BIOL 230: Cell & Molecular Biology

Fall 2019 17-205 M, Aug. 19

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1. Pre-Lab writeups due each Mon. (for M&W!!) at the start of lab. (*briefly*, **What**? **Why**? **How**? for each expt.). **Hypothesis**?!
2. Don't forget to complete the ***Lab #1 Internet Activity***!
3. ***Bi-weekly quizzes: Practice Quiz posted soon on SMCCD Canvas: https://smccd.instructure.com/***
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**

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REVIEW

1. List and describe 6 properties of ***LIFE*** (truly living things).

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

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**.
4. List and define the general **structures and functions of the 4 major classes of macromolecules**. Provide specific examples.
5. 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)
6. Describe the **levels of protein structure**, and illustrate each with a specific example.

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

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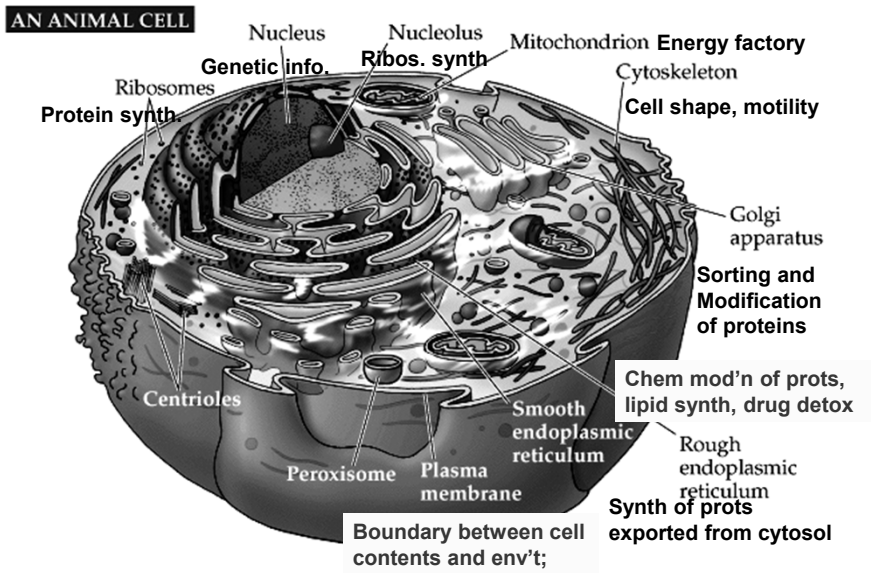
The Eukaryotic/Animal Cell

fig. 4.7 (2004)



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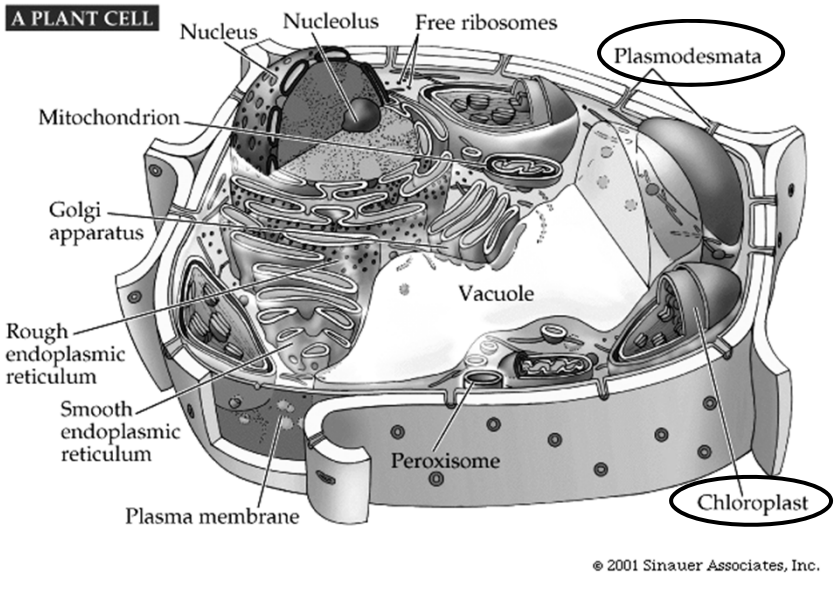
The Eukaryotic/Plant Cell

fig. 4.7 (2004)



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Eukaryotic Organelles

1. **Plasma Membrane**
   - Define cell boundaries/ cytoplasm
   - Regulates entry/exit
2. **Nucleus** – contains the chromosomal DNA (genetic material)
3. **Nucleolus** – dark strx within the nucleus – site of ribosome synthesis
4. **Ribosomes** – free in cytoplasm or associated with the Endoplasmic Reticulum – responsible for protein synthesis
5. **Mitochondria** – the powerhouses of the cell; convert stored chemical energy into a form useable by the cell
6. **Endoplasmic Reticulum** – continuous with the nuclear envelope
   a) **Rough ER** – "studded" with ribosomes; synthesis of proteins which function outside of the cytosol (secreted, membrane, or organellar)
   b) **Smooth ER** – chemical modification of proteins, lipid synthesis, detoxification of drugs
7. **Golgi Apparatus** – storage, modification, and packaging of proteins for delivery
8. **Cytoskeleton** – protein fibers (scaffold) which provide structural support, shape, & motility to cells

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Understanding the Cell: How does life work?

- **LIFE = organized CHEMISTRY!** (fundamentally)
  - Bio-chemicals and their reactions.

1. **6** elements = **98%** of living mass.
   - **C, H, N, O, P, S**
2. **Outer shell electrons** = chemistry of atoms
3. Molecule = two or more atoms linked by chemical bonds.
4. **Octet rule** = 8 electrons in outer shell is stable!

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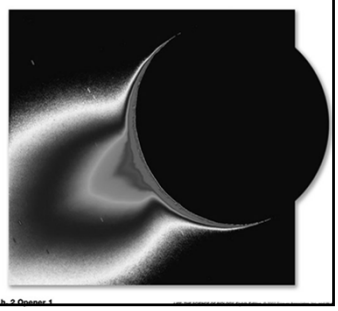
Ch. 2: Life and Chemistry: Small Molecules

1. Atoms: The Constituents of Matter
2. Chemical Bonds: Linking Atoms Together
3. Chemical Reactions: Atoms Change Partners
4. Water: Structure and Properties
5. Acids, Bases, and the pH Scale
6. Properties of Molecules

Water spray and vapor from Saturn's moon, Enceladus

Robotic rover, Opportunity (not Curiosity), on Mars



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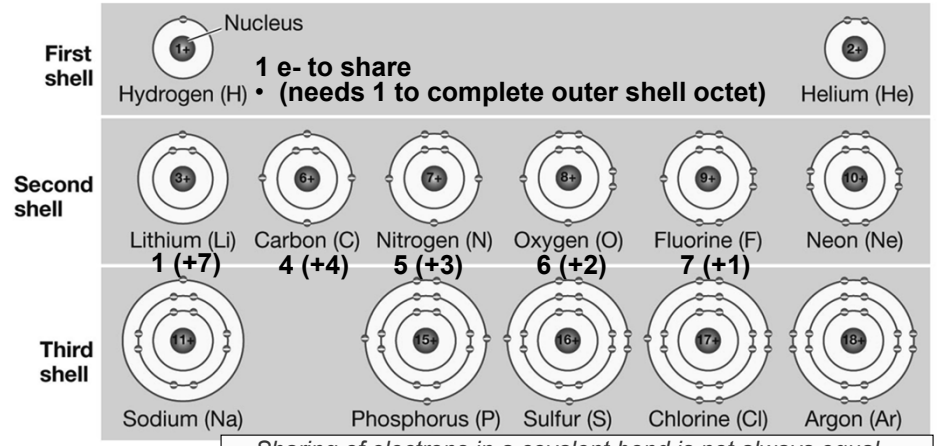
2.1) ATOMS: The basic units of matter

Electron shells determine the reactivity of atoms



- *Sharing of electrons in a covalent bond is not always equal.*
  - ❖ ***Electronegativity**: the attractive force that an atomic nucleus exerts on electrons. **OCTET RULE!!***
- *It depends on the number of protons and the distance between the nucleus and electrons.*

***LIFE 9e*, Figure 2.5**

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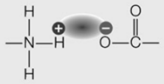
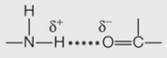
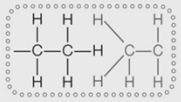
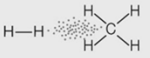
2.2) CHEMICAL BONDS

TABLE 2.1

Chemical Bonds and Interactions

	NAME	BASIS OF INTERACTION	STRUCTURE	BOND ENERGY[a] (KCAL/MOL)
1.	Covalent bond	Sharing of electron pairs		50–110
2.	Ionic bond	Attraction of opposite charges		3–7
3.	Hydrogen bond	Sharing of H atom		3–7
4.	Hydrophobic interaction	Interaction of nonpolar substances in the presence of polar substances (especially water)		1–2
5.	van der Waals interaction	Interaction of electrons of nonpolar substances		1

[a]Bond energy is the amount of energy needed to separate two bonded or interacting atoms under physiological conditions.

- *Sharing of electrons in a covalent bond is not always equal.*
- ***Electronegativity**: the attractive force that an atomic nucleus exerts on electrons.*
- *It depends on the number of protons and the distance between the nucleus and electrons.*

***LIFE 9e*, Table 2.1**

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1. Covalent Bonds: Fig 2.7, Table 2.2

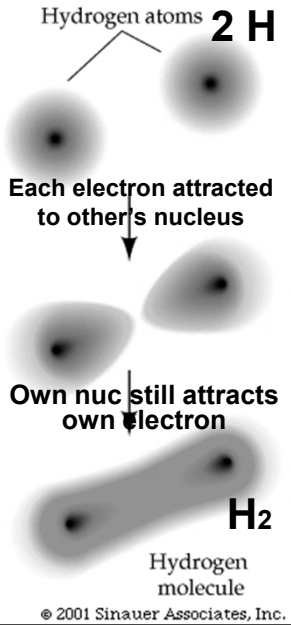

TABLE 2.2

Covalent Bonding Capabilities of Some Biologically Important Elements

ELEMENT	USUAL NUMBER OF COVALENT BONDS
Hydrogen (H)	1
Oxygen (O)	2
Sulfur (S)	2
Nitrogen (N)	3
Carbon (C)	4
Phosphorus (P)	5

***LIFE 8e*, Table 2.2**

- **= Sharing of pairs of electrons between atoms.** *(nonpolar, polar)*

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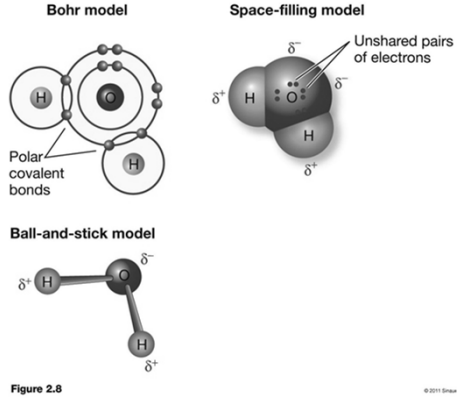
Polar Covalent Bonds & *Electronegativity*



- **Polar covalent bond =**
  - **unequal sharing of electrons**
  - **Related to *Octet Rule.***

❖**More Electronegative atoms draw electrons more strongly towards themselves** during covalent bonding

- Gain a partial negative charge
- Other bonded atom gains a partial positive charge
- A "weak ionic bond" is formed

TABLE 2.3

Some Electronegativities

ELEMENT	ELECTRONEGATIVITY
Oxygen (O)	3.5
Chlorine (Cl)	3.1
Nitrogen (N)	3.0
Carbon (C)	2.5
Phosphorus (P)	2.1
Hydrogen (H)	2.1
Sodium (Na)	0.9
Potassium (K)	0.8

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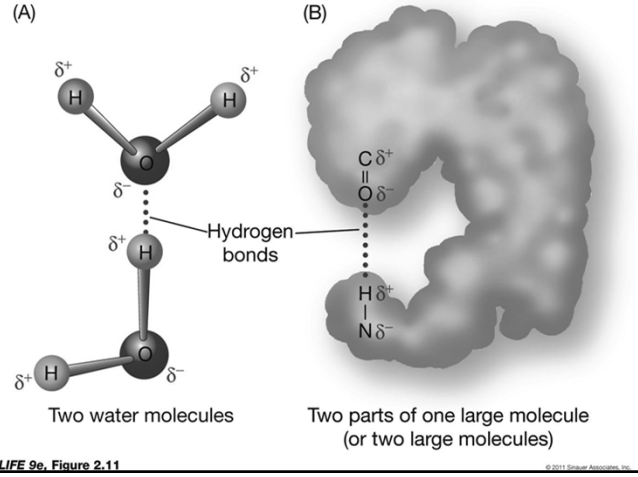
2. Hydrogen Bonds

- **= weak electrostatic attraction between partial charges on polar molecules**
- 2 electronegative atoms partially share an H atom
  - -- important in Water, DNA, Proteins, carbohydrates,…..



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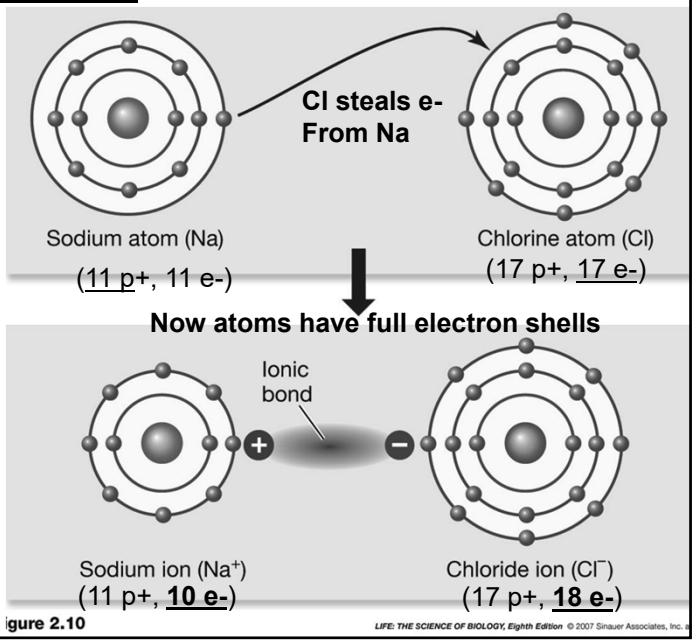
3. Ionic Bonds = attraction of opposite charges

- **Octet achieved on each atom!**
  = stable!
  (one now +, other now -)



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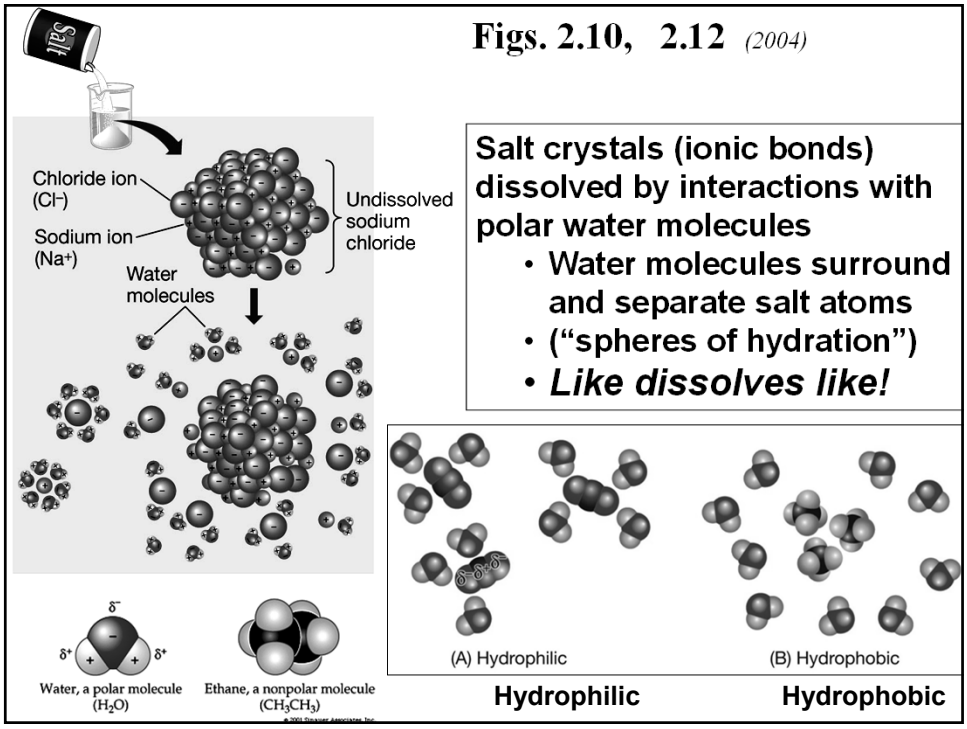

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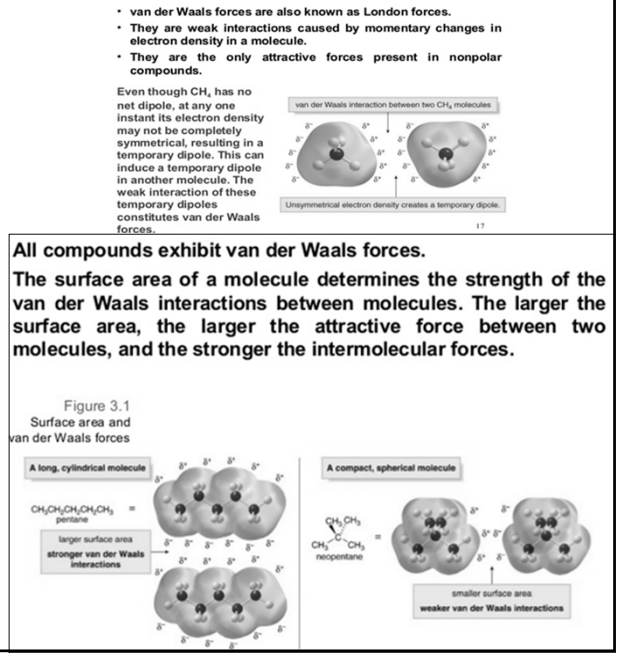
4. Van der Waals Forces

- Brief, weak attraction between molecules in close proximity (***London Dispersion Forces***)
- Very weak opposite charge interactions between **"<u>sparse" (more pos</u>.)** and **"<u>dense" (more neg</u>.)** regions of each molecule's electron cloud
- Strengthened by the sum of many interactions over surface of a large nonpolar molecule



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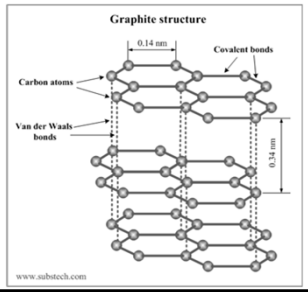
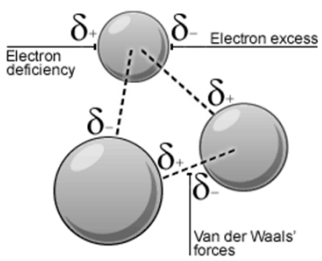
5. Hydrophobic Interactions

- **Exclusion of nonpolar** substances from interactions with polar or ionic molecules
  - Eg: oil in water – clumps together/separates
- **Enhanced by <u>Van der Waals Forces</u>**





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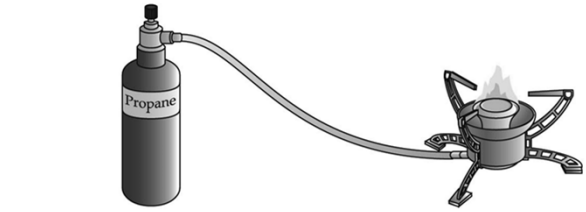
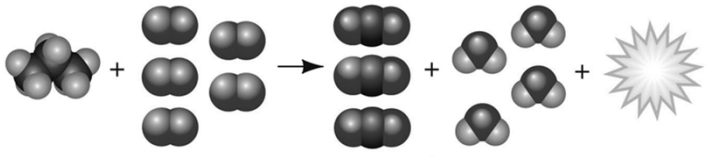
2.3) Chemical Reactions:

changing of bonding partners and energy





C_3H_8 + 5 O_2 → 3 CO_2 + 4 H_2O + Heat and light

Propane + Oxygen gas → Carbon dioxide + Water + Energy

Reactants Products

LIFE 8e, Figure 2.13

Reaction is COMPLETE!!

← Products similar to reactions in biological metabolism!!

~ Glucose sugar + O_2 → CO_2 and H_2O and Energy

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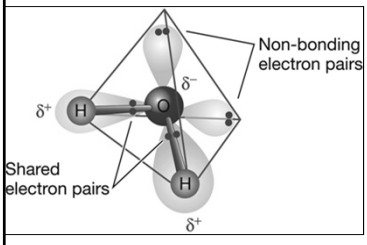
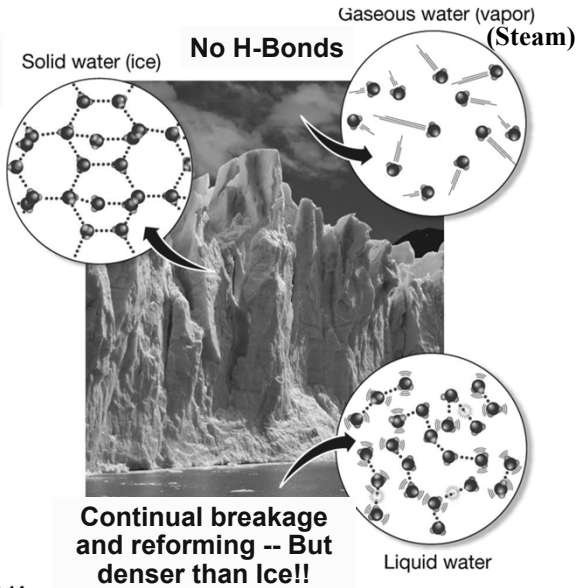
2.4) WATER:

H-Bonds hold water molecules together

Rigid – But low density; Floats!





Continual breakage and reforming -- But denser than Ice!!

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Water: Strx and Properties

1. **Tetrahedral** shape – 4 *e*- orbitals repel each other
   - **Structure → Properties → BIOLOGICAL FUNCTION!!**

2. **H-bonding** – highly cohesive and adhesive
   – great **solvent (polarity!!)**
3. Solid / **Ice** = less dense than liquid → **floats**!
   - Aquatic env't = insulating, protective

4. **Lot of heat energy to melt ice or freeze liq.**
   - Great moderator of temperature changes
   - **High heat capacity/ specific heat** – lots of heat to raise the temp of water, break H-bonds
     – = good Temperature buffer!
     – In cells, aquatic envt, atmosphere

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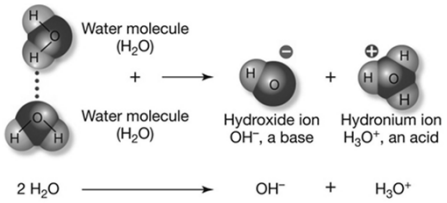
2.5) Acids and Bases

1. Pure water ionizes to acidic or basic components **(OH^- or H_3O^+)**
   - but remains neutral in pH (7) when pure, since this ionization is reciprocal.
2. **ACIDs** = donate proton (H^+, actually H_3O^+), accept ^-OH
   - $HCl \rightarrow H^+ + Cl^-$



3. **BASES** = accept proton, release hydroxide
   - $NaOH \rightarrow Na^+ + OH^-$
4. **pH (potential of Hydrogen)** = **$- \log [H^+]$;**
   - Concentration in molar units **(Molar= moles/L)**

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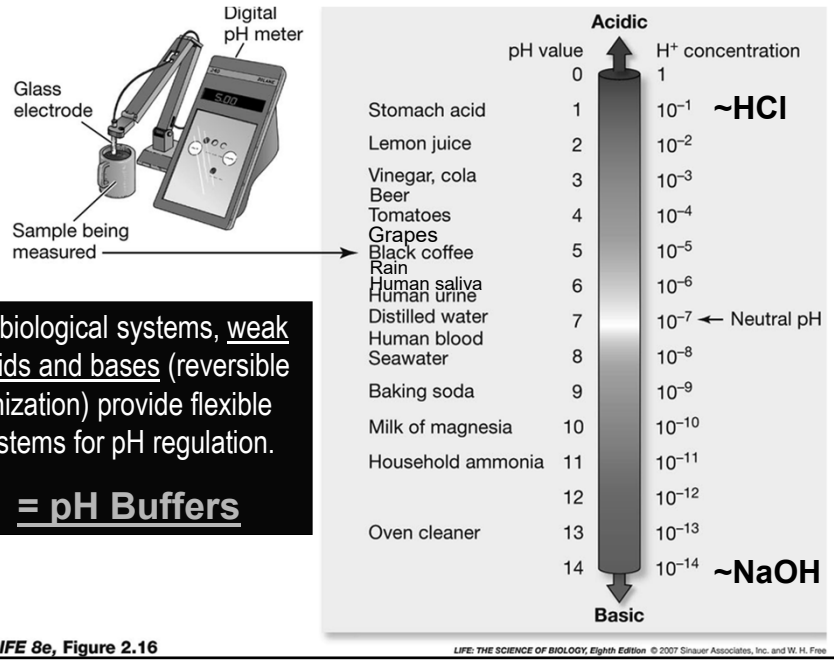
pH values of some familiar substances



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

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pH Buffers = 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: **H_2CO_3/HCO_3^-** (carbonic acid/ bicarbonate) ***buffer system*** – 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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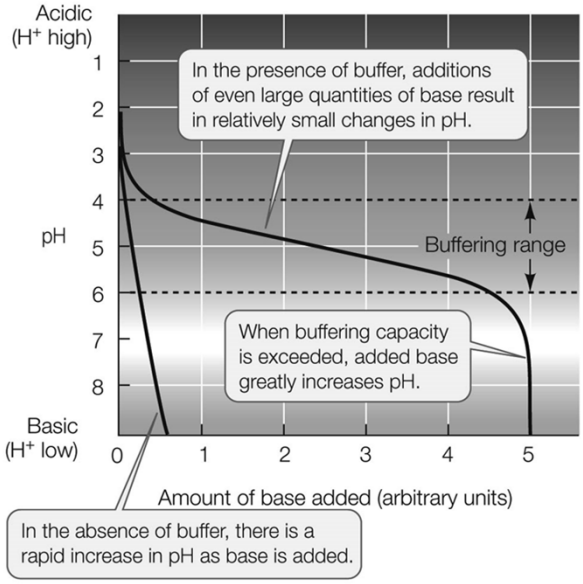
Buffers minimize changes in pH



LIFE 9e, Figure 2.17

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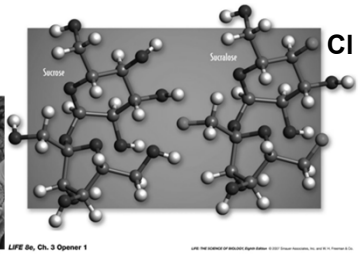
CHAPTER 3
Macromolecules: Their Chemistry and Biology

1. Carbohydrates
2. Lipids
3. Proteins
4. [Ch. 4: Nucleic Acids]



LIFE 8e, Ch. 3 Opener 1

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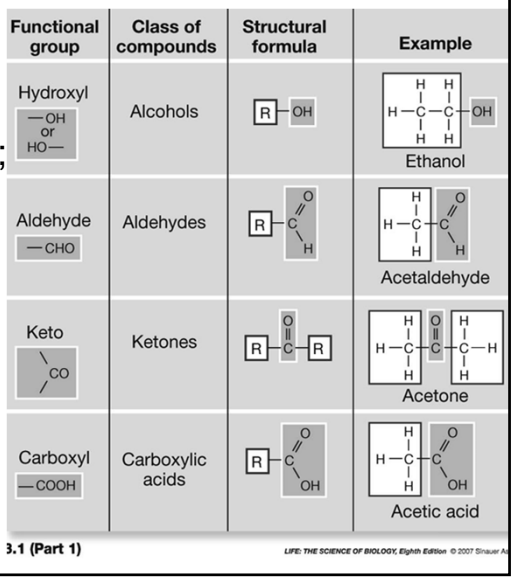
3.1) Functional Groups give particular properties to larger biomolecules

Classify Molecules by:

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



3.1 (Part 1)

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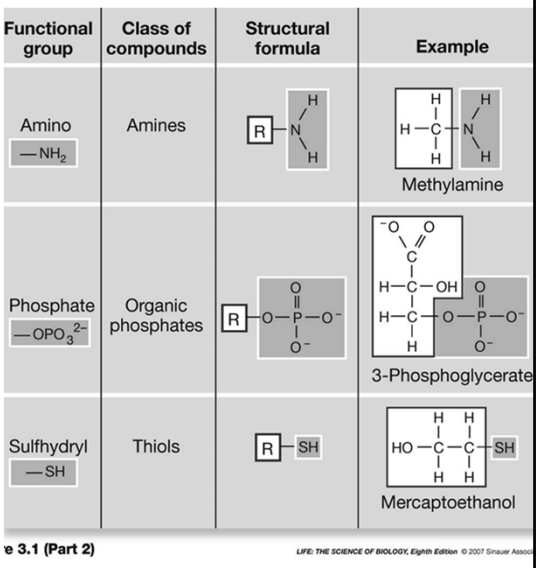
Functional Groups Important to living systems, cont'd Fig 3.1

4. **Amino** ($-NH_2$)
   - [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)

……..



e 3.1 (Part 2)

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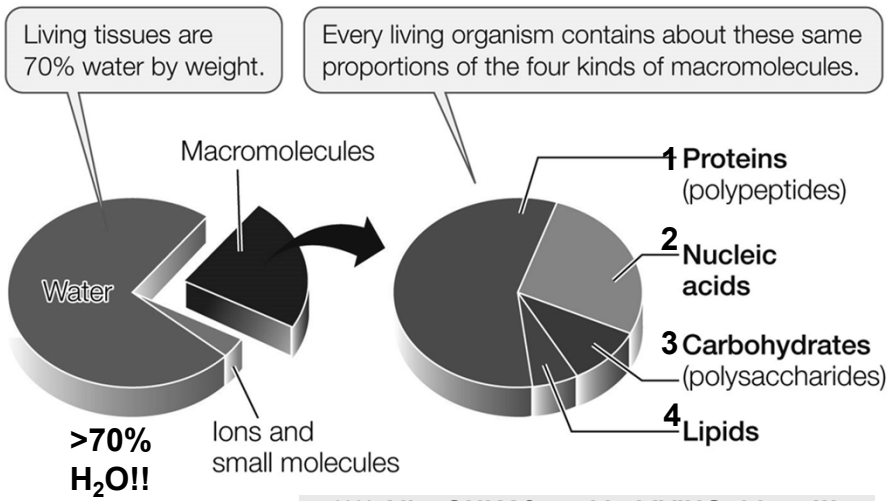
A. Substances in living tissues



- ****** 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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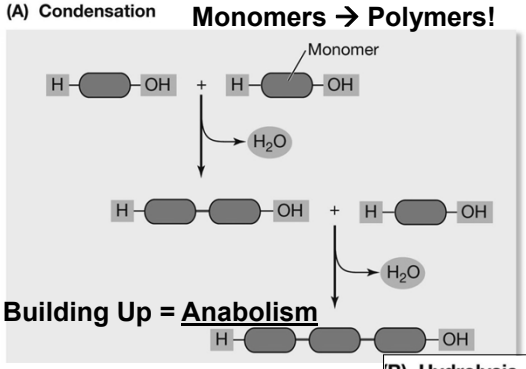
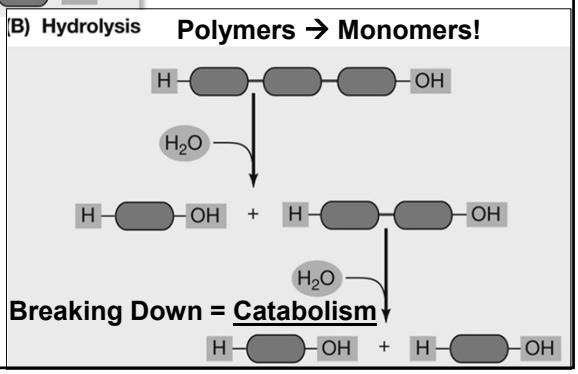
Condensation and Hydrolysis

Fig 3.4

A-H + B-OH → A-B + H_2O





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

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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**

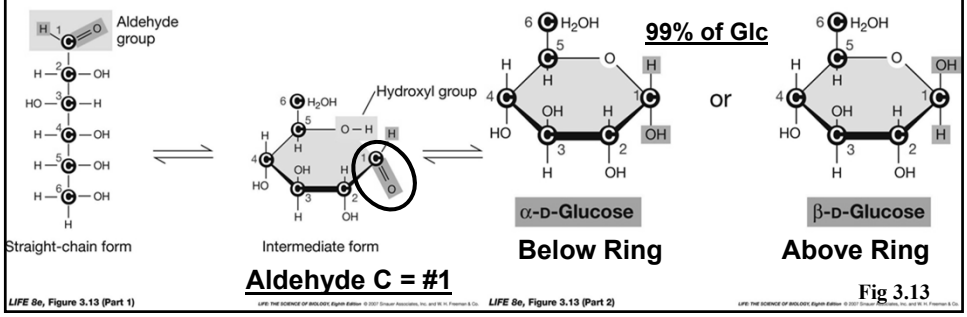

Fig 3.13

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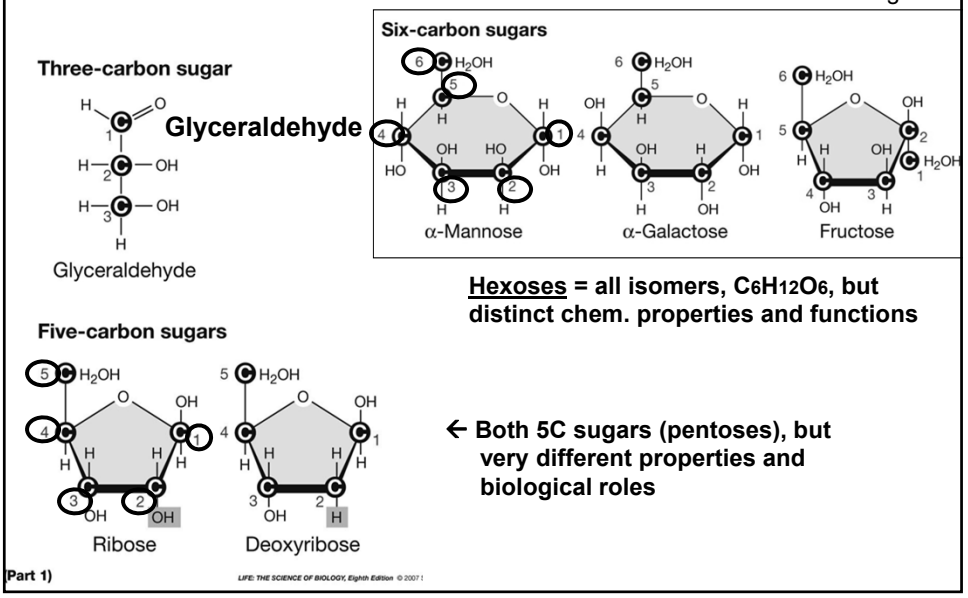
A. Monosaccharides = simple sugars

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

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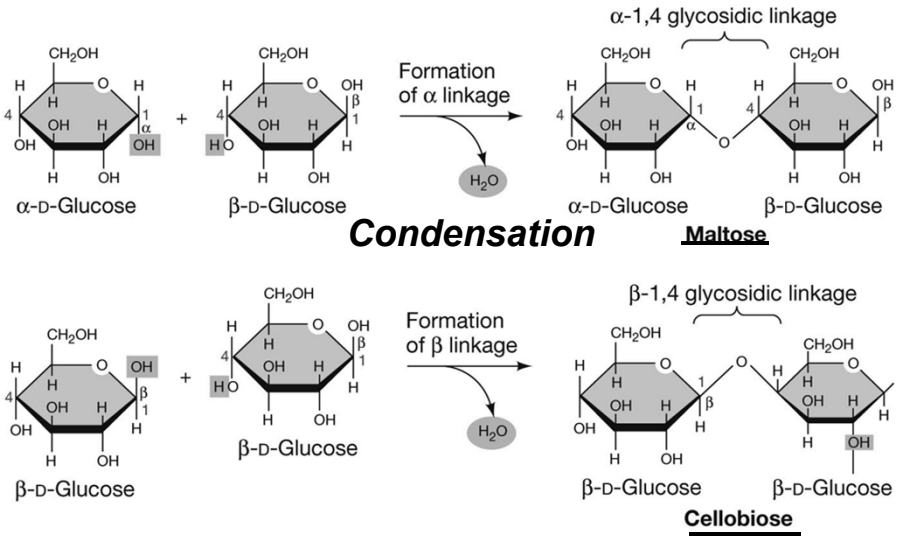
B. Disaccharides are formed by Glycosidic linkages

Fig 3.15



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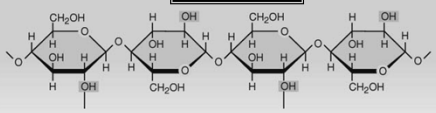
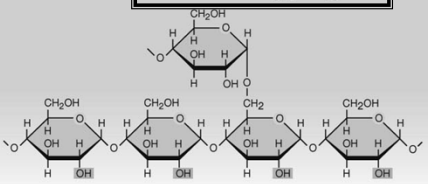
C. Representative Polysaccharides

(A) Molecular structure

Unbranched poly-Glc,
• β-1,4
Cellulose



Branched poly-Glc
• α-1,4, with α-1,6 branches
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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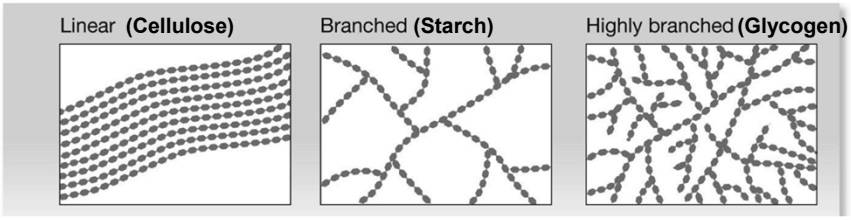
Structure Dictates Function!!

(B) Macromolecular structure



(C) Polysaccharides in cells

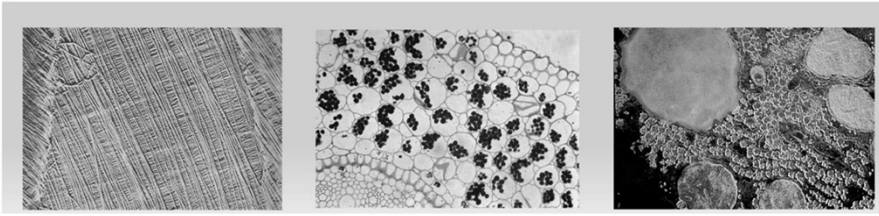


Fig 3.16bc

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

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Chemically Modified CHOs

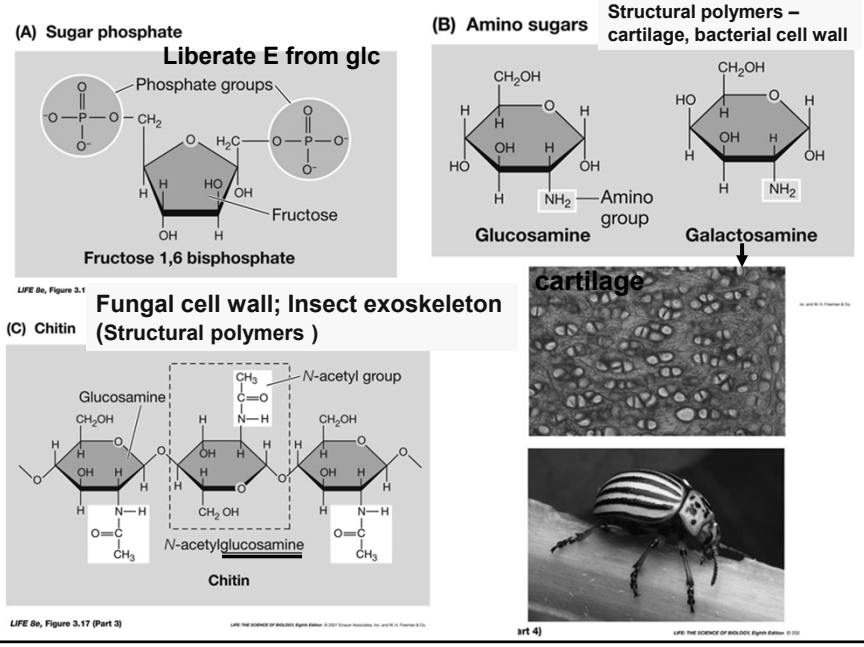

Fig 3.17

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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. **Fats** and **Oils** – Energy Storage
2. **Phospholipids** – Cell Membrane Strx
3. Carotenoids (pigments) – capture light
4. **Cholesterol** and Steroids – Hormones, cell membrane
5. **Vitamins** – 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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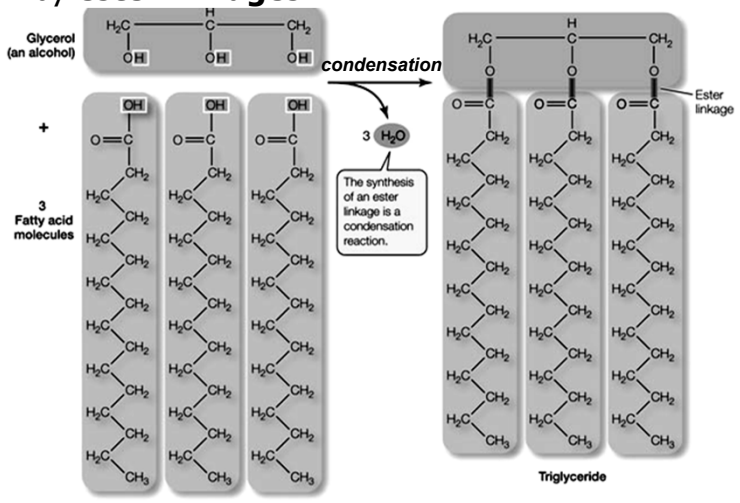
A. Fats and oils = triglycerides

- **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!!!

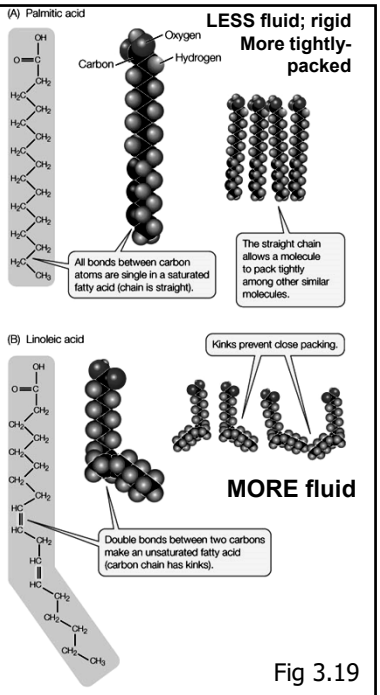

Fig 3.19

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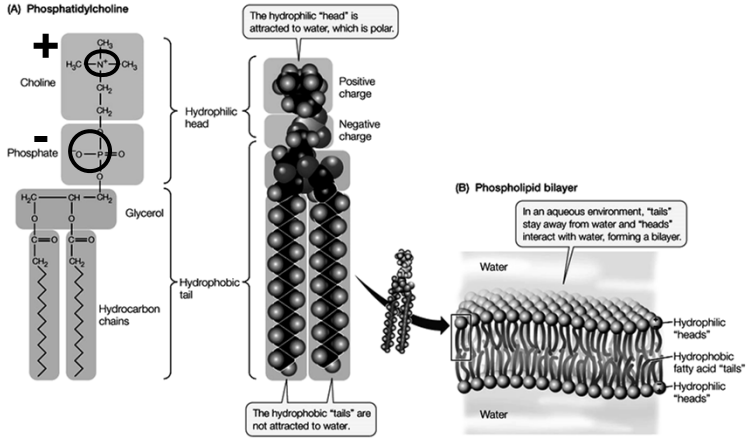
B. Phospholipids

- 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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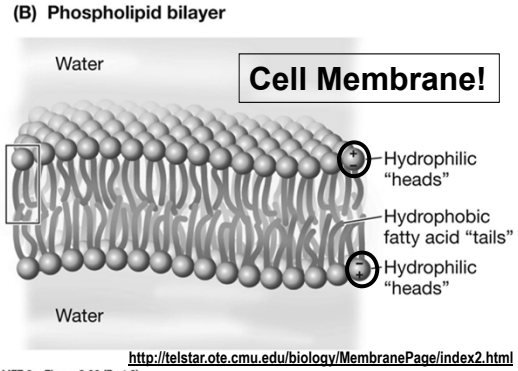
** PhosphoLipid Bilayer

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
   - Free lateral diffusion,
   - but ***"no" Flip-Flop/ transverse diffusion***!



STRX → FXN!!!

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

LIFE 9e, Figure 3.20 (Part 2)

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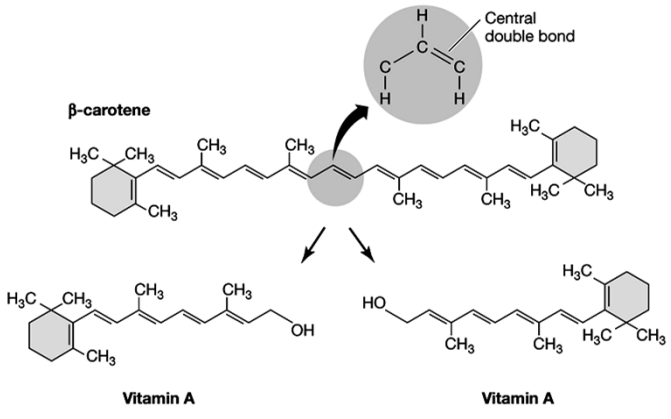
C. Carotenoids

- 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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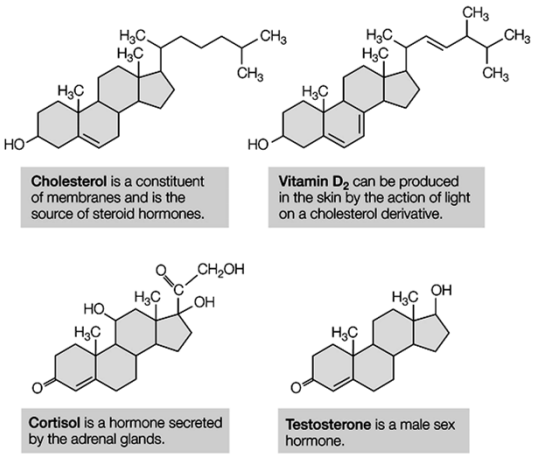
D. Steroids and Cholesterol

- 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 Triglycerides (droplets of fat) and Phospholipids (membranes) are in *high quantities***



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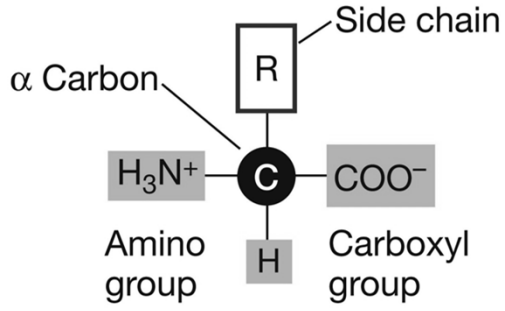
3.4) Proteins: Polymers of Amino Acids

- **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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