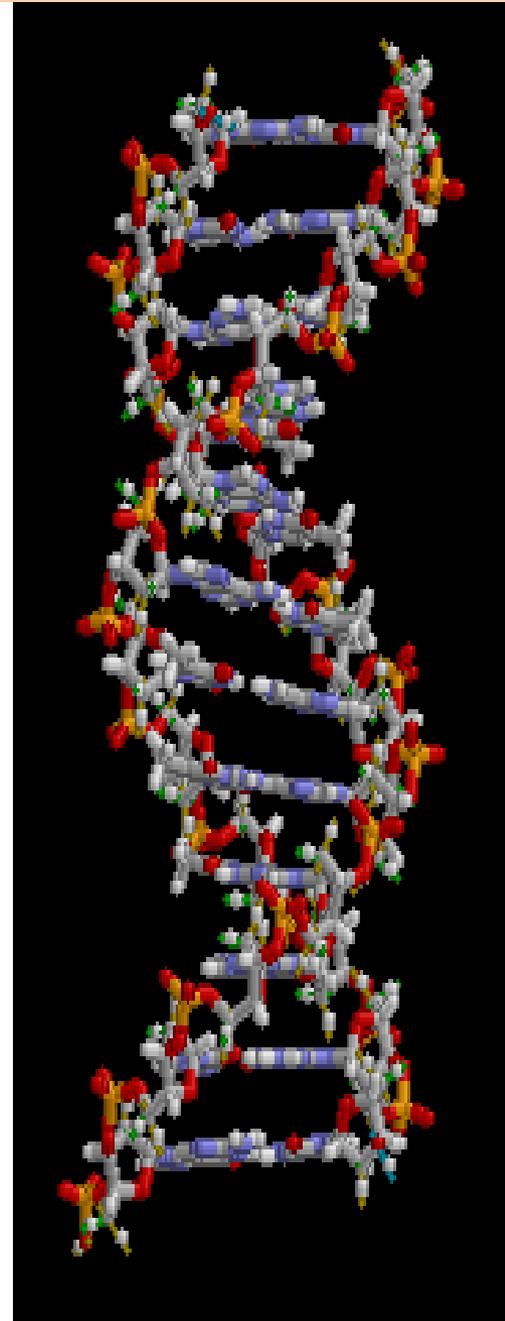
- The sister strands of the DNA molecule run in opposite directions (**antiparallel**)
- They are joined by the bases
- Each base is paired with a specific partner:

A is always paired with **T**
(two hydrogen bonds)

G is always paired with **C**
(three hydrogen bonds)

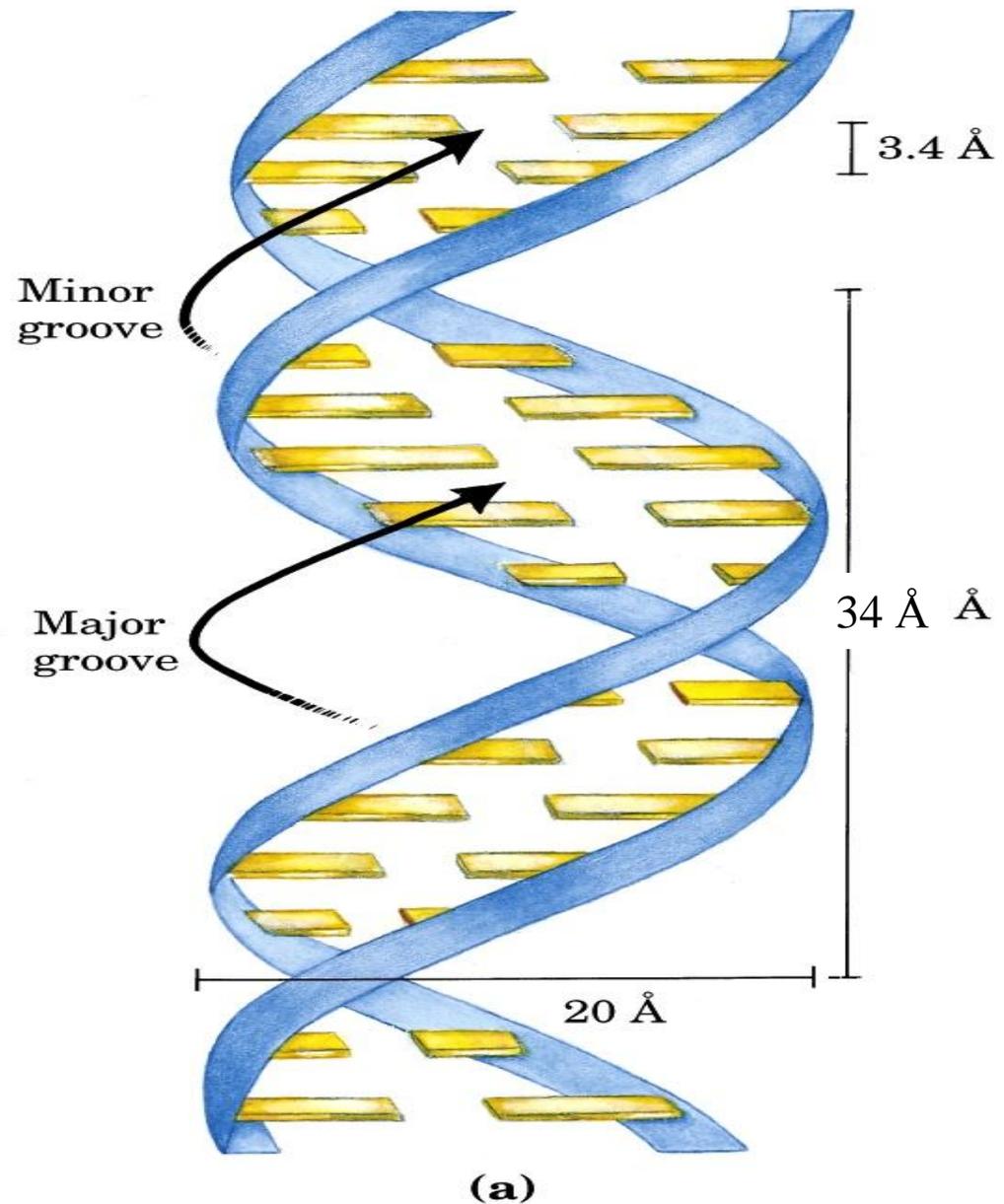
Purine with Pyrimidine

- Thus the double strands are **complementary** but not identical



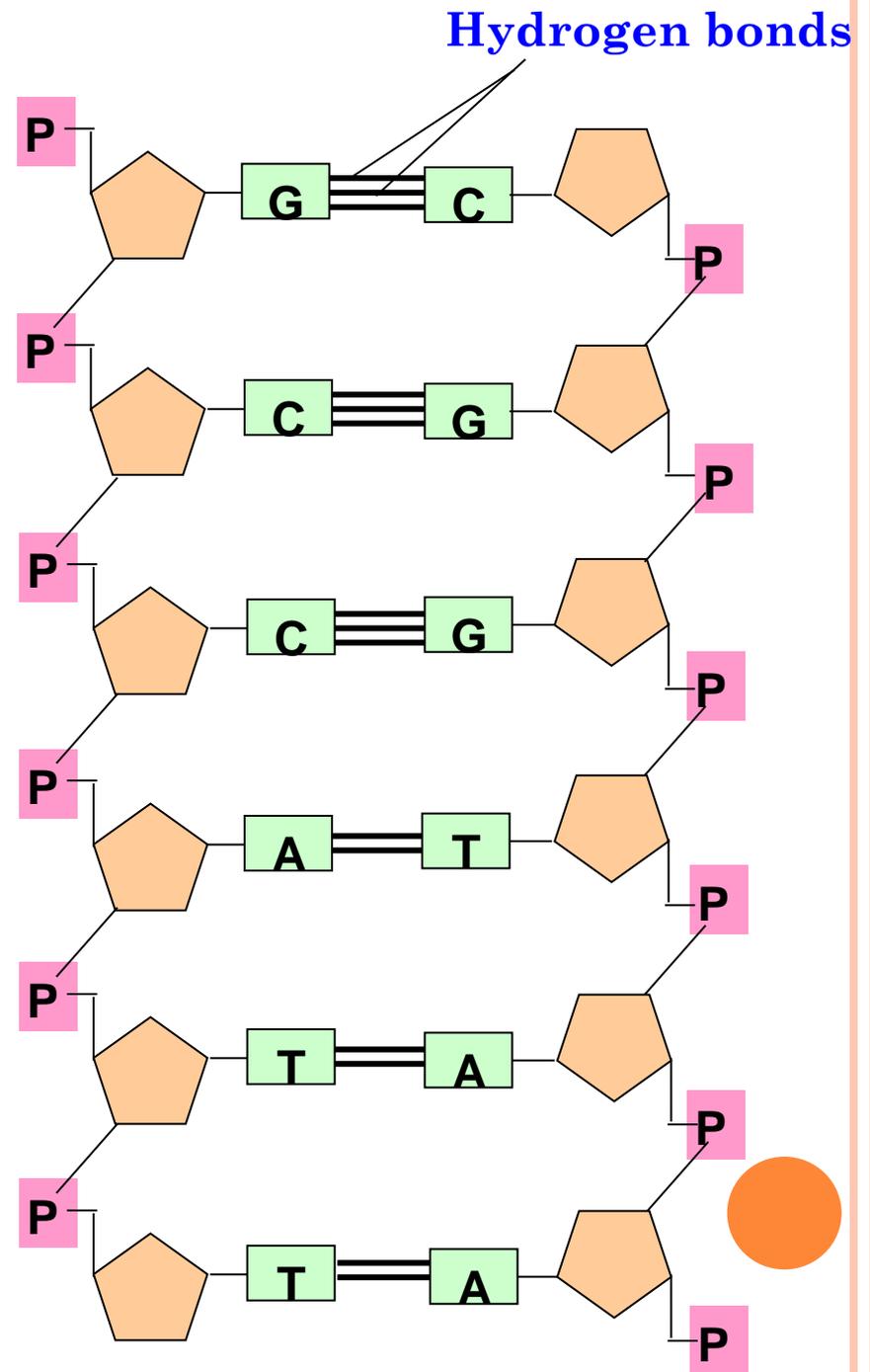
Watson-Crick model for the structure of DNA...

- The diameter of the helix is 20\AA
- Adjacent bases are separated by 3.4\AA along the helix axis and the helical structure repeats after ten residues on each chain, that is
- At intervals of 34\AA



DNA IS MADE OF TWO STRANDS OF POLYNUCLEOTIDE

- The ratio of **purine** to **pyrimidine** bases in the DNA is always around one (1)
- $G+A : T+C = 1$
- $G+A / T+C = 1$
- $G+A = C+T$

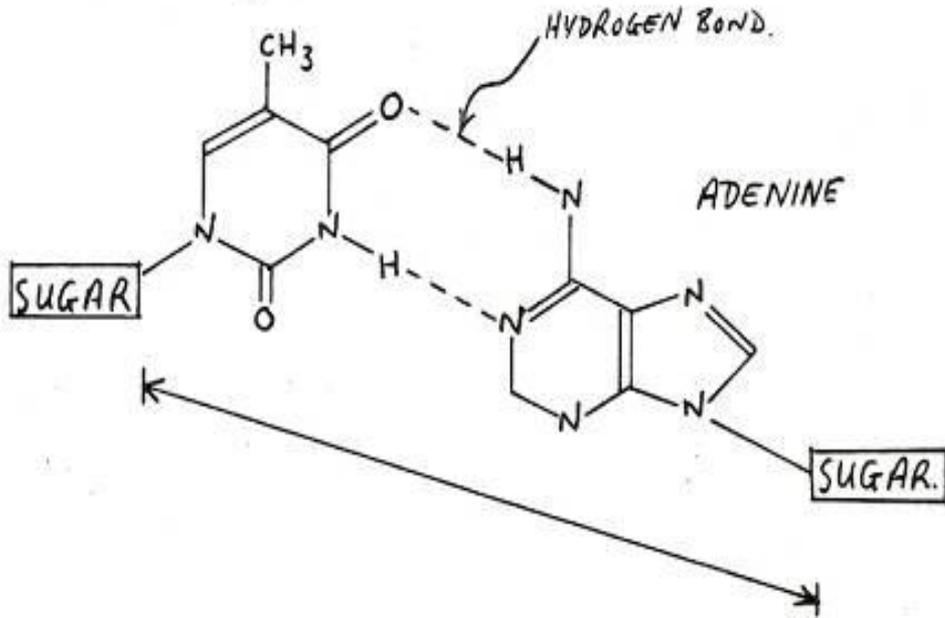


WATSON & CRICK DNA BASE PAIRING

THYMINE

HYDROGEN BOND.

ADENINE

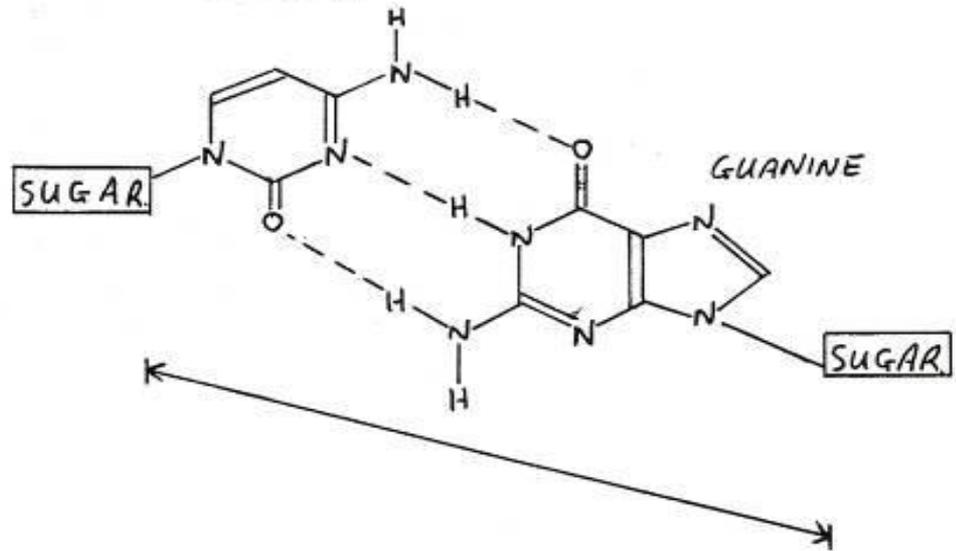


T = A

C ≡ G

CYTOSINE

GUANINE



Tertiary Structure of DNA

- **Tertiary structure:** Is the supercoiling of DNA double helix which is winding, bending and twisting to form more compact shape.
- DNA molecules are either **linear** or **circular**
- **In circular DNA**, the ends of the DNA are joined to create a closed circle with no free 3' and 5' hydroxyl and phosphoryl groups .
- The DNA in human chromosomes are **linear**



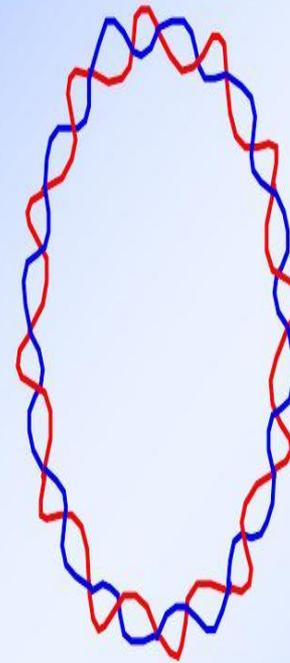
Tertiary Structure of DNA

○ A DNA molecule without any super helical turns is known as a **relaxed molecule**

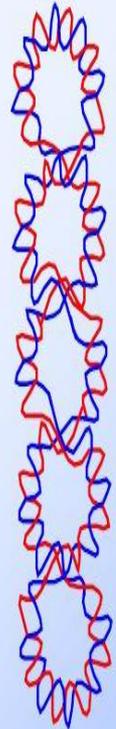
○ **Supercoiling** is biologically important because:

A **supercoil** DNA molecule has more compact shape than does it in relaxed state

Tertiary structure of DNA



Relaxed



Supercoiled

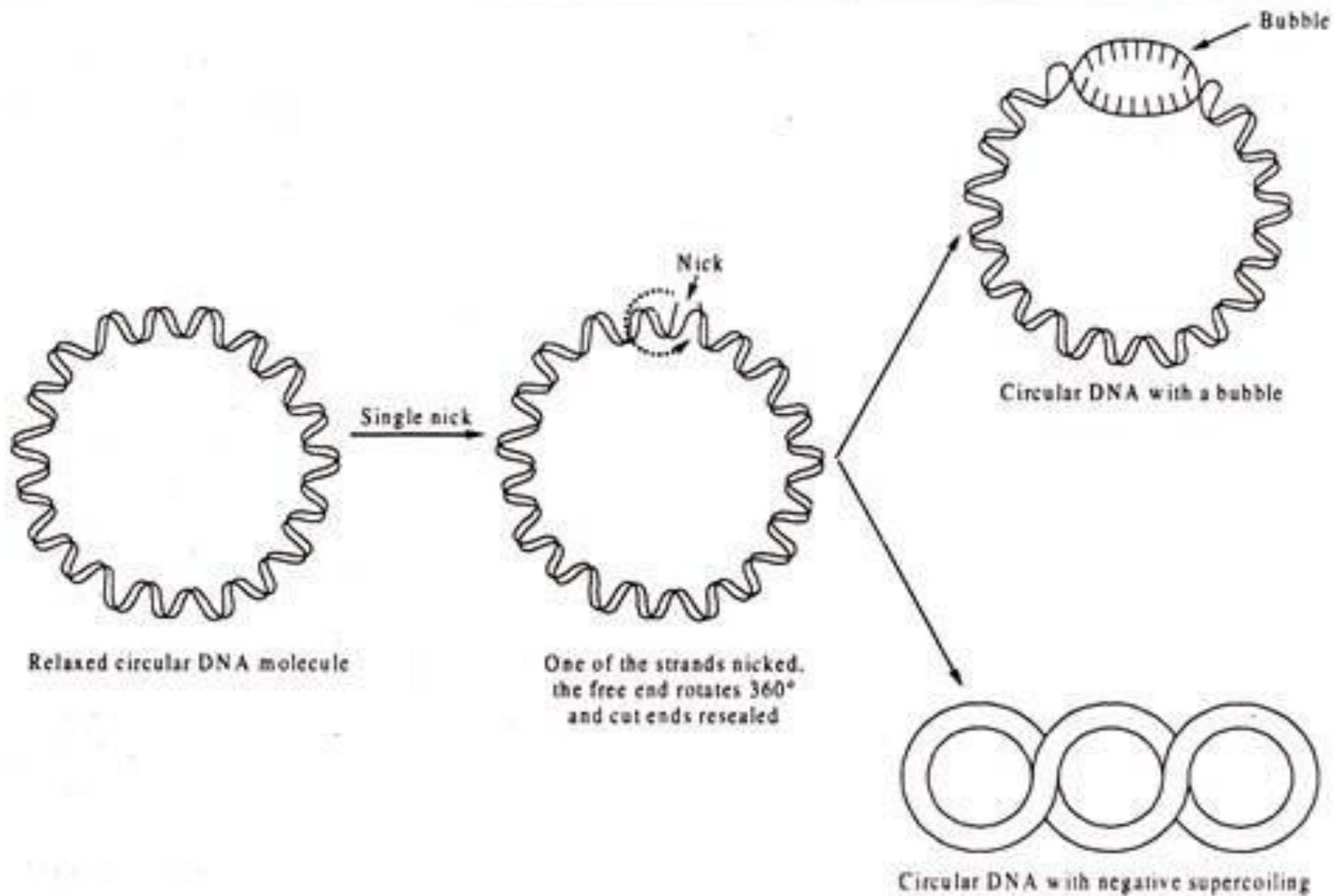


Fig. 9.9 : Different states of circular DNA. A nick in a DNA strand and rotation through 360° relaxes the pressure of the helix and leads to formation of either a bubble or a negative supercoiling

Lecture 9



Functions of DNA

i) DNA is the genetic material capable of storing and transmitting genetic information (heredity character) from parents to their off springs.

ii) All cellular functions are under the control of DNA

iii) DNA acts as a template for the synthesis of mRNA by a process called transcription. The mRNA thus produced helps protein synthesis in the cytoplasm by translation in combination with tRNA

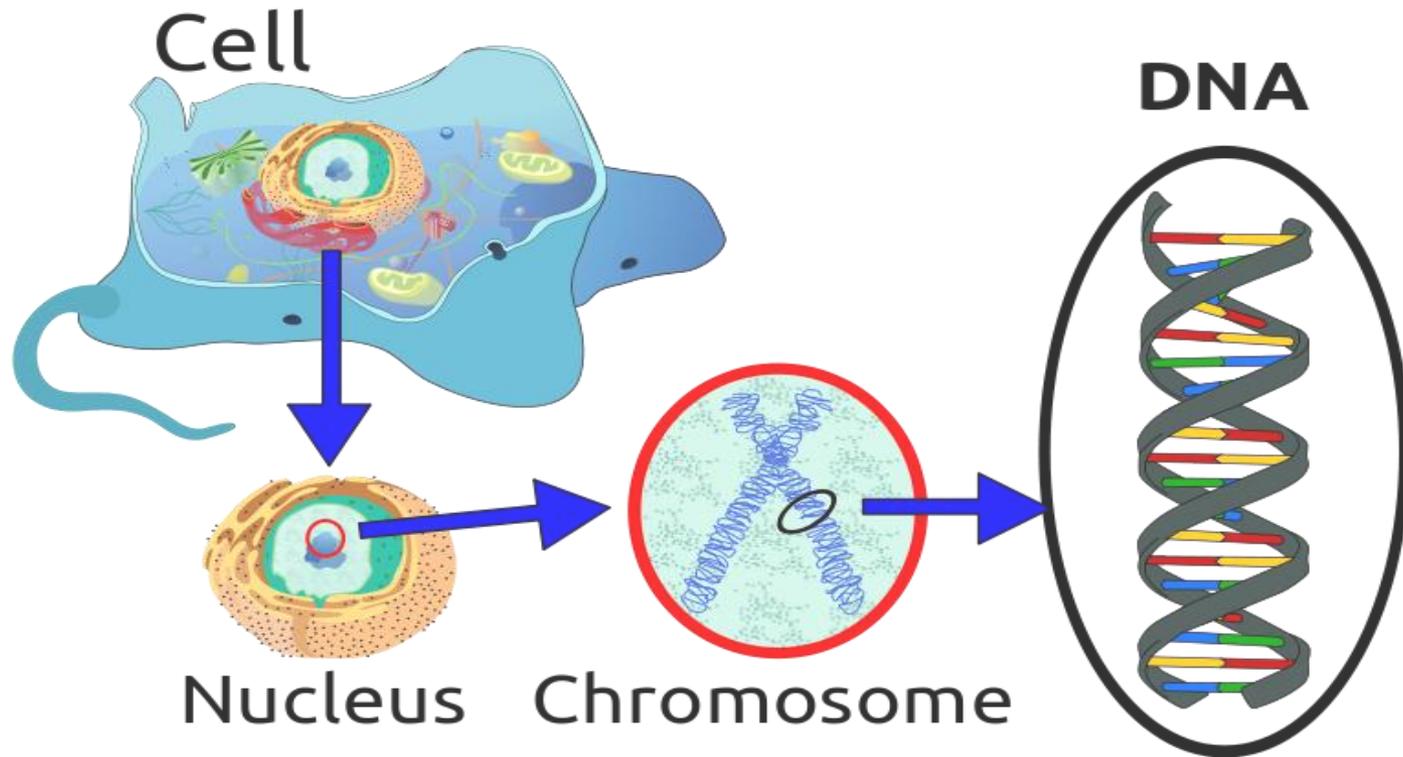
$$\text{DNA} \xrightarrow[\text{n}]{\text{transcription}} \text{mRNA} \xrightarrow{\text{translation}} \text{Protein}$$

iv) DNA acts as a cofactor in the synthesis of ATP which in turn is necessary for the production of RNA and protein in the nucleus.

v) DNA produces mutations resulting in new

Nucleic acid

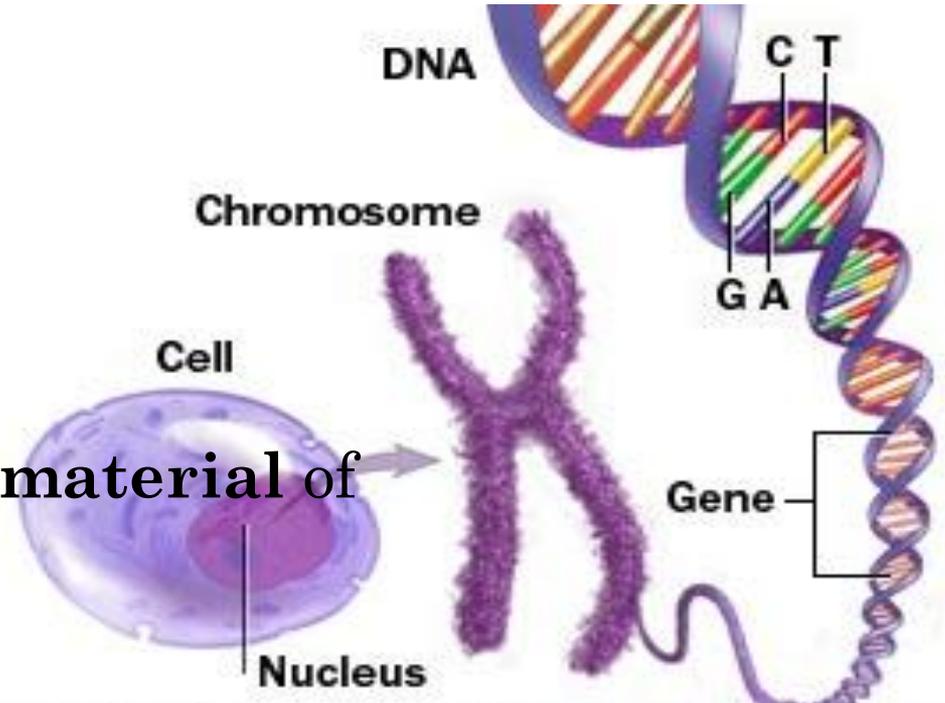
- **Chromosome:** is a large single double helix DNA molecule containing many genes and functioning to store and transmit genetic information.



Nucleic acid

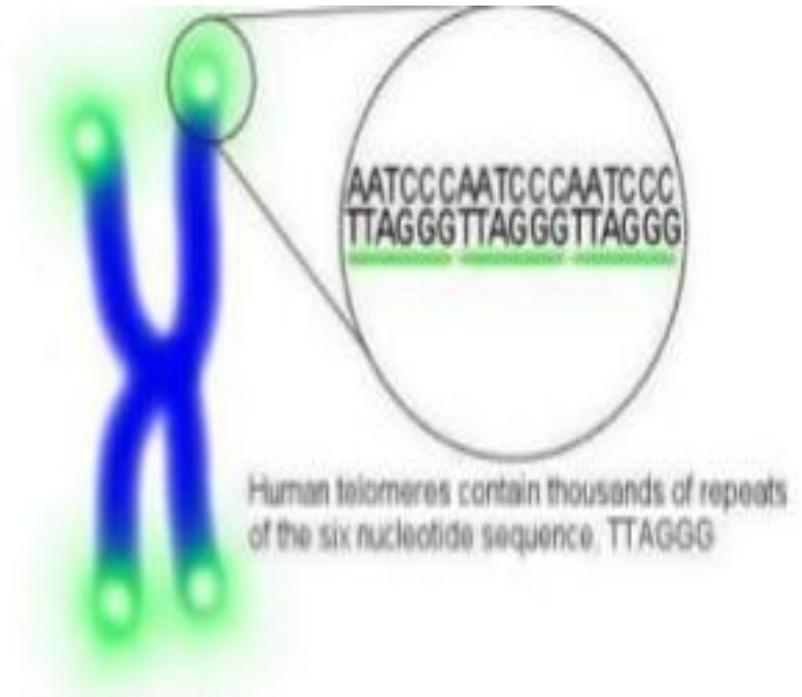
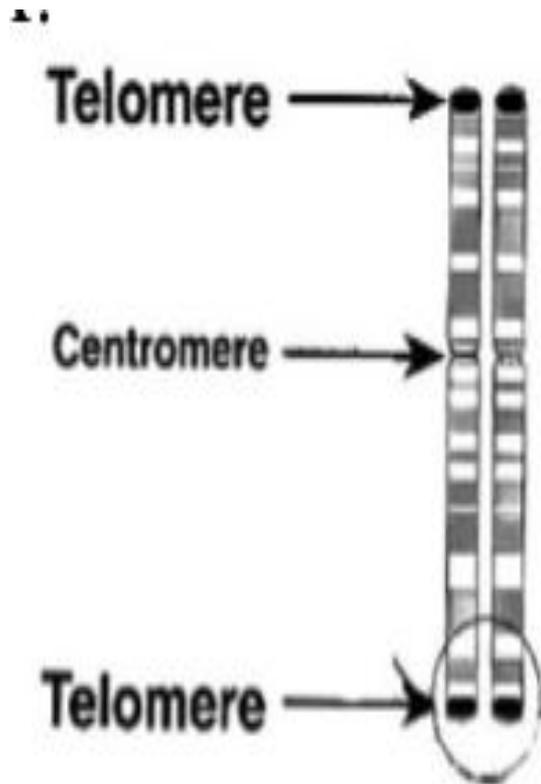
- **Gene:** is a sequence (segment) of a chromosome which codes for a molecule that has a function (polypeptide or protein).

- **Genome:** is the genetic material of an organism.



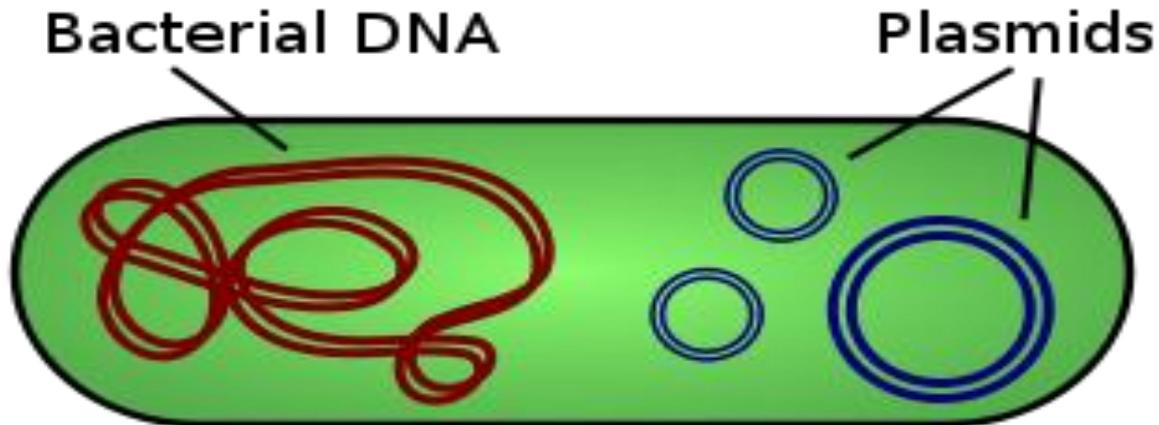
Nucleic acid

- **Satellite DNA:** are DNA segments of highly repeated sequence of about 10 b.p. (consists of a single sequence repeated many times over)



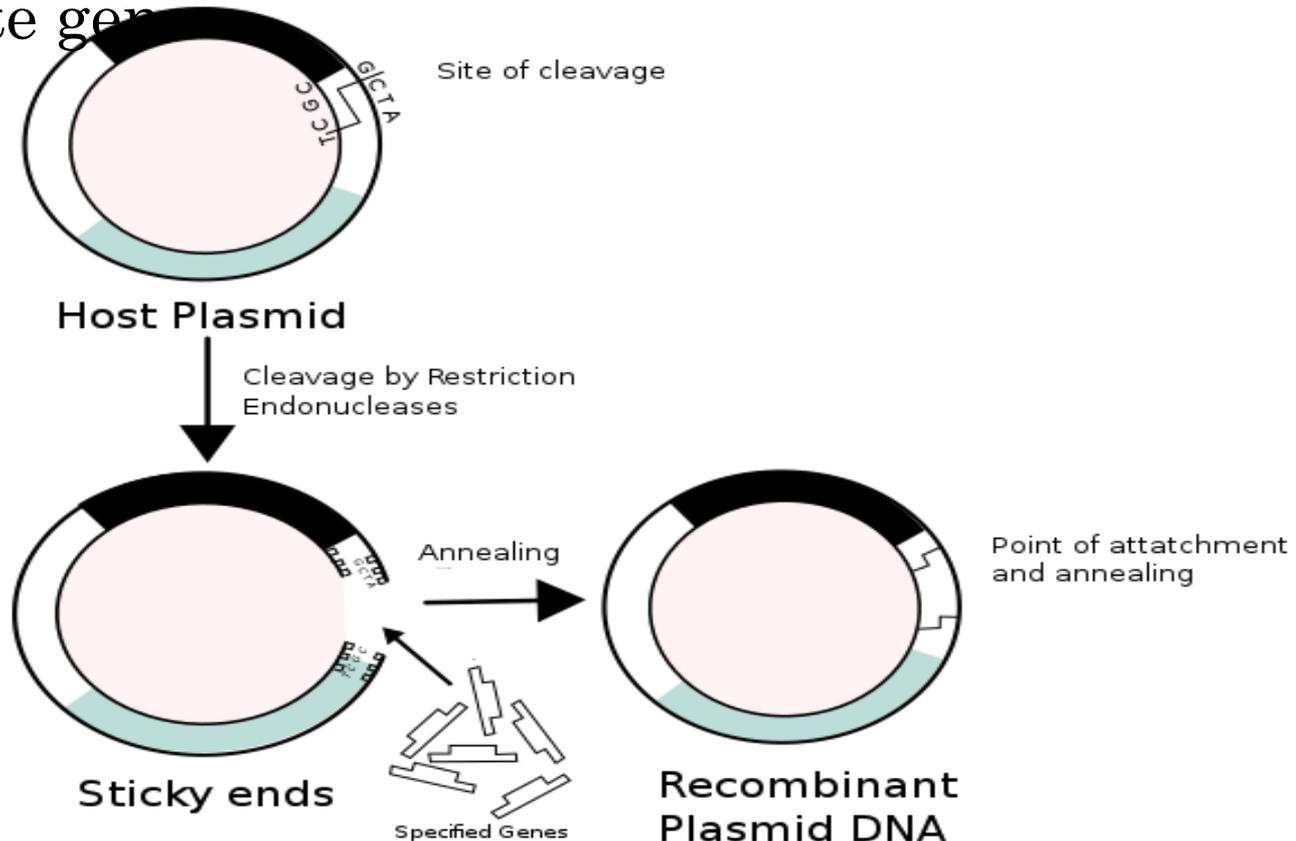
Nucleic acid

- **Plasmids:** is a small DNA molecule within a cell that is physically separated from a chromosomal DNA and can replicate independently.
- They are most commonly found as small circular, double-stranded DNA molecules in bacteria; however, plasmids are sometimes present in archaea and eukaryotic organisms. In nature, plasmids often carry genes that may benefit the survival of the organism, for example antibiotic resistance



Nucleic acid

- **Recombinant DNA:** joining together of DNA molecules from two different species that are inserted into a host organism to produce new genetic combinations that are of value to science, medicine, agriculture, and industry. Since the focus of all genetics is the gene, the fundamental goal of laboratory geneticists is to isolate, characterize, and manipulate genes.



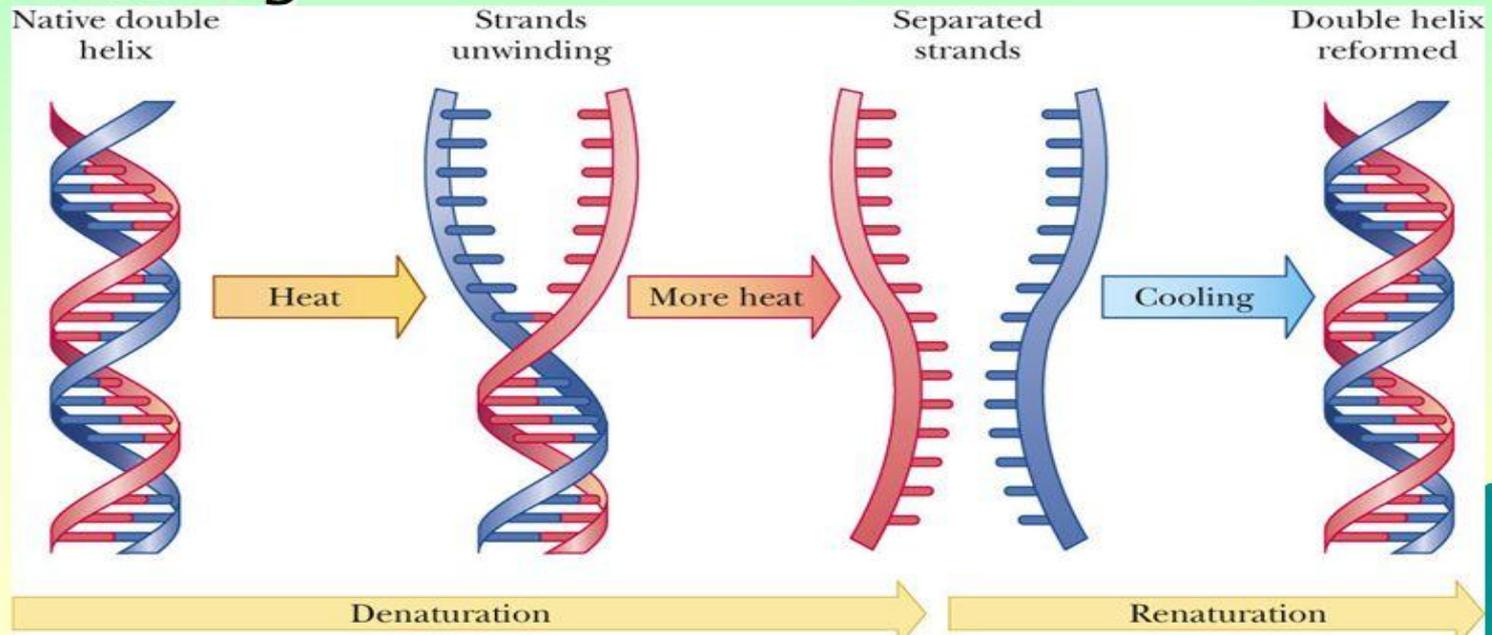
Physical Properties of DNA

1- Denaturation of DNA:

2- Renaturation (Annealing):

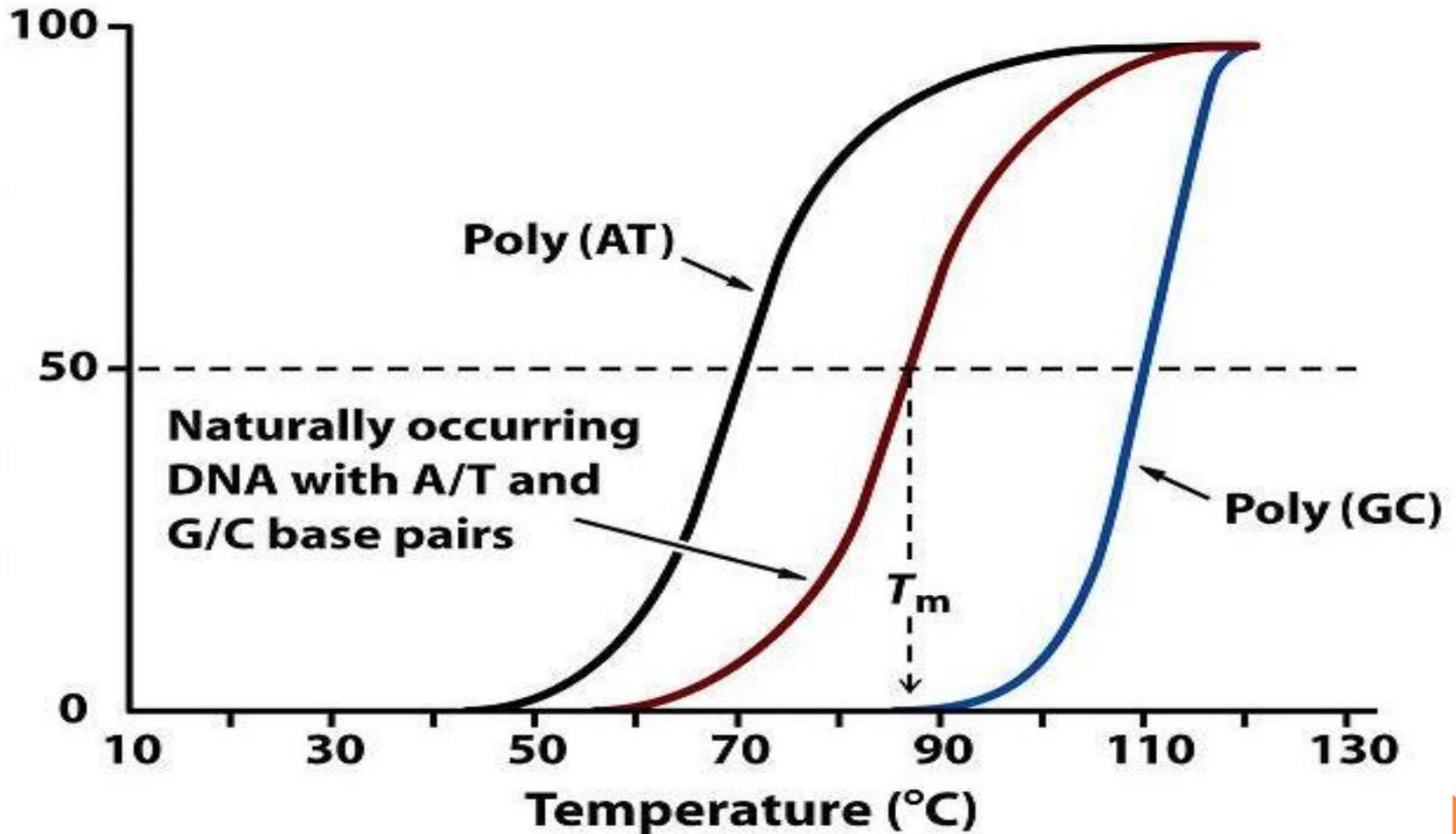
Denaturation of DNA

- ◆ Double helix unwinds when DNA is denatured
- ◆ Can be re-formed with slow cooling and annealing



Physical Properties of DNA

3- Melting Temp (T_m):



Physical Properties of DNA

4- Mutation:

a. Exposure to U.V. light, X -rays or γ -rays causes alteration such as adjacent T=T dimerization.

b. Deamination of nitrogen bases by exposure to nitrous compounds as HNO_3 and NaNO_2 converting:

Cytosine \longrightarrow Uracil + NH_3

Adenine \longrightarrow Hypoxanthine + NH_3

c. Xenobiotics (nitrogen base analogues) such as : Caffeine may replace Thymine (T)

d. Alkylating agents: agents that can add R- groups such as $-\text{CH}_3$, $-\text{C}_2\text{H}_5$, to the nitrogen bases altering their molecular structure.

Lecture 10

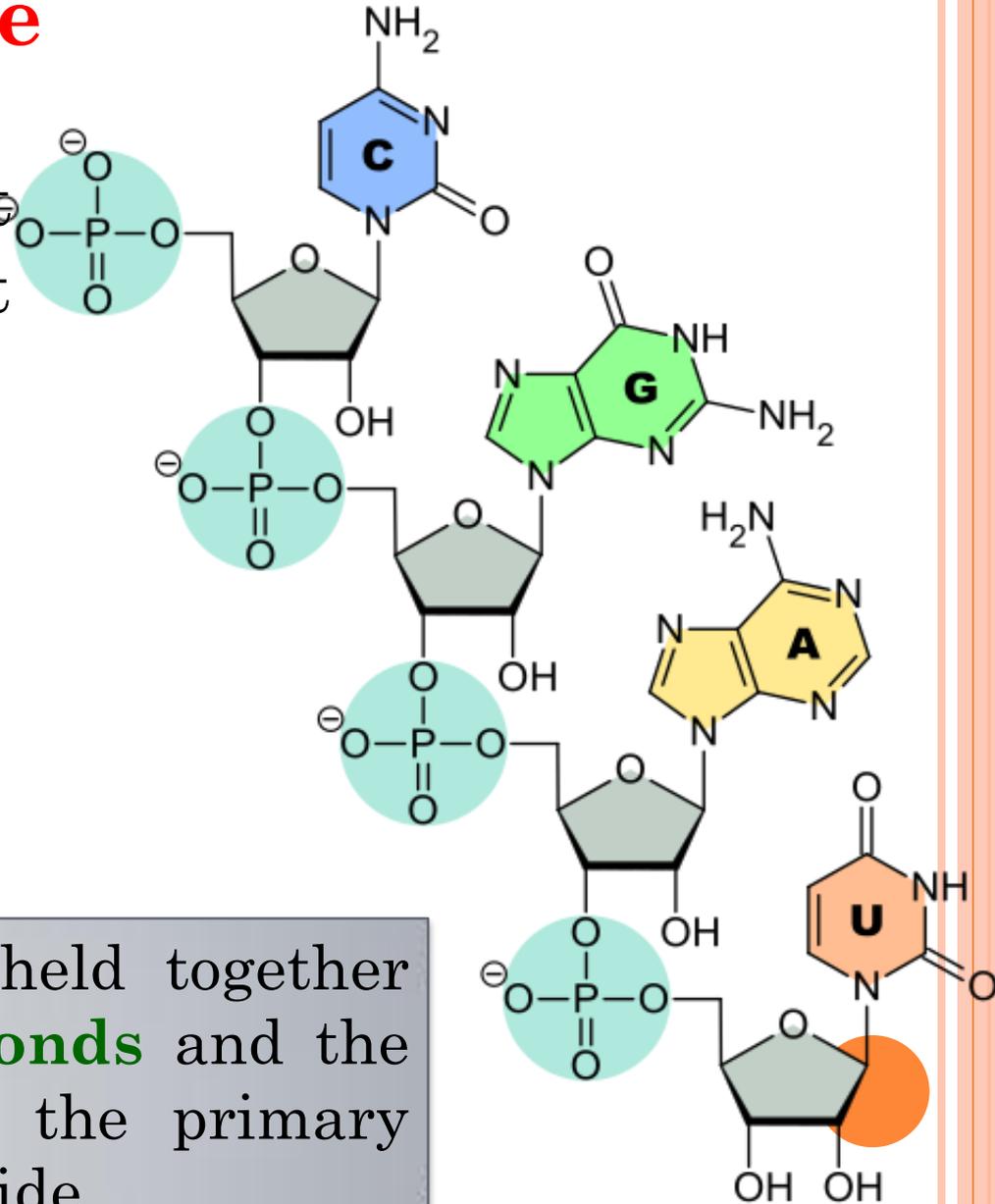


RNA Structure and Function

1. Primary structure

- RNA is a polymer of ribonucleotides. Thus, it is polyribonucleotide. It contains four types of ribonucleotides viz
- Adenosine monophosphate
- Guanosine monophosphate
- Uridine monophosphate
- Cytidine monophosphate

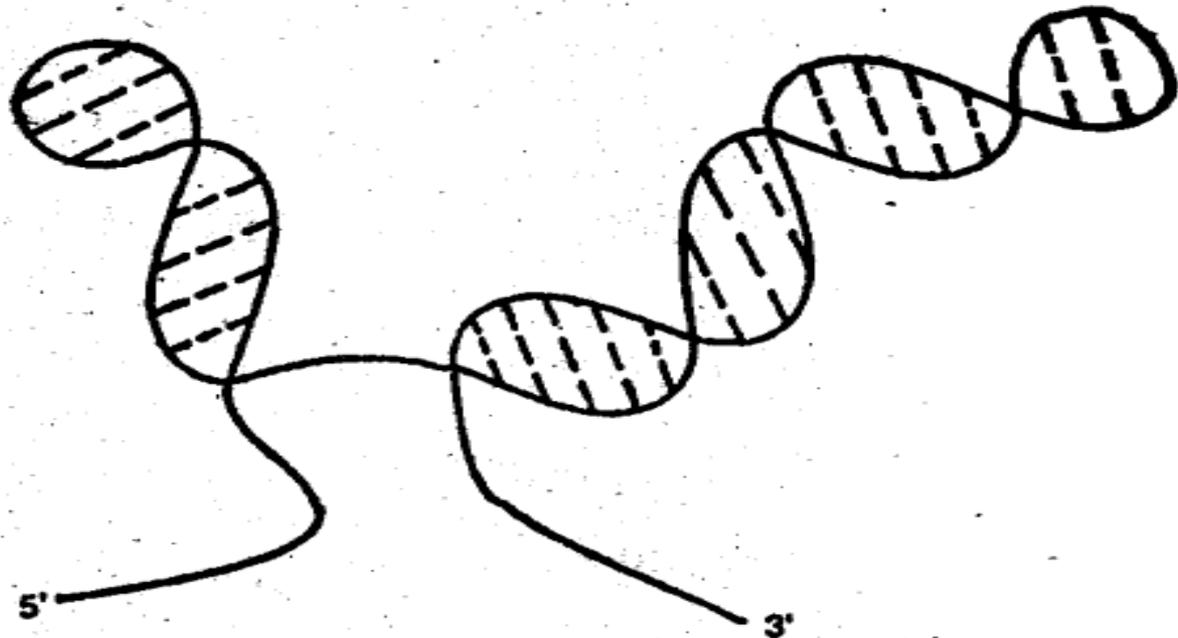
The mononucleotides are held together by **3',5'phosphodiester bonds** and the base sequence constitutes the primary structure of the polynucleotide



RNA Structure and Function

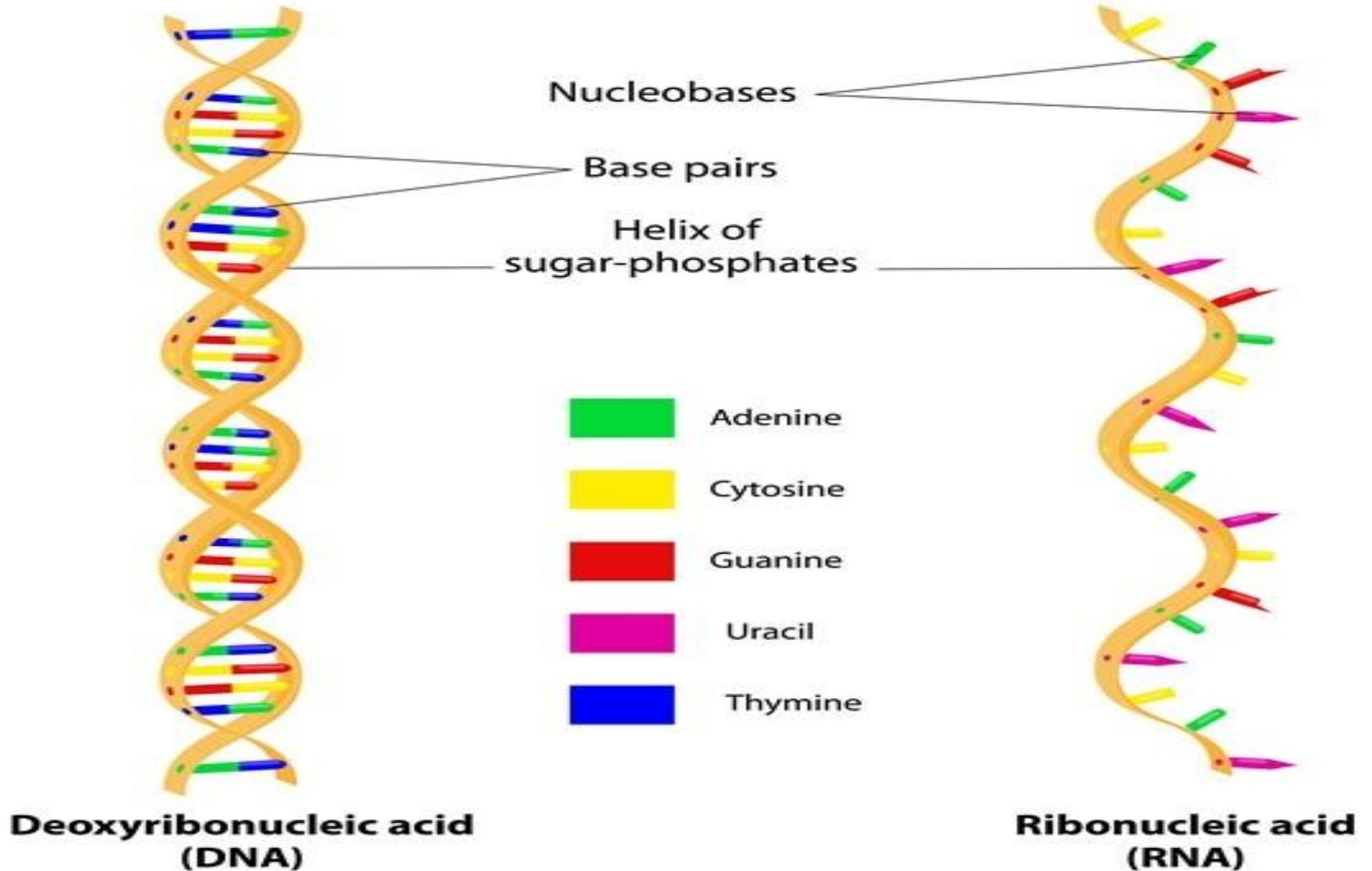
1. Secondary structure

- RNA occurs as a single strand molecule. There is internal hydrogen bonding within the chain to keep it in a coiled or helical form.
- The coiled strand folds back on itself and thus acquires double-stranded characteristics



Difference between RNA and DNA

Structure of DNA & RNA



Difference between RNA and DNA

DNA	RNA
General genetic material present predominantly in nucleus	Genetic material of some viruses present in cytoplasm
The sugar moiety is deoxyribose	The Sugar moiety is ribose
Exists as double strand helix	Exists as single strand helix
Consists of adenine, guanine, cytosine and thymine	Consists of adenine guanine, cytosine and uracil
There is only one type of DNA	There are three types of RNA
Denatured on heating	
Denatured on heating	Stable towards heat

RNA Structure and Function

Three Types of RNA

1- Messenger RNA (mRNA)

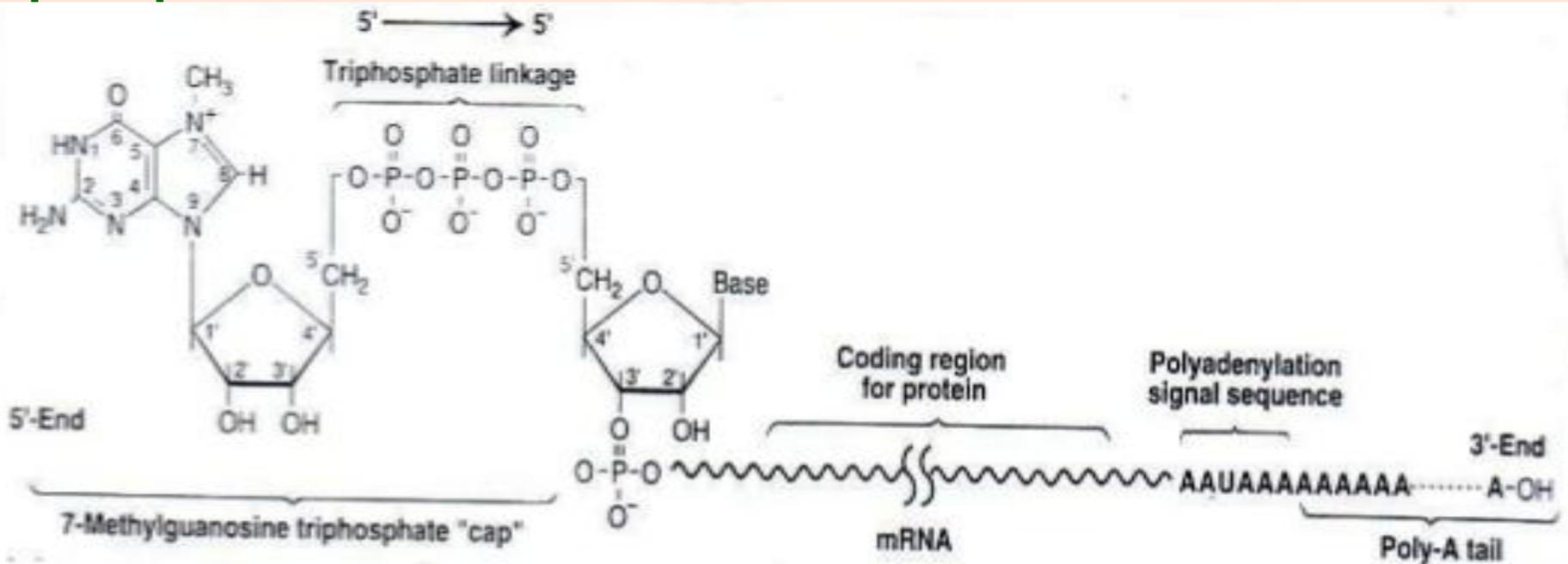
2- Transfer RNA (tRNA)

3- Ribosomal RNA (rRNA)



- *Messenger RNA* - mRNA is a copy of the genetic information that was transcribed from the cell's original blueprint, DNA.
- This is so named because it is the type of RNA which carries message for protein synthesis from DNA (gene) to the sites of protein formation (ribosomes).
- Only about 5% of total cellular content of RNA is mRNA.
- mRNA is formed from DNA by transcription in the nucleus and then migrated into the cytoplasm and attached itself to a number of ribosomes

- **Messenger RNA** The **5'** end of mRNA is “capped” by a 7-methyl-guanosine triphosphate (m7 GPT).
- A poly(A) “tail” attached to the other **3'** end of mRNA. This tail consist of series of adenylate residues 200-250 nucleotides in length joined by **3',5' phosphodiester**



Function

mRNA serves as a messenger by carrying genetic information from DNA to the sites of protein synthesis (ribosomes).

- **Transfer RNA** - Transfer RNA constitutes about 10-15% of total RNA of the cell
- The Amino Acid Suppliers: tRNA is also part of the process of building proteins. Like a little truck, tRNA brings the amino acid to the ribosome. Which amino acid it brings depends on which was coded for in the mRNA instructions. At the ribosome, these amino acids are joined together to form proteins.

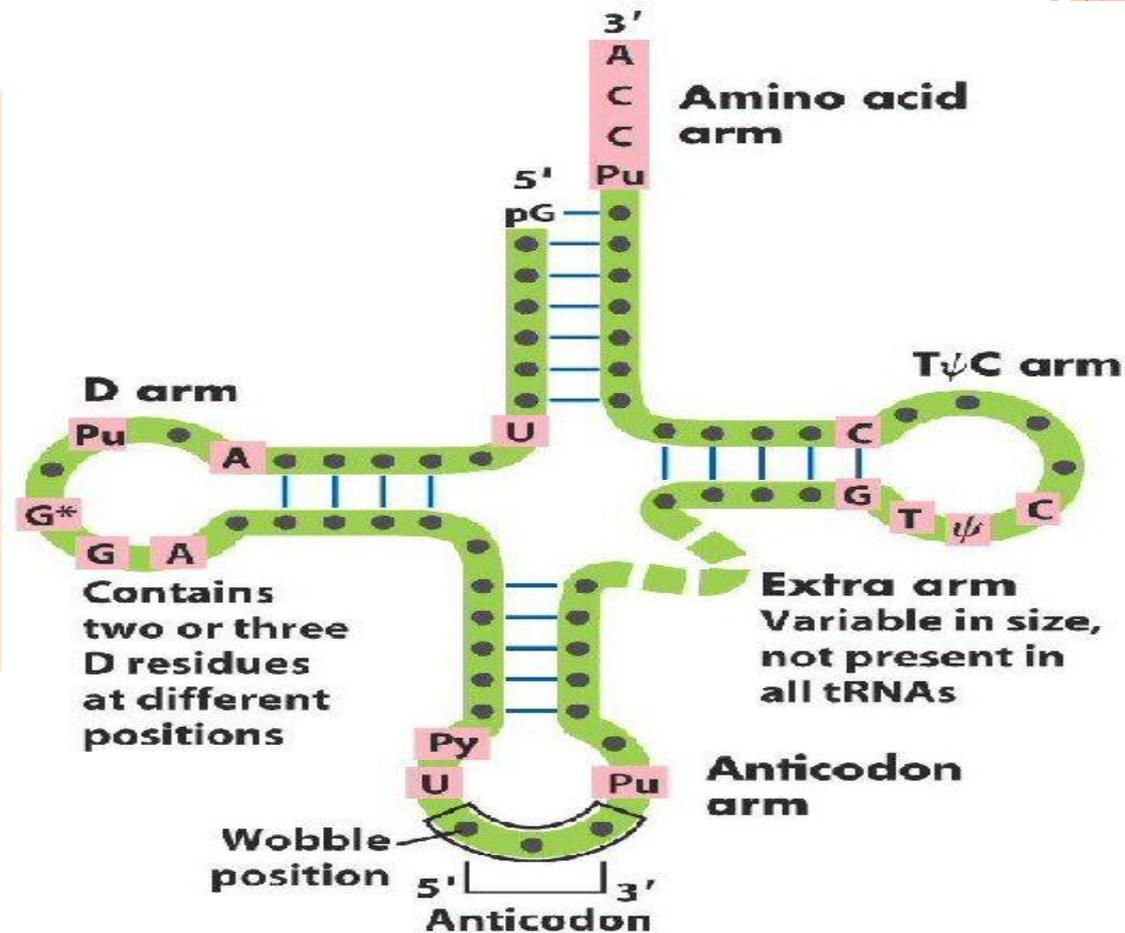
Transfer RNA is the smallest of the RNA species containing approximately 75 nucleotides with a molecular weight of 25,000. It has a cloverleaf structure with four attachment sites or arms.

Function

The rRNA molecules serve as adapters for the translation of the information in the mRNA into specific amino acids for protein synthesis

tRNA structure

- 1- The acceptor arm
- 2- The D arm
- 3- The anticodon arm
- 4- The T ψ C arm
- 5- The extra arm



- **Ribosomal RNA** -The Protein Factories: Most of the RNA in cells is part of the structure of small cellular organelles known as ribosomes, the protein factories of the cells.

Ribosomal RNA constitutes about 80% of the total RNA of the cell. It occurs as nucleoprotein in the minute round particles called ribosomes located in cytoplasm

Functions

- i) rRNA plays a prominent role in binding m-RNA to ribosomes and its translation to tRNA.
- ii) An rRNA component is found to perform the peptidyl transferase activity. Thus it acts as an enzyme called ribozyme.

مع تمنياتي بالموفقية والنجاح

د. صبا زهير حسين

