BIOL 230: Cell & Molecular Biology
Fall 2019 17-205 MW, Aug. 26-28

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http://accounts.smccd.edu/staplesn/biol230/

1. Pre-Lab writeups due each Mon. (for both M&W!!) at the start of lab. (*briefly*, **What**? **Why**? **How**? for each expt.). Question & **Hypothesis**?!
2. **LAB this week: Gel Filtration Chromatography; Cell Transport.**
3. ***Bi-weekly quizzes: Practice Quiz*** *posted on SMCCD* ***CANVAS: https://smccd.instructure.com/. QUIZ #1 DUE next week!***
4. **BLUEBOOKS/ Class Journals today!!!**
5. **Join the STEM/MESA program!!** Contact Cathy Lipe:. Scholarships, internships, interview workshops, application workshops, etc.
   a) To get the STEM Scoop via email each week, add your name to the list by filling out this 2 minute survey **https://bit.ly/2BC4gle**
   b) **See CANVAS for STEM Canvas Page and STEM Scoop!!!! (Contact Marcella Grant at grantm@smccd.edu)**
   c) **STEM News:** https://www.canadacollege.edu/stemcenter/events.php
   d) And it is posted on the STEM facebook page too **https://www.facebook.com/STEMCanadaCollege**

1

REVIEW

1. Describe the structures and functions of typical plant and animal **cell components (organelles)**, including characteristics unique to each cell type.
2. List & define **5 types** of **molecular interactions** that are important to cells.
3. Define & illustrate **5 properties of water** that make it the best "solvent of life". Explain how water interacts with **acids, bases,** and **buffers**.

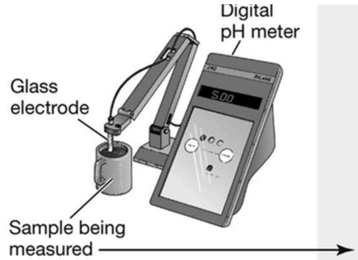
TODAY's Objectives: Students should be able to....

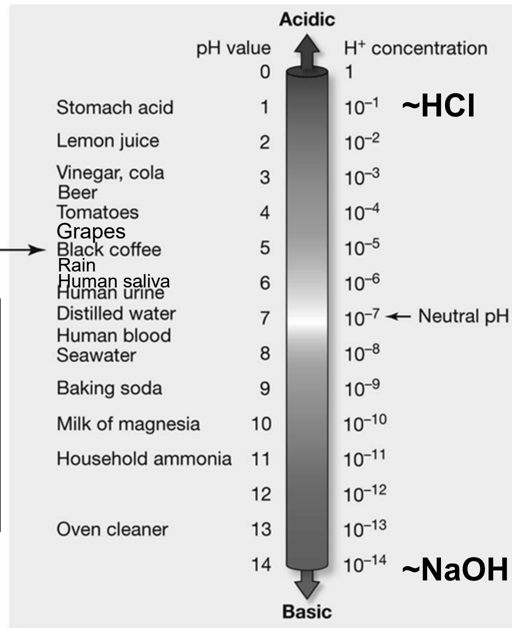
1. List and define the general **structures and functions of the 4 major classes of macromolecules**. Provide specific examples.
2. Illustrate how the chemical **structures** of carbohydrates, lipids, nucleic acids and proteins generate their various **functions**. Describe & draw specific examples.
   - Note the relative elemental content and functional groups of each macromolecule. (eg: DNA vs. RNA, lipids, CHOs)
3. Describe the **levels of protein structure**, and illustrate each with a specific example.
4. Compare the structures and stabilities of **DNA and RNA**. How is each molecule suited to its biological function??

❖ ***Objectives and Study Guide Questions are your HOMEWORK between classes!!! DUE every WED. at the end of Lecture!!***

2

pH values of some familiar substances





- In biological systems, <u>weak acids and bases</u> (reversible ionization) provide flexible systems for pH regulation.
  - **<u>= pH Buffers</u>**

IFE 8e, **Figure 2.16**

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<u>pH Buffers</u> = important for Homeostasis

1. ***= Molecules that can minimize changes in pH, even when acid or base is added to a solution.***
2. Can both **accept or donate H+** depending upon the overall pH range of a solution
3. **REVERSABILITY OF CHEMICAL REACTIONS** → produces flexibility / adaptability of biochemical / biological systems!!
4. eg: <u>**H_2CO_3/HCO_3-** (carbonic acid/ bicarbonate)</u> ***<u>buffer system</u>*** – minimizes pH changes:

$HCO_3^- + H^+ \leftrightarrow H_2CO_3$

(add acid)→ ←(add base)

– ** = mixture of an acid that does not completely ionize in H_2O and its corresponding/conjugate base.

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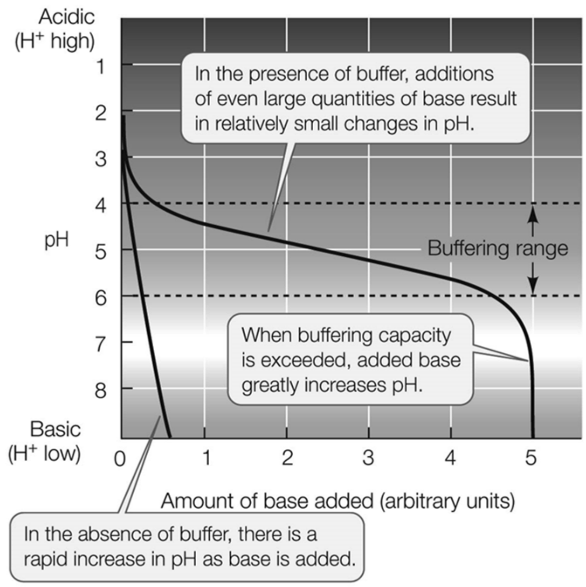
Buffers minimize changes in pH



***LIFE 9e*, Figure 2.17**

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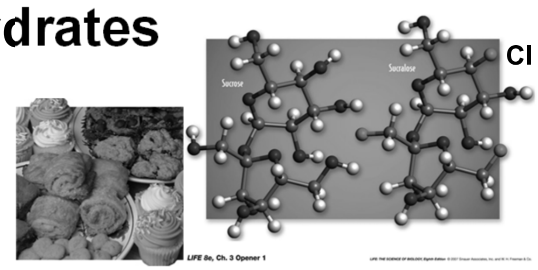
CHAPTER 3
Macromolecules: Their Chemistry and Biology

1. **Carbohydrates**
2. **Lipids**
3. **Proteins**



LIFE 9e, Ch. 3 Opener 1

4. **[Ch. 4: Nucleic Acids]**

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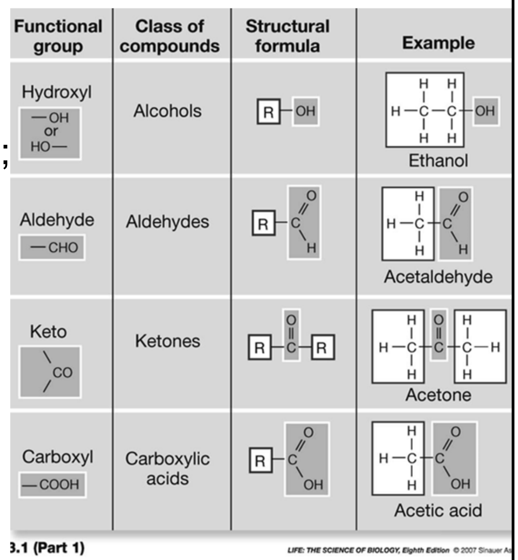
3.1) <u>Functional Groups</u> give particular properties to larger biomolecules

<u>Classify Molecules by:</u>

1. **Hydroxyl** groups (--OH; alcohols)
2. **Carbonyl** (***aldehydes*** and ***ketones, esters***, --CH=O, --C=O)
3. **<u>Carboxyl</u>** <u>group</u> (--COOH = acid),



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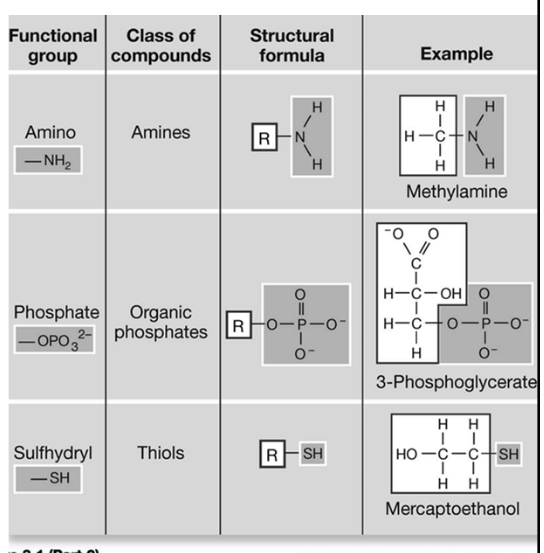
Functional Groups Important to living systems, cont'd Fig 3.1

4. **<u>Amino</u>** (-NH_2)
   - [both = in **amino acids**!]
5. **Phosphate** groups (--OPO_3^{2-})
   - releases energy to fuel biochem. Rxns
   - modify structure and activity of proteins!!
6. **Sulfhydryl** (--SH) (3D strx of proteins) …………..



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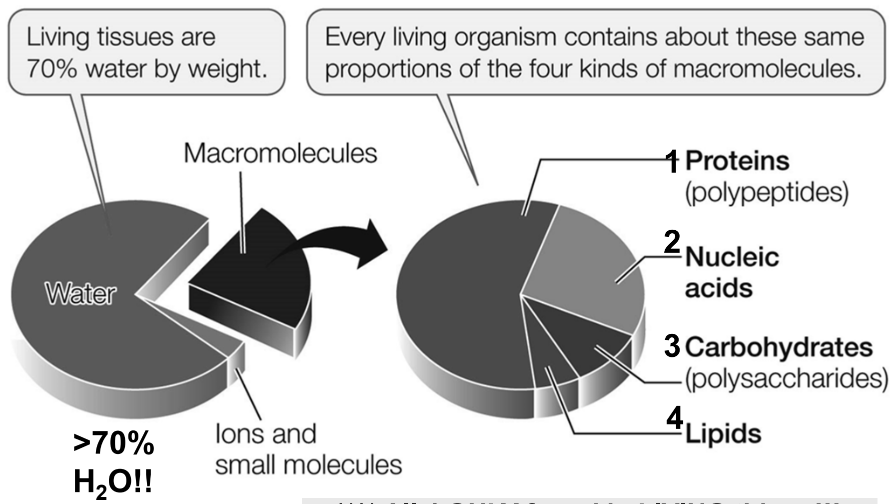
A. Substances in living tissues



- ****** All 4 ONLY found in LIVING things!!!**
- *Biochemical unity:* same rough proportions and similar functions in all living organisms.

***LIFE 9e*, Figure 3.3**

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B. Macromolecules = formed by covalent bonds between monomers

- polysaccharides, proteins, and nucleic acids

TABLE 3.1

The Building Blocks of Organisms

(“oligo-” = short polymer)

MONOMER	COMPLEX POLYMER (MACROMOLECULE)
Amino acid	Polypeptide (protein)
Monosaccharide (sugar)	Polysaccharide (carbohydrate)
Nucleotide	Nucleic acid

- ***Proteins:*** **combinations of 20 amino acids.**
- ***Carbohydrates*****: sugar monomers (monosaccharides) are linked to form polysaccharides.**
- ***Nucleic acids*****: 4 kinds of nucleotide monomers.**
- ***Lipids*****: noncovalent forces maintain interactions between lipid monomers.**

Amoeba Sisters: https://youtu.be/YO244P1e9QM

***LIFE 8e*, Table 3.1**

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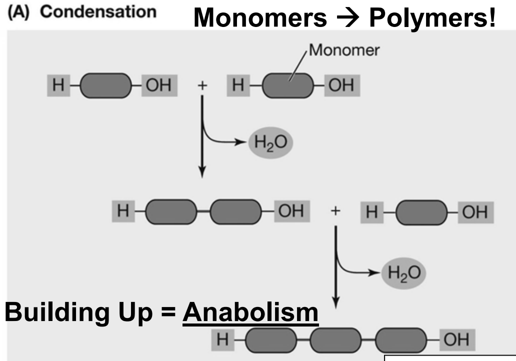
Condensation and Hydrolysis

Fig 3.4

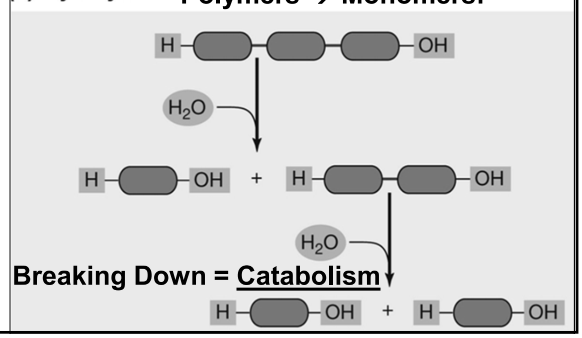
A-H + B-OH → A-B + H_2O

(A) Condensation **Monomers → Polymers!**



- **Water is an active part of these biochemical reactions!!**
  - These types of rxns are a part of cellular metabolism (anabolism, catabolism)

(B) Hydrolysis **Polymers → Monomers!**



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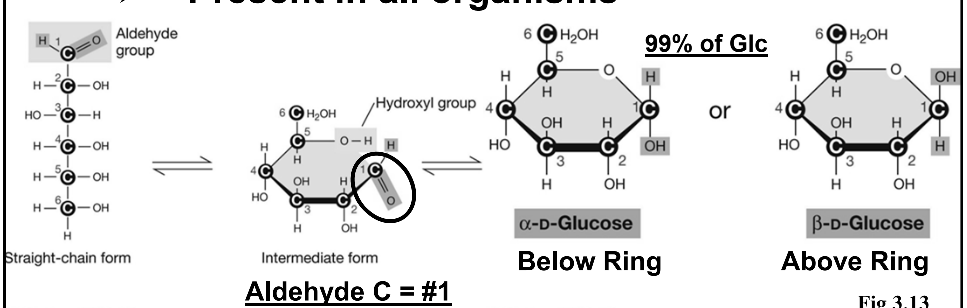
3.2) Carbohydrates: Sugars & Sugar Polymers

- All carbohydrates contain carbon bonded to H and OH groups.
- General formula = **$(CH_2O)n$**
  - Eg: Forms of Glucose (ALL in equilibrium!)
    - **Present in all organisms**



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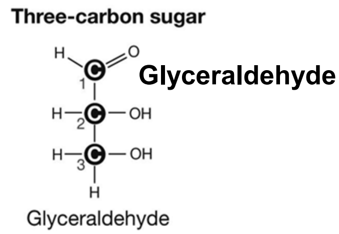
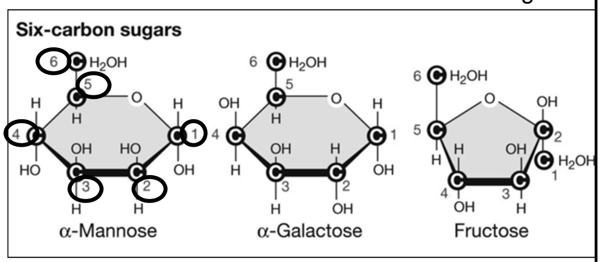
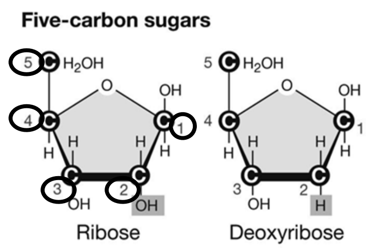
A. Monosaccharides = simple sugars

Fig 3.14





Hexoses = all isomers, $C_6H_{12}O_6$, but distinct chem. properties and functions



← Both 5C sugars (pentoses), but very different properties and biological roles

(Part 1)

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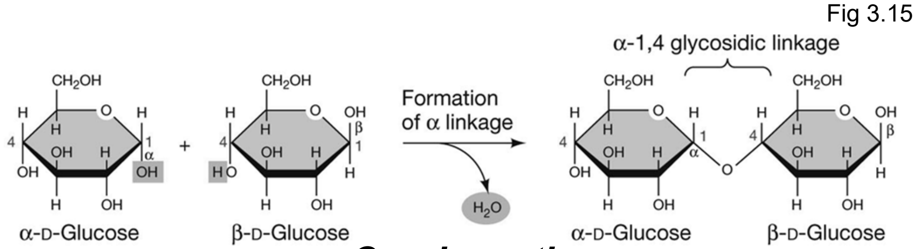
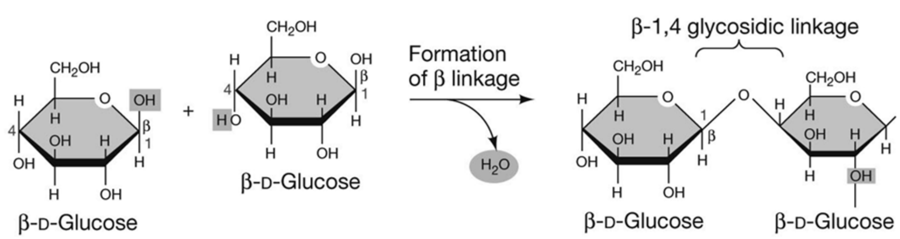
B. Disaccharides are formed by Glycosidic linkages

Fig 3.15



Condensation **Maltose**



Cellobiose

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C. Representative Polysaccharides

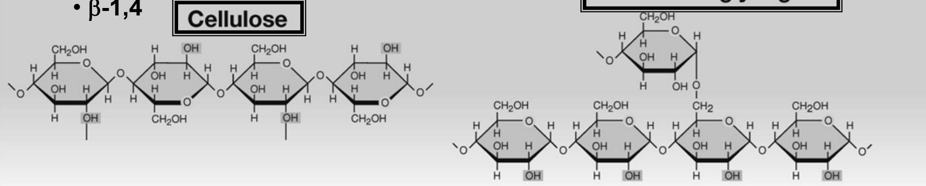
(A) Molecular structure

Branched poly-Glc
- α-1,4, with α-1,6 branches

Unbranched poly-Glc,
- β-1,4

Cellulose

Starch and glycogen



- **Linear**
- **Insoluble**
- **Rigid, H-bonded fibers**
- **High tensile strength**
- **Inert**

- **Highly Branched**
- **Soluble**
- **Reduce osmotic Pressure for energy/glc storage**
- **Easily hydrolyzed for Energy**

LIFE 8e, **Figure 3.16 (Part 1)**

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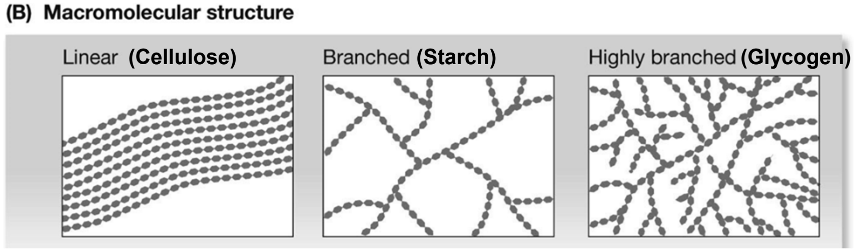
Structure Dictates Function!!

(B) Macromolecular structure



(C) Polysaccharides in cells

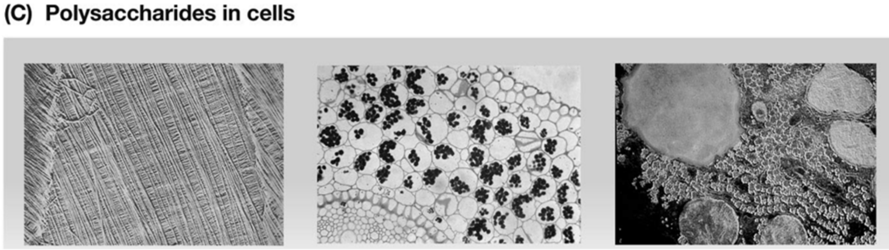


Fig 3.16bc

- **All are Just GLUCOSE!!!!**
- **Differ only in Branching and glycosidic linkages**
- **Very Different Functions/ Properties *[Strx.→ Fxn.]***

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Chemically Modified CHOs

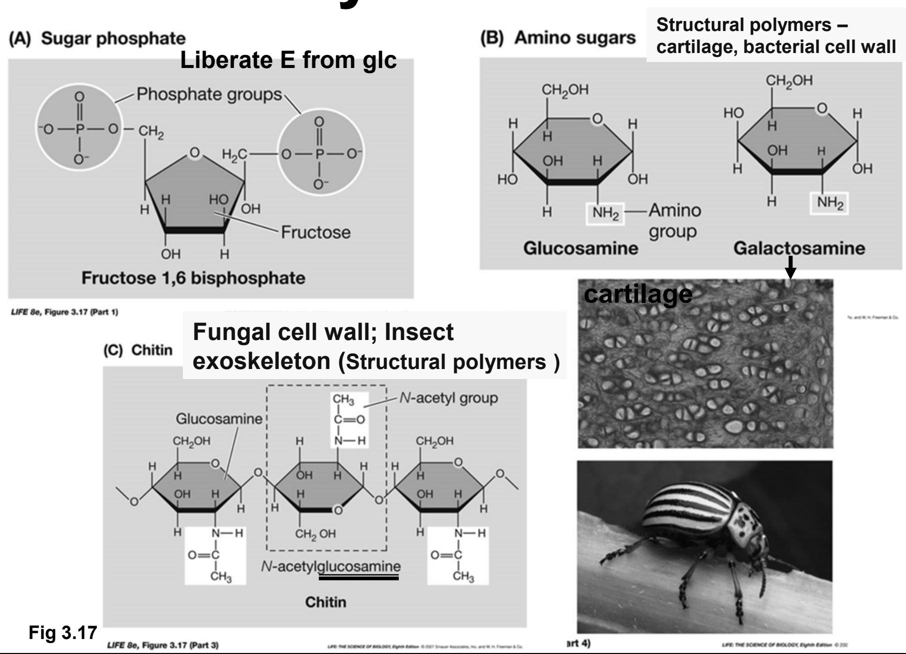

Fig 3.17

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3.3) Lipids: Water-Insoluble Molecules

- Not true macromolecules (b/c not covalently bonded in final interactions), but ......
- Form ***large aggregate structures* –**
  - **"PUSHED TOGETHER" by many surrounding water molecules (hydrophobic),**
  - **then weak but additive *VDW forces* hold them together.**

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Lipids and their Fxns

1. **<u>Fats</u>** and **<u>Oils</u>** – Energy Storage
2. **<u>Phospholipids</u>** – Cell Membrane Strx
3. <u>Carotenoids</u> (pigments) – capture light
4. **<u>Cholesterol</u>** and <u>Steroids</u> – Hormones, cell membrane
5. **<u>Vitamins</u>** – A, D, E, K
   a. ***A = visual pigments***
   b. ***D = bones (Ca++ and P metabolism)***
   c. ***E = antioxidant; protects cell components***
   d. ***K = blood clotting***

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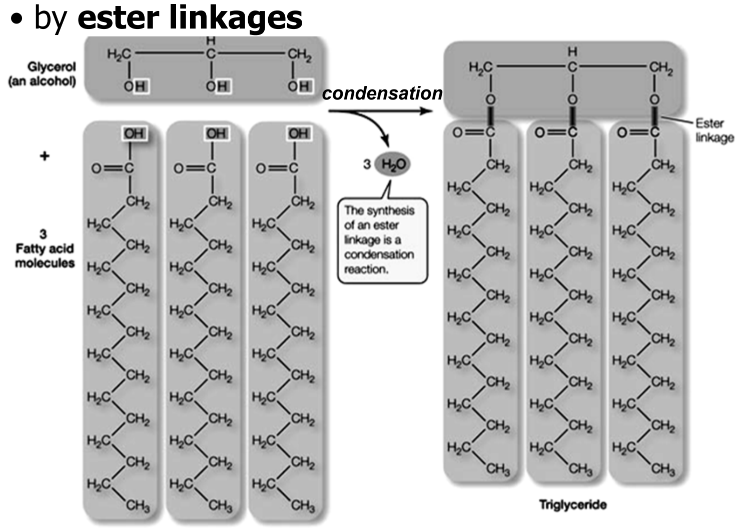
A. <u>Fats and oils</u> = <u>triglycerides</u>

- **three fatty acids** covalently bonded
- to a **glycerol** molecule
- by **ester linkages**



LIFE 8e, Figure 3.18

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Lipid Saturation:
- regulates fluidity

- ***Saturated*** **fatty acids:**
  - hydrocarbon chain with no double bonds.
  - (in solid **FATS**)
    - Longer chains too....
- ***Unsaturated*** **fatty acids**:
  - one or more double bonds bend the chain
  - close packing difficult.
  - (in liquid **OILS**)

STRX → FXN!!!

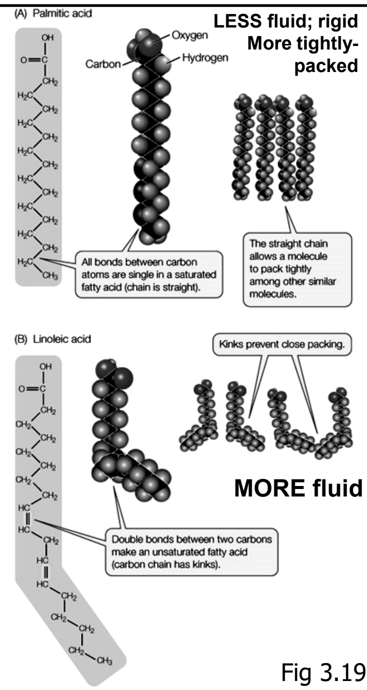

Fig 3.19

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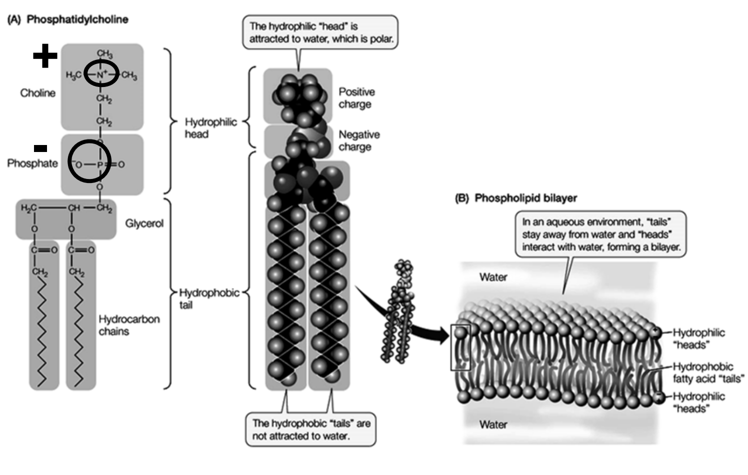
B. Phospholipids

- Have a *hydrophobic* ***hydrocarbon*** "*tail*" and a *hydrophilic* ***phosphate*** "*head.*"
  - Like a triglyceride with one FA replaced with a PO_4^{3-} group.



LIFE 9e, **Figure 3.20**

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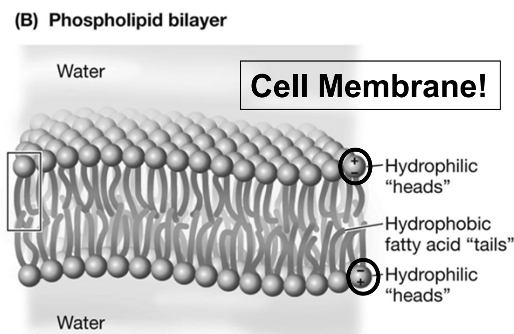
** PhosphoLipid Bilayer

1. In water,
   - hydrophobic tails and hydrophilic heads
   - generate a phospholipid bilayer
   - two molecules thick
2. ***Head groups*** are directed outward, interacting with surrounding water
3. ***Tails*** are packed in the interior
   - <u>Free lateral diffusion</u>,
   - but ***<u>"no" Flip-Flop/ transverse diffusion</u>***!



STRX → FXN!!!

http://telstar.ote.cmu.edu/biology/MembranePage/index2.html

LIFE 9e, Figure 3.20 (Part 2)

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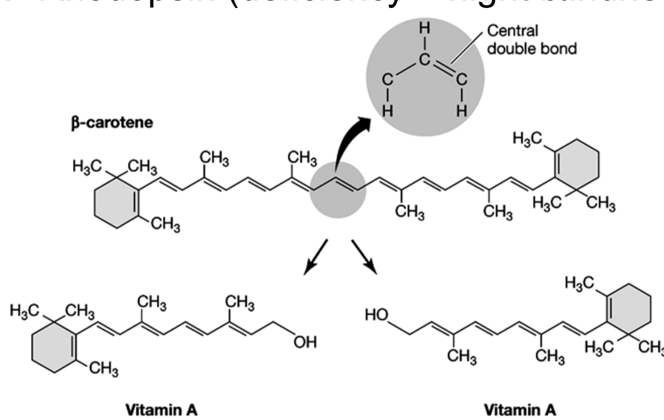
C. Carotenoids

- trap light energy in green plants
- **β-Carotene** can be split to form **vitamin A**, a lipid vitamin
  - → Rhodopsin (deficiency = night blindness)



LIFE 9e, Figure 3.21

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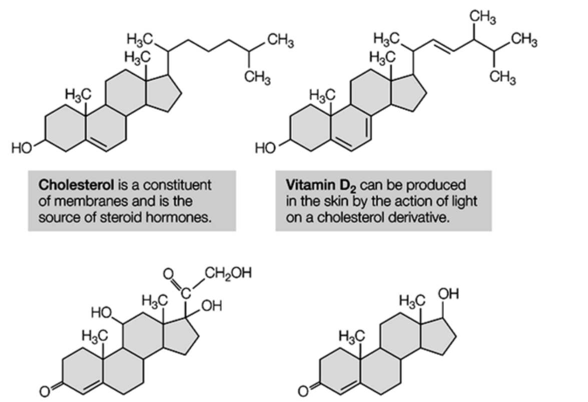
D. Steroids and Cholesterol

- Some steroids = hormones.
- **Cholesterol**
  - regulates membrane fluidity
  - digestion of other fats
  - Precursor to steroid hormones and vitamins
- Vitamins
  - **A, D, E, K**

**** In cells – only <u>Triglycerides</u> (droplets of fat) and <u>Phospholipids</u> (membranes) are in *high quantities***



Cholesterol is a constituent of membranes and is the source of steroid hormones.

Vitamin D_2 can be produced in the skin by the action of light on a cholesterol derivative.

Cortisol is a hormone secreted by the adrenal glands.

Testosterone is a male sex hormone.

LIFE 9e, **Figure 3.22**

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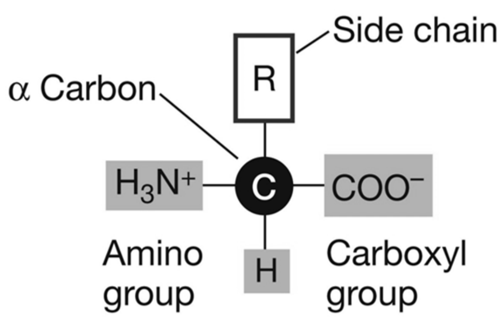
3.4) Proteins: Polymers of Amino Acids

- **Functions:**
  (most major cellular fxns! Except genetic info.)
  1. **support**
  2. **protection**
  3. **catalysis**
  4. **transport**
  5. **defense**
  6. **regulation**
  7. **movement**



- **They sometimes require an attached prosthetic group.**

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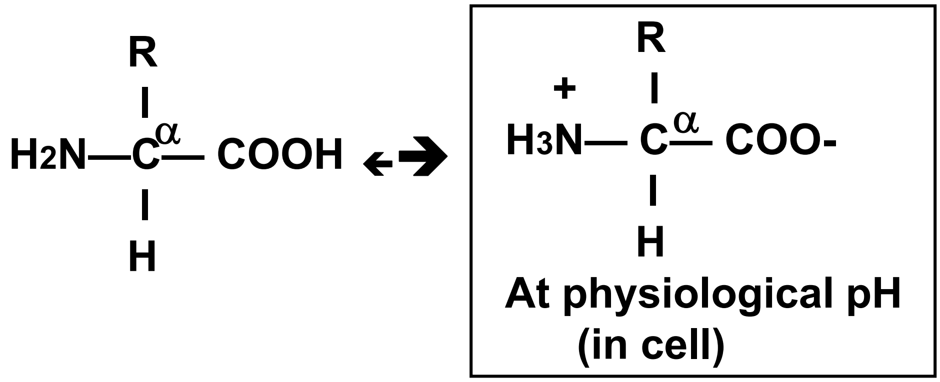
A. 20 amino acids (basic strx) =

amino, carboxy, H atom, & R group (on α-C)



- Side chains of amino acids may be <u>charged</u>, <u>polar</u>, or <u>hydrophobic</u>.

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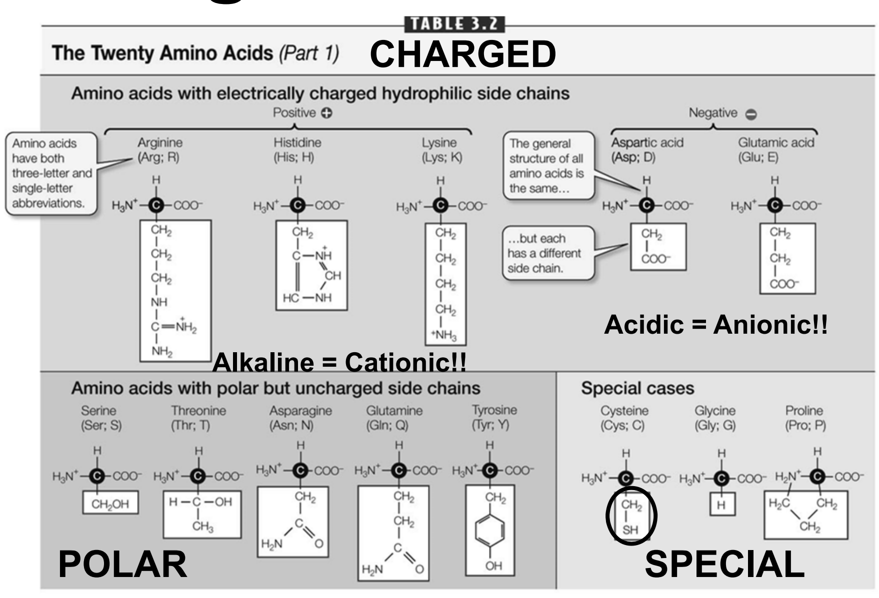
Charged & Polar AA's



LIFE 8e, Table 3.2 (Part 1)

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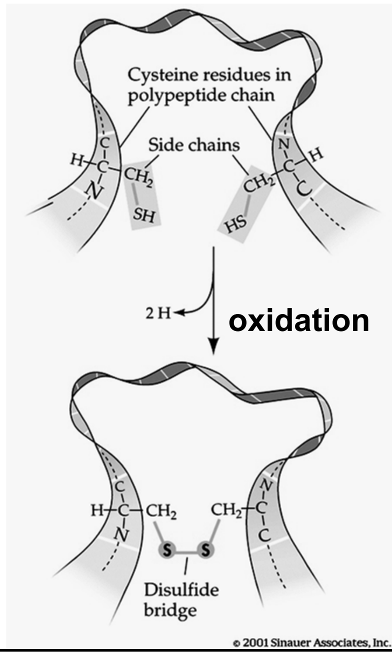
SH groups can form disulfide bridges

Cysteine residues
(cys)



- ***Within a protein or***
- ***Between separate polypeptides***

figure 3.3 (2004, 7e)
[see fig. 3.5, 2007/2010]

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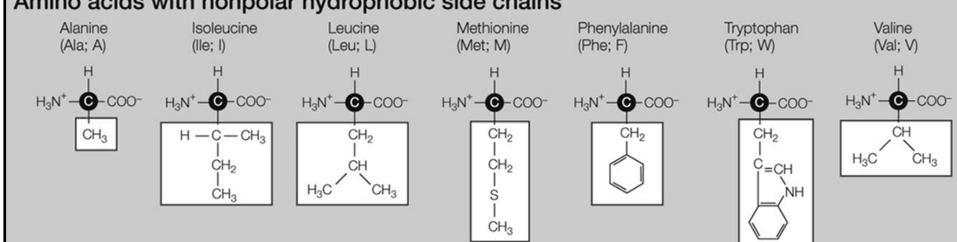
Hydrophobic AA's

TABLE 3.2

The Twenty Amino Acids *(Part 2)* **HYDROPHOBIC**

Amino acids with nonpolar hydrophobic side chains



***LIFE 8e*, Table 3.2 (Part 2)**

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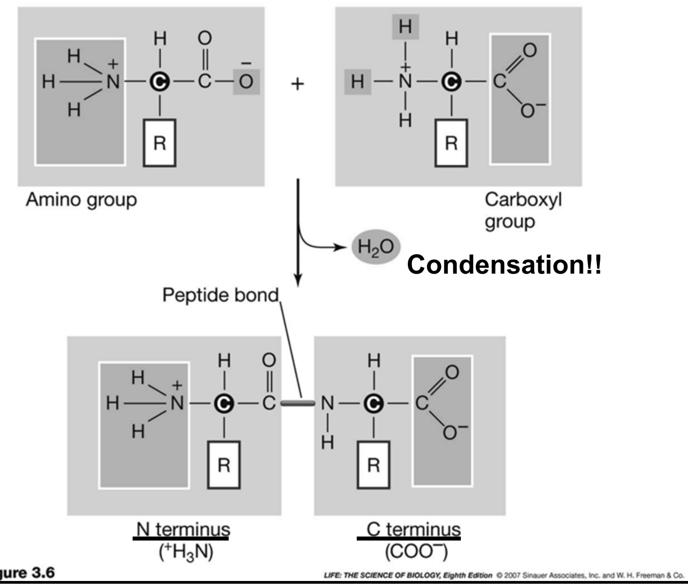
B. Amino acids are covalently bonded together by Peptide Linkages



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C. Protein Structure: Polypeptide chains are folded into specific 3D shapes

- **Hierarchy: Primary → Secondary → Tertiary → Quaternary Structures**
  - ***AA sequence ultimately determines 3D structure and Prot. FUNCTION!!***
  - ***** [(Monomers →) 3D structure → Fxn] *****
- ***All protein structure and function is ultimately specified by DNA!!!***

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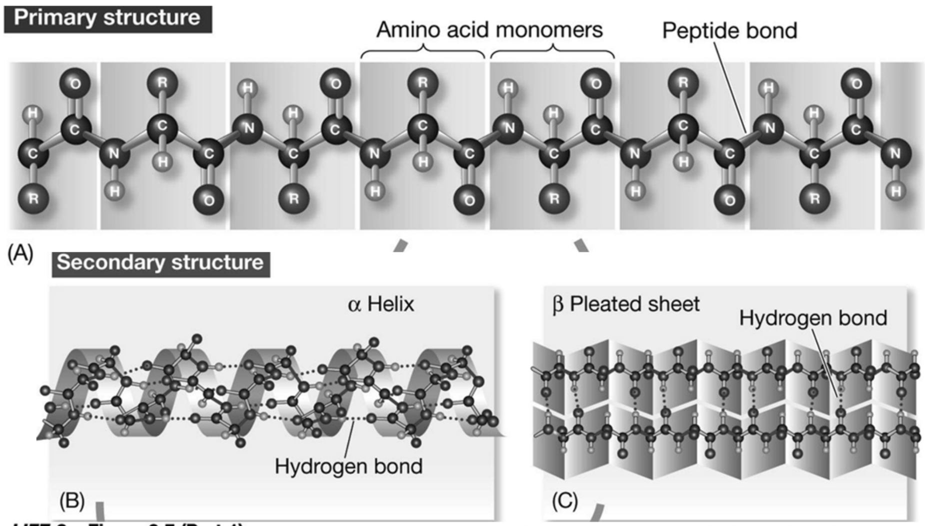
1. **Primary structure** = the sequence of amino acids
   - peptide linkages (covalent bonds); NCC-NCC-NCC-…. backbone.
2. **Secondary structures** = maintained by hydrogen bonds between atoms of the amino acid residues (weak bonds).



LIFE 8e, Figure 3.7 (Part 1)

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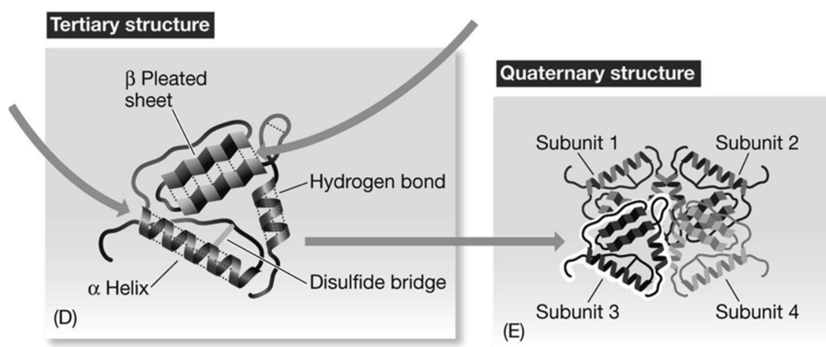
3. **Tertiary structure** = 3D bending and folding of the polypeptide chain (weak and S-S covalent bonding).
4. **Quaternary structure** = arrangement of polypeptides in a single functional unit consisting of more than one polypeptide subunit (weak bonding).



LIFE 8e, Figure 3.7 (Part 3)

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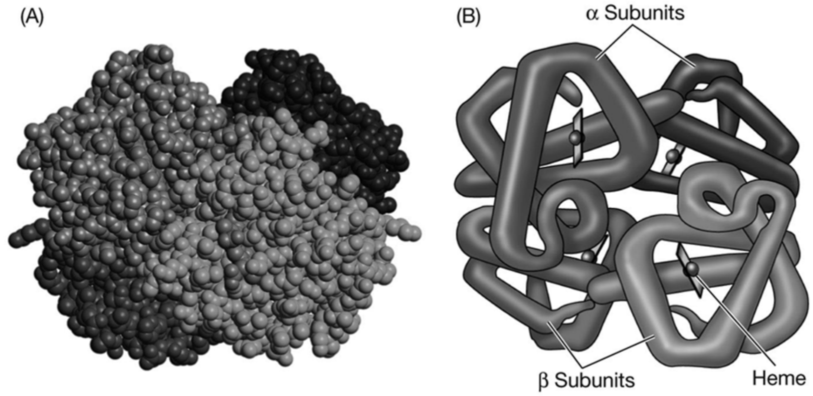
Hemoglobin and Quaternary Strx



LIFE 8e, Figure 3.9

- **Quaternary structure** = Multi-Subunit proteins!!
  - (> 1 polypeptide)

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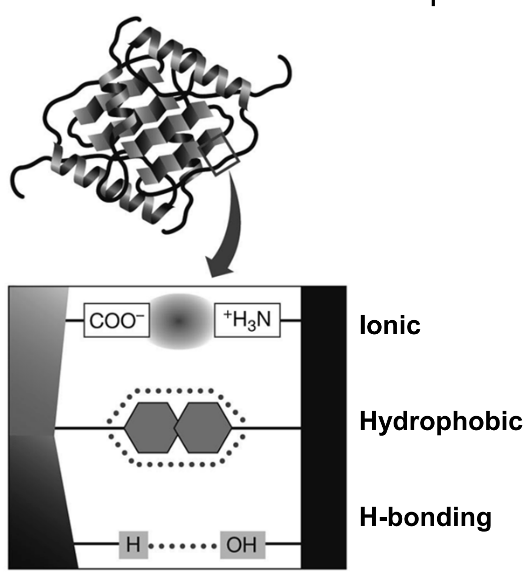
D. Binding of proteins to other molecules

- Weak chemical interactions are important!!



8e, Figure 3.10

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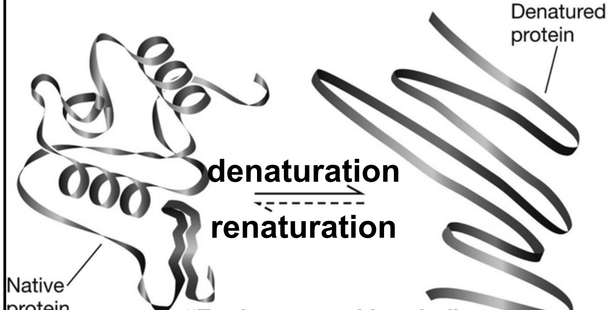
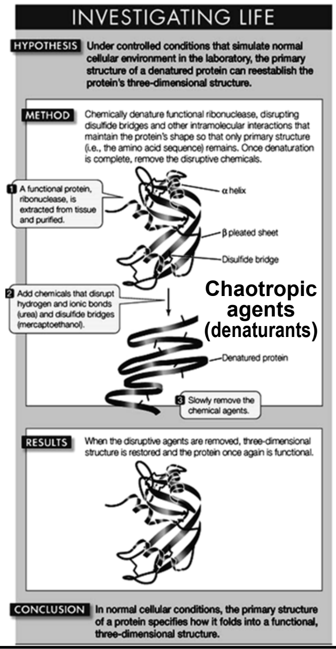
E. Proteins can be Denatured:

- by heat, acid, or chemicals (salts, solvents, etc.)
- lose tertiary and secondary structure and …
  - → *Lose biological function*



"Environmental insults"
- High temperature (and low)
- pH changes
- High concentrations of ions/salts
- Nonpolar substances (solvents)



LIFE 8e, Figure 3.11

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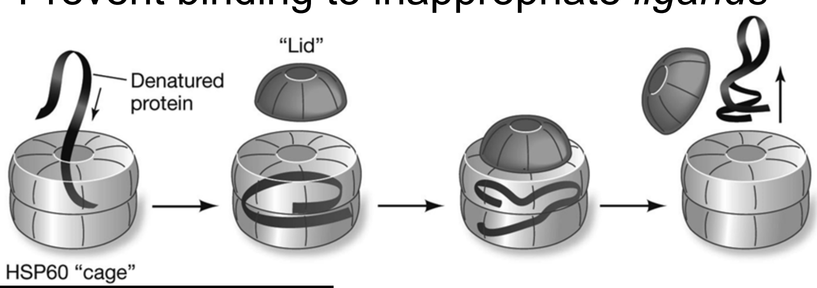
Chaperonins assist protein folding

- "***Molecular Chaperones***" – prevent inappropriate interactions
  - (like human Chaperones!)
- Prevent binding to inappropriate *ligands*



Newly synthesized, or denatured protein

LIFE 9e, Figure 3.12

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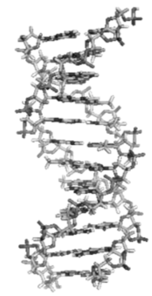
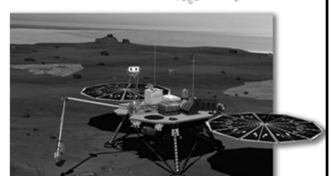
Chapter 4:

Nucleic Acids and the Origin of Life



1) **4.1 What Are the Chemical Structures and Functions of Nucleic Acids?**
2) **4.2 How and Where Did the Small Molecules of Life Originate?**
3) **4.3 How Did the Large Molecules of Life Originate?**
4) **4.4 How Did the First Cells Originate?**



NASA *Viking* project, *Phoenix* robotic space lab - Mars

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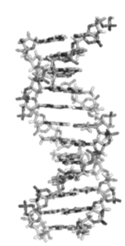
4.1) Nucleic Acids:

Informational Macromolecules

- In cells, **DNA** is the hereditary material.
- **DNA** and **RNA** play roles in **protein** formation.



❖**<u>Question:</u>**

***** WHAT COMPOSITIONS, STRUCTURES, AND PROPERTIES OF NA's permit them to play these fundamental informational roles?? *****

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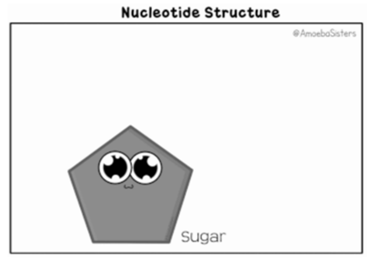
Nucleic Acids:
Informational Macromolecules



1. Nucleic acids = polymers of
2. **<u>Nucleotide</u>** =
   a) **Phosphate** group
   b) **Sugar (5C)**
      - <u>Ribose</u> in RNA, or <u>Deoxyribose</u> in DNA
   c) Nitrogen-containing **base** (purine or pyrimidine)
3. <u>DNA:</u> bases are Adenine, Guanine, Cytosine, and **Thymine** (AGC**<u>T</u>**)
4. <u>RNA:</u> **Uracil** substitutes for thymine (AGC**<u>U</u>**)

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Nucleo<u>t</u>ides vs. Nucleo<u>s</u>ides

- In the nucleic acids, bases extend from a <u>sugar–phosphate backbone</u>.
- **DNA and RNA <u>information</u>** resides in their **<u>base</u> sequences**

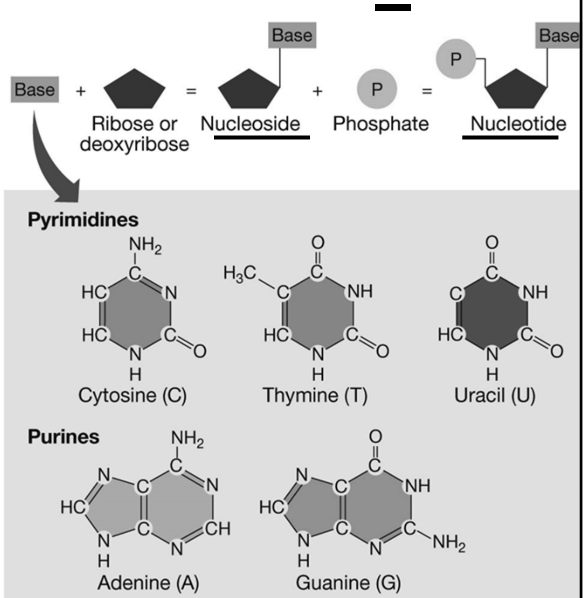

Figure 4.1

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4.2) DNA vs. RNA

DNA

1. Deoxyribose sugar
2. Bases ACG<u>T</u>
3. Double stranded
   - (antiparallel)
4. Chemically stable

RNA

1. Ribose sugar
2. Bases ACG<u>U</u>
3. Single stranded
4. Chemically labile

STRUCTURE → FUNCTION

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RNA

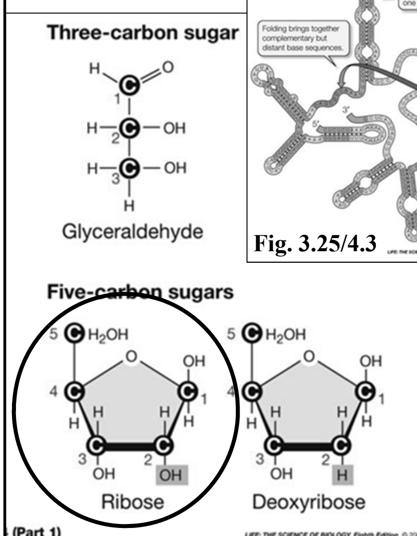

Fig. 3.14

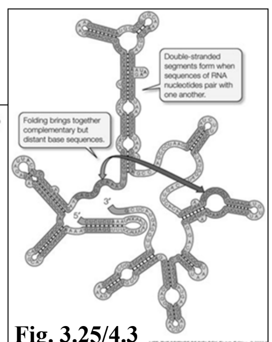

Fig. 3.25/4.3

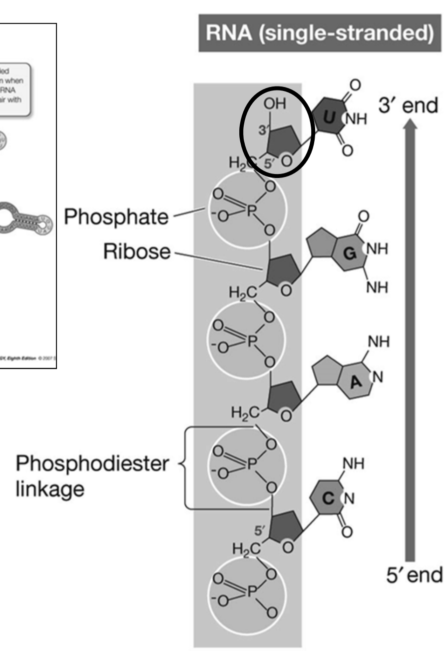

Figure 4.2 (Part 1)

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DNA

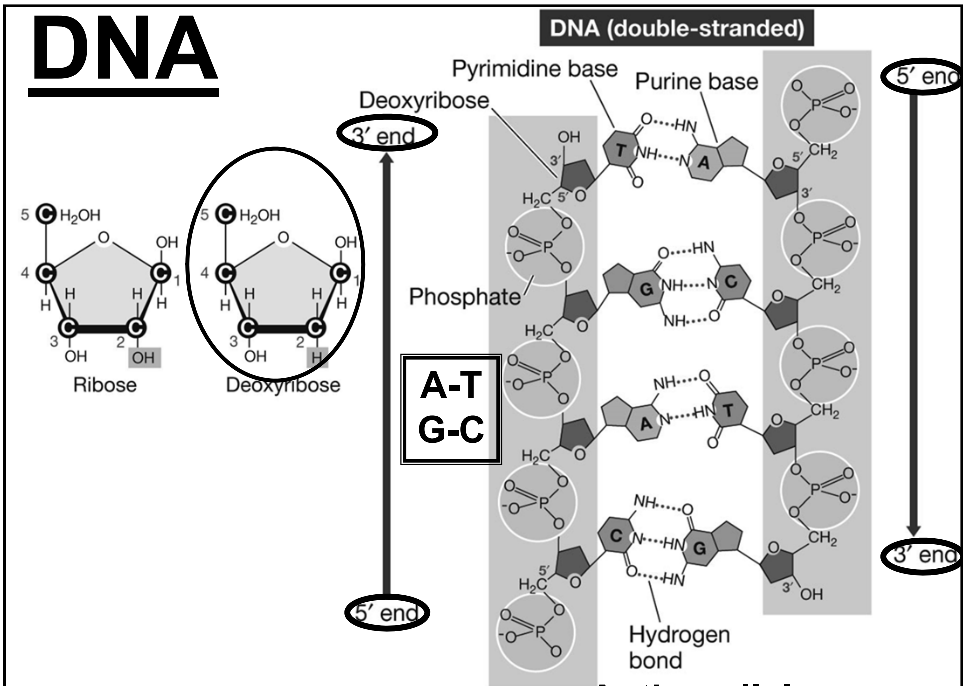

Figure 4.2 (Part 2)

Antiparallel

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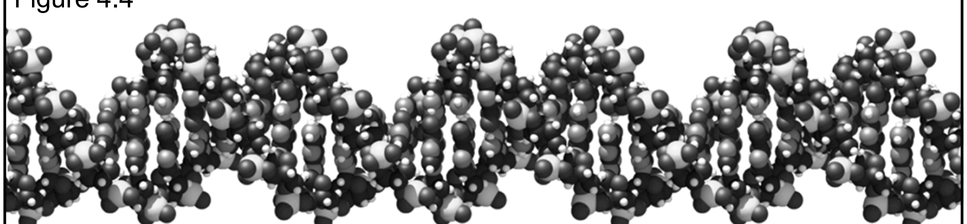
DNA Double Helix

Yell = **P**hosphorus
Red = **O**xygen
White = **H**ydrogen
Lt. Blue = **N**itrogen
Dk. Blue = **C**arbon

Figure 4.4



- **Stacks of bases, H-bonded at center (attached to sugar)**
  - **Hydrophobically stabilizing the double helix**
- **Hydrophilic sugar-phosphate backbone outside helix**

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Nucleic Acids: Uses of DNA Sequence Information

- **Comparing the DNA base sequences of different species:**
  - → information on evolutionary relatedness
  - Some unpredictable relationships based on observable forms, bodies, etc.

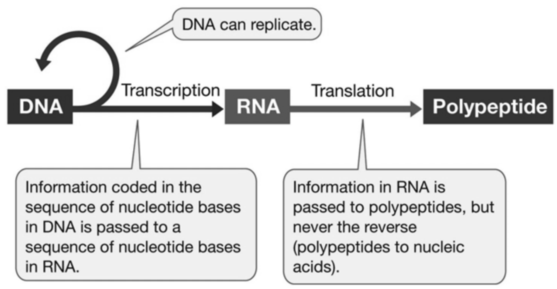

Figure 4.5 DNA Stores Information

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4.3) The Interactions of Macromolecules

- Both covalent and noncovalent linkages are found between the various classes
  - **Glycoproteins**
  - **Glycolipids**
  - **Lipoproteins**
  - **DNA-binding proteins, etc…**

    - .....energy, enzymes, and metabolism!!!.......

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