# Cell – Structure and chemical composition
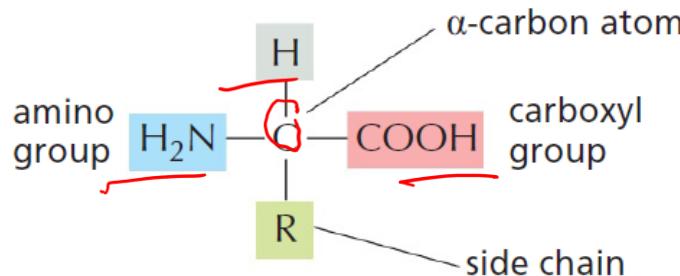
**INDRAPRASTHA INSTITUTE *of* INFORMATION TECHNOLOGY DELHI**

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**Email ID: jaspreet@iiitd.ac.in**
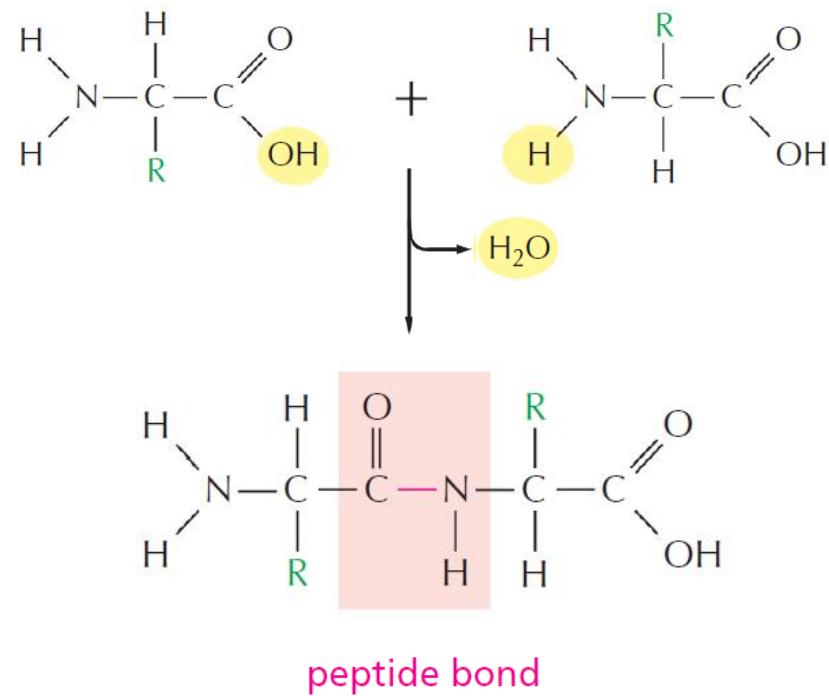
*January 09, 2025*

# Amino acids
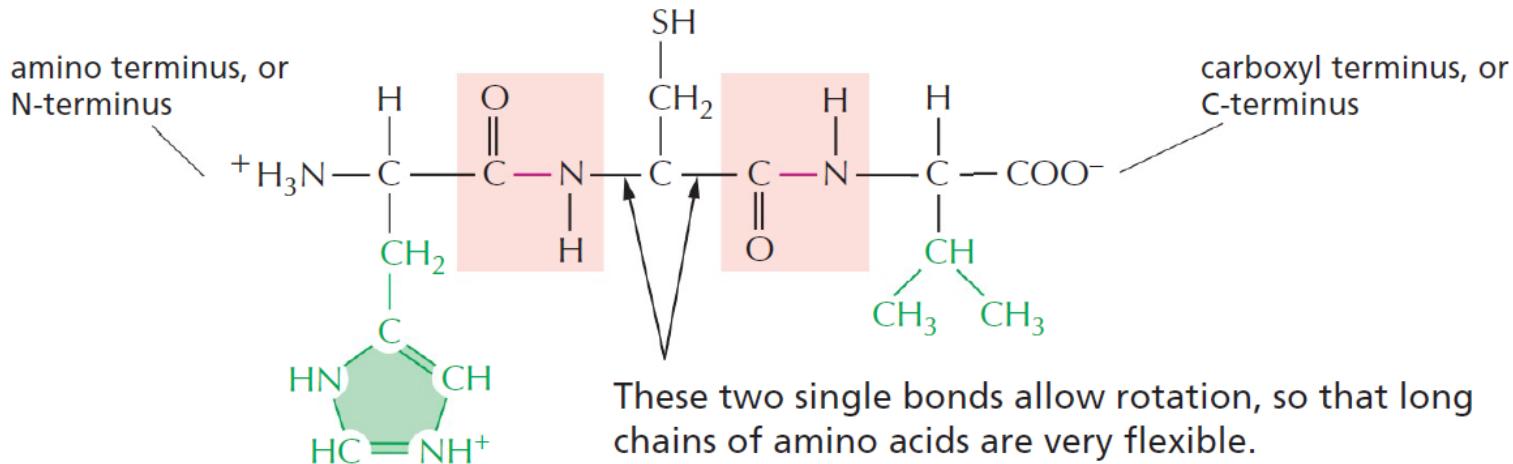
## General structure of an amino acid



amino group — $H_2N$

carboxyl group — COOH

α-carbon atom

side chain — R

## Peptide bond formation



$H_2O$

peptide bond

# Amino acids



amino terminus, or N-terminus

carboxyl terminus, or C-terminus

These two single bonds allow rotation, so that long chains of amino acids are very flexible.
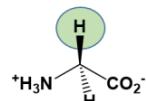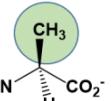
**Amino acids are the building blocks of proteins**

# Different types of Amino acids
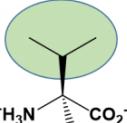
## Nonpolar (Hydrophobic) Amino Acids
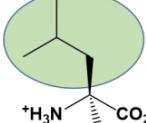
Glycine
Gly, G
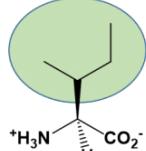
Alanine
Ala, A
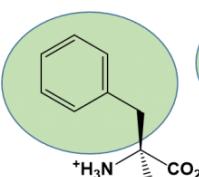
Valine
Val, V
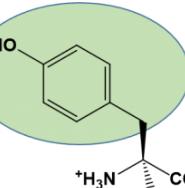
Leucine
Leu, L
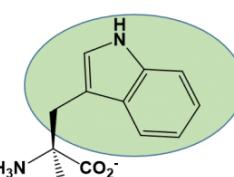
Isoleucine
Ile, I
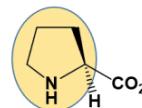
Phenylalanine
Phe, F
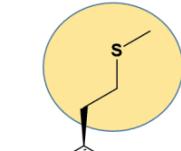
Tyrosine
Tyr, Y

Tryptophan
Trp, W
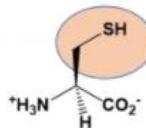
Proline
Pro, P
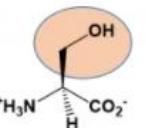
Methionine
Met, M
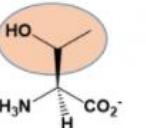
## Polar (Hydrophilic) Amino Acids
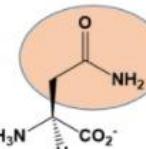
Cysteine
Cys, C
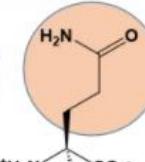
Serine
Ser, S

Threonine
Thr, T
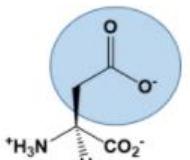
Asparagine
Asn, N
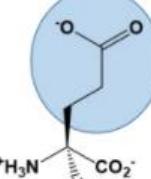
Glutamine
Gln, Q

## Acidic Amino Acids
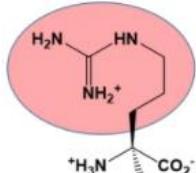
Aspartic Acid
Asp, D
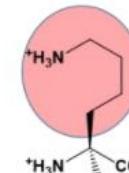
Glutamic Acid
Glu, E
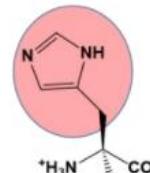
## Basic Amino Acids

Arginine
Arg, R
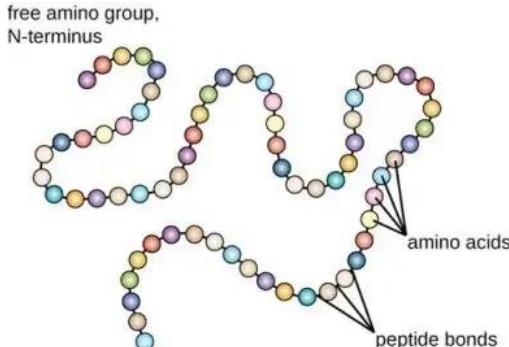
Lysine
Lys, K

Histidine
His, H

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# Structure of protein



free amino group,
N-terminus
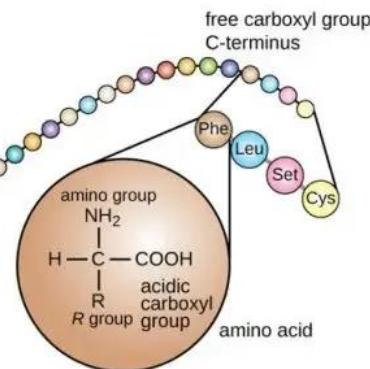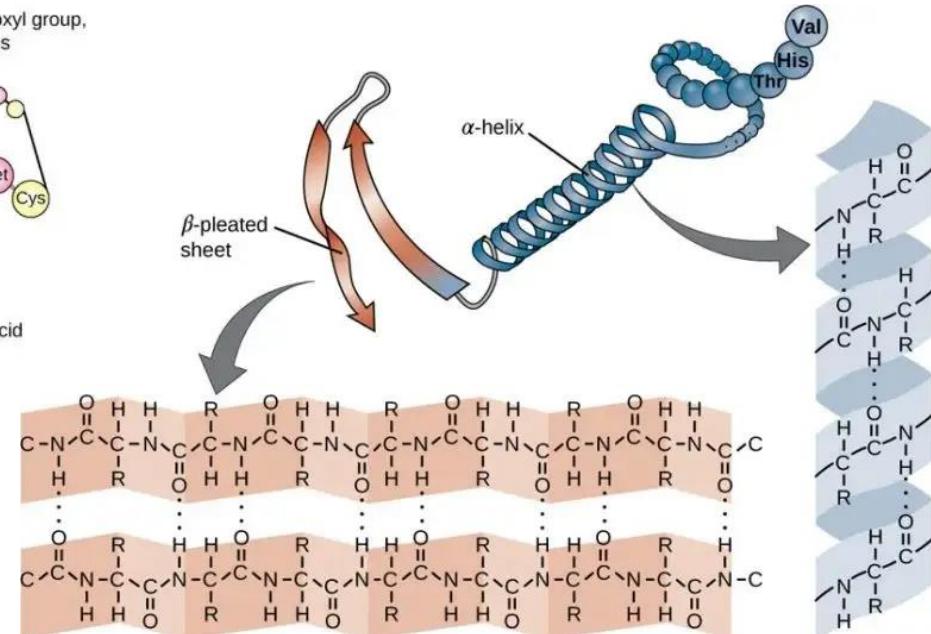
The primary protein structure
is the chain of amino acids
that makes up the protein.
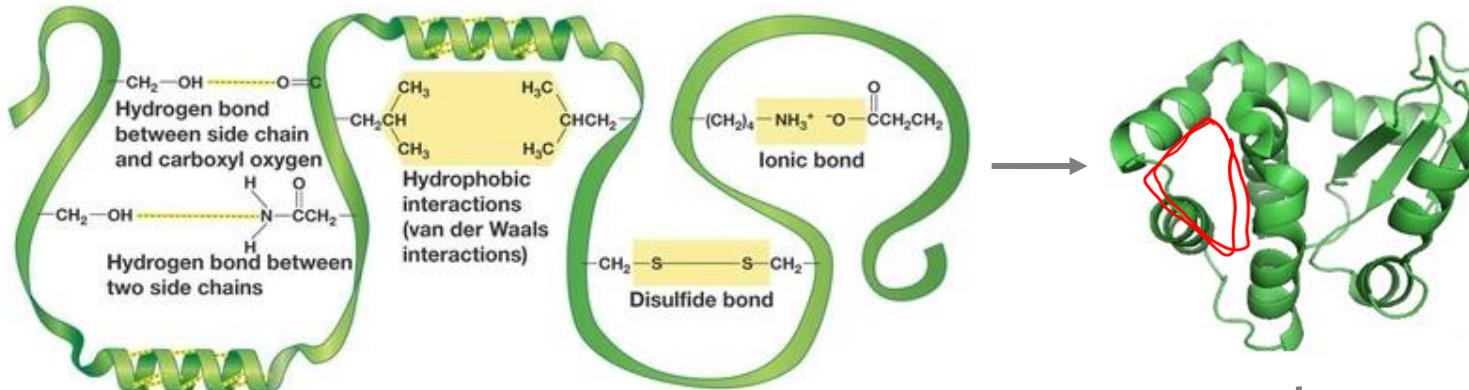
amino acids

peptide bonds

free carboxyl group,
C-terminus

Phe
Leu
Set
Cys

amino group
NH₂

H—C—COOH

R group   acidic
          carboxyl
R group   group

amino acid

## Primary structure of protein

This level of structure is determined by the sequence of amino acids that join to form a polypeptide.

Val
His
Thr

α-helix

β-pleated
sheet

## Secondary structure of protein

Hydrogen bonding between amino acids cause the polypeptide to form an alpha helix or a pleated sheet.

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# Structure of protein



**Tertiary structure of protein**

This level of structure is determined by the sequence of amino acids that join to form a polypeptide.

**Quaternary structure of protein**

This level of structure forms when two or more tertiary structures combine to form a single protein

# Functions of proteins
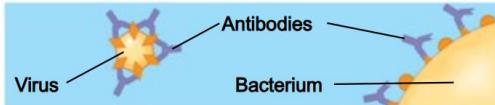


## Enzymatic proteins
Function: Selective acceleration of chemical reactions
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

Enzyme
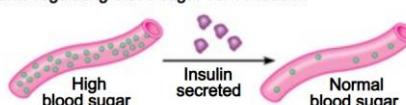
## Defensive proteins
Function: Protection against disease
Example: Antibodies inactivate and help destroy viruses and bacteria.

Antibodies
Virus
Bacterium
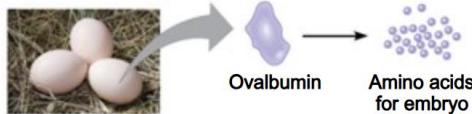
## Hormonal proteins
Function: Coordination of an organism's activities
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration

High blood sugar — Insulin secreted — Normal blood sugar
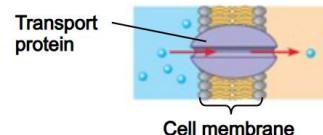
## Storage proteins
Function: Storage of amino acids
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.

Ovalbumin        Amino acids for embryo
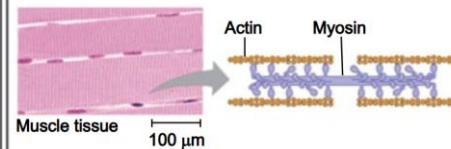
## Transport proteins
Function: Transport of substances
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.

Transport protein
Cell membrane
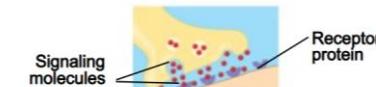
## Contractile and motor proteins
Function: Movement
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.

Actin     Myosin
Muscle tissue     100 μm
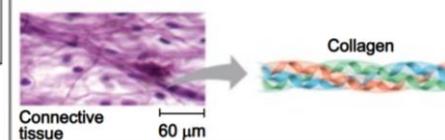
## Receptor proteins
Function: Response of cell to chemical stimuli
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.

Signaling molecules        Receptor protein
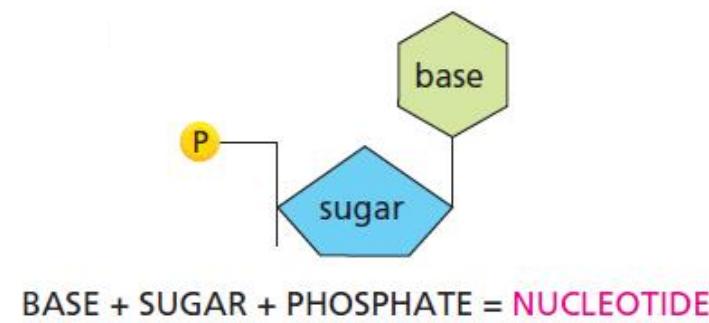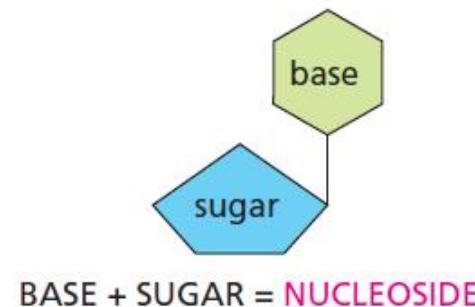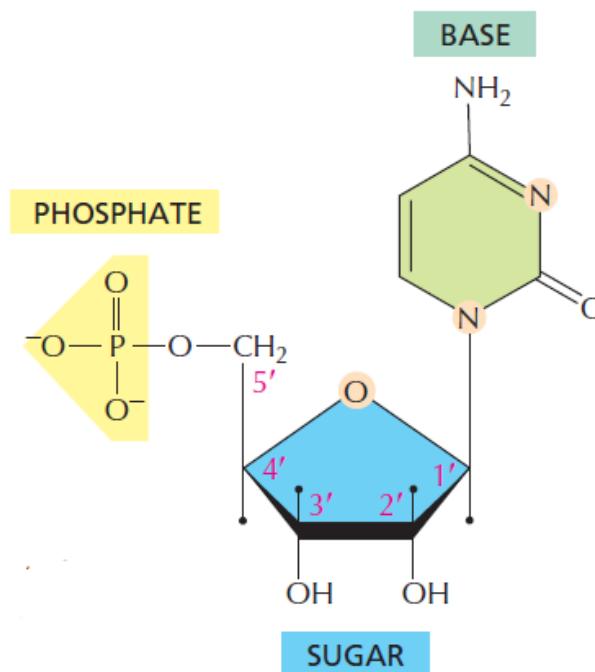
## Structural proteins
Function: Support
Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.

Collagen
Connective tissue     60 μm
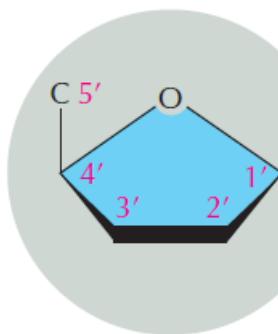
# Nucleotides

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



BASE + SUGAR = NUCLEOSIDE

BASE + SUGAR + PHOSPHATE = NUCLEOTIDE
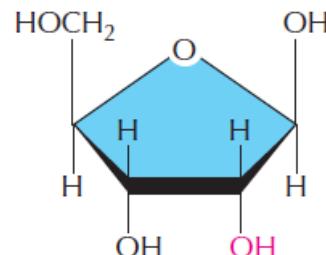
# Nucleotides
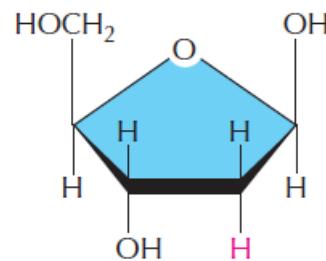
## Sugars



PENTOSE
a five-carbon sugar

two kinds of pentoses are used
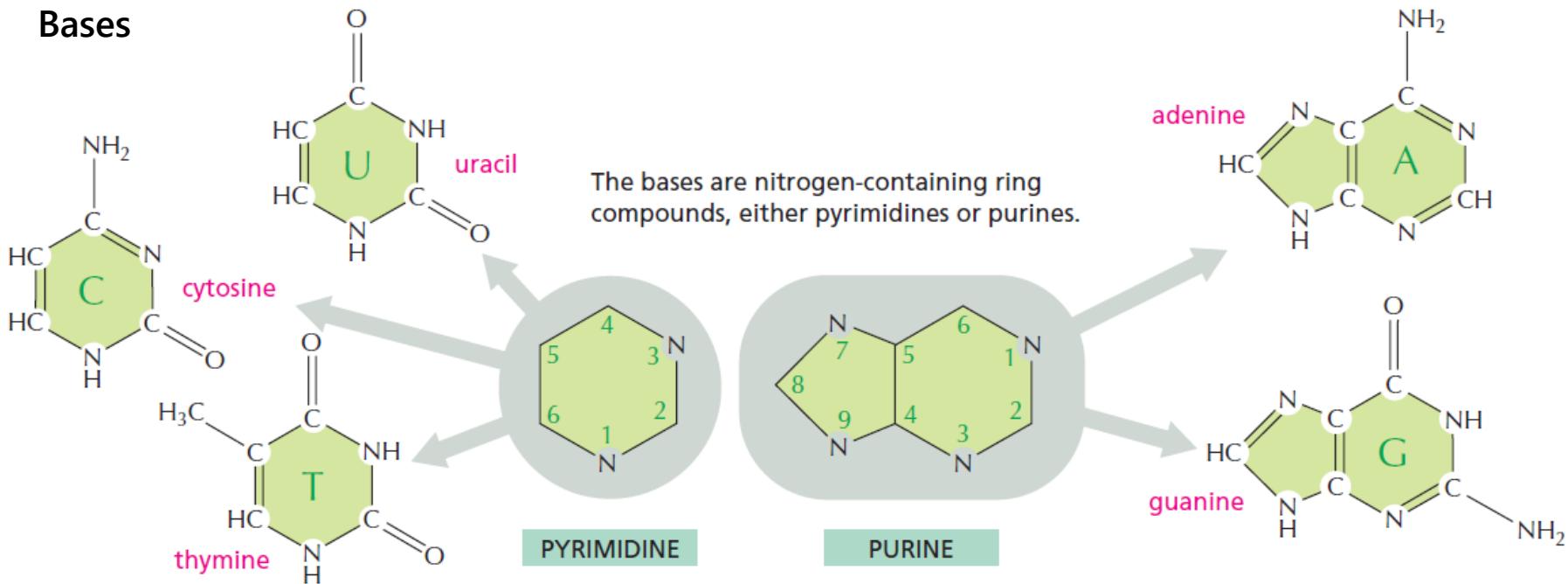
β-D-ribose
used in ribonucleic acid (RNA)

β-D-2-deoxyribose
used in deoxyribonucleic acid (DNA)

# Nucleotides



**Bases**

The bases are nitrogen-containing ring compounds, either pyrimidines or purines.

uracil
cytosine
thymine
adenine
guanine

PYRIMIDINE

PURINE
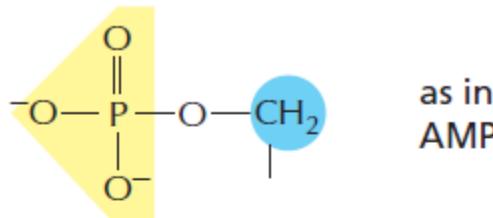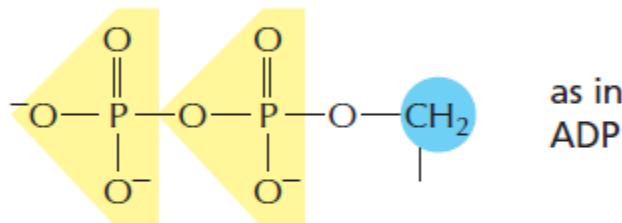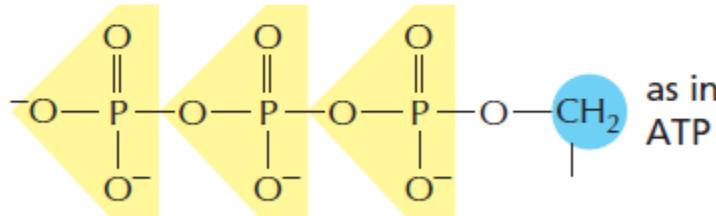
# Nucleotides

**Phosphate groups**
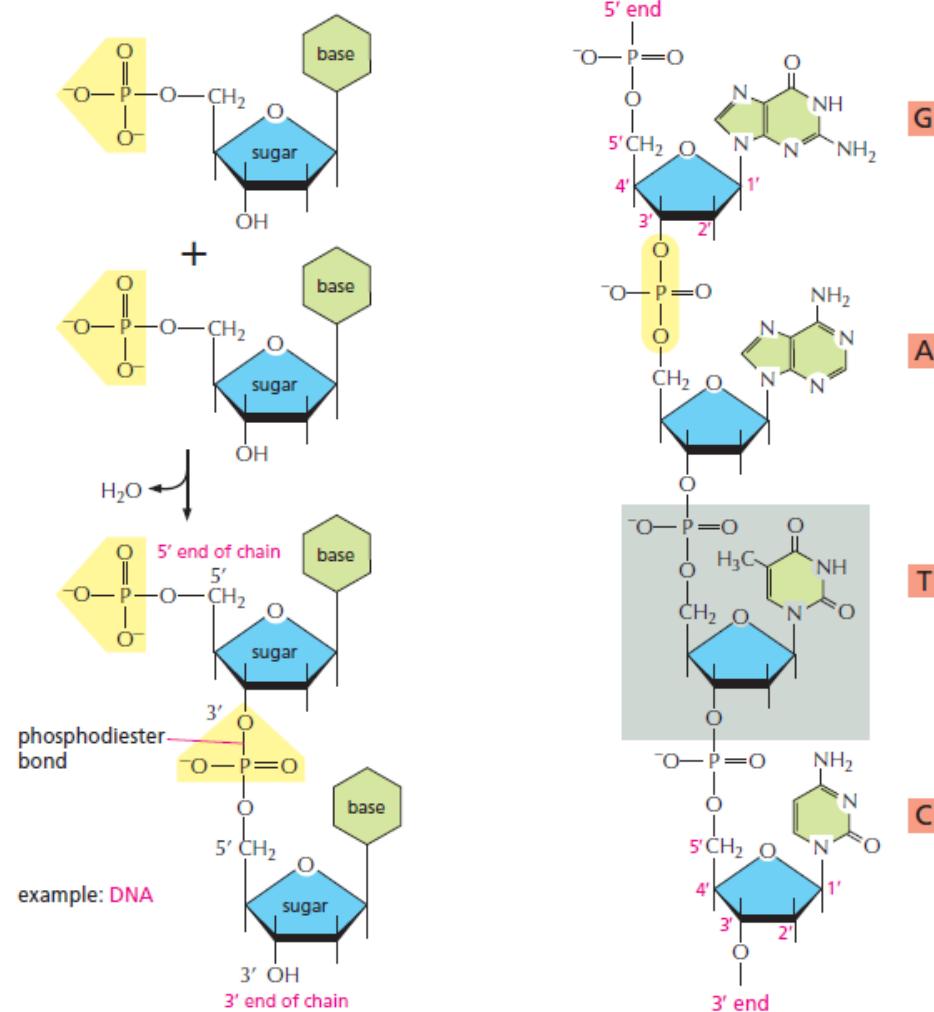


The phosphate makes a nucleotide negatively charged.
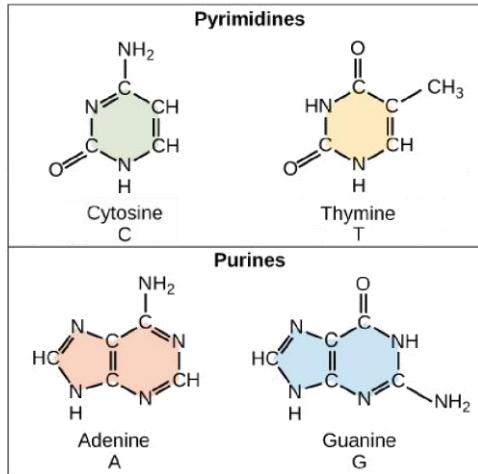
# Nucleotides

Nucleotides are the building blocks of DNA
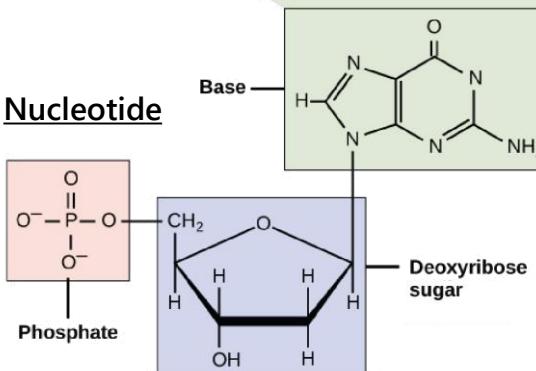
They have a fundamental role in the storage and retrieval of biological information.
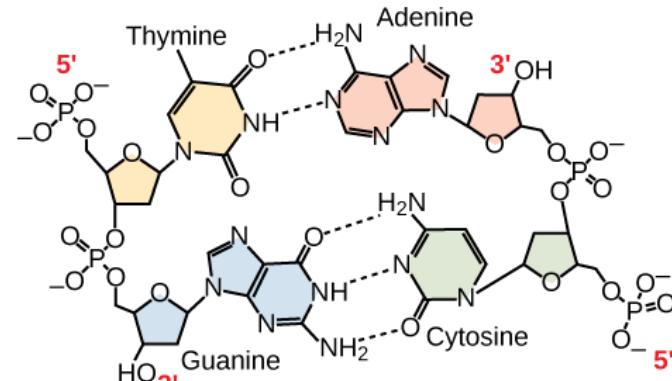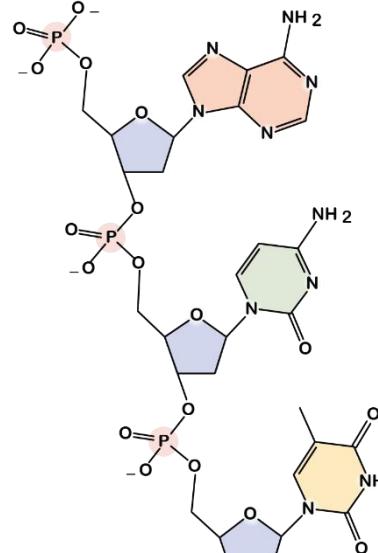
# Structure of DNA



Pyrimidines

Cytosine C

Thymine T

Purines

Adenine A

Guanine G

**Nucleotide**

Base

Deoxyribose sugar

Phosphate

**Single strand of DNA**

Phosphodiester bond

Thymine   Adenine

5'   3'

Guanine   Cytosine

3'   5'

**Double stranded DNA**

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# Structure of DNA

**Complementary base pairing**

**Antiparallel strands**

5′  3′

C — G
A — T
C — G

G — C
A — A
C — G
T — A

3.4 nm

A — T
G — C
T — A
C — G

0.34 nm

G — C
A — T
C — G

5′  3′

2 nm

Phosphorus

Carbon in sugar-phosphate "backbone"

Hydrogen

Oxygen

Minor groove

Major groove

Bases
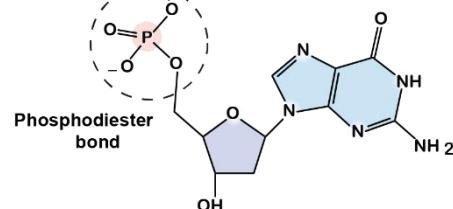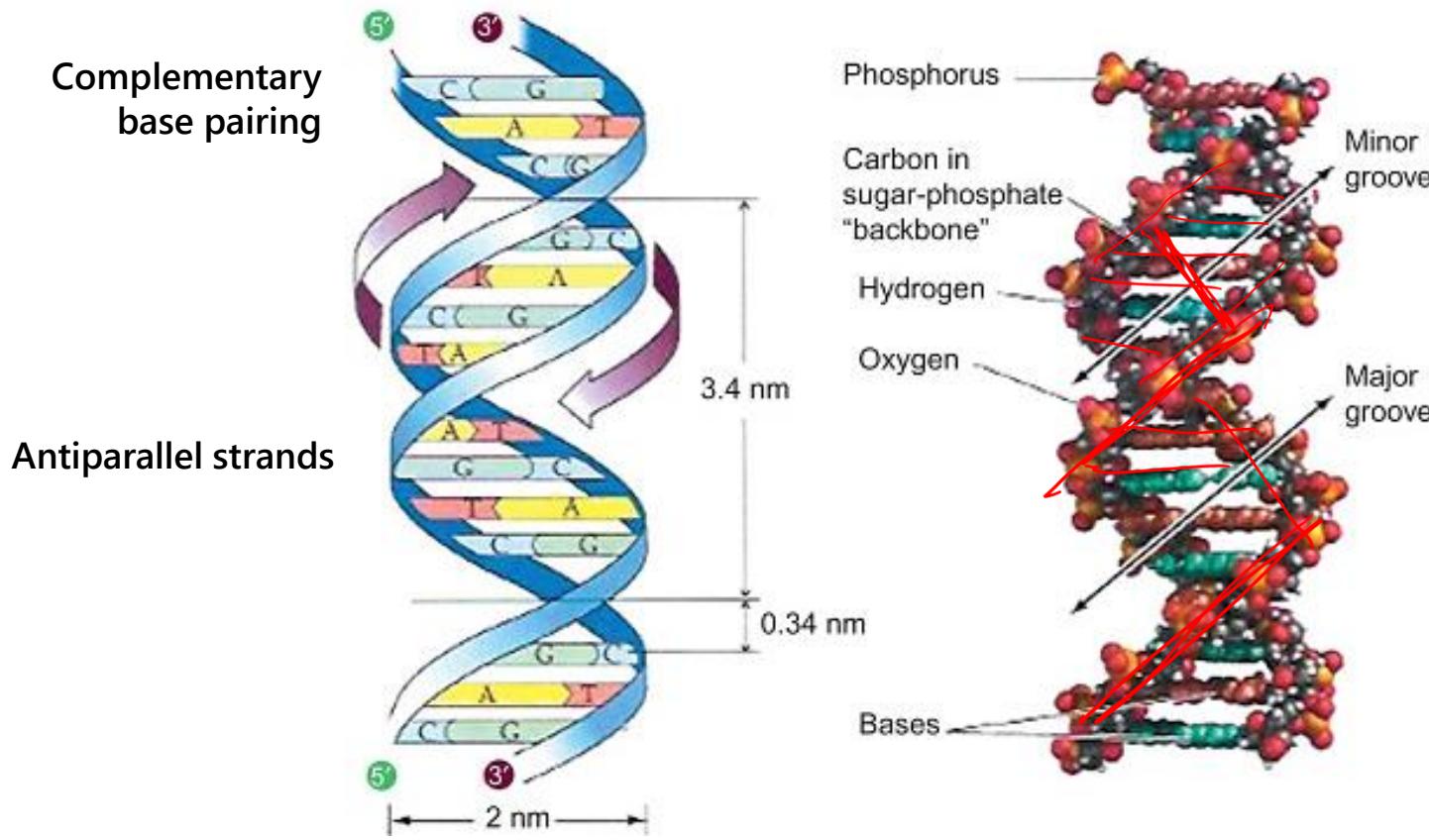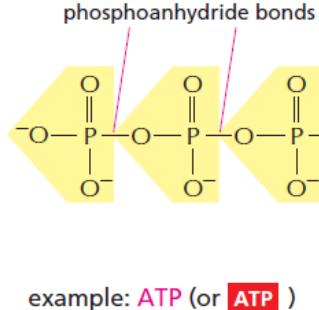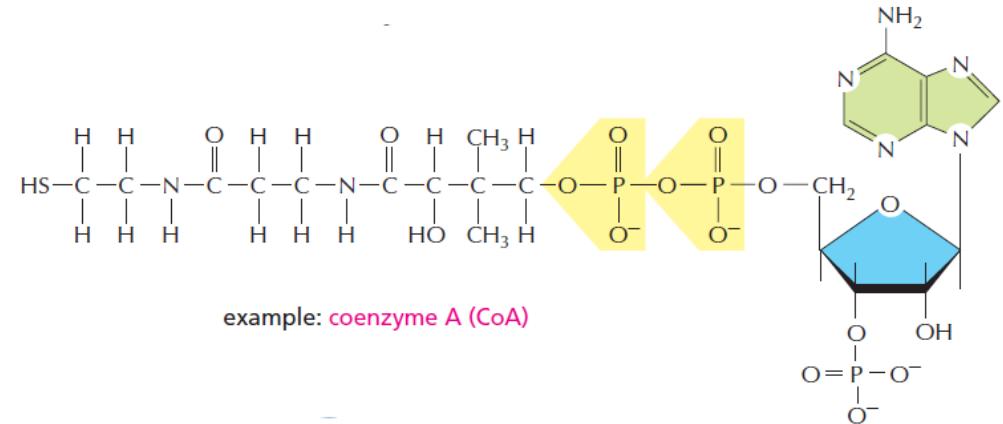
# Nucleotides

**They carry chemical energy in their easily hydrolyzed phosphoanhydride bonds**



example: ATP (or ATP )
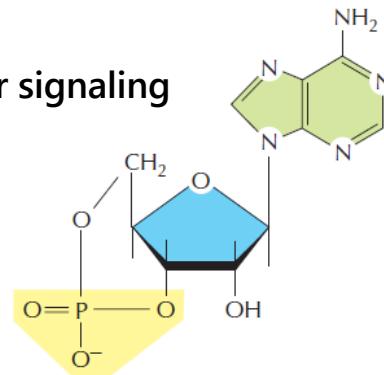
**They combine with other groups to form coenzymes**



example: coenzyme A (CoA)

**They are used as small intracellular signaling molecules in the cell.**



example: cyclic AMP

# Let's try to answer these

1. The nucleotide sequence of one DNA strand of a DNA double helix is
   5'-GGATTTTTGTCCACAATCA-3'.
   What is the sequence of the complementary strand?

   3' – CCTAAAAACAGGTGTTAGT – 5'

2. 13% of the nucleotides in a DNA double helix are adenine. What are the percentages of the other nucleotides?

   T- 13%     C- 37%     G-37%

3. How many possible nucleotide sequences can be formed for a stretch of DNA that is 100 nucleotides long?

   $4^{100}$

# Let's try to answer these

4. **The two strands of a DNA double helix can be separated by heating (called melting).**

   **If you raised the temperature of a solution containing the following three DNA molecules, in what order do you suppose they would melt?**

   ```
   5'-GCGGGCCAGCCCGAGTGGGTAGCCCAGG-3'
   3'-CGCCCGGTCGGGCTCACCCATCGGGTCC-5'

   5'-ATTATAAATATTTAGATACTATATTTACAA-3'
   3'-TAATATTTTATAAATCTATGATATAAATGTT-5'

   5'-AGAGCTAGATCGAT-3'
   3'-TCTCGATCTAGCTA-5'
   ```

   **5'-GCGGGCCAGCCCGAGTGGGTAGCCCAGG-3'**
   **3'-CGCCCGGTCGGGCTCACCCATCGGGTCC-5'**