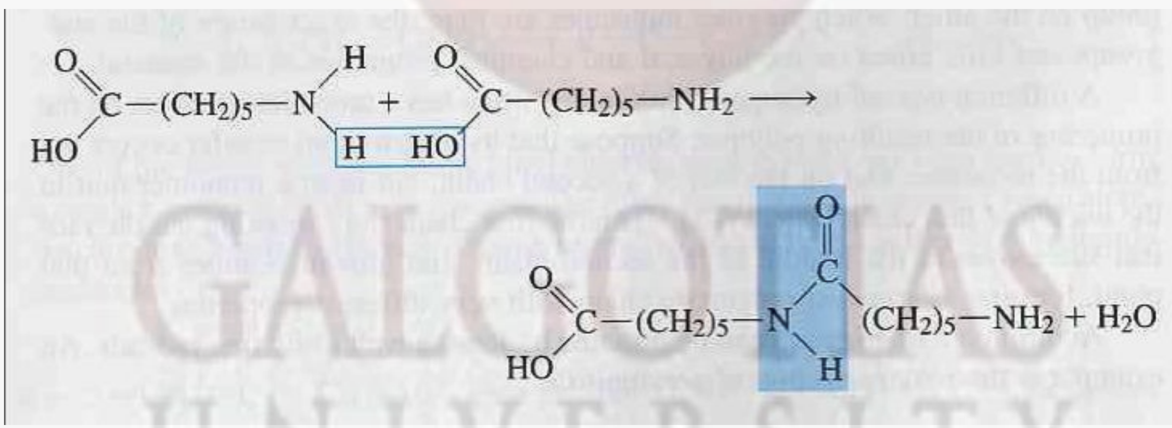
Condensation polymerization

Condensation polymerization: the polymer grows from monomers by splitting off a small molecule such as water or carbon dioxide.

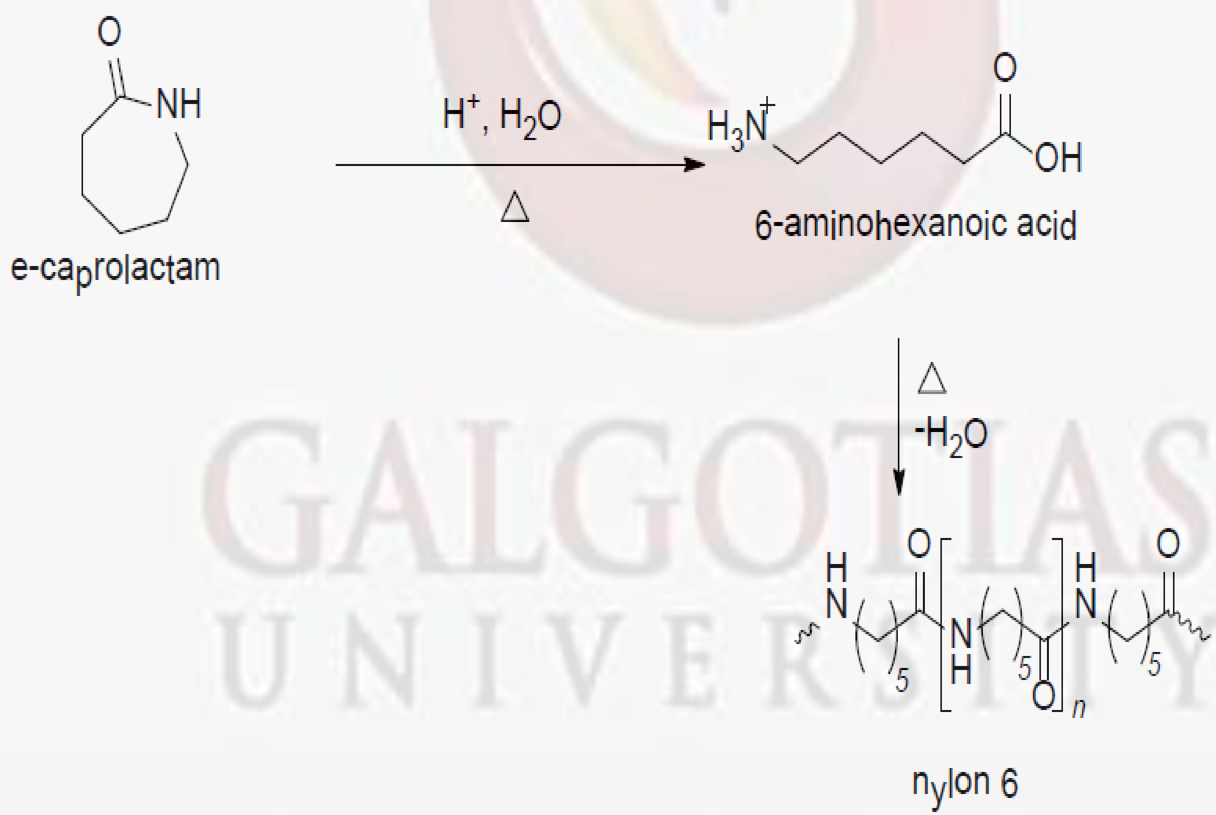
Example: formation of amide links and loss of water

Monomers

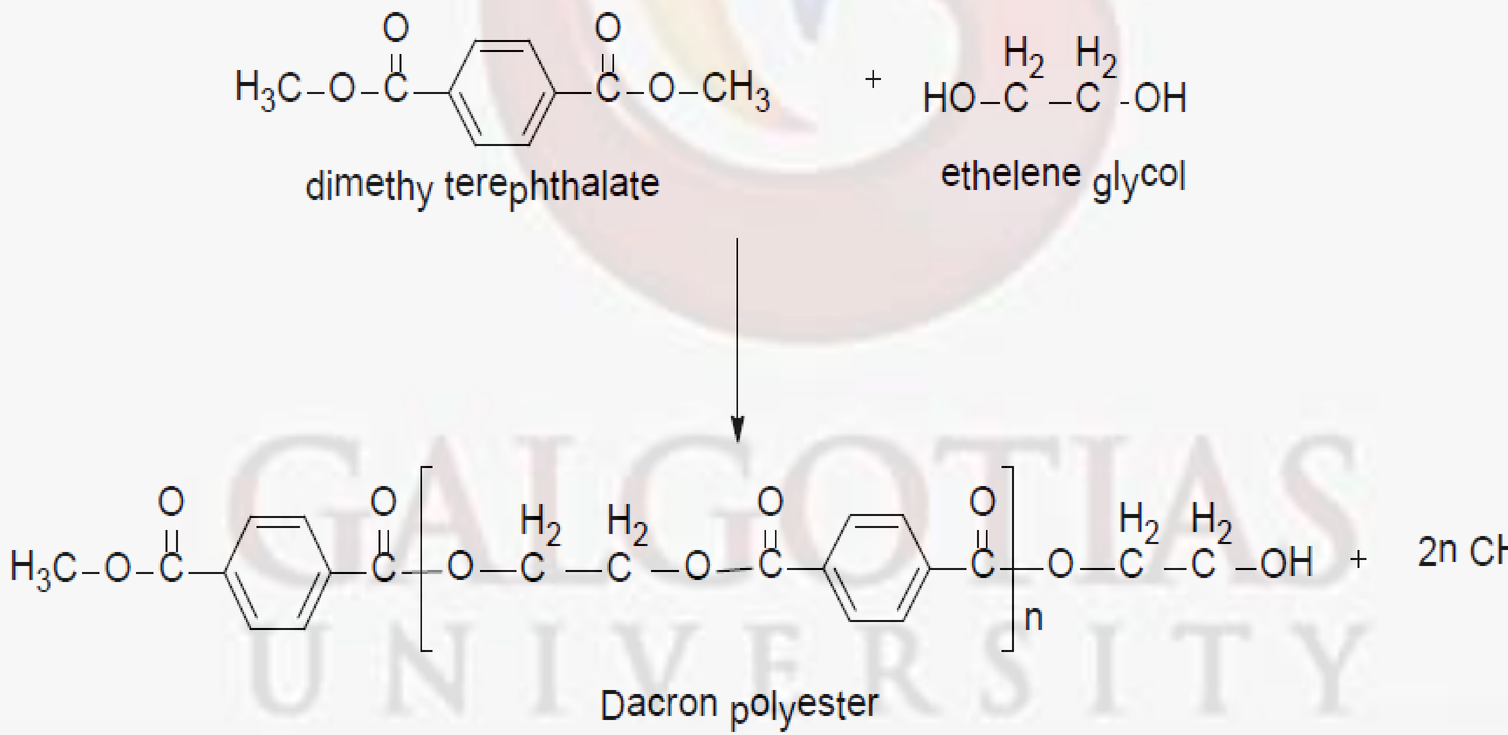


First unit of polymer + H_2O

***Polyamides*:** This type of polymers is formed by the result of generation of amide bonds in the polymerization reaction. Nylon 6 and nylon 66 are important examples for this type of polymers nylon 6 is synthesized from ϵ-caprolactam, which on heating decomposes into 6-aminohexanoic acid that polymerizes into nylon 6. Here the number 6 represents the number of carbon atoms present in the monomer unit.

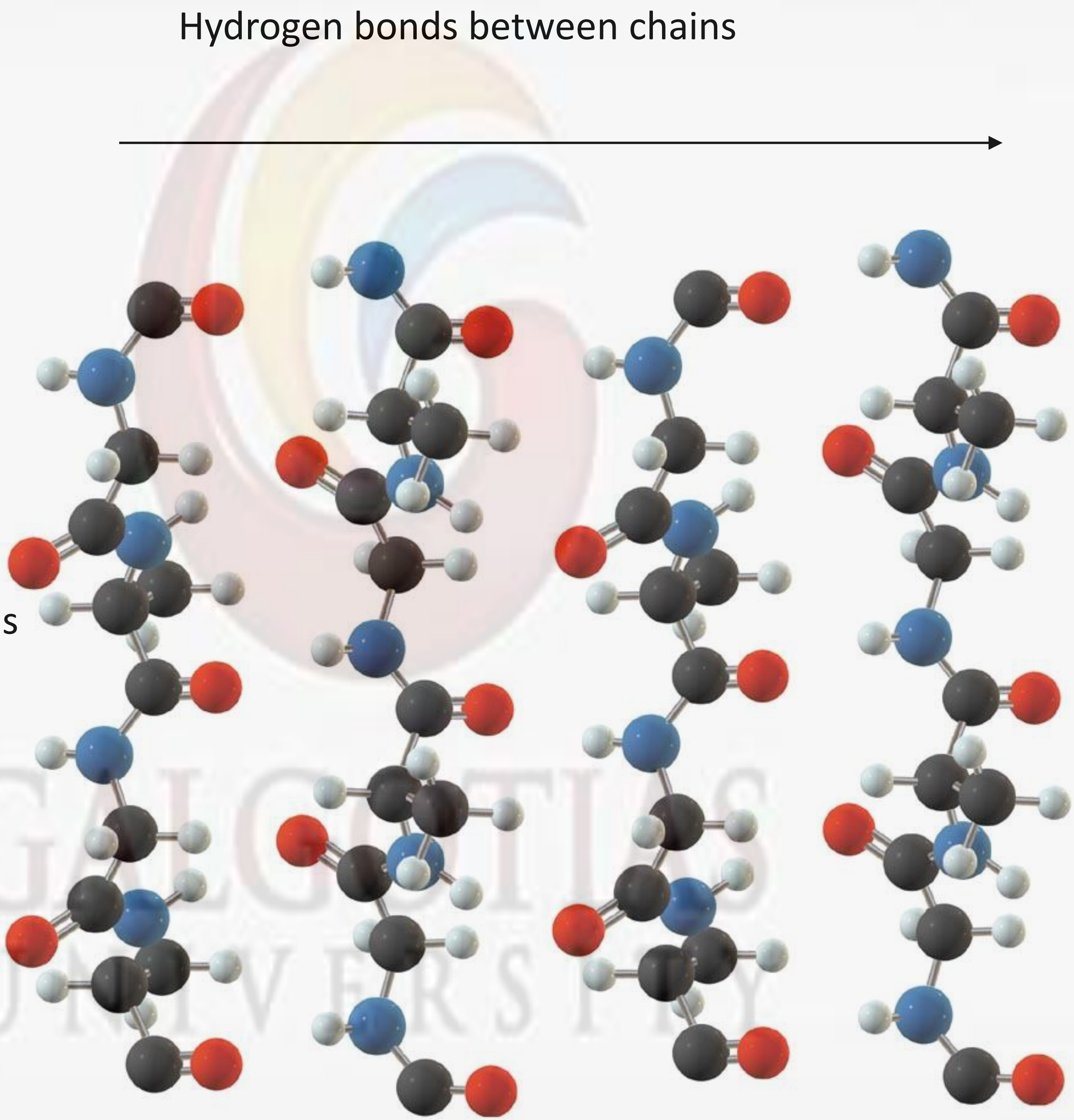


***Polyesters*:** This type of polymers is generated by the result of formation of ester bon the polymer chain by the condensation reaction between two monomer units. Dacron a well-known polyester, synthesized by the transesterification of dimethyl terephth with ethylene glycol.

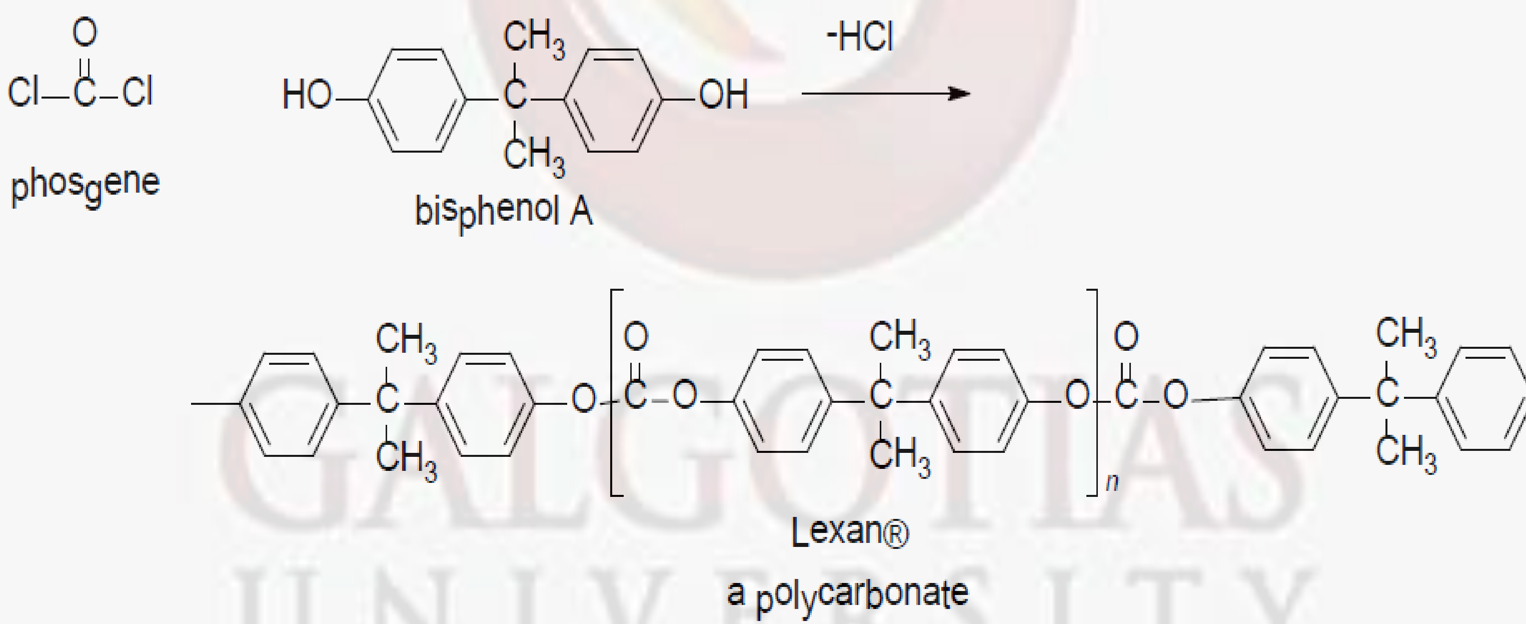


Supramolecular Structure of nylon

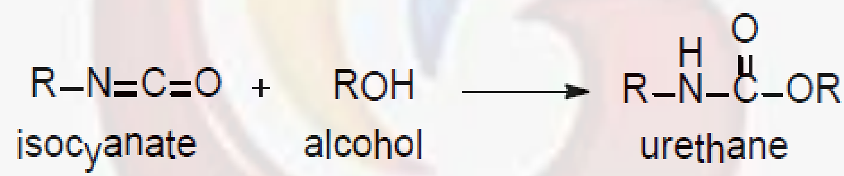
Intermolecular hydrogen bonds give nylon enormous tensile strength

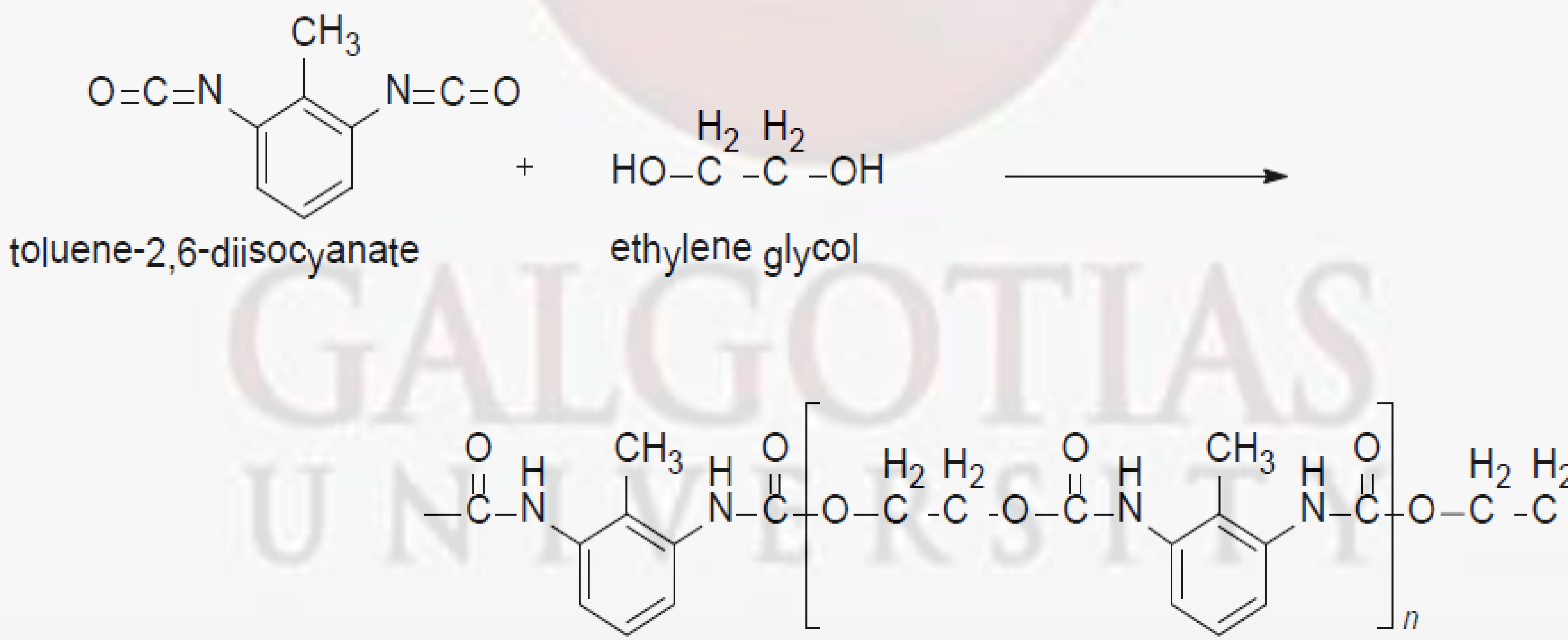


Polycarbonates: This is an example for condensation of step-growth polymer. Here the polymer chain is linked together by carbonate bonds. Lexan®, a polycarbonate formed by the condensation reaction between the two monomers phosgene and bisphenol A. This is used for manufacturing bulletproof windows.



Polyurethane: A carbamate functional group is synthesized by the addition reaction of an alcohol with an isocyanate molecule. This is also called as urethane. If a polymer chain is linked together by urethane bonds are called as polyurethane. Typically, polyuretha are prepared by the addition reaction of diol monomers with diisocyanate monom Polyurethane in the form of foams has been used for furniture stuffing, carpet backi and insulations.





Biopolymers

Nucleic acid polymers (DNA, RNA)

Amino acids polymers (Proteins)

Sugar polymers (Carbohydrates)

Genetic information for the cell: DNA

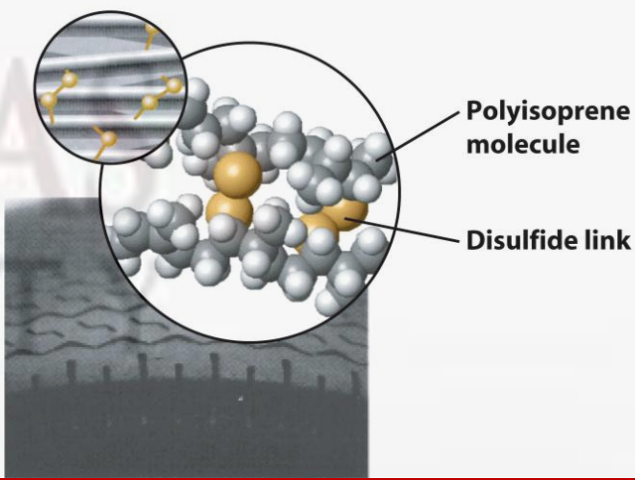
Structural strength and catalysis: Proteins

Energy source: Carbohydrates

Proteins: Proteins are large biological molecules, made up of the smallest units called α-amino acids. They are building blocks of plant and animal cells. Many proteins are enzymes that catalyze biochemical reactions and are essential to metabolic functions.

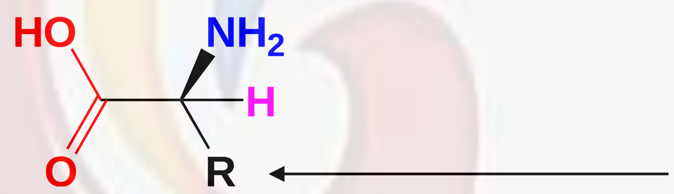
***Natural Rubber*:** Natural rubber is the polymer of isoprene. This is mainly harvested as a sticky milky colloidal form called latex from the bark of the rubber tree.

natural rubber



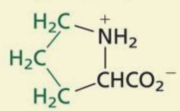
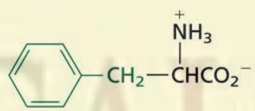
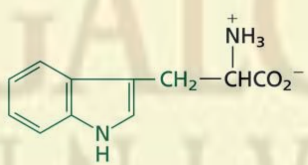
Proteins: amino acid monomers

The basic structure of an amino acid monomer



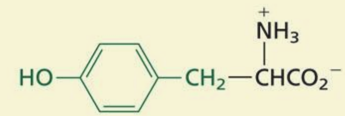
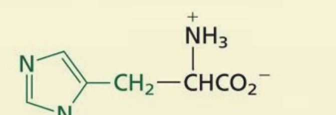
The difference between amino acids is the R group

TABLE 27.1 α-Amino Acids Found in Proteins

Name	Abbreviation	Structural formula*
Amino acids with nonpolar side chains		
Glycine	Gly (G)	$H-CH(\overset{+}{N}H_3)CO_2^-$
Alanine	Ala (A)	$H_3C-CH(\overset{+}{N}H_3)CO_2^-$
Valine†	Val (V)	$(CH_3)_2CH-CH(\overset{+}{N}H_3)CO_2^-$
Leucine†	Leu (L)	$(CH_3)_2CHCH_2-CH(\overset{+}{N}H_3)CO_2^-$
Isoleucine†	Ile (I)	$CH_3CH_2CH(CH_3)-CH(\overset{+}{N}H_3)CO_2^-$
Methionine†	Met (M)	$CH_3SCH_2CH_2-CH(\overset{+}{N}H_3)CO_2^-$
Proline	Pro (P)	
Phenylalanine†	Phe (F)	
Tryptophan†	Trp (W)	
Amino acids with polar but nonionized side chains		
Asparagine	Asn (N)	$H_2NC(=O)CH_2-CH(\overset{+}{N}H_3)CO_2^-$

*All amino acids are shown in the form present in greatest concentration at pH 7.
†An essential amino acid, which must be present in the diet of animals to ensure normal growth.

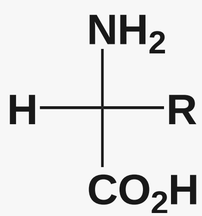
TABLE 27.1 α-Amino Acids Found in Proteins (continued)

Name	Abbreviation	Structural formula*
Amino acids with polar but nonionized side chains		
Glutamine	Gln (Q)	$H_2NC(=O)CH_2CH_2-CH(\overset{+}{N}H_3)CO_2^-$
Serine	Ser (S)	$HOCH_2-CH(\overset{+}{N}H_3)CO_2^-$
Threonine†	Thr (T)	$CH_3CH(OH)-CH(\overset{+}{N}H_3)CO_2^-$
Tyrosine	Tyr (Y)	
Cysteine	Cys (C)	$HSCH_2-CH(\overset{+}{N}H_3)CO_2^-$
Amino acids with acidic side chains		
Aspartic acid	Asp (D)	$^-OC(=O)CH_2-CH(\overset{+}{N}H_3)CO_2^-$
Glutamic acid	Glu (E)	$^-OC(=O)CH_2CH_2-CH(\overset{+}{N}H_3)CO_2^-$
Amino acids with basic side chains		
Lysine†	Lys (K)	$H_3\overset{+}{N}CH_2CH_2CH_2CH_2-CH(\overset{+}{N}H_3)CO_2^-$
Arginine†	Arg (R)	$H_2NC(=\overset{+}{N}H_2)NHCH_2CH_2CH_2-CH(\overset{+}{N}H_3)CO_2^-$
Histidine†	His (H)	

Proteins: condensation polymers

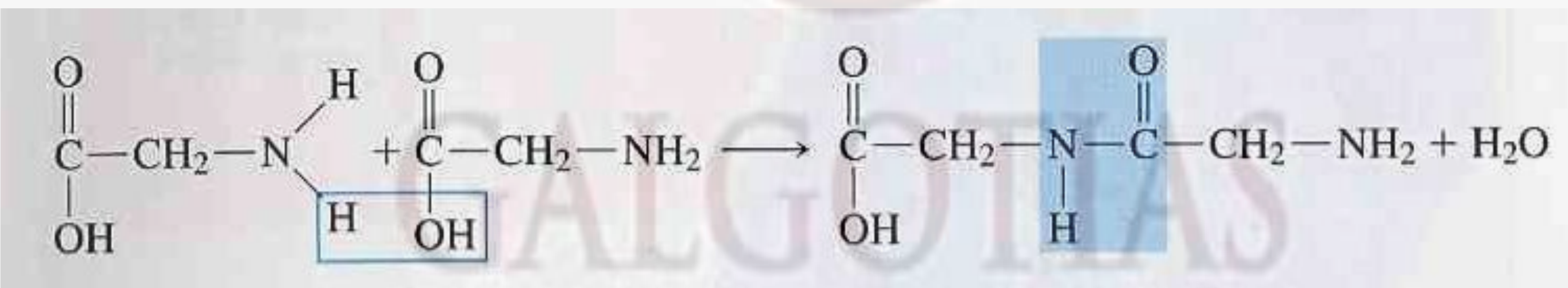
Formed by condensation polymerization of amino acids

Monomers: 20 essential amino acids



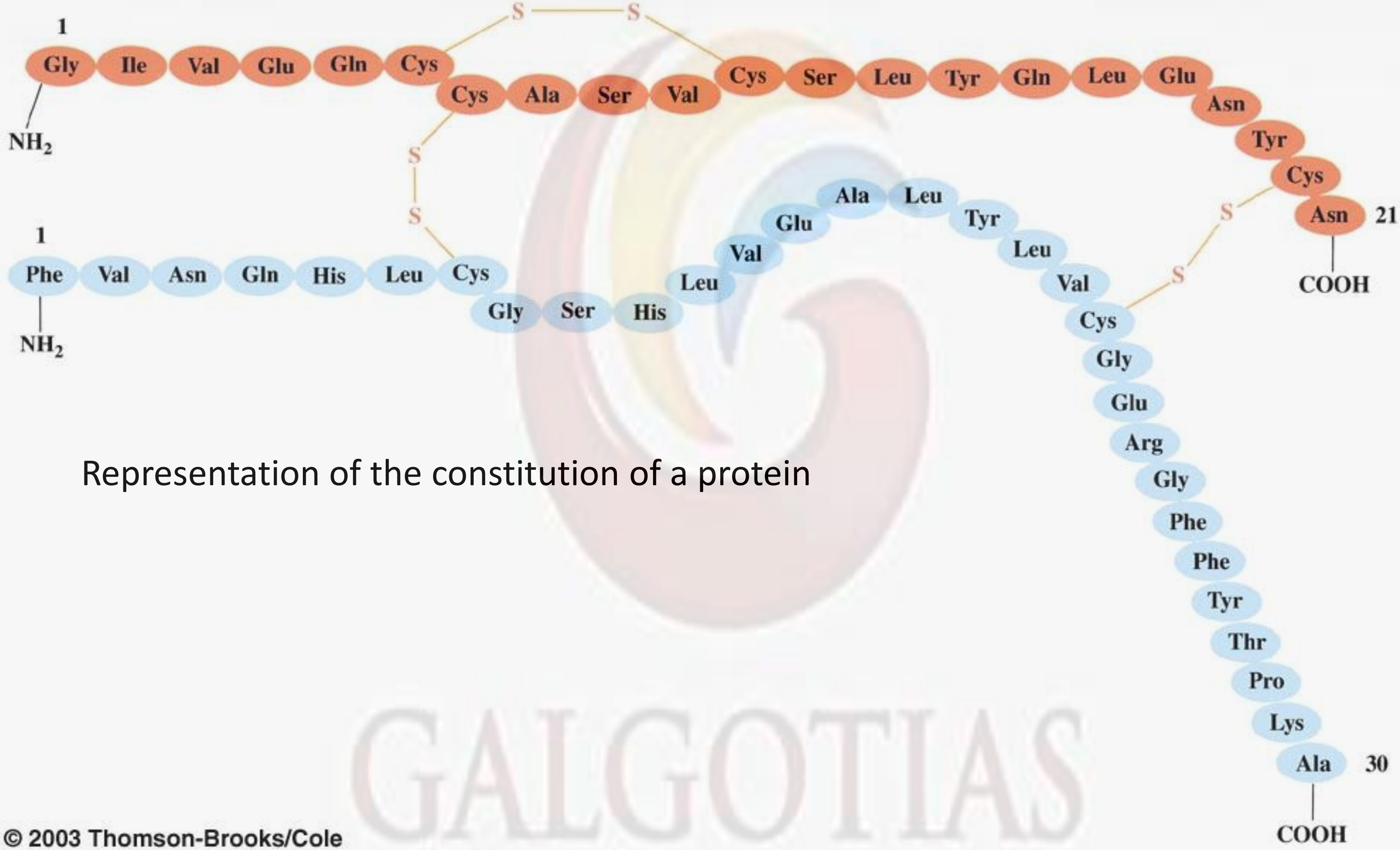
General structure of an amino acid

R is the only variable group



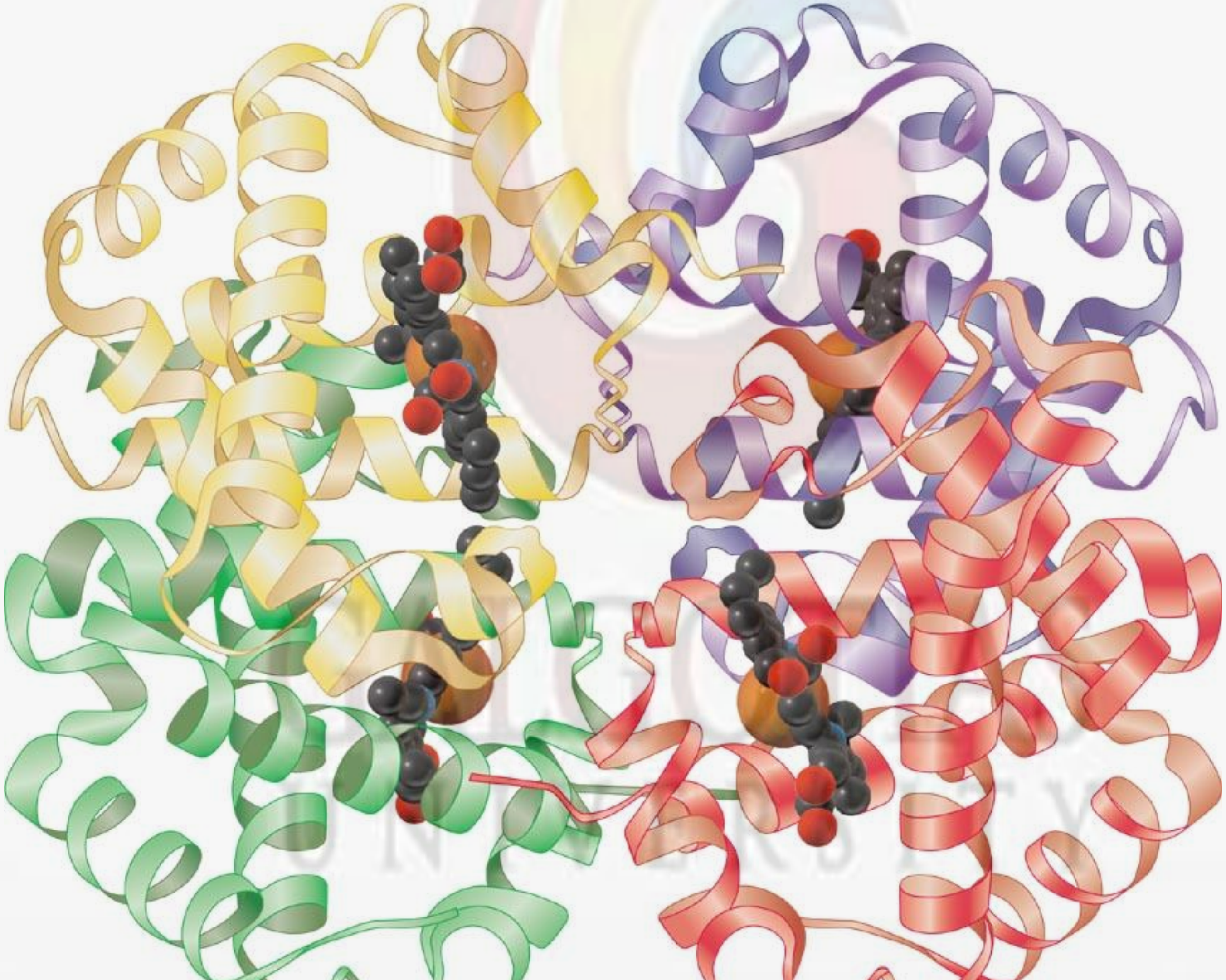
Glycine (R = H) + Glycine

First step toward poly(glycine)



Representation of the constitution of a protein

Three D representation of the structure of a protein



The monomers:

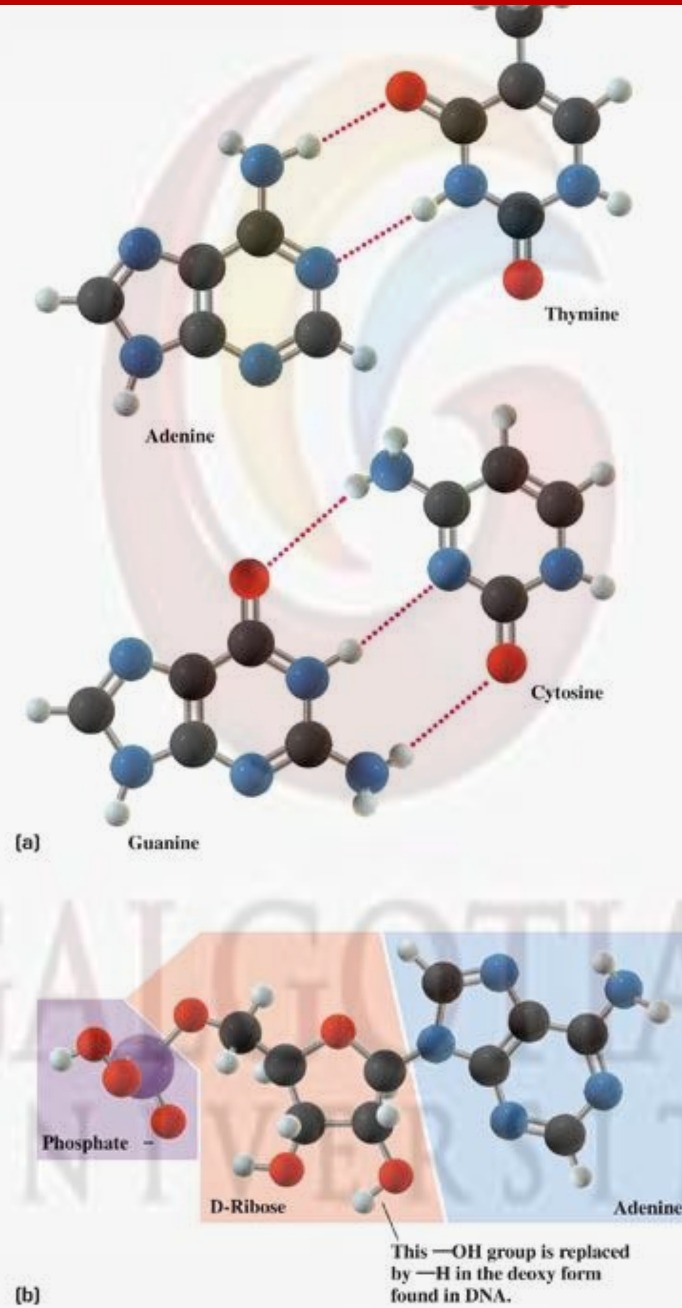
Adenine (A)

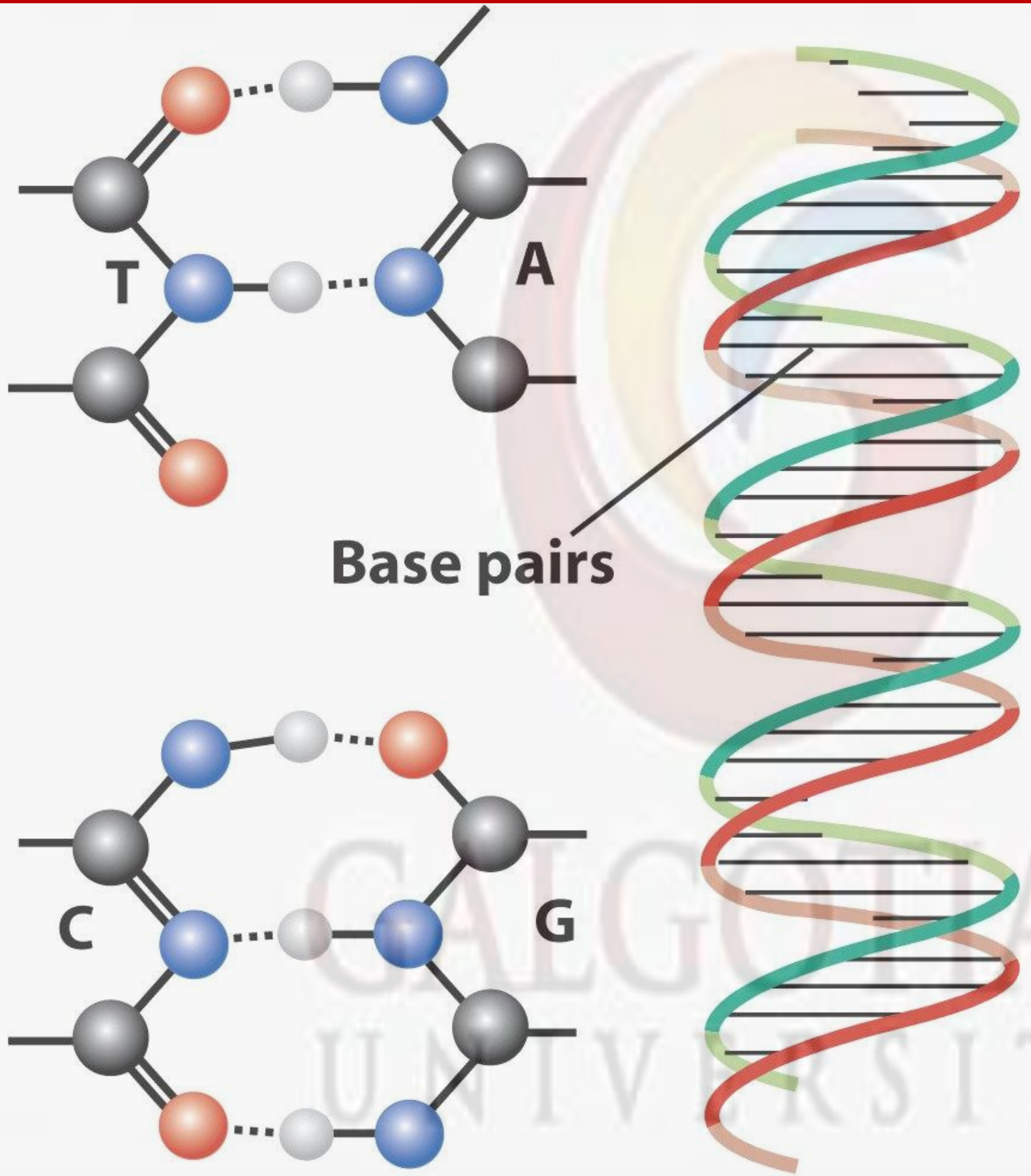
Guanine (G)

Thymine (T)

Cytosine (C)

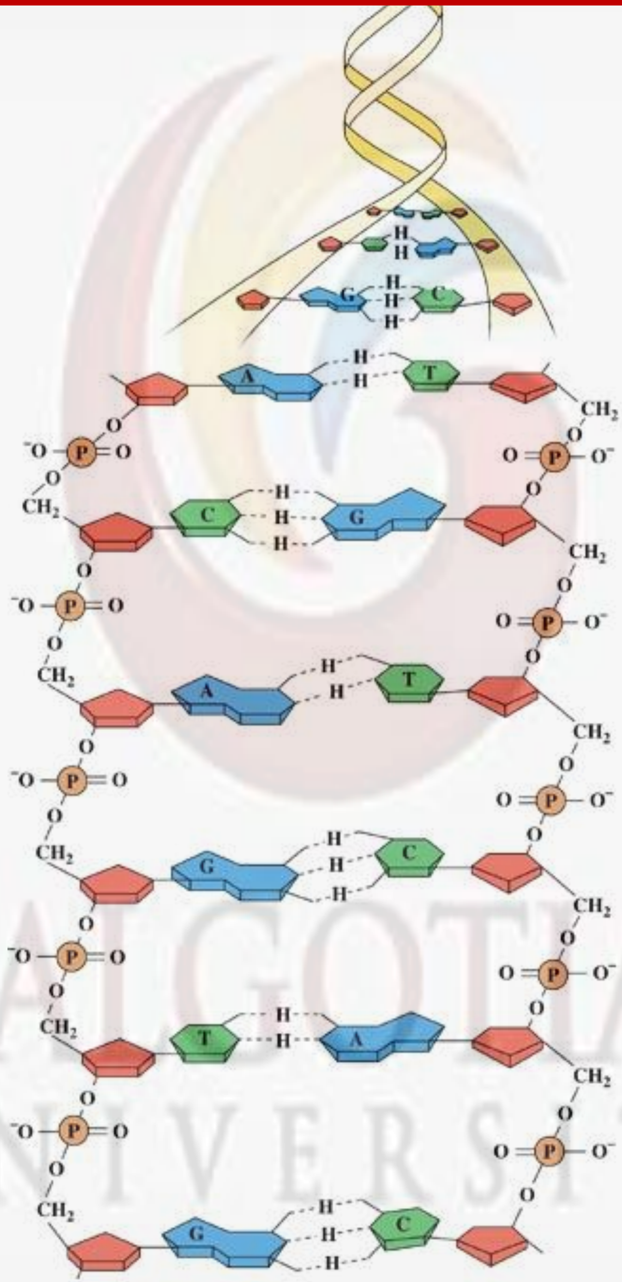
Phosphate-
Sugar (backbone) of
DNA



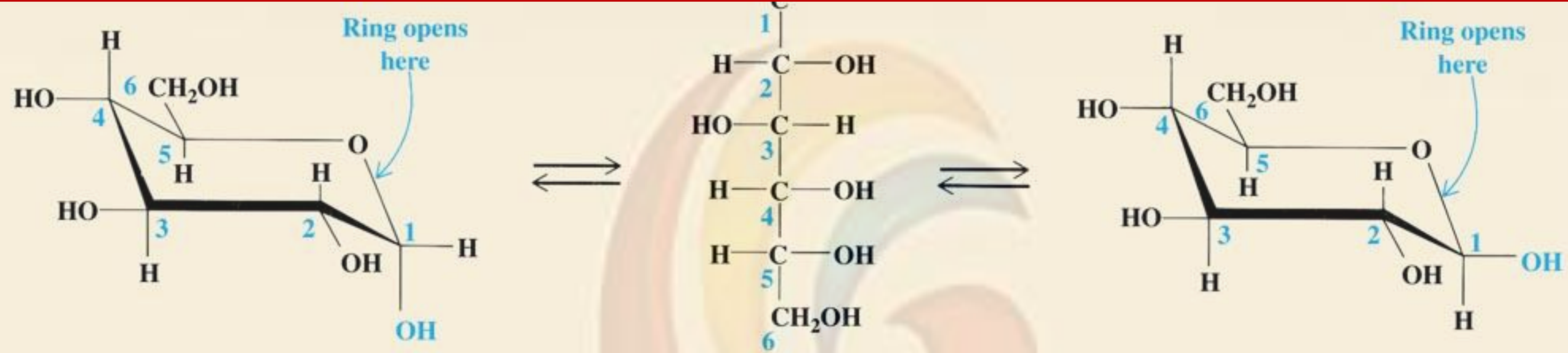


Phosphate-sugar backbone holds the DNA macromolecule together

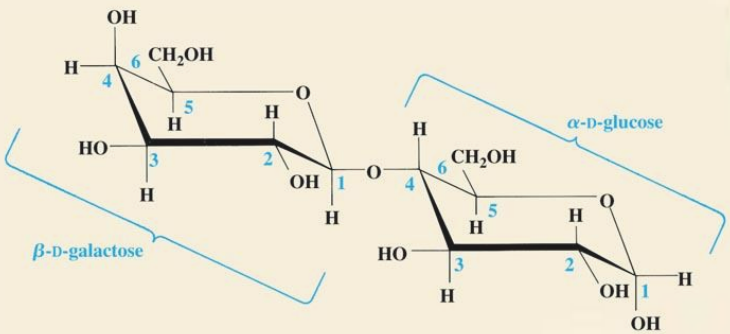
One strand unwinds to duplicate its complement via a polymerization of the monomers
C, G, A and T



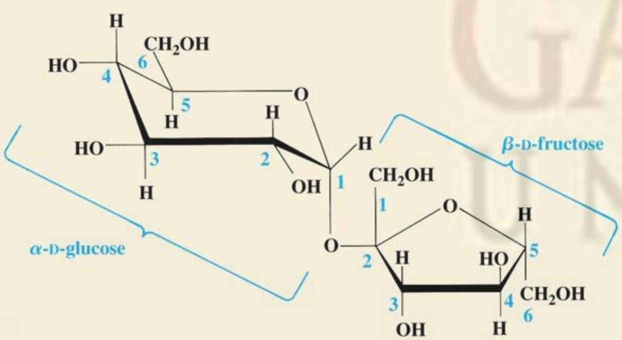
Carbohydrates

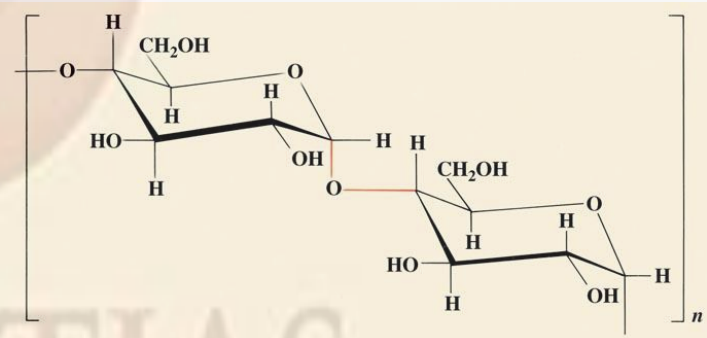


(a) α-D-glucose (b) Open-chain D-glucose (c) β-D-glucose

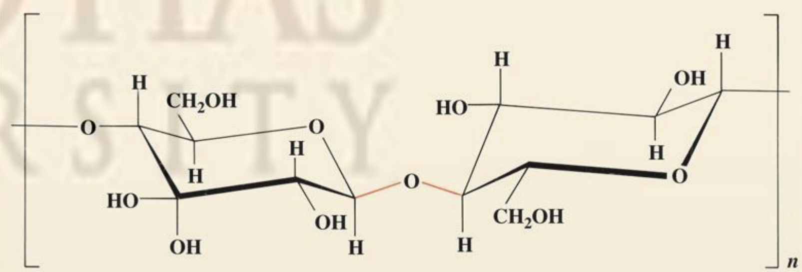


Lactose





(a) Starch



(b) Cellulose

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- Feldman, Dorel (January 2008). "Polymer History". Designed Monomers and Polymers. **11 (1): 1–15. doi:10.1163/156855508X292383. ISSN 1568-5551. S2CID 219539020.**
- **"Lord Todd: the state of chemistry". Chemical & Engineering News Archive. 58 (40): 28–33. 1980-10-06. doi:10.1021/cen-v058n040.p028. ISSN 0009-2347.**

School of Basic & Applied Sciences

Course Code : BSCC3004 **Course Name: Organic Chemistry V**

References and suggestions for further reading:

1. Textbook of Polymer Science by Fred W. Billmeyer, Wiley
2. Polymer Chemistry by Charles E Carraher, Jr., Marcel Dekker, Inc.
3. Principle of Polymerization by George Odian, Wiley