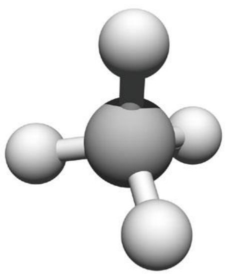
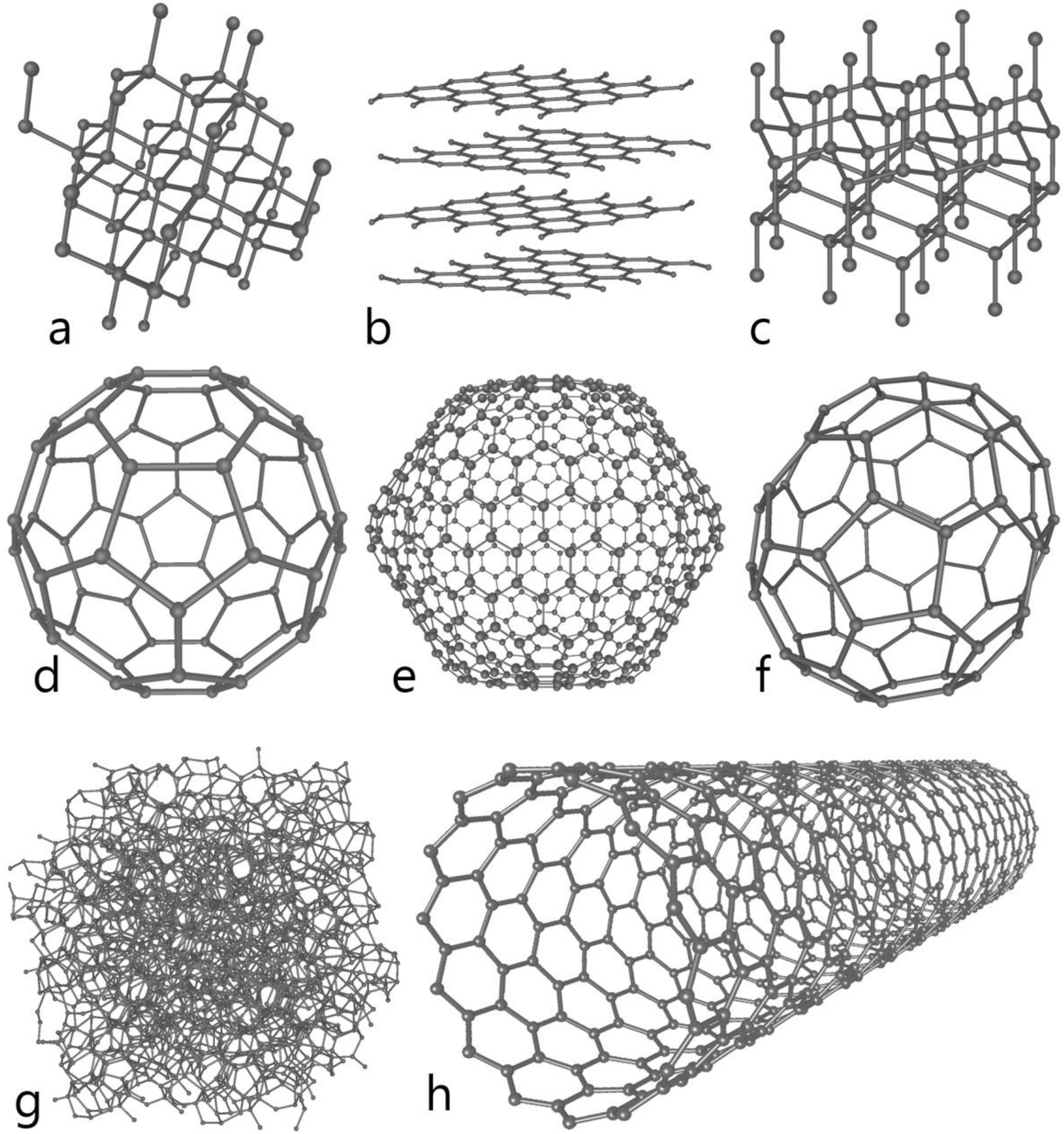
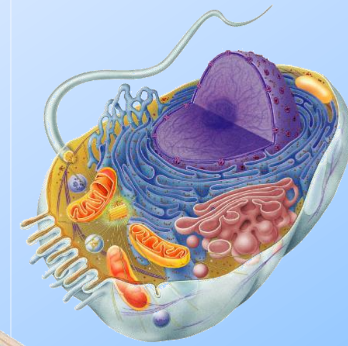
The Star of The Show (Ch. 3)

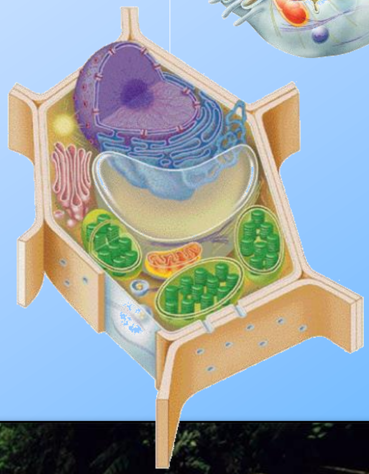


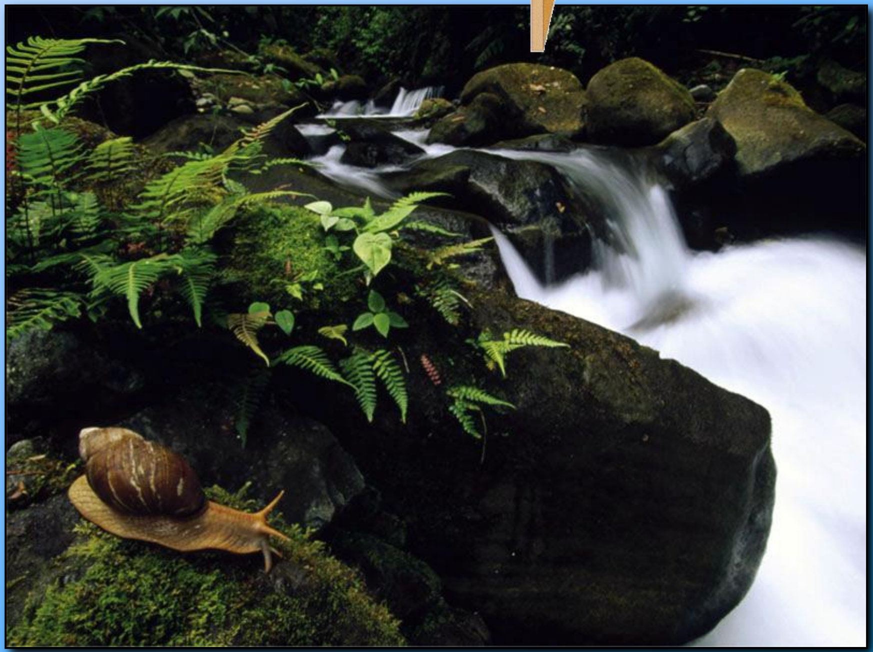


Why study Carbon?

- All of life is built on carbon
- Cells
  - ~72% H_2O
  - ~25% carbon compounds
    - carbohydrates
    - lipids
    - proteins
    - nucleic acids
  - ~3% salts
    - Na, Cl, K…

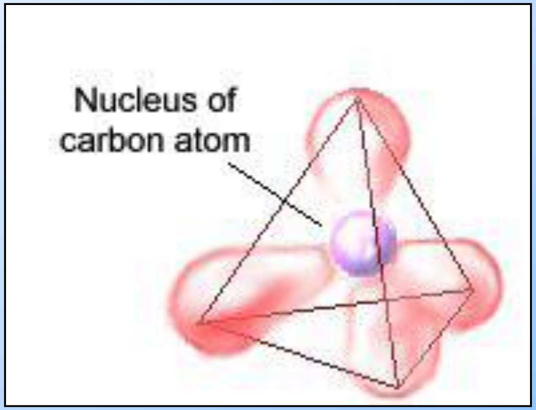


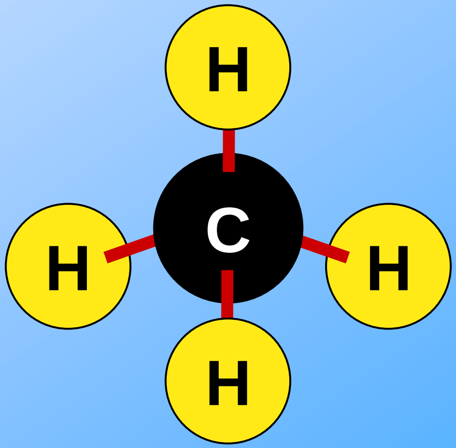


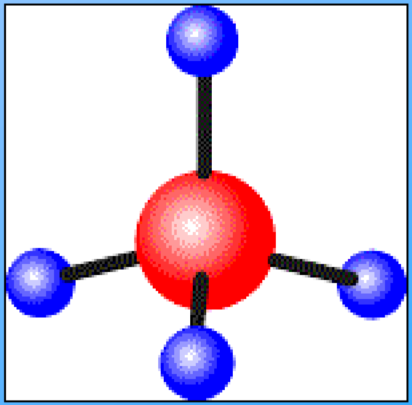


Chemistry of Life

- Organic chemistry is the study of carbon compounds
- C atoms are versatile building blocks
  - bonding properties
  - 4 stable covalent bonds



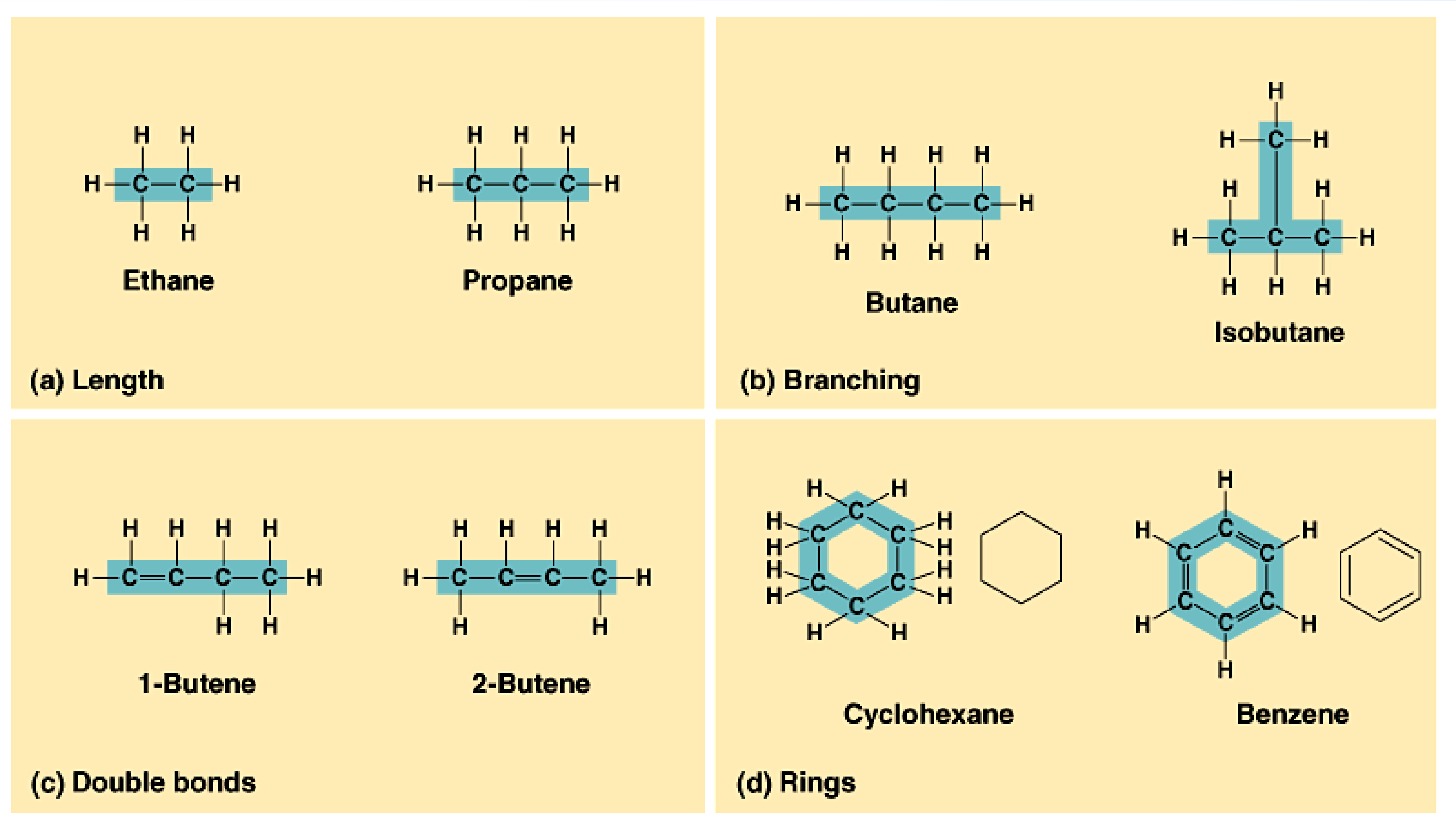




Characteristics of Carbon

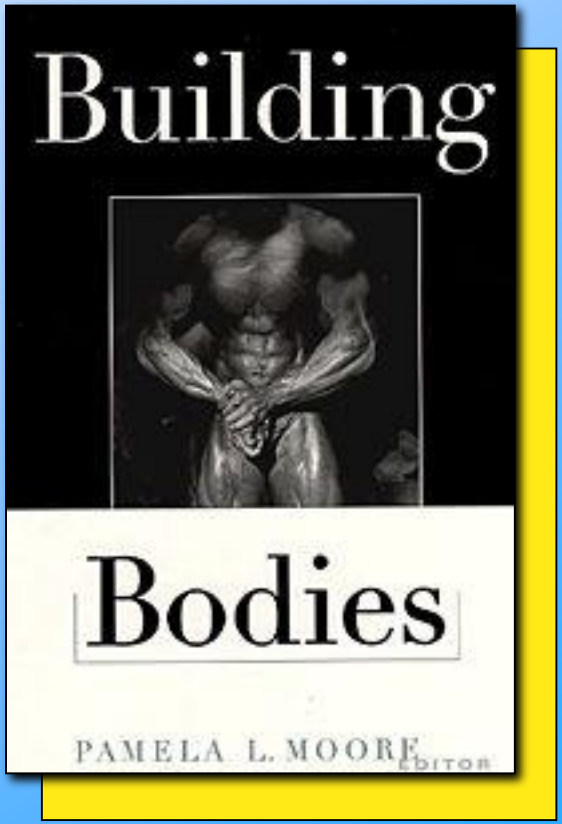
- Abundant
- Has 4 valence electrons → forms 4 bonds
- Forms Covalent (strong) bonds
- Forms chains with other carbons
- Can form double and triple bonds
- Stores energy in C – H bonds

Hydrocarbons can grow



Macromolecules

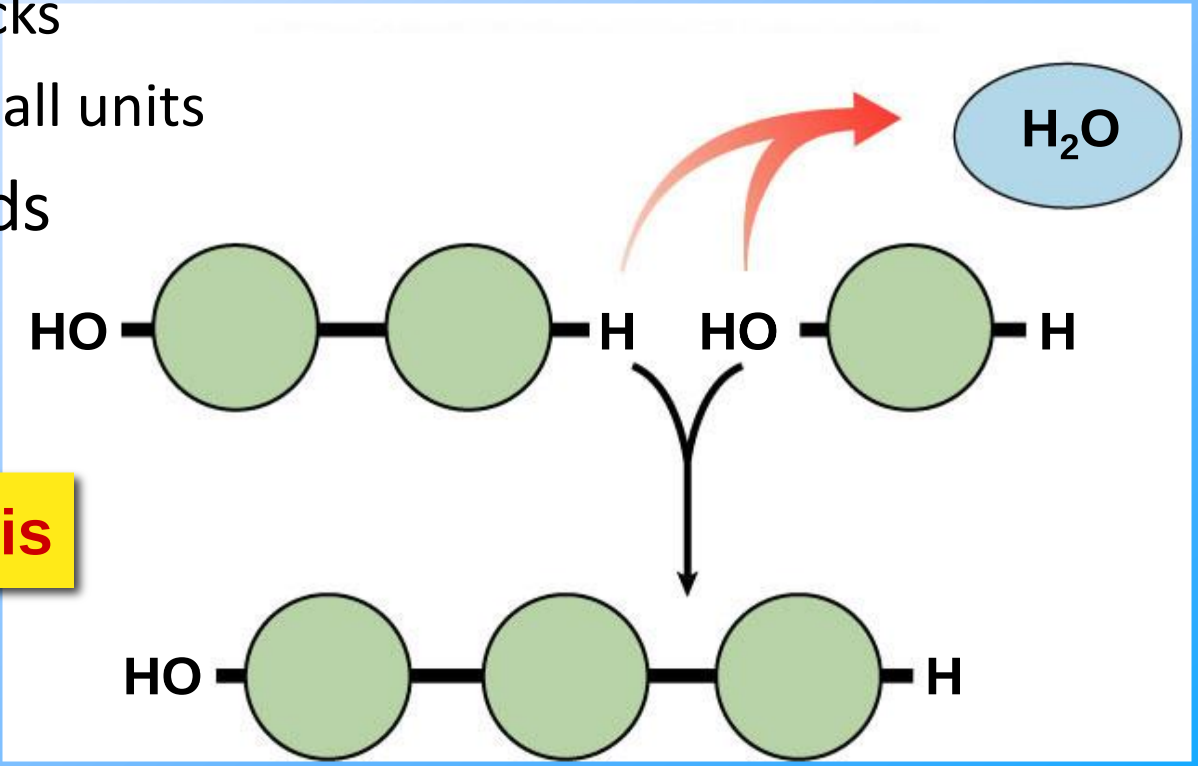
- Smaller organic molecules join together to form larger molecules
  - macromolecules
- 4 major classes of macromolecules:
  - carbohydrates
  - lipids
  - proteins
  - nucleic acids



Polymers

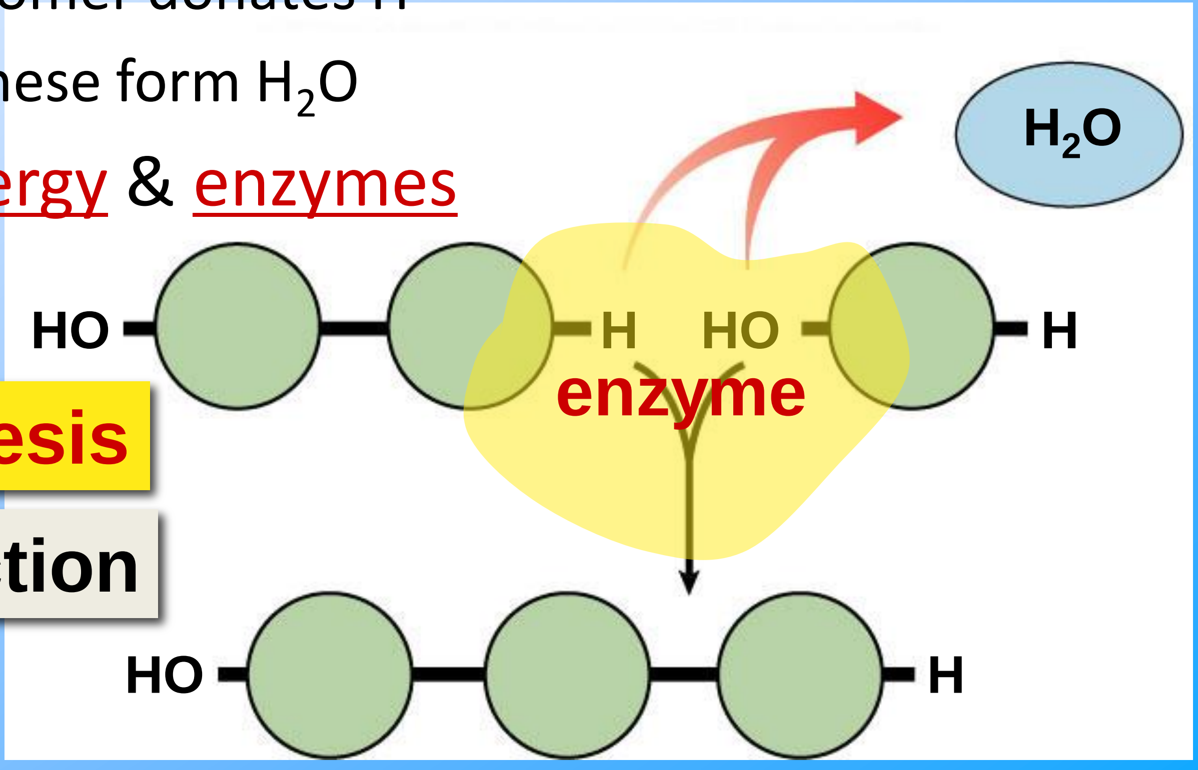
- Long molecules built by linking repeating building blocks in a chain
  - monomers
    - building blocks
    - repeated small units
  - covalent bonds

Dehydration synthesis



How to build a pol

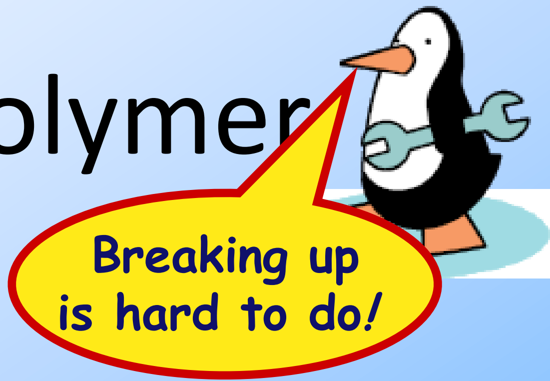
- Synthesis
  - joins monomers by "taking" H_2O out
    - one monomer donates OH^-
    - other monomer donates H^+
    - together these form H_2O
  - requires energy & enzymes



Dehydration synthesis

Condensation reaction

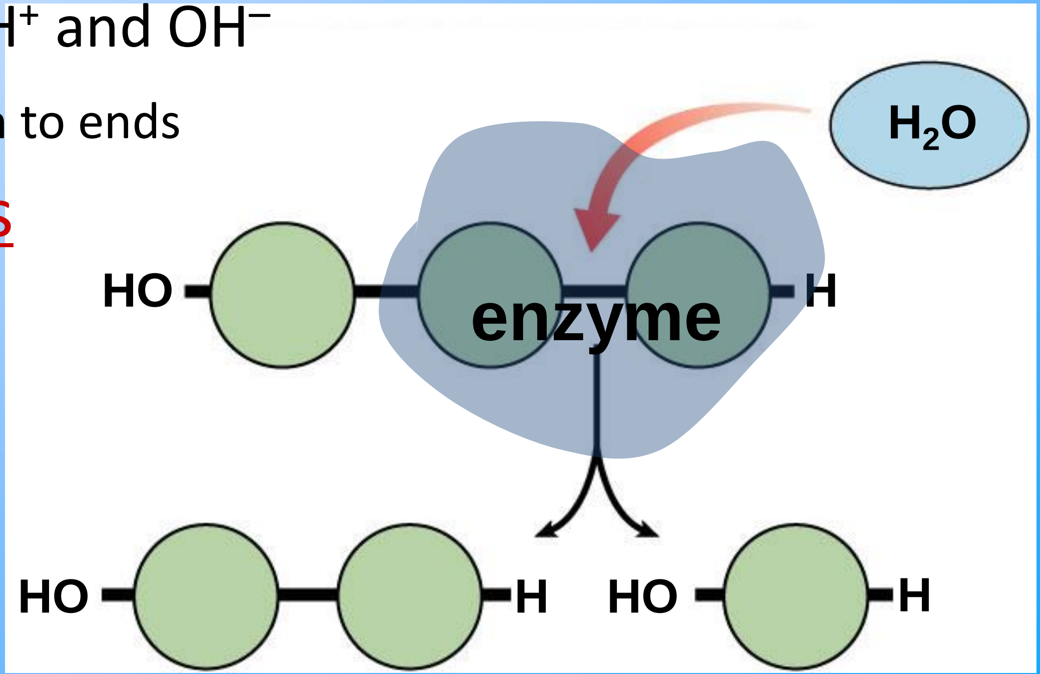
How to break down a polymer

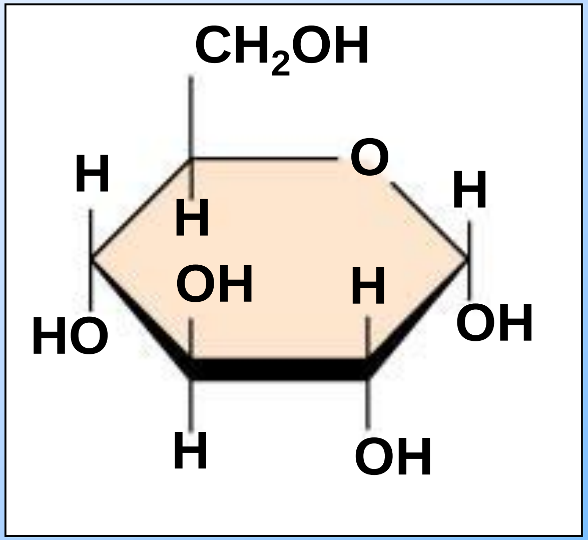


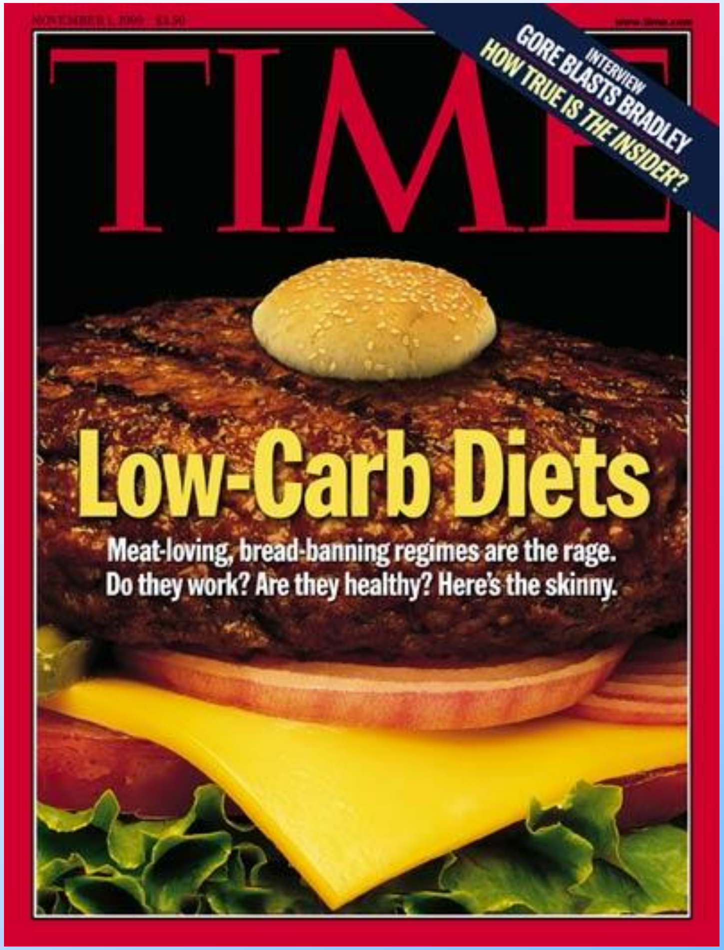
- Digestion
  - use H_2O to breakdown polymers
    - reverse of dehydration synthesis
    - cleave off one monomer at a time
    - H_2O is split into H^+ and OH^-
      - H^+ & OH^- attach to ends
  - requires enzymes
  - releases energy

Hydrolysis

Digestion







Carbohydrates

energy molecules

Carbohydrates

- Carbohydrates are composed of C, H, O

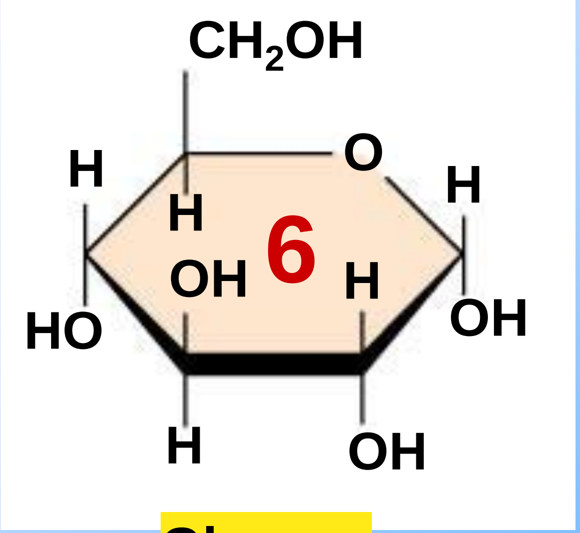
carbo - hydr - ate

CH_2O

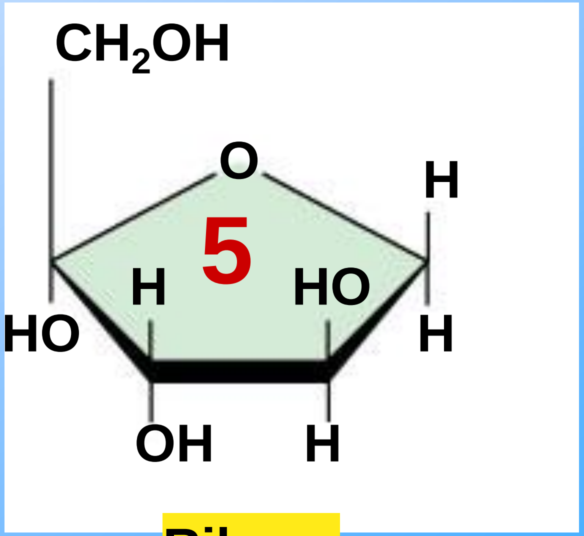
- Function:
  - <u>energy</u> $(CH_2O)_x \longrightarrow C_6H_{12}O_6$
  - <u>energy storage</u>
  - <u>raw materials</u>
  - <u>structural materials</u>
- Monomer: sugars
- ex: sugars, starches, cellulose

Sugars

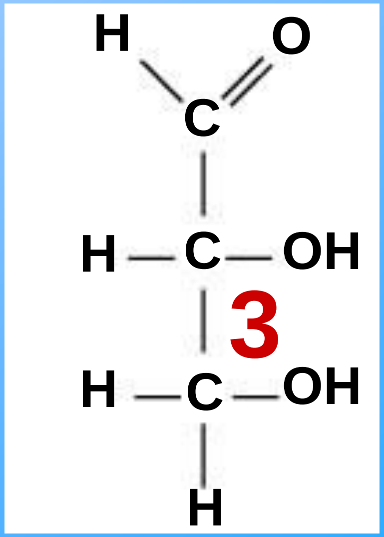
- Most names for sugars end in *-ose*
- Classified by number of carbons
  - 6C = hexose
  - 5C = pentose
  - 3C = triose



Glucose



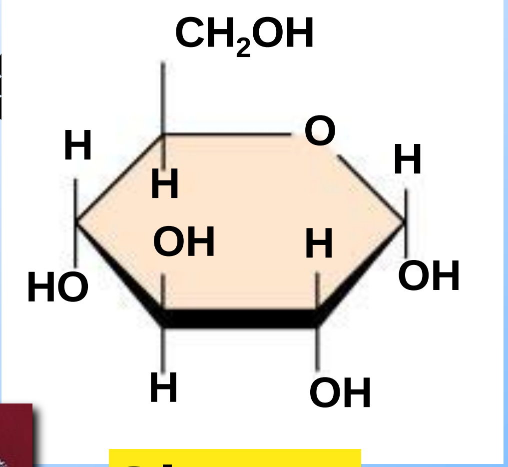
Ribose



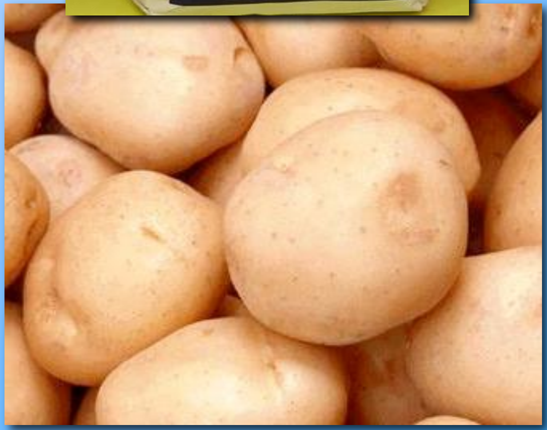
Glyceraldehyde

Simple & complex su

- Monosaccharides
  - glucose
- Disaccharides
  - sucrose
- Polysaccharides
  - glycogen
  - Starch
  - Chiten



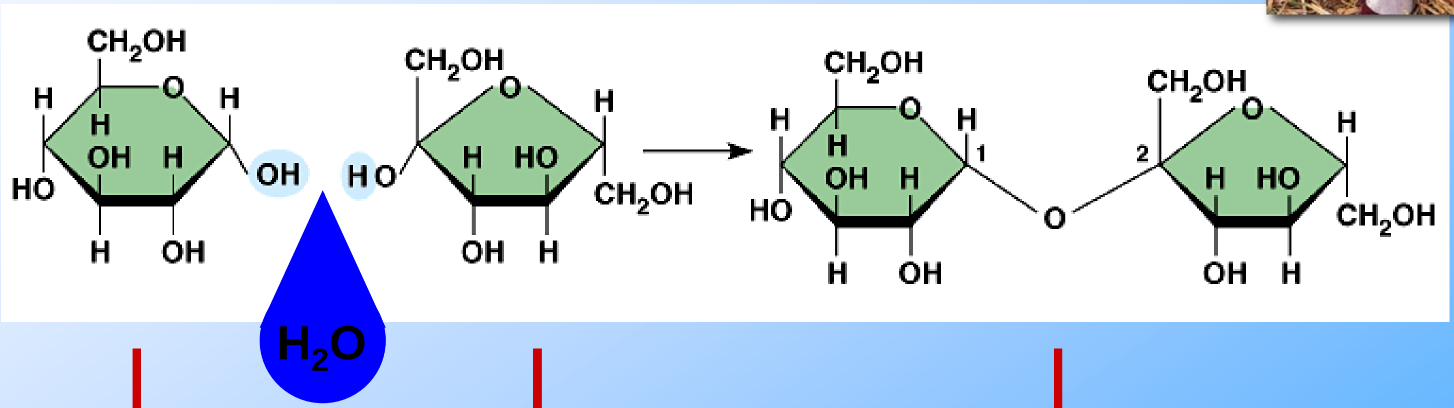
Glucose



Building sugars

- Dehydration synthesis

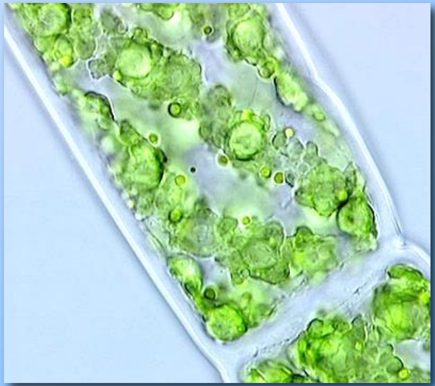
monosaccharides **disaccharide**



glucose **fructose** **sucrose (table sugar)**

Polysaccharides

- Function:
  - energy storage
    - starch (plants)
    - glycogen (animals)
      - in liver & muscles
  - structure
    - cellulose (plants)
    - chitin (arthropods & fungi)

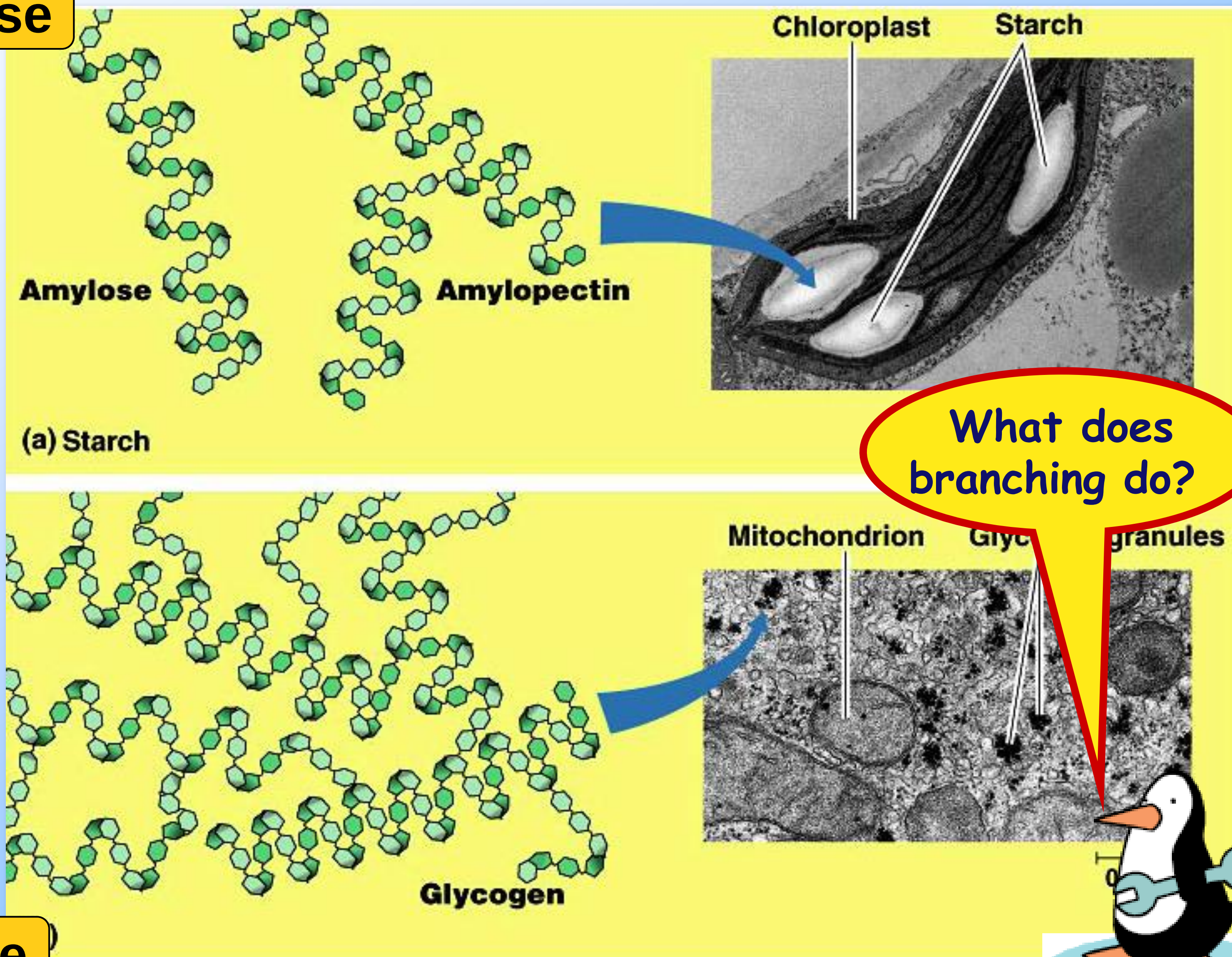


Linear vs. branched polysaccharides

slow release

starch
(plant)

energy storage



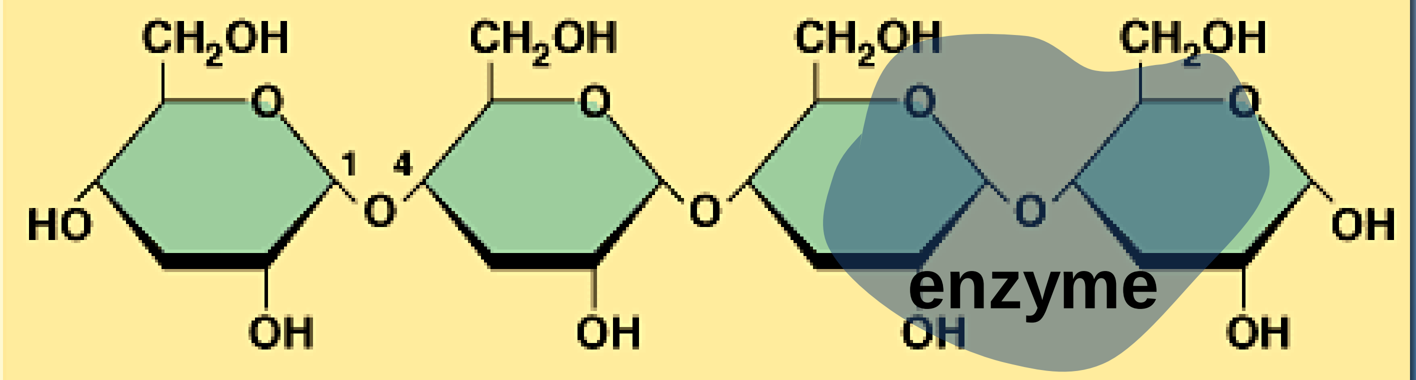
What does branching do?

glycogen
(animal)

fast release

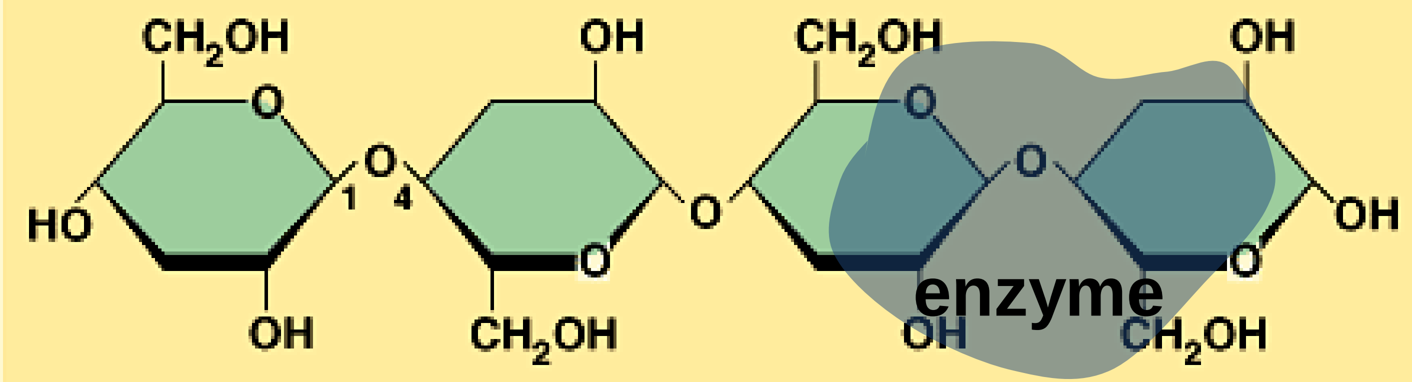
Digesting starch vs. cellulose

starch
easy to digest



(b) Starch: 1–4 linkage of α glucose monomers

cellulose
hard to digest



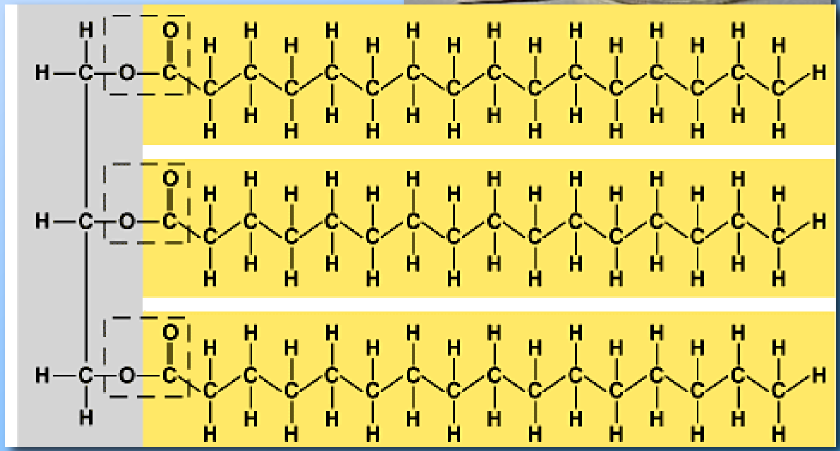
(c) Cellulose: 1–4 linkage of β glucose monomers

Lipids

long term energy storage
concentrated energy

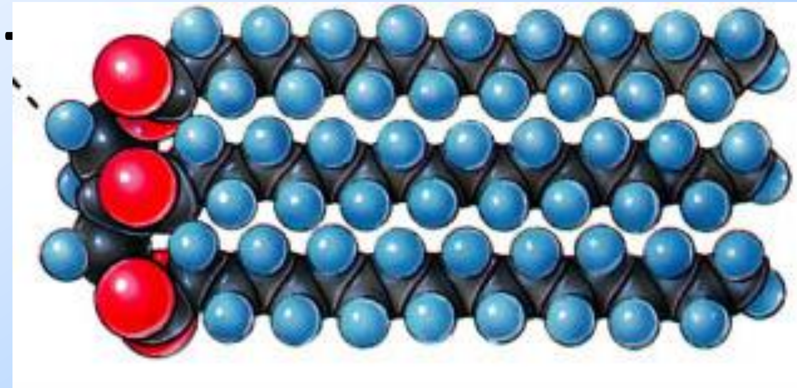
Lipids

- Lipids are composed of C, H, O
  - long hydrocarbon chains (H-C)
  - H:O ratio >> 2:1
- 3 Main types
  - fats
  - phospholipids
  - steroids

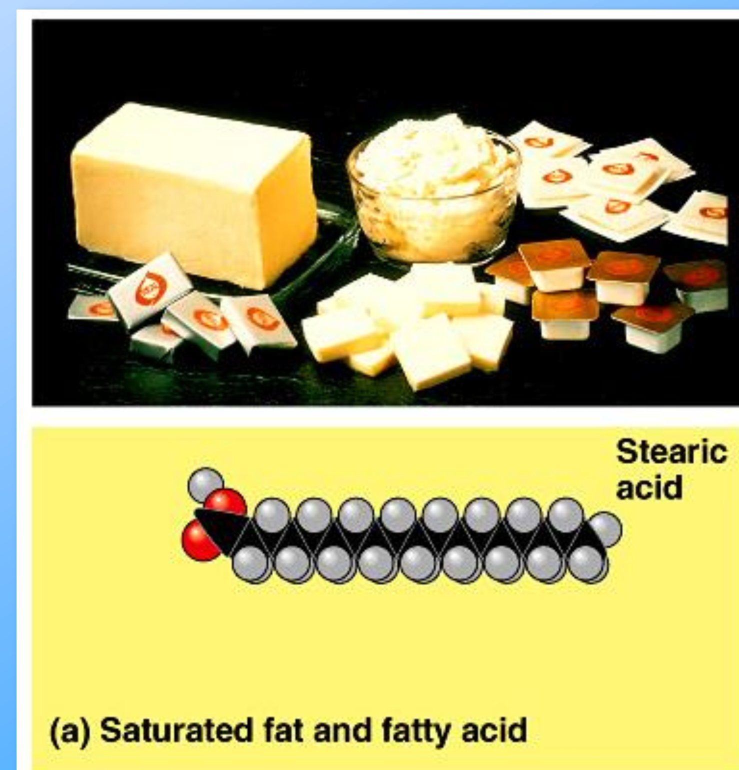


- Do not form polymers
  - big molecules made of smaller subunits
  - not a continuing chain

Saturated

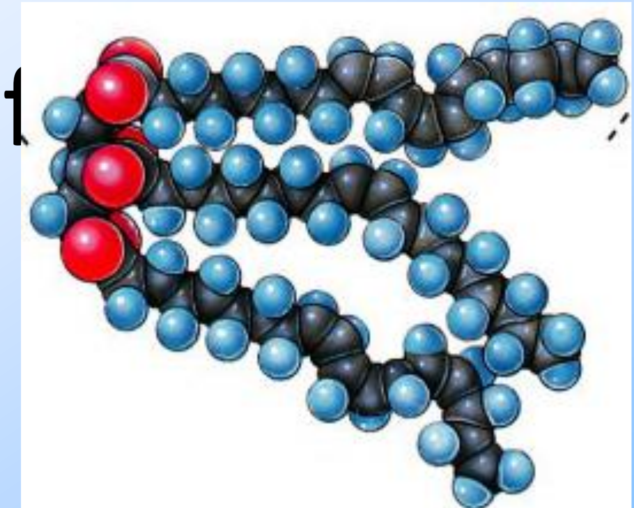


- All C bonded to H
- No C=C double bonds
  - long, straight chain
  - most animal fats
  - solid at room temp.
    - contributes to cardiovascular disease (atherosclerosis) = plaque deposits

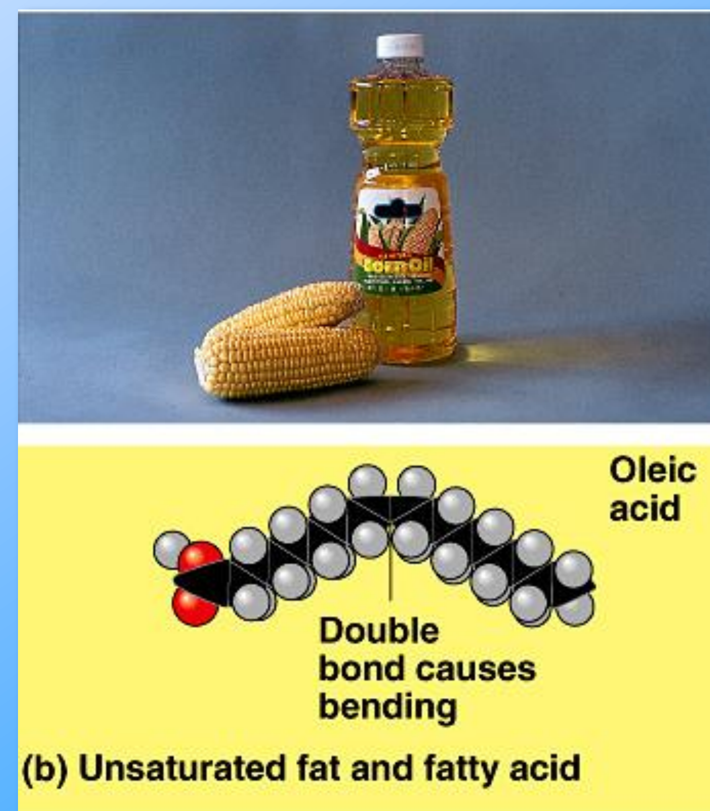


(a) Saturated fat and fatty acid

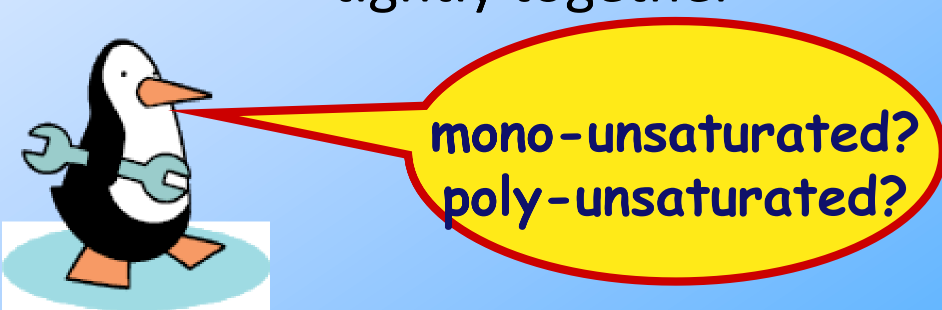
Unsaturated f



- C=C double bonds in the fatty acids
  - plant & fish fats
  - vegetable oils
  - liquid at room temperature
    - the kinks made by double bonded C prevent the molecules from packing tightly together

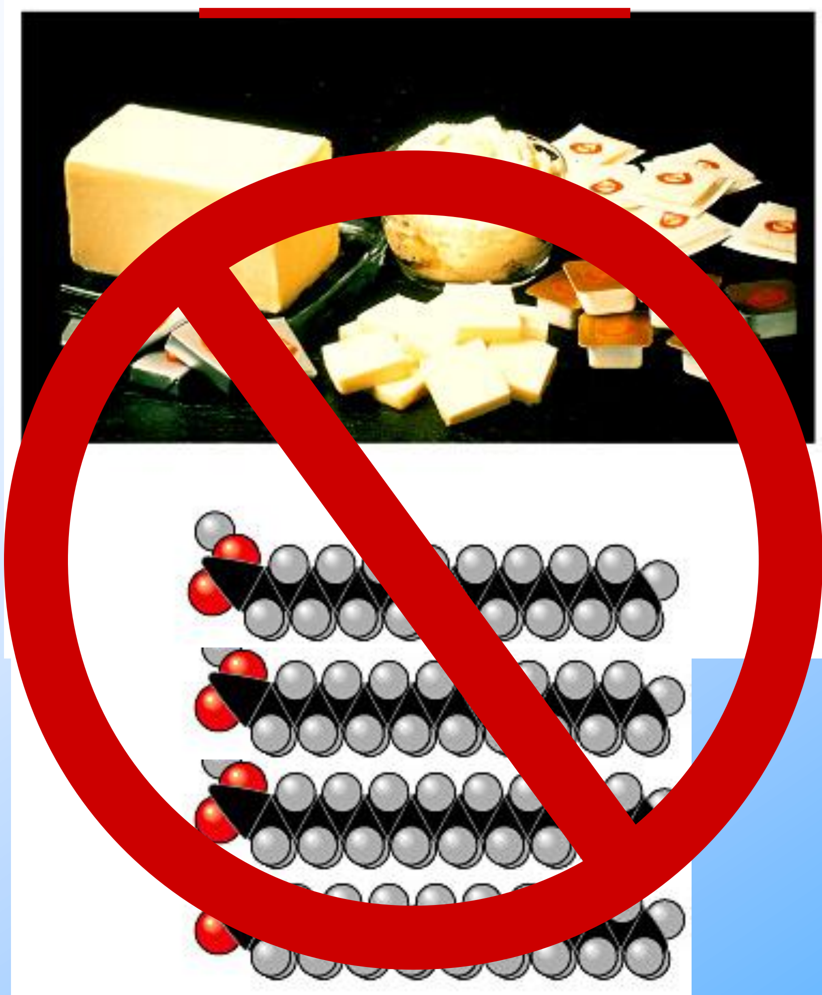


(b) Unsaturated fat and fatty acid

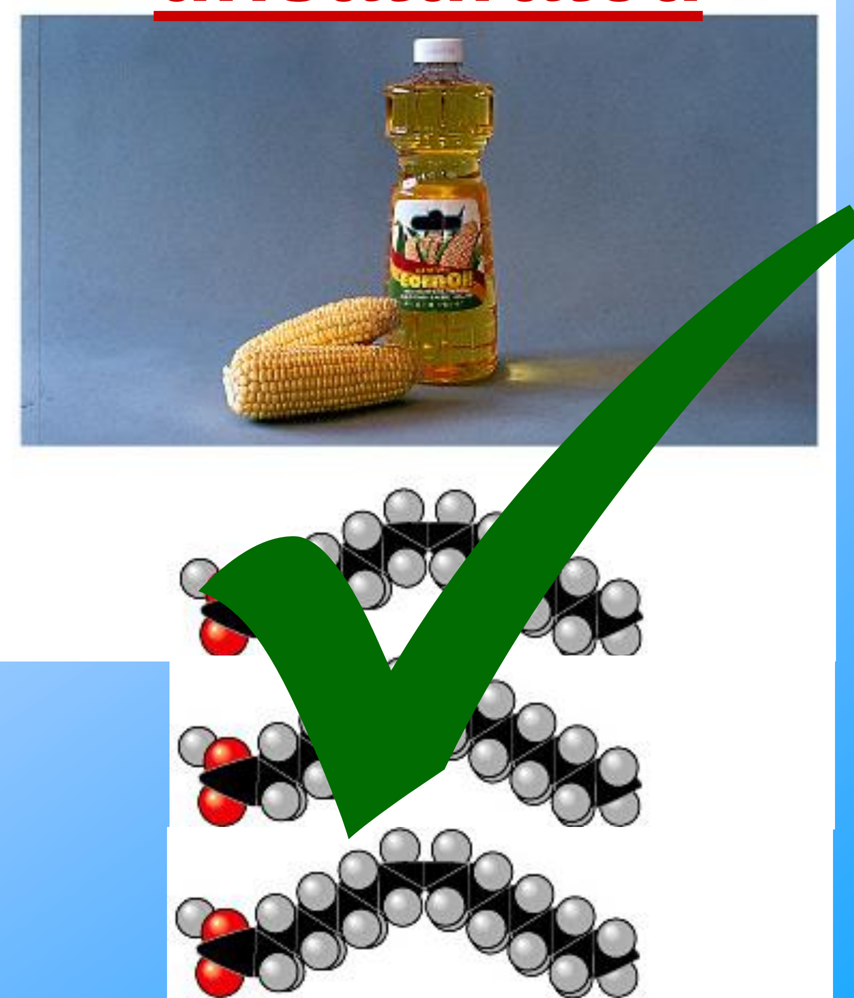


Saturated vs. unsaturated

saturated

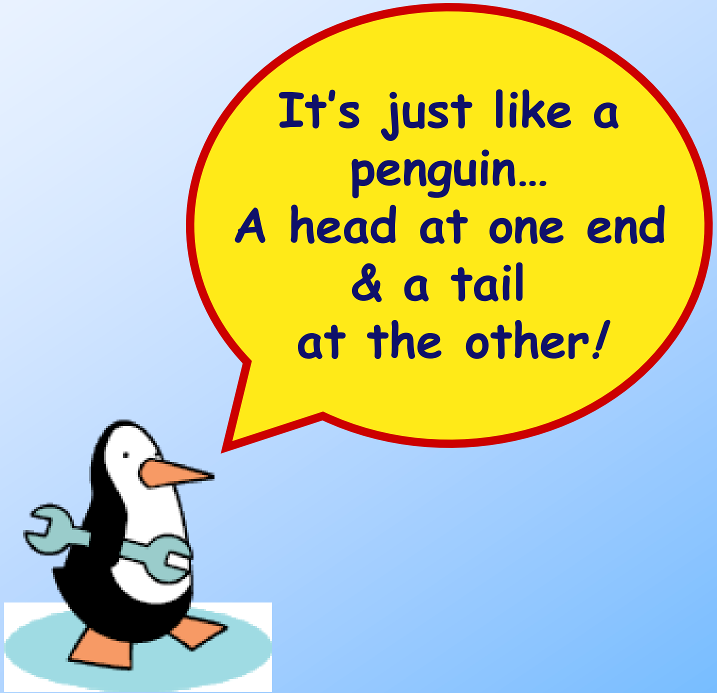


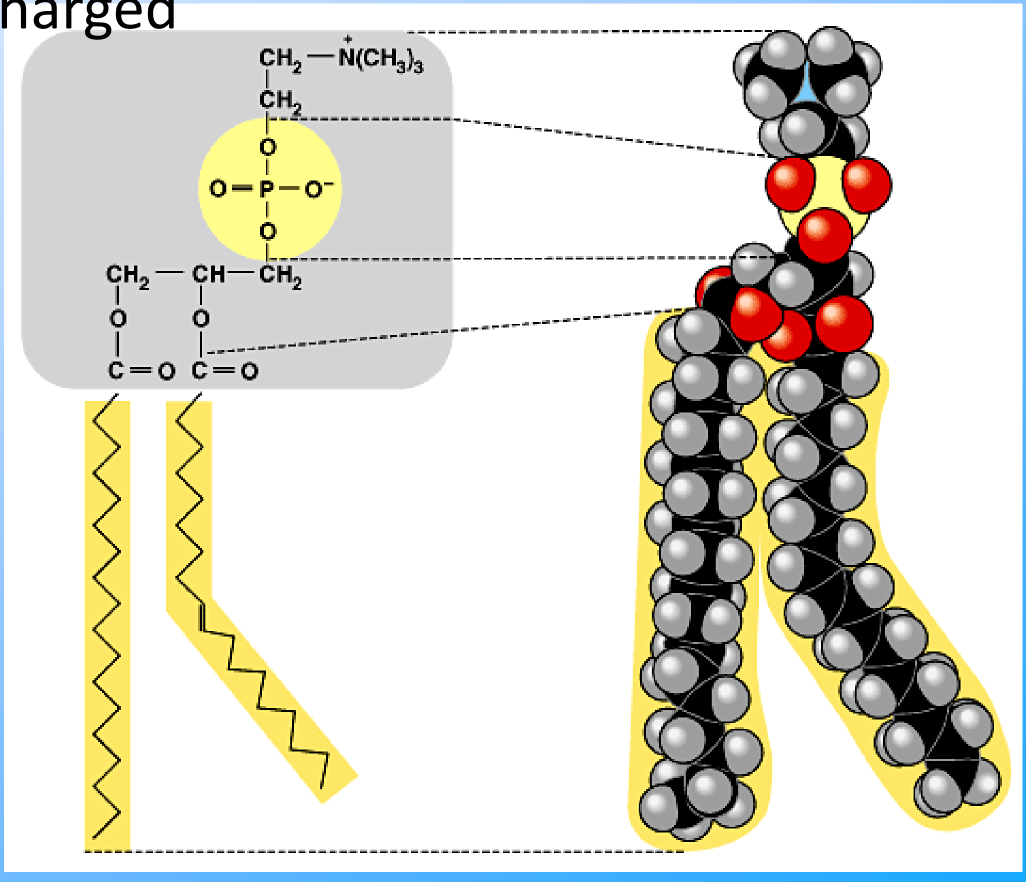
unsaturated



Phospholipids

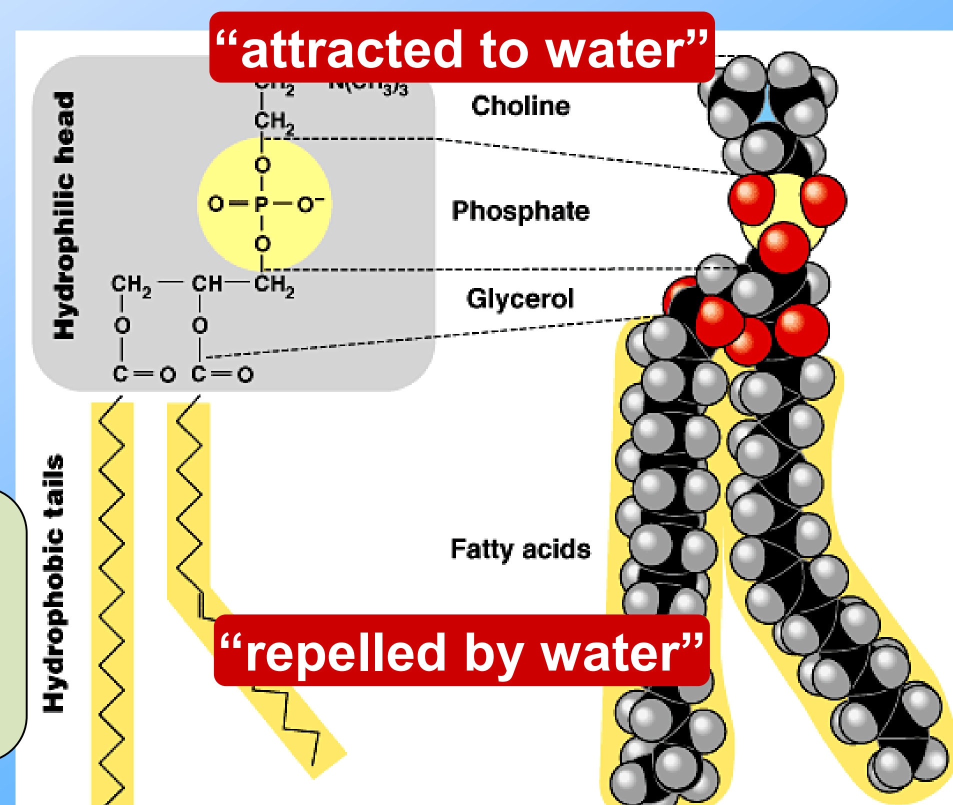
- Structure:
  - glycerol + 2 fatty acids + PO_4
    - PO_4 = negatively charged





Phospholipids

- Hydrophobic or hydrophilic?
  - fatty acid tails = **hydrophobic**
  - PO_4 head = **hydrophillic**
  - split "personality"

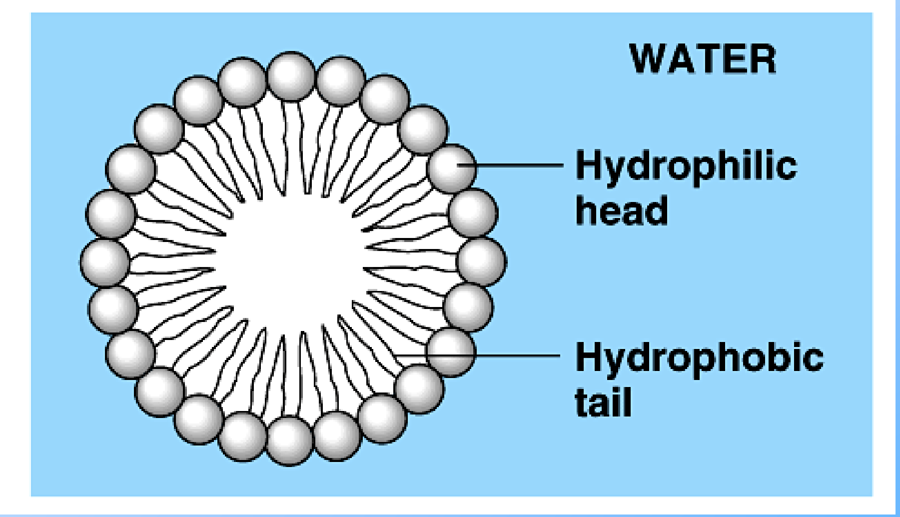


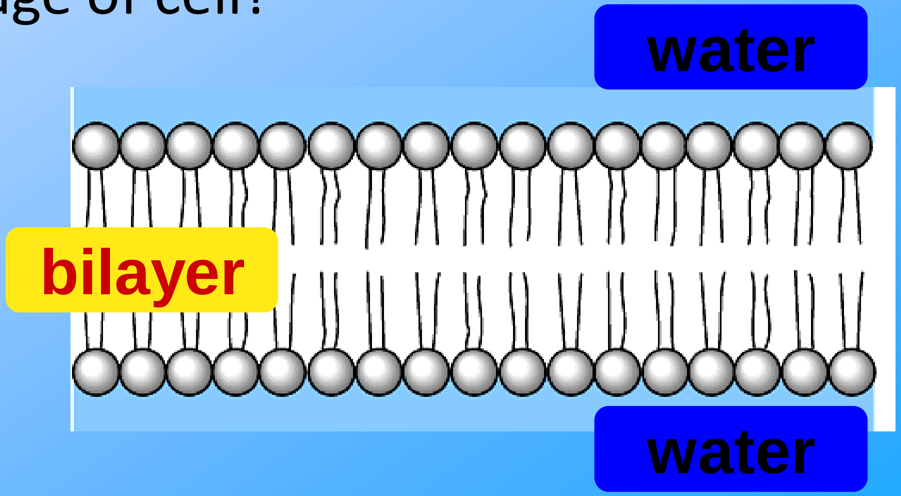
Come here,
No, go away!
Come here,
No, go away!

interaction with H_2O is complex & <u>very</u> <u>important</u>!

Phospholipids in water

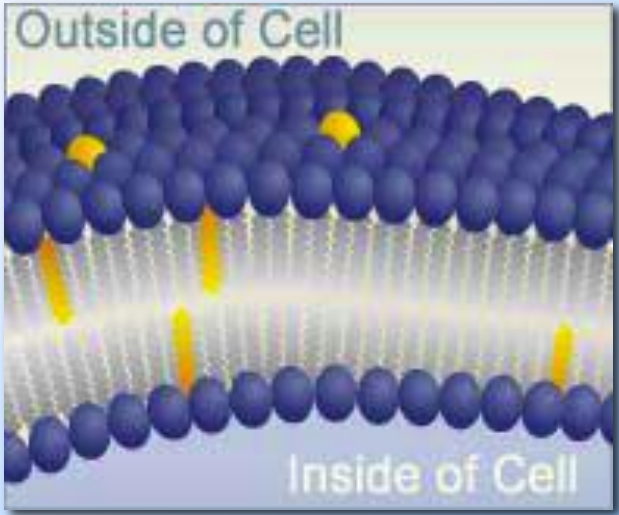
- Hydrophilic heads "attracted" to H_2O
- Hydrophobic tails "hide" from H_2O
  - can self-assemble into "bubbles"
    - bubble = "micelle"
    - can also form a phospholipid bilayer
    - early evolutionary stage of cell?

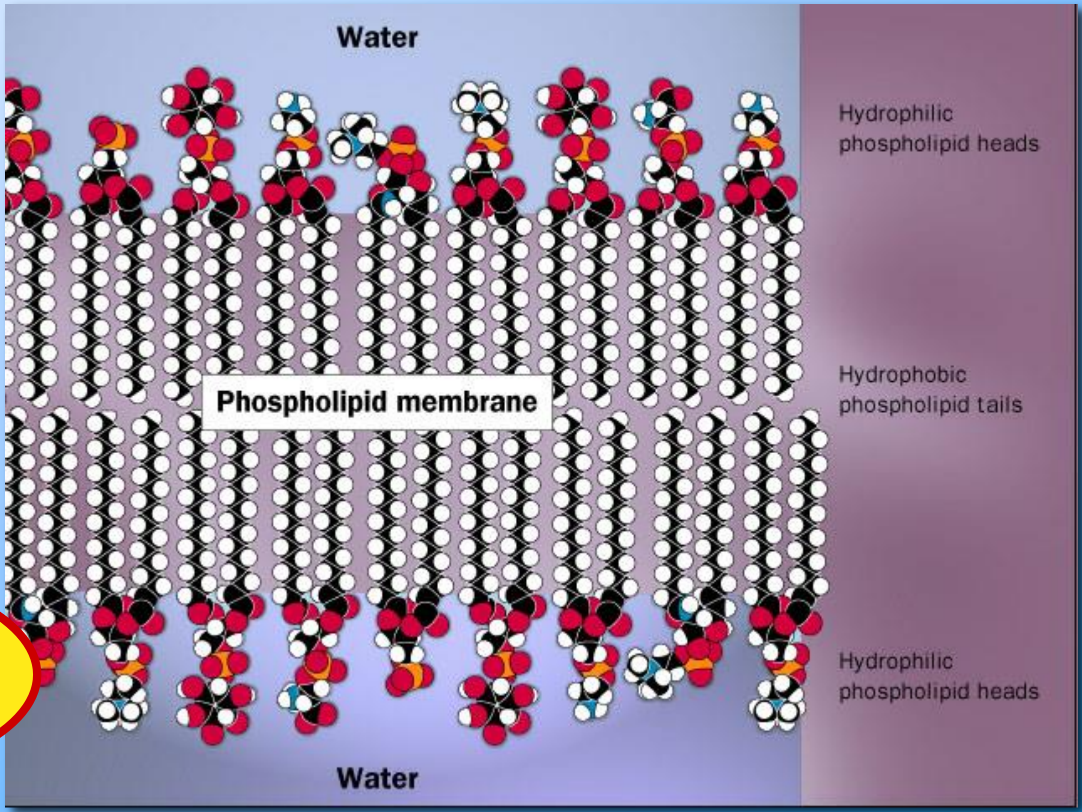




Why is this important?

- Phospholipids create a barrier in water
  - define outside vs. inside
  - they make cell membranes!

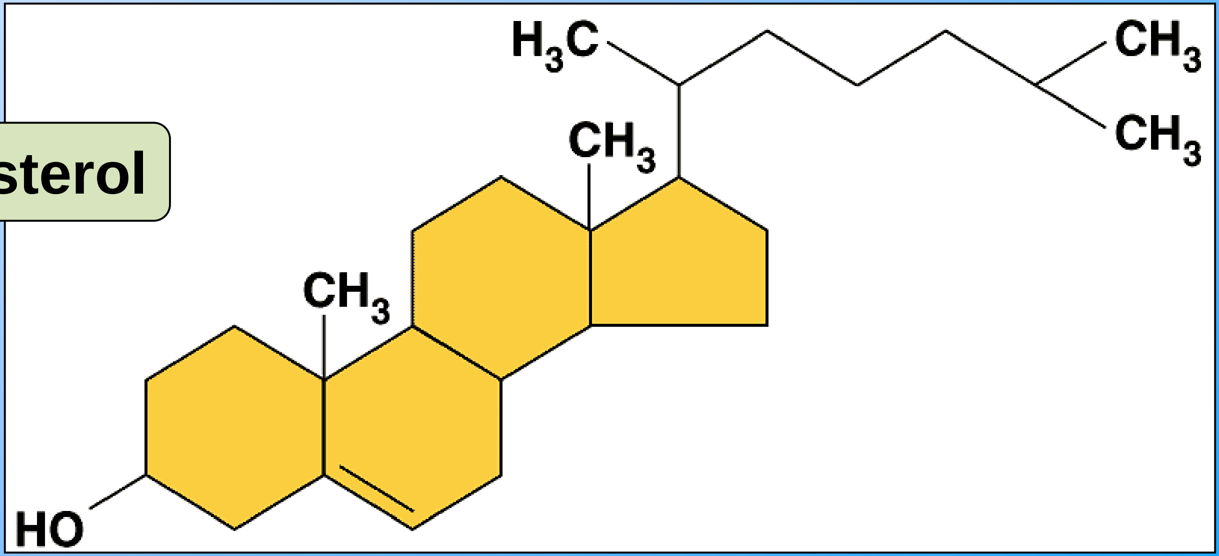




Steroids

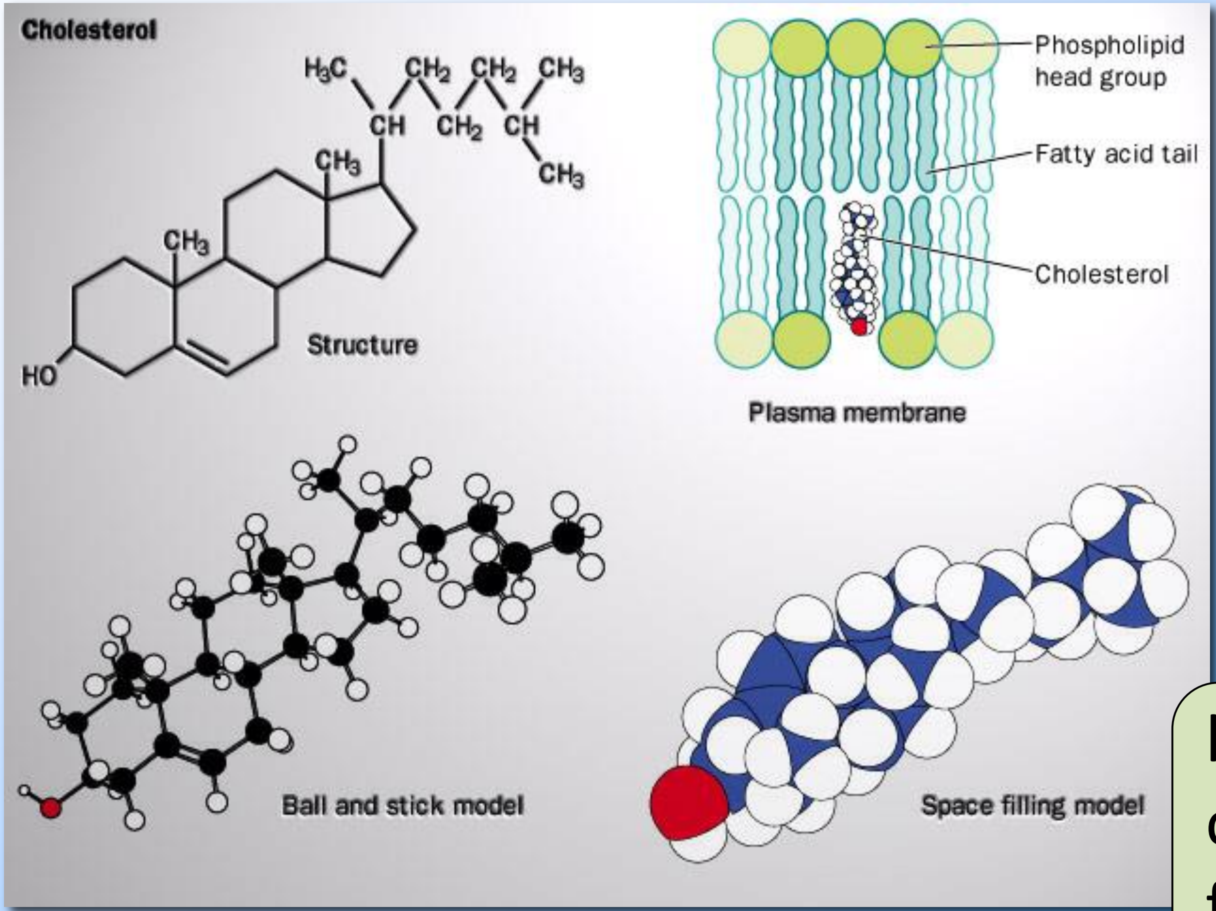
- Structure:
  - 4 fused C rings + ??
    - different steroids created by attaching different functional groups to rings
  - examples: cholesterol, sex hormones

cholesterol



Cholesterol

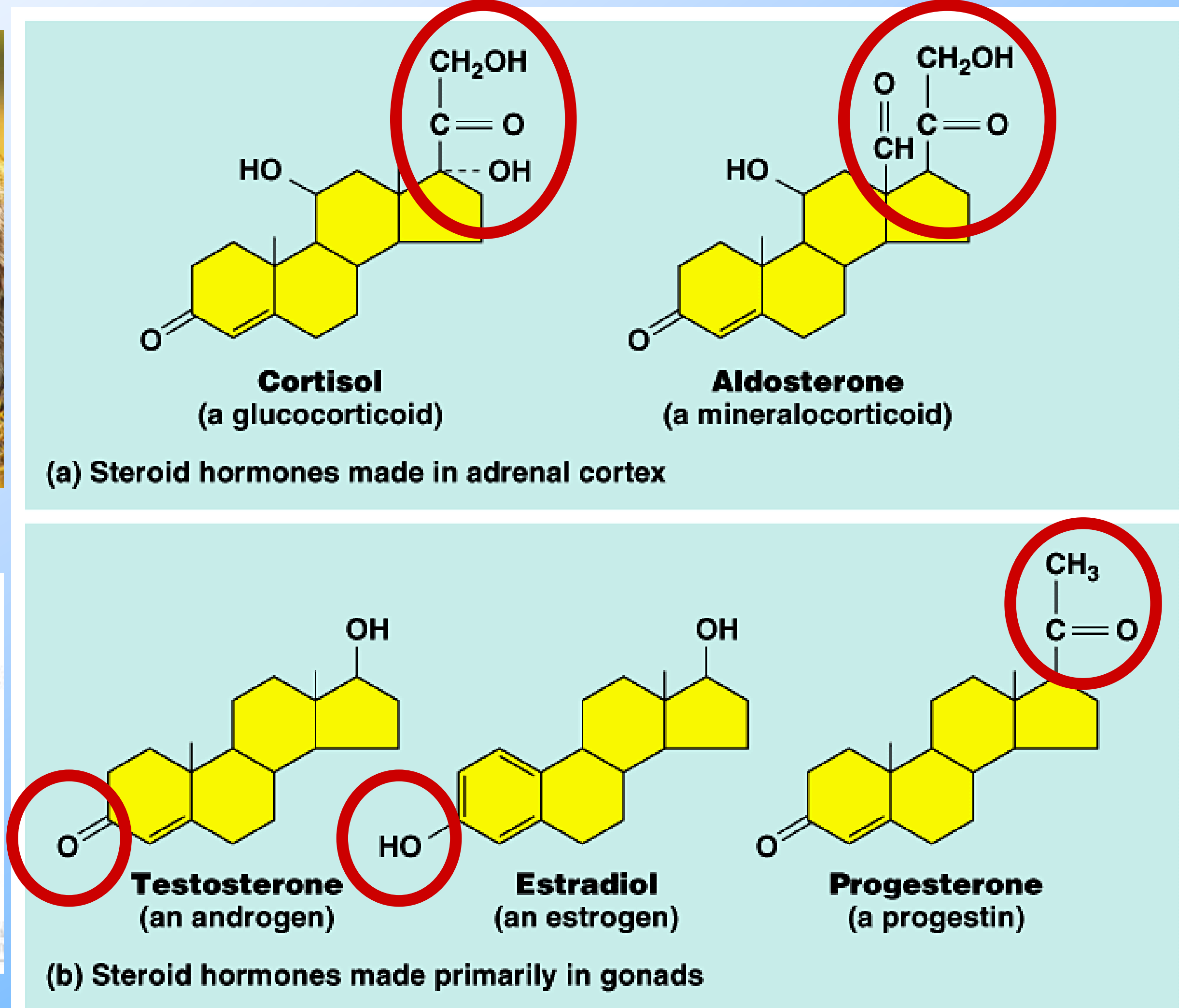
Important component of cell membrane

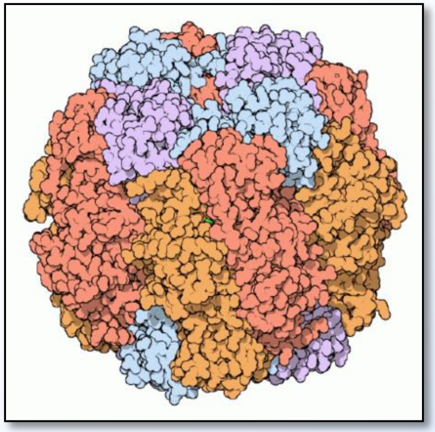


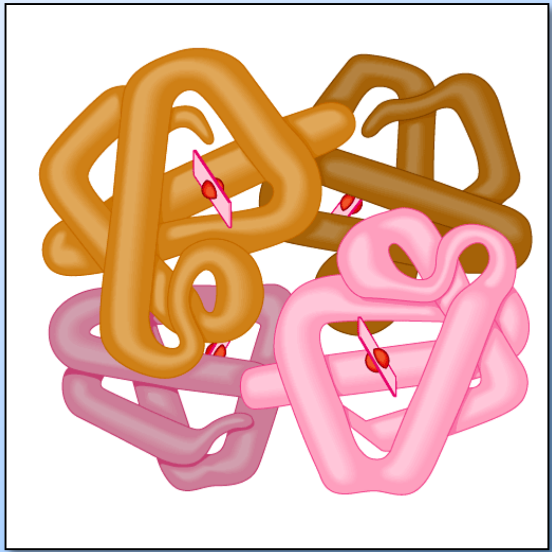
helps keep
cell membranes
fluid & flexible

From Cholesterol → Sex Hormones

- What a big difference a few atoms can make!

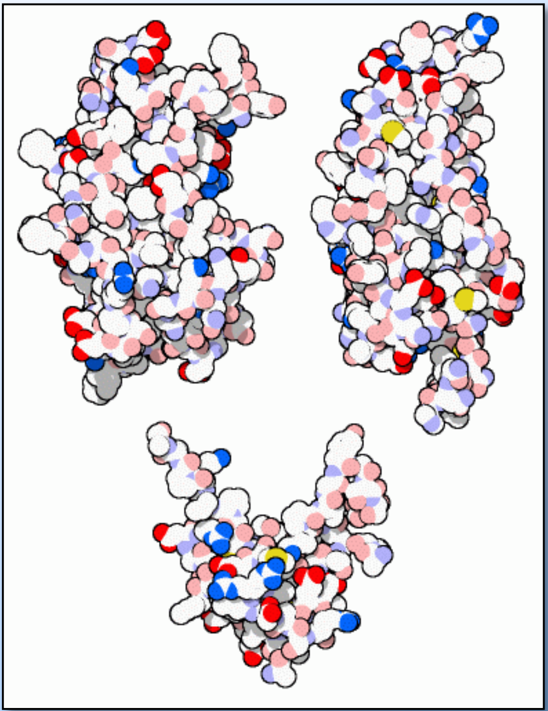



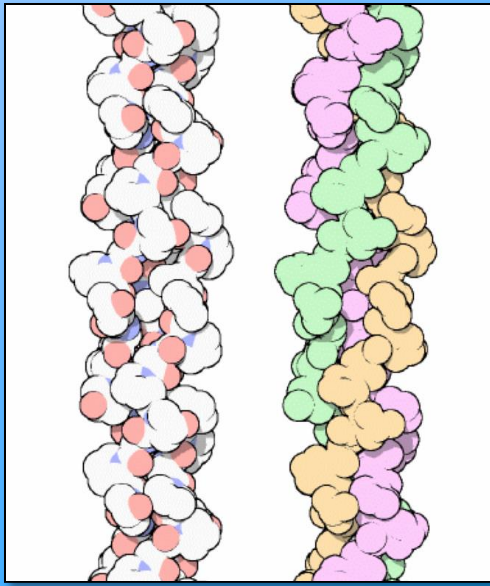




Proteins

Multipurpose molecules



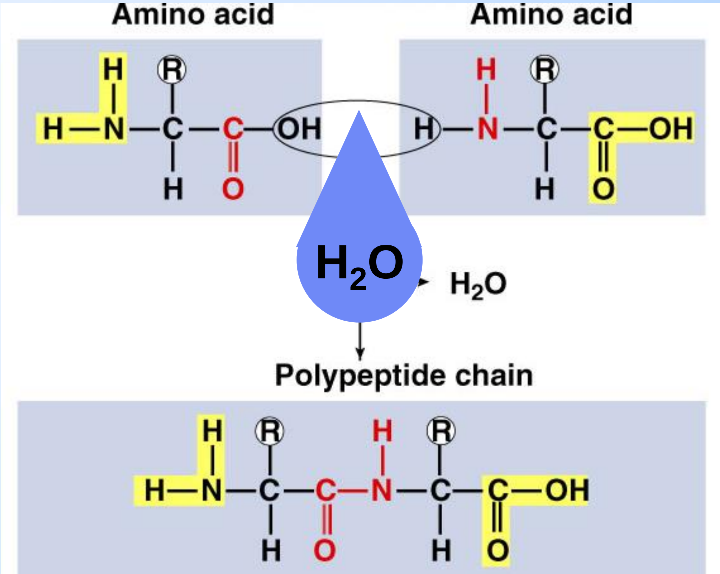


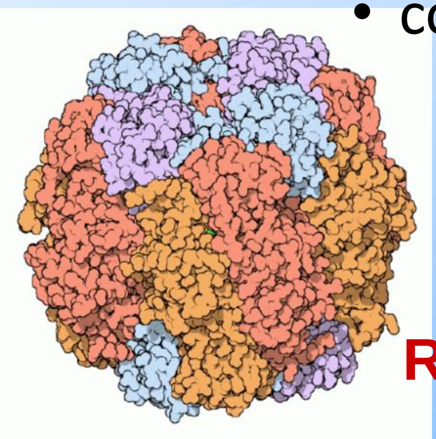
Proteins

- Most structurally & functionally diverse group
- Function: involved in almost everything
  - enzymes (pepsin, DNA polymerase)
  - structure (keratin, collagen)
  - carriers & transport (hemoglobin, aquaporin)
  - cell communication
    - signals (insulin & other hormones)
    - receptors
  - defense (antibodies)
  - movement (actin & myosin)
  - storage (bean seed proteins)

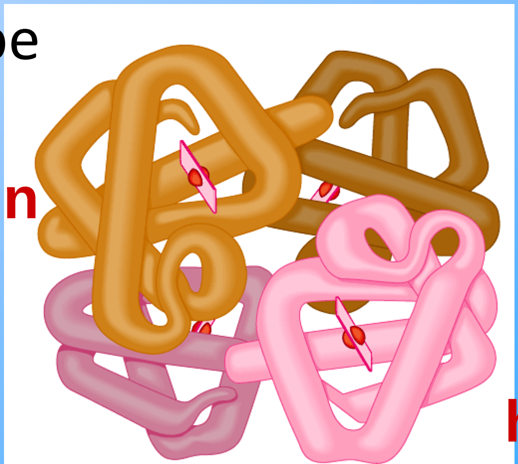
Proteins

- Structure
  - monomer = amino acids
    - 20 different amino acids
  - polymer = polypeptide
    - protein can be one or more polypeptide chains folded & bonded together
    - large & complex molecules
    - complex 3-D shape

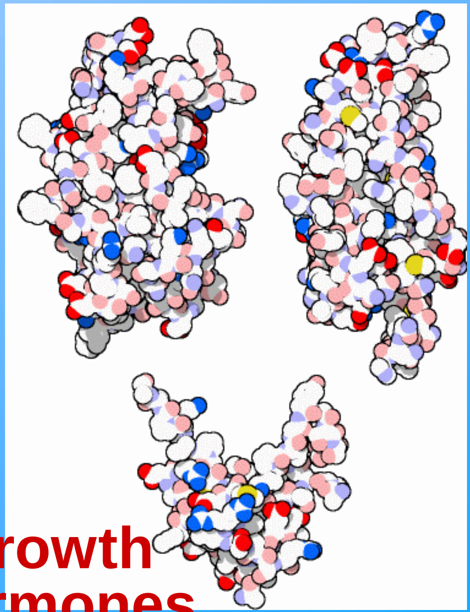




Rubisco



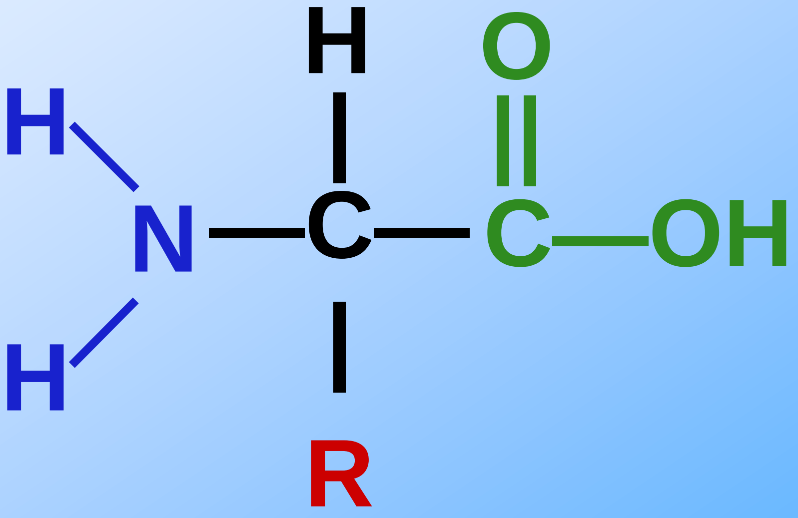
hemoglobin

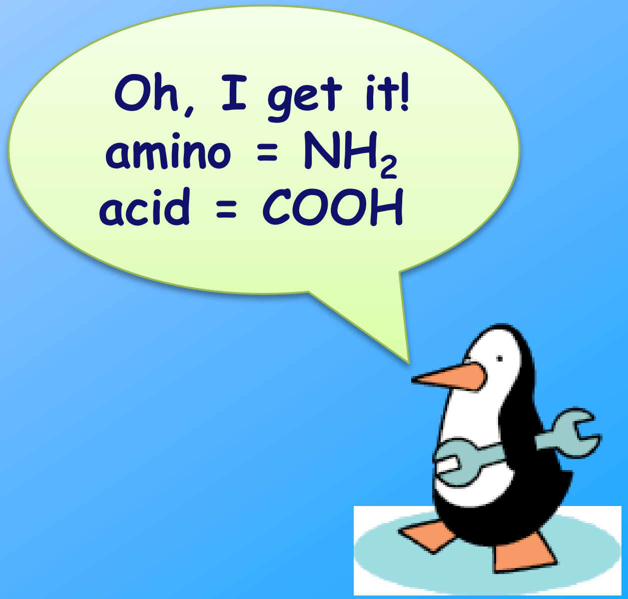


growth hormones

Amino acids

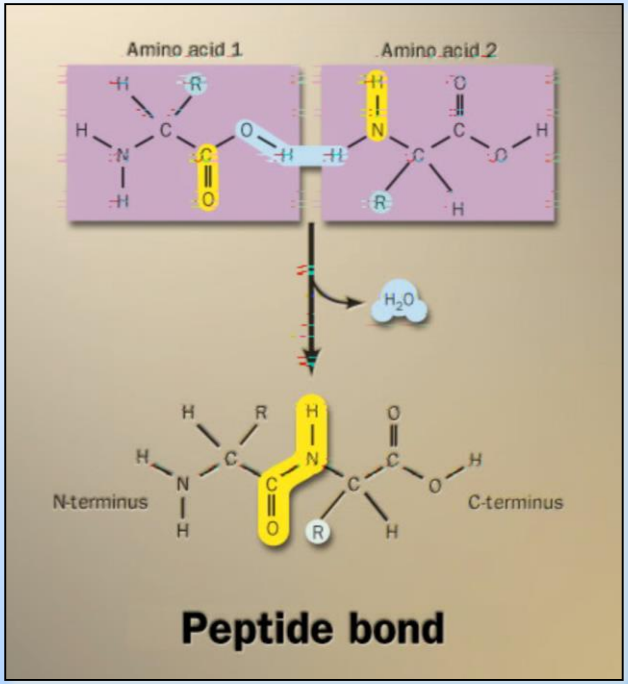
- Structure
  - central carbon
  - amino group
  - carboxyl group (acid)
  - R group (side chain)
    - variable group
    - different for each amino acid
    - confers unique chemical properties to each amino acid
      - like 20 different letters of an alphabet
      - can make many words (proteins)



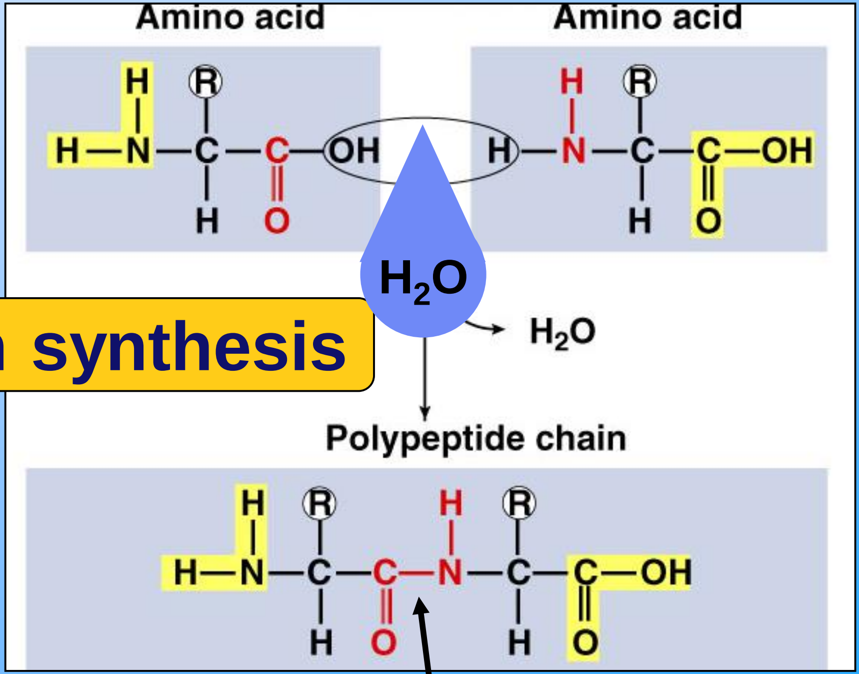


Building proteins

- <u>Peptide bonds</u>
  - covalent bond between NH_2 (amine) of one amino acid & COOH (carboxyl) of another
  - C–N bond



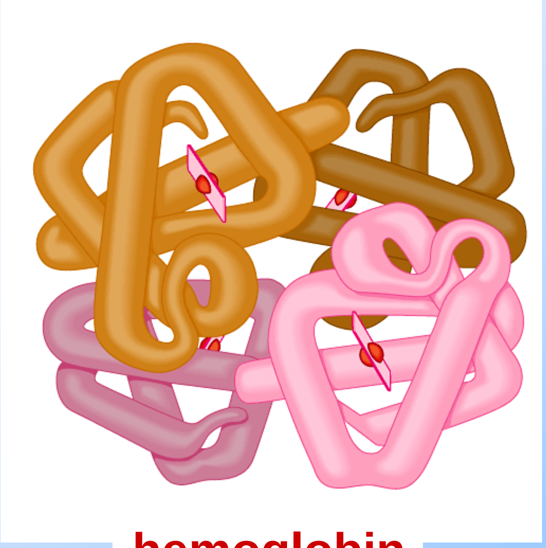
dehydration synthesis



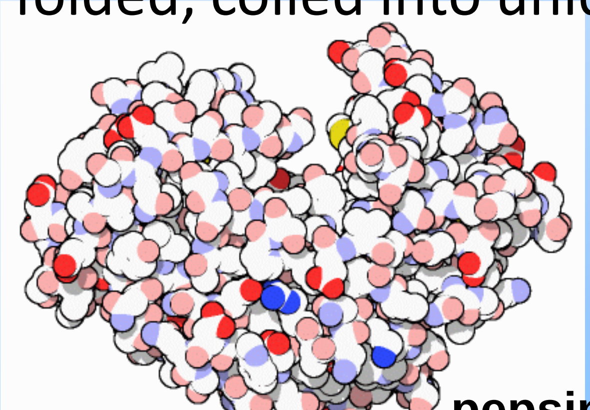
peptide bond

Protein structure & function

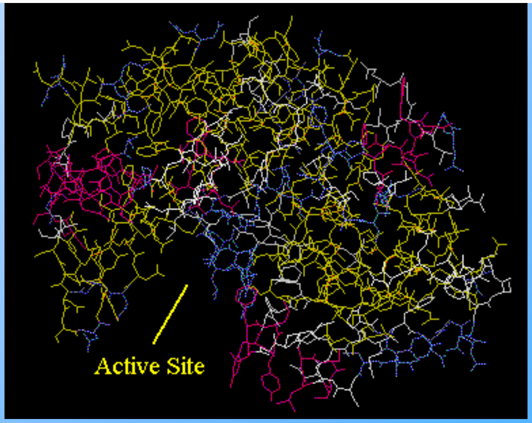
- Function depends on structure
  - 3-D structure
    - twisted, folded, coiled into unique shape

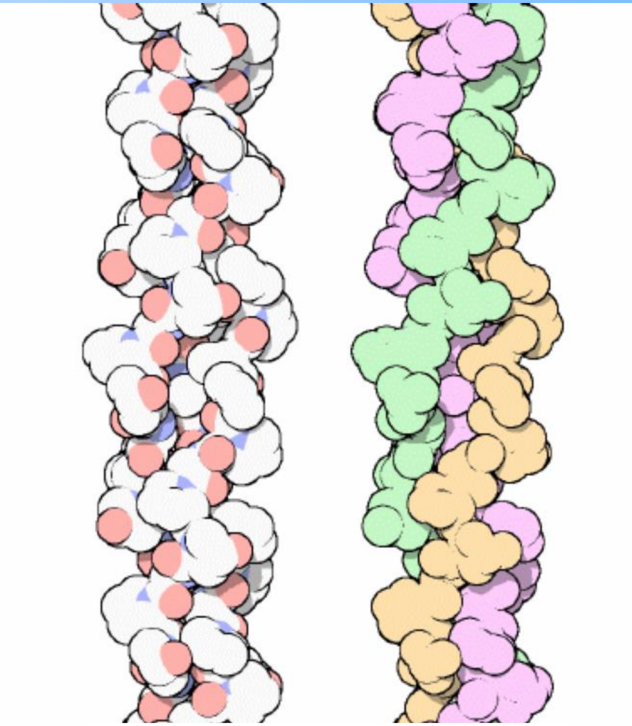


hemoglobin



pepsin

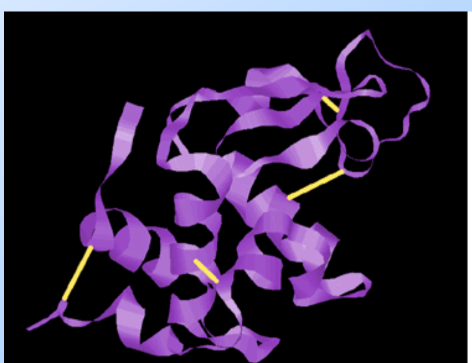


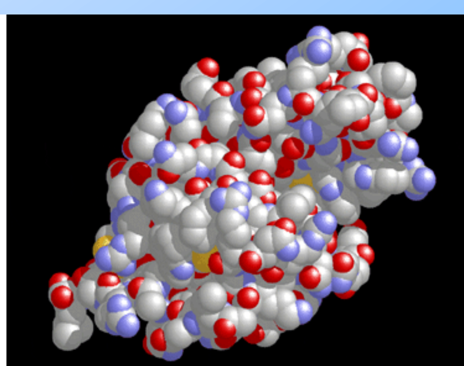


collagen

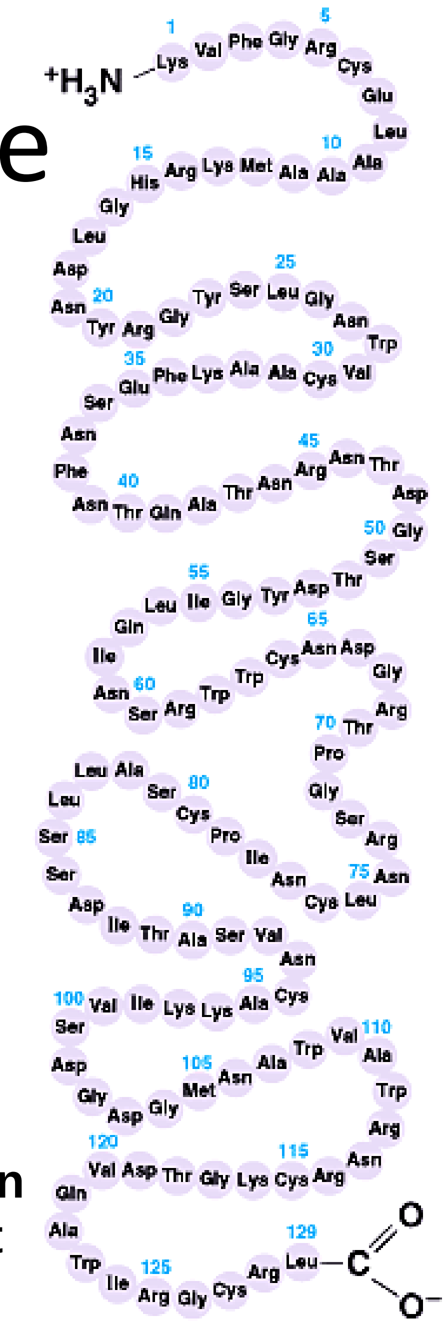
Primary (1°) structure

- <u>Order of amino acids in chain</u>
  - amino acid sequence determined by gene (DNA)
  - slight change in amino acid sequence can make all the difference!



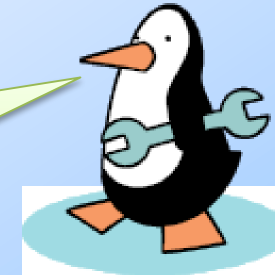


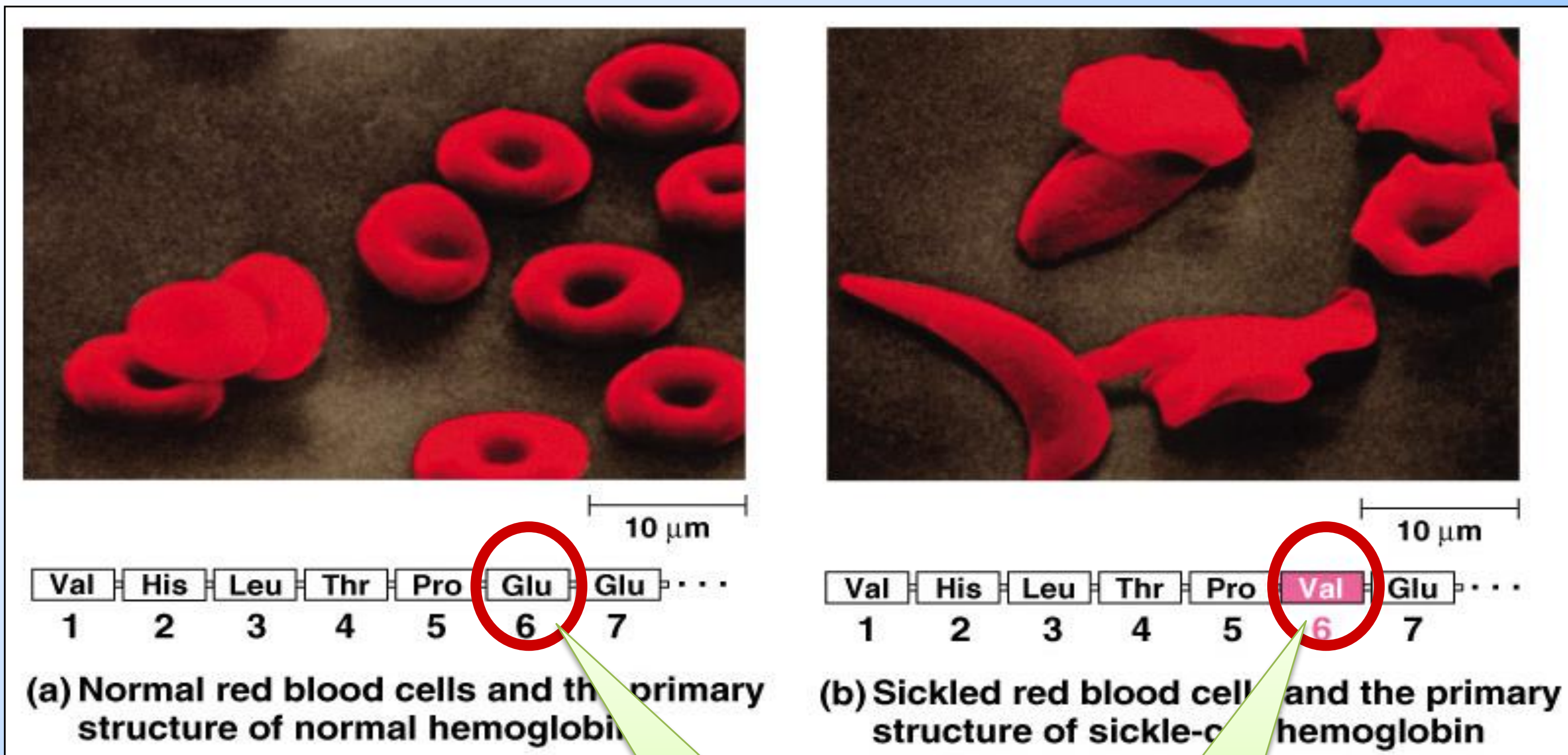
lysozyme: enzyme in tears & mucus that kills bacteria



Sickle cell anemia

Just 1
out of 146
amino acids!





(a) Normal red blood cells and th primary structure of normal hemoglobi

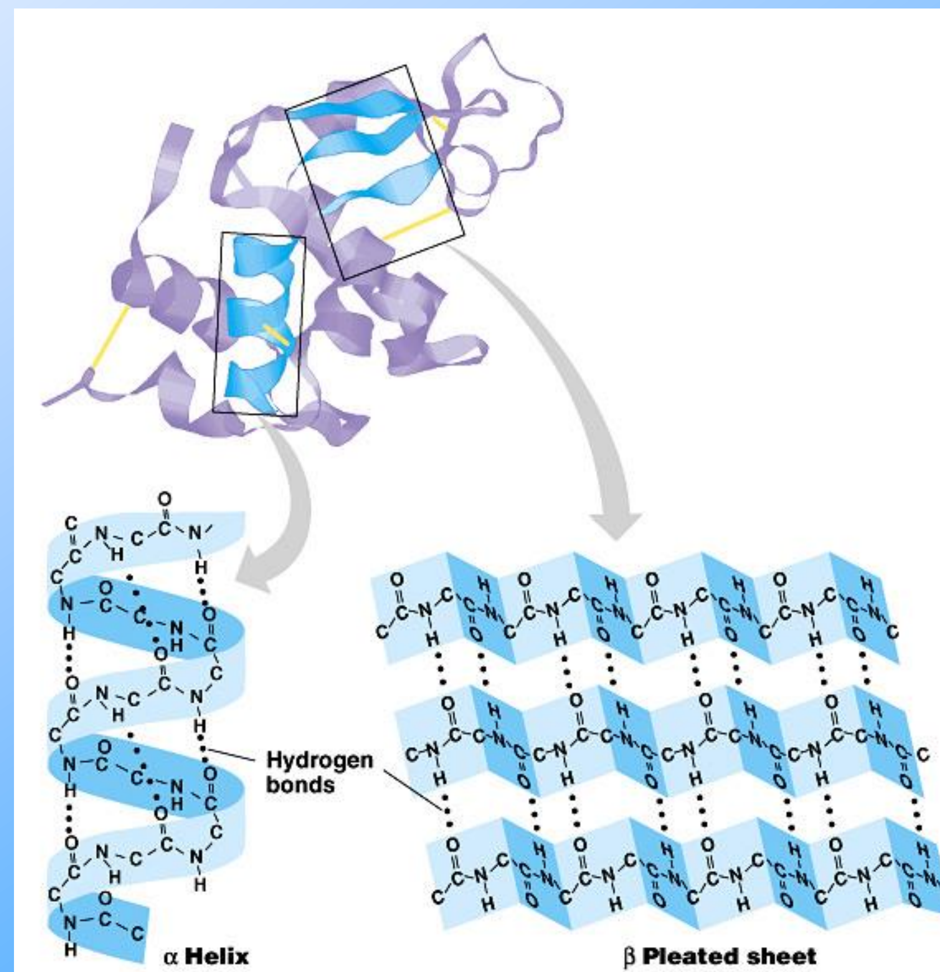
(b) Sickled red blood cell and the primary structure of sickle-c hemoglobin

I'm
hydrophilic!

But I'm
hydrophobic!

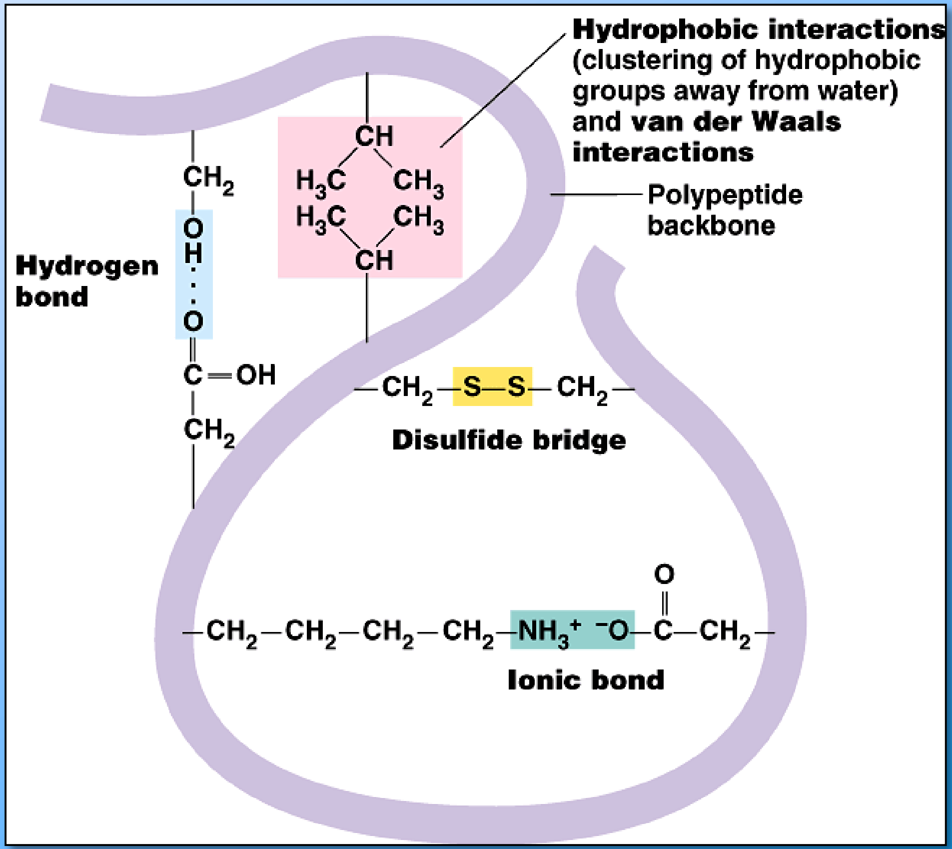
Secondary (2°) structure

- folding along short sections of polypeptide
- H bonds between carboxyls and amines of amino acids
- forms sections of 3-D structure
  - α–helix
  - β-pleated sheet



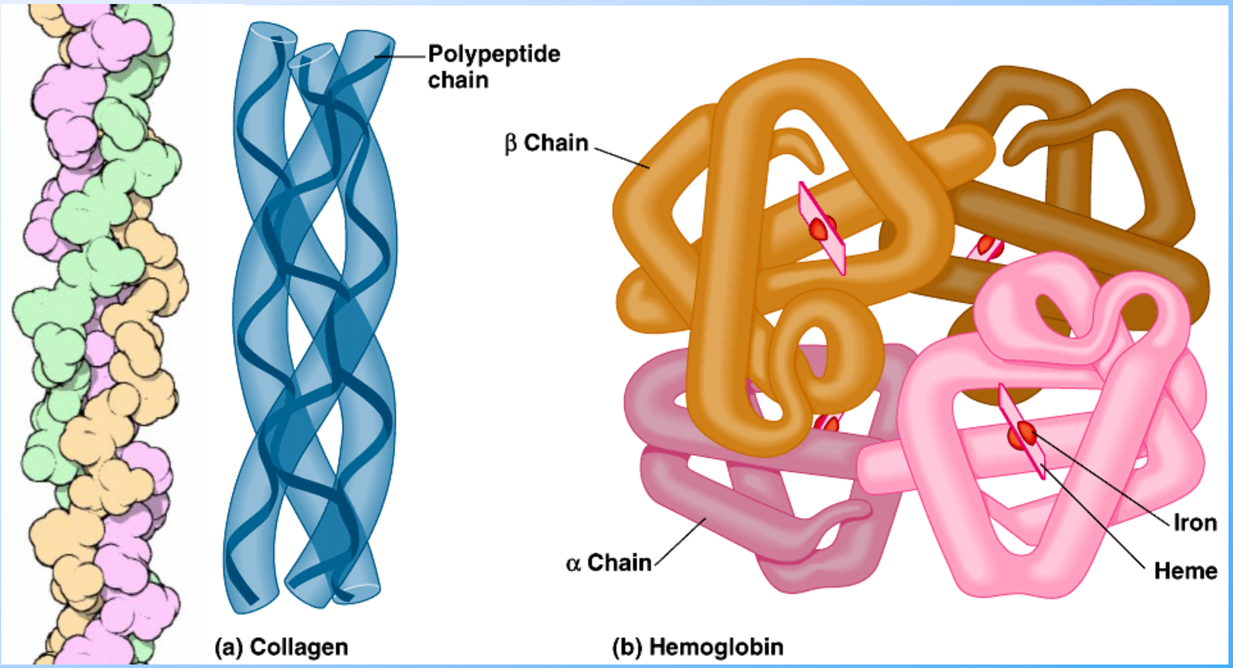
Tertiary (3°) structure

- "<u>Whole molecule folding</u>"
  - interactions between R groups of amino acids
    - <u>hydrophobic R groups</u>
      - nonpolar amino acids cluster away from water
    - <u>H bonds & ionic bonds</u>
    - <u>disulfide bridges</u>
      - covalent bonds between sulfurs in R groups



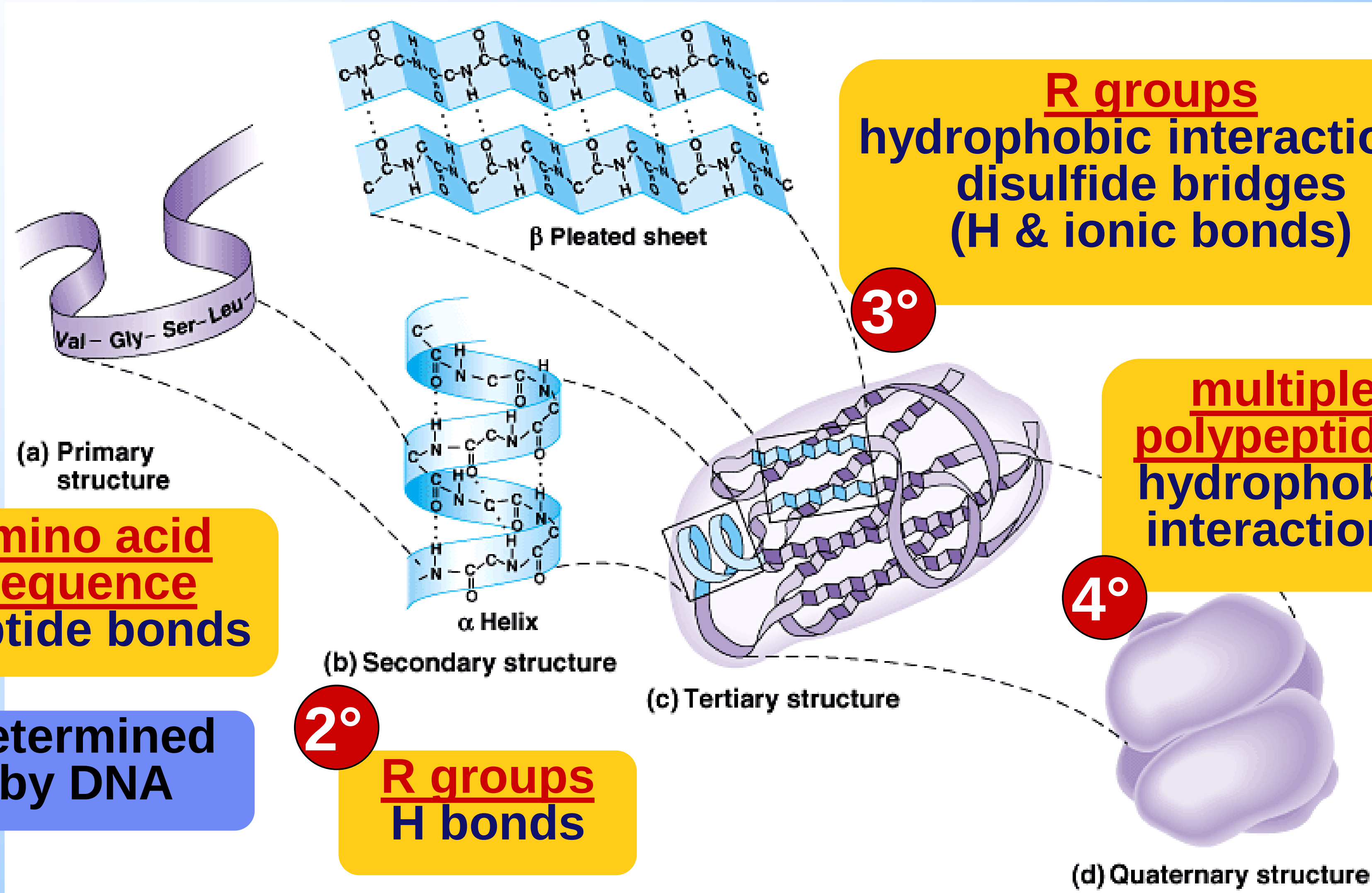
Quaternary (4˚) structure

- <u>Only if more than one polypeptide chain</u> bonded together
- How the multiple chains bond together



collagen = skin & tendons **hemoglobin**

Protein structure (review)



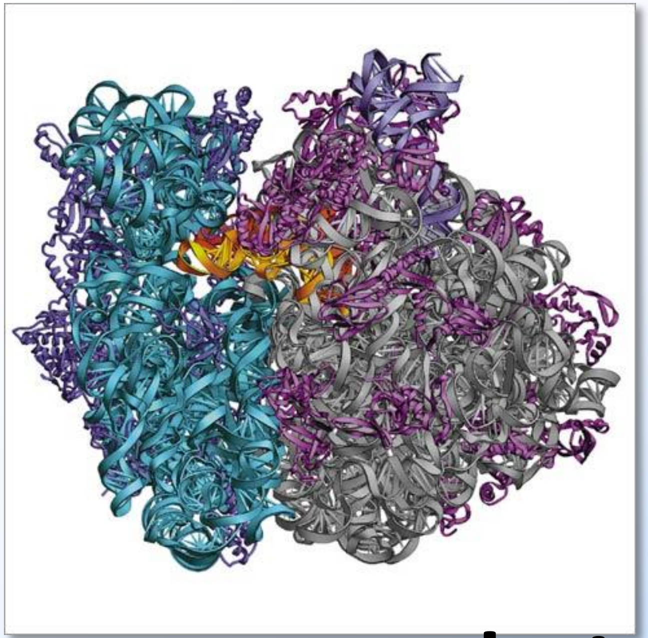
1°
amino acid sequence
peptide bonds

determined by DNA

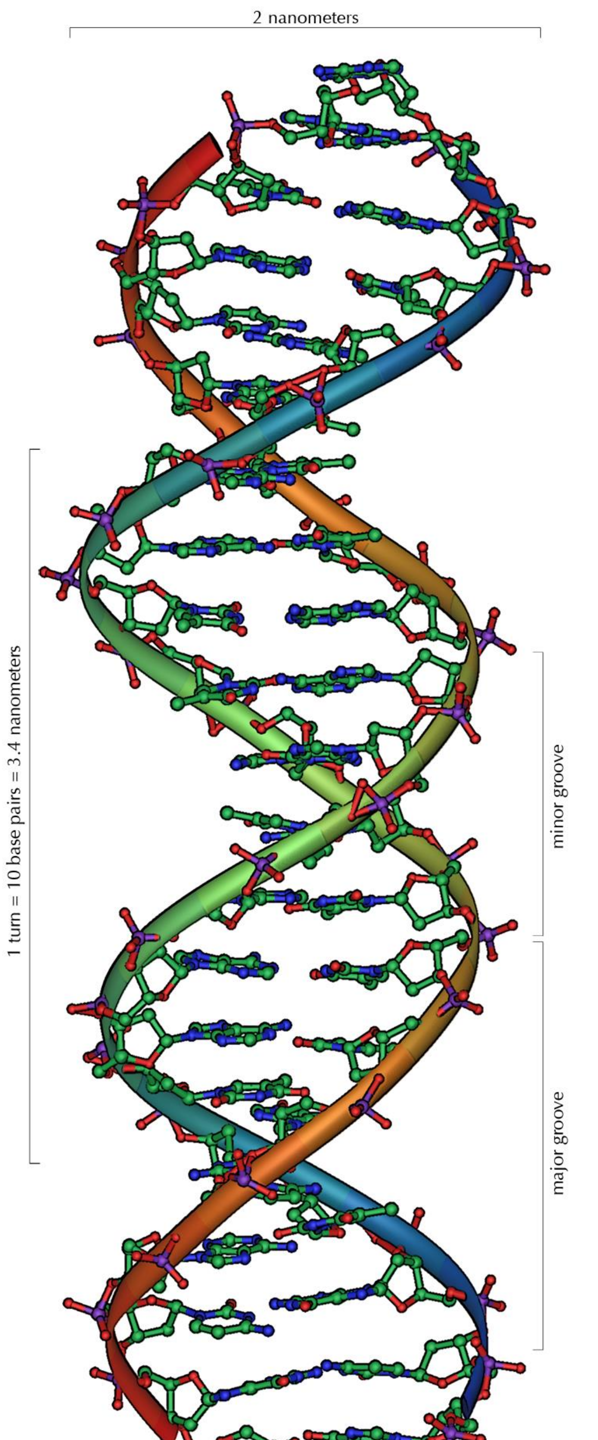
2°
R groups
H bonds

3°
R groups
hydrophobic interactions
disulfide bridges
(H & ionic bonds)

4°
multiple polypeptides
hydrophobic interactions

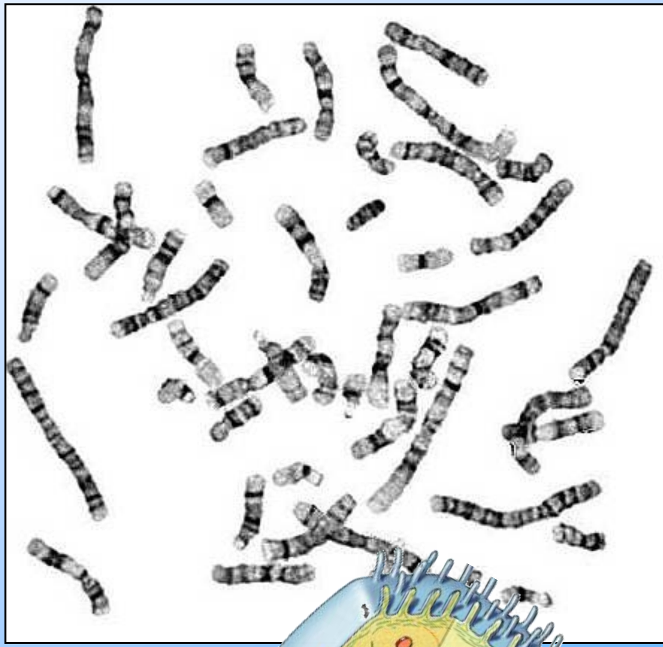


Nucleic Acids

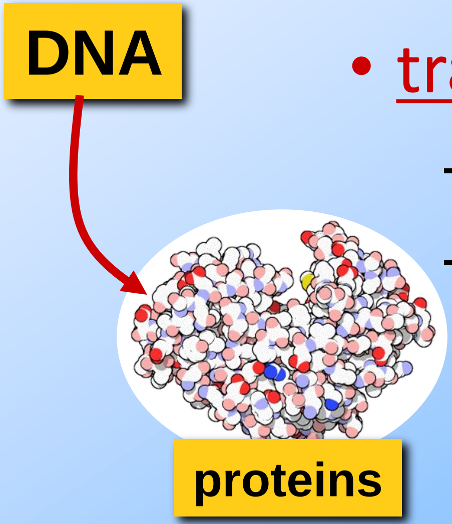


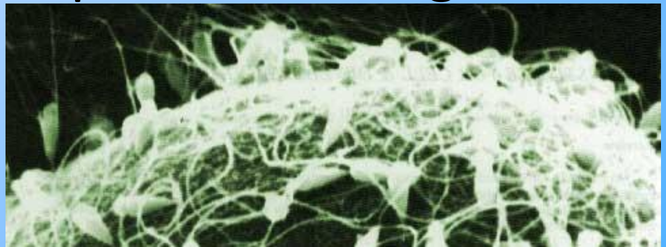
<u>Information storage</u>

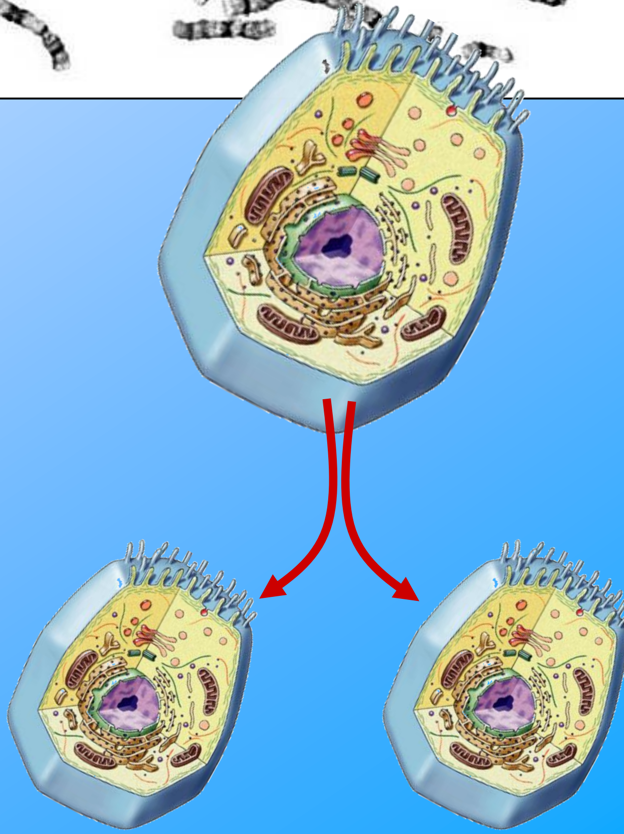
Nucleic Acids



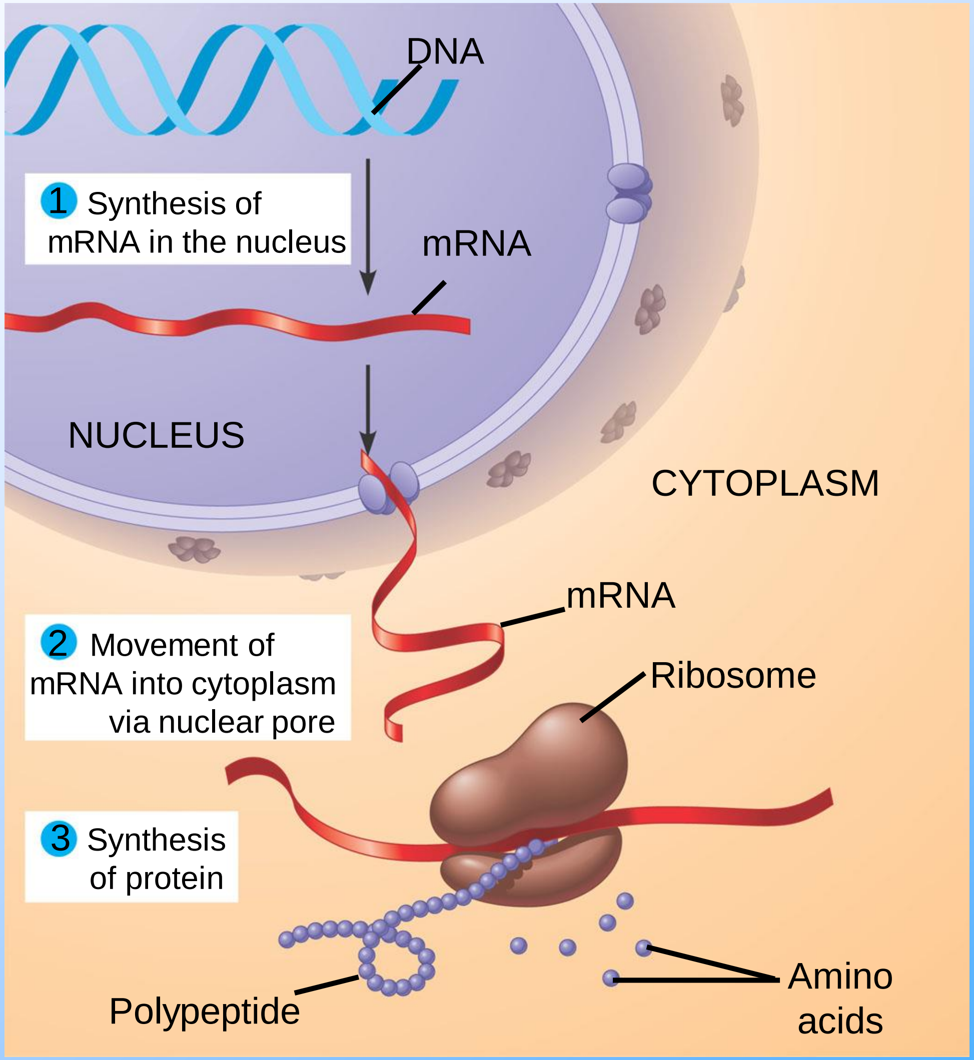
- Function:
  - genetic material
    - stores information
      - genes
      - blueprint for building proteins
        - » DNA → RNA → proteins
    - transfers information
      - blueprint for new cells
      - blueprint for next generation





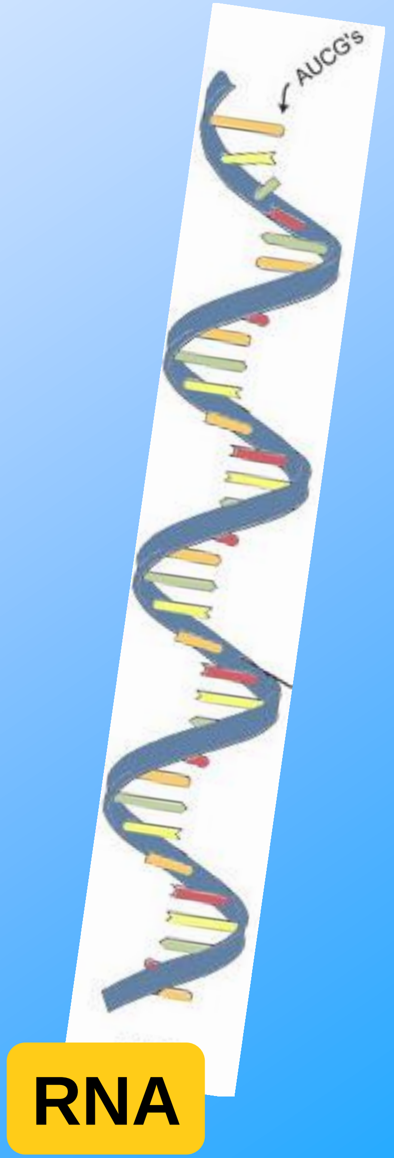


DNA → RNA → protein: information flow in a cell



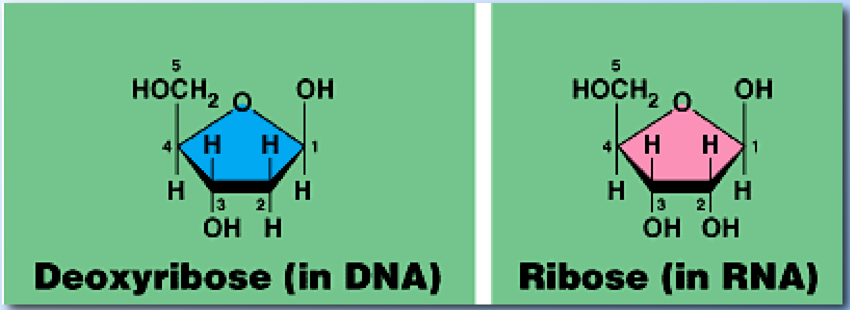
Nucleic Acids

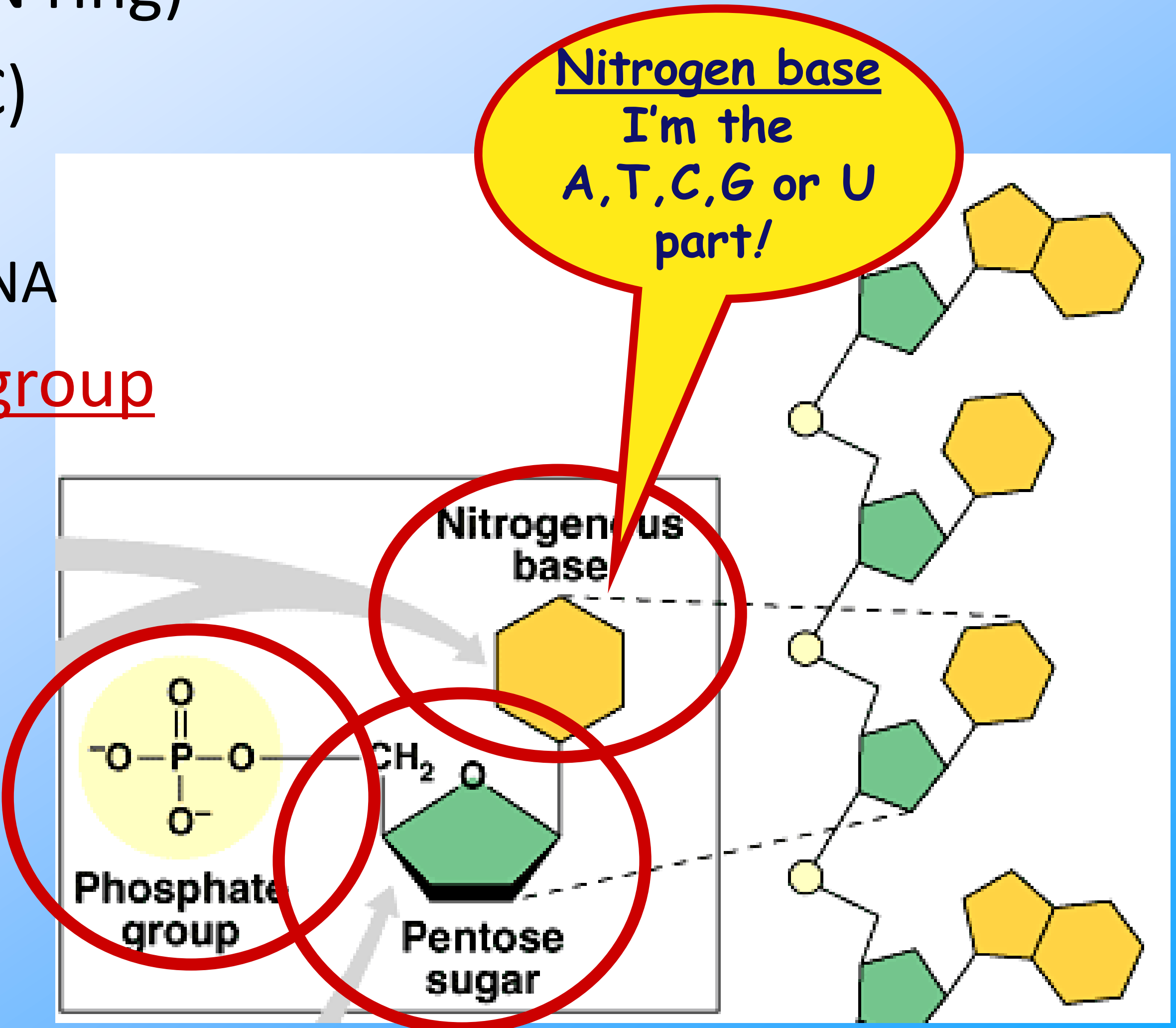
- Examples:
  - RNA (ribonucleic acid)
    - single helix
  - DNA (deoxyribonucleic acid)
    - double helix
- Structure:
  - monomers = nucleotides

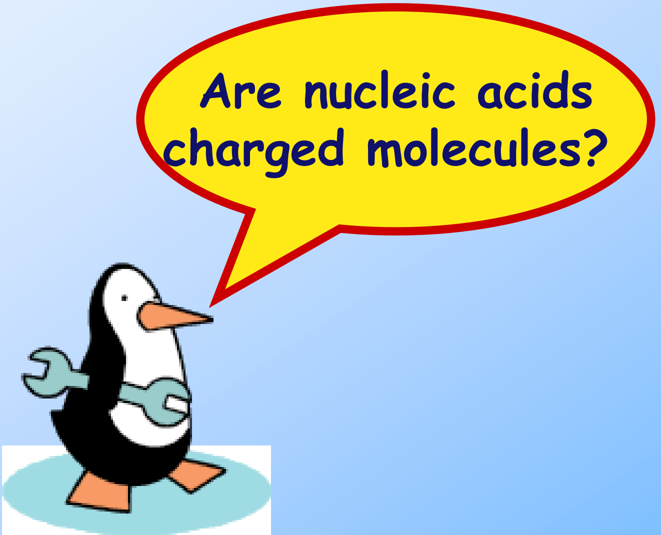


Nucleotides

- 3 parts
  - nitrogen base (C-N ring)
  - pentose sugar (5C)
    - ribose in RNA
    - deoxyribose in DNA
  - phosphate (PO_4) group







DNA molecule

- Double helix
  - H bonds between bases join the 2 strands
    - A :: T
    - C :: G