جامعة الملك سعود
King Saud University

بسم الله الرحمن الرحيم

King Saud University

College of Science

Department of Biochemistry

General Biochemistry (BCH 202)

Chapter 1:

The composition of the living matter

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Topic	No of Weeks	Lectures
• Introduction • The composition of living matter. • Biomolecules • The elements of biomolecules - shape, - dimensions and - functional groups • Building blocks of biomolecules - amino acids, - nitrogenous bases, - simple sugars and - fatty acids	1	2-4

What is Biochemistry?

- Biochemistry is the chemistry of the living cell.
  - It describes in molecular terms the structures, mechanisms, function and chemical processes shared by all living organisms.
  - It provides fundamental understanding of the molecular basis for the function of living things.
  - It provides a broad understanding of the molecular basis of life.
  - It explains what goes wrong to produce a disease.
- Examples:
  - The chemical structures of biomolecules.
  - Interactions leading to formation of supermacro-molecules , cells, multi-cellular tissues, and organisms.
  - Bioenergetics of the reactions in the cell.
  - Storage and transmission of information.
  - Chemical changes during reproduction, aging, and death of cells.
  - Regulation of chemical reactions inside living cells.

The origin of Life

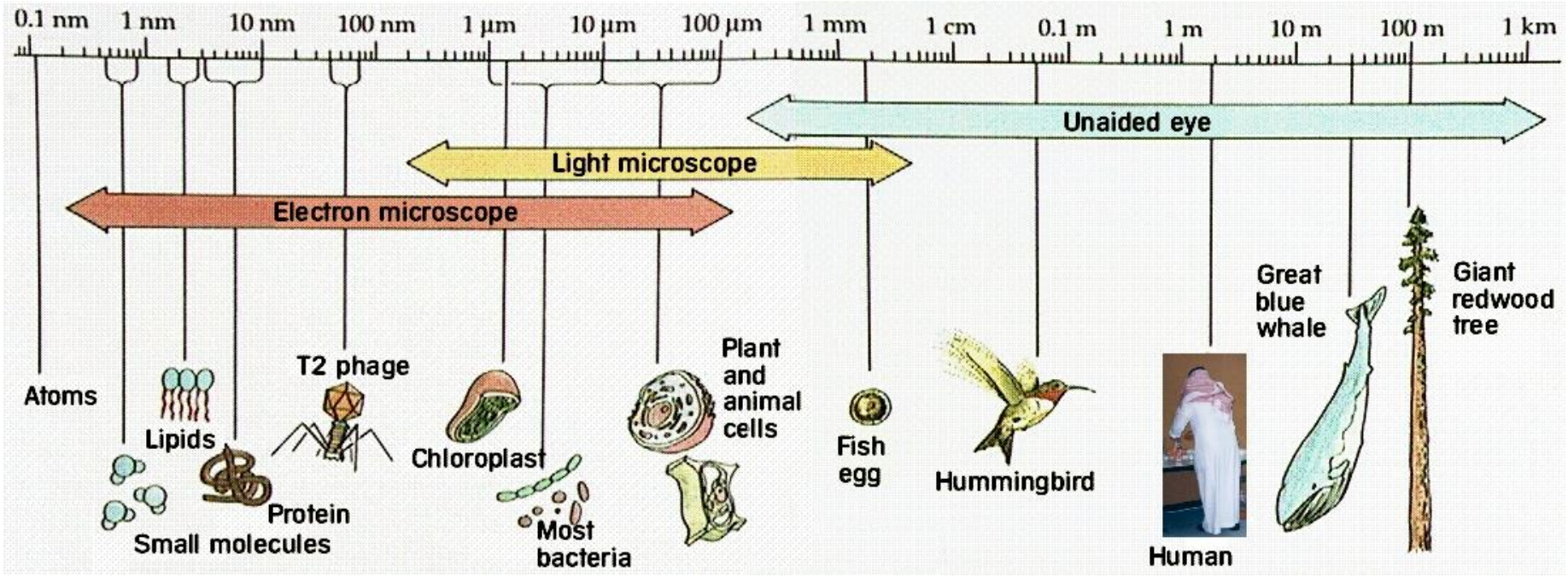
- Living matter consists of some chemical elements.
- Those elements bind together to form molecules.
- Most of compounds in Biological systems are organic compounds (have Carbon)
- Chemical compounds have reactive functional groups that participate in biological structure and biochemical reactions.
- Polymerization of organic molecules form more complex structure by the mean of condensation reaction with the removal of water.
- The key of origin of living matter is the formation of membranes that separate the critical molecules required for replication and energy capture.
- Larger polymers of molecules form macromolecules that all together provide biological specificity of the living matter. E.g. carbohydrates, proteins, genetic material (DNA and RNA) etc.

Biological Hierarchies

- Biological Hierarchy: Simple Molecules are used to Build Complex Structures

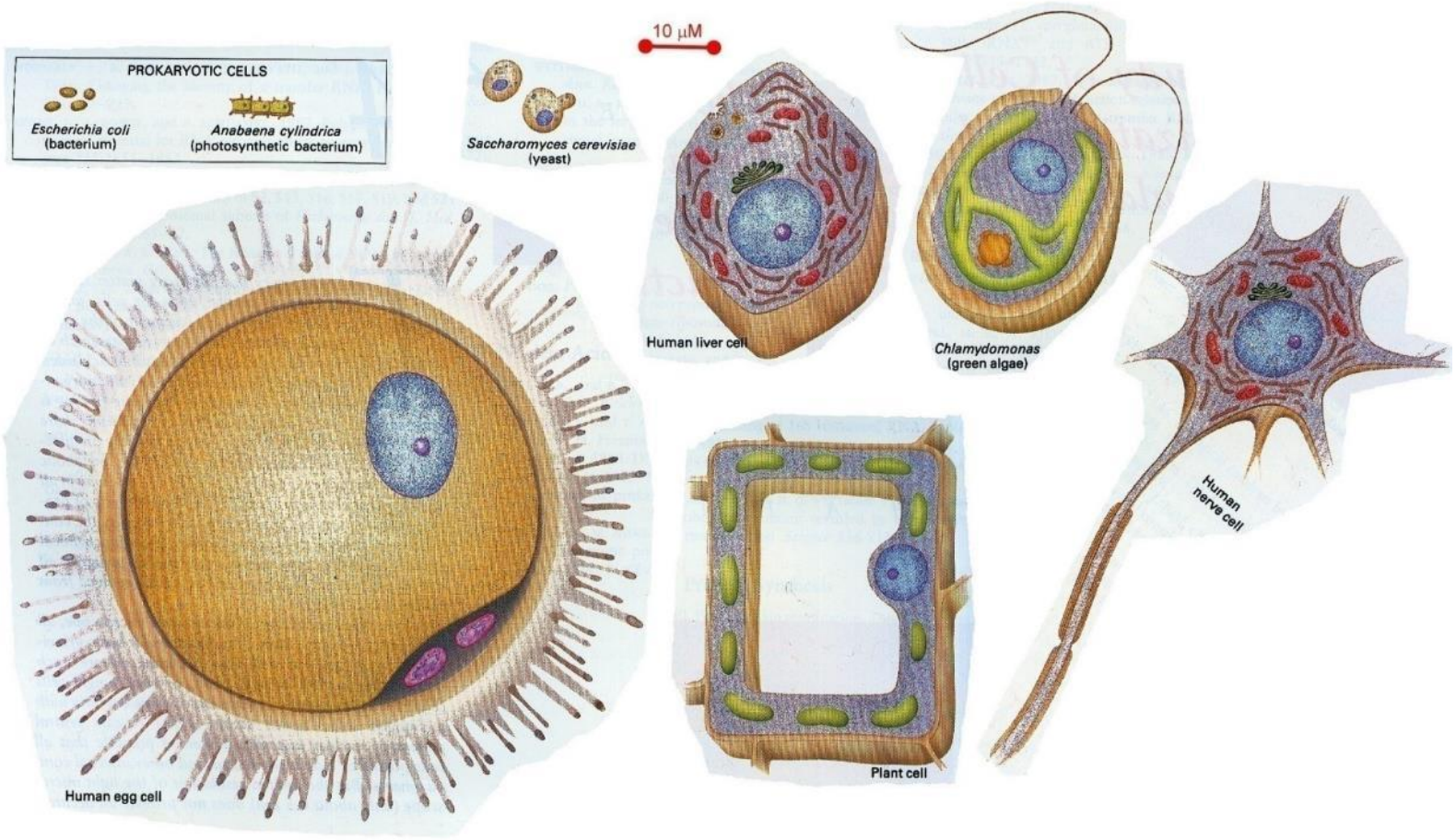
Elements → Molecule → Cell → Tissue → Organ → Organism → Population →Species → Biosphere

- Relative sizes (or ranges) for some biological things, and the resolving power of available tools!
  - Note that the scale is logarithmic.
  - Remember: 1 m = 10 dm = 100 cm = 1000mm = 10^6 μm =10^9 nm = 10^{10} A°



Sizes and Shapes of Cells

Notice: Cells in the figure is represented according to the proportion of its size using the suitable scale.



Prokaryotes

- Prokaryotes; all in one!!
  - It shows a limited range of morphologies but very diverse metabolic capabilities.
- Prokaryotes are single-celled organisms.
  - Do NOT have true nucleus or organelles.
  - Most have circular or "looped" DNA
  - lack much of the internal membranous compartmentalization
  - Mainly unicellular organisms
- Prokaryotes are divided into two major lineage:
  - Archeabacteria (Greek *arche-*, "origin"): most inhabit extreme environments—salt lakes, hot springs, highly acidic bogs, and the ocean depths. It includes:
    - Methanogens (oxygen-free milieus)
    - Halophiles (require high concentrations of salt)
    - Thermophiles (live in hot regions, 80^{o}C, in a pH< 2)
  - Eubacteria (true bacteria): inhabit soils, surface waters, and the tissues of other living or decaying organisms. Most of the well studied bacteria, including *Escherichia coli*, are eubacteria.

Prokaryotic Cells

Prokaryotes have different shapes:

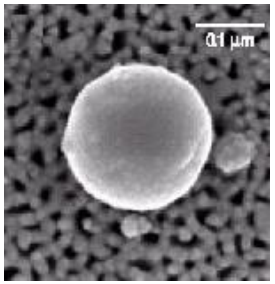
- Rode-like (Bacillus)
- Round (Coccus)
- Thread-like (Spirillum)

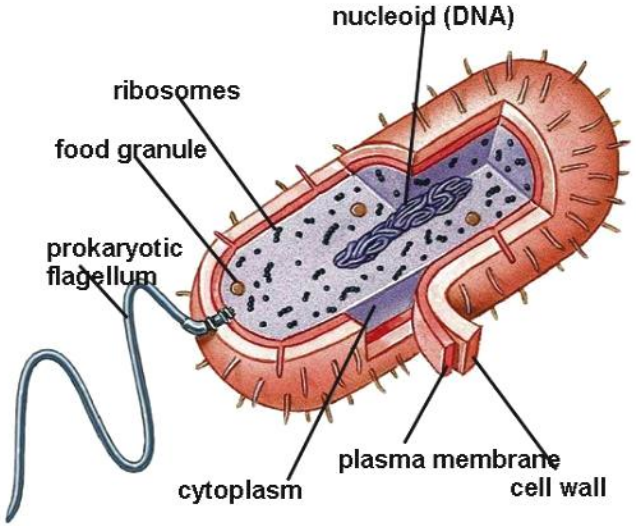
Bacillus-

The typical model of prokaryotes has:

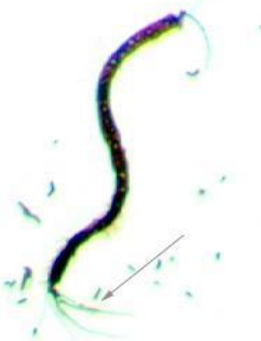
- cell wall (capsule or pili),
- cell membrane,
- nucleoid region, Contains a single, simple, long circular DNA.
- Ribosomes (site of protein synthesis)
- Flagella (for movement)

Coccus-





Spirillum-



Eukaryotic Cells

- Eukaryotes are found in Animal, Plant, Protists, and Fungi kingdoms
  - Few eukaryotes are single-cell but the majority are multicellular organisms
    - So, not all unicellular organisms are eukaryotes because bacteria are unicellular prokaryotic organisms
    - On contrary, all multicellular organisms are eukaryotes

- Eukaryotic cells are complex cells (different sizes, shapes, and structures) and specialized but they all have:
  - Membrane-bound nucleus which contains the cell's genetic material; DNA
  - Eukaryotic DNA is organized in linear structures (chromosomes), associated with proteins (histones)
  - Organelles, each is surrounded by a membrane or two like lysosome, Golgi bodies, endoplasmic reticulum, mitochondria, etc

Generic Animal Cell

- The animal cell is surrounded by lipid bilayer plasma membrane.
- The content inside the plasma membrane is called protoplasm. It contains many organelles and subcellular structures as:
  - **Nucleus:** contain the genetic materials and surrounded by porous nuclear membrane. It contains liquid called neucleoplasm.
  - **Mitochondria:** the site of energy production. It is a double –walled organelle having many enzymes for energy production (The Power House). The inner membrane is highly folded to increase the area of energy production. The number of mitochondria increases as the energy needs increases.
  - **Lysosome:** the site of removal of cell degraded waste substances. It contains many digestive enzymes and it is known as suicide bag as it bursts and its contents release to lyse the cell when the cell die.
  - **Endoplasmic reticulum (ER);** a network of membranes that may carry ribosomes or not. It shares in the synthesis and export of proteins and membrane lipids.
  - **Ribosome:** the site of protein synthesis. It is a group of protein subunits and ribosomal RNA. I does NOT surrounded by any membrane.
  - **Golgi Bodies,** a membranous structure. It packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination.
  - **Centrosome; It presents only in animal cells** and serves as the main microtubule organizing center of the animal cell as well as a regulator of cell-cycle progression.

Organisms, Organs, & Organelle

- Organism is a complete living entity
  - Unicellular organisms such as Bacteria (mostly prokaryotic) and Protists (Eukaryotic).
  - Multicellular organisms such as all animals and most plants. These organisms have different Levels of Cellular Organization, (eukaryotic).

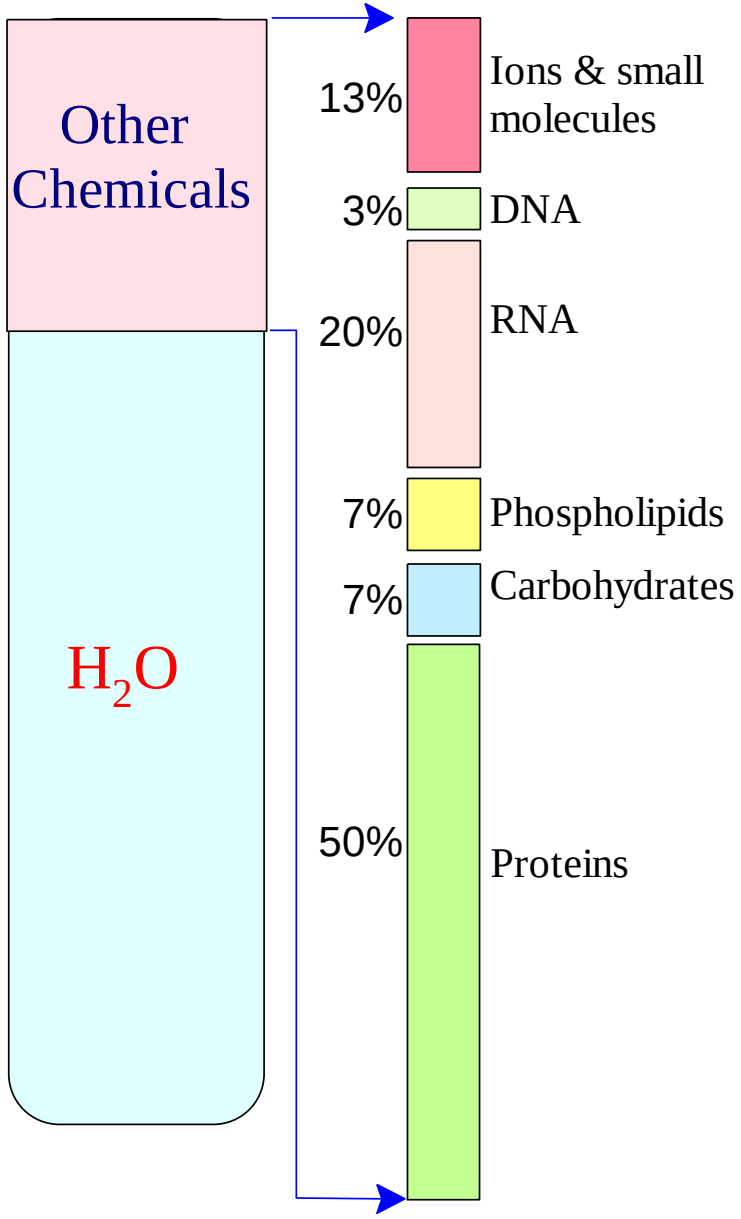
- The Level of Cellular Organization is arranged from lower to higher level as follows:
  1. Cells
  2. Tissues (Epithelia, Connective, Muscle, Nerve Tissue)
  3. Organs (Heart, skin, kidney, etc.)
  4. Organ systems (circulatory, respiratory, digestive, etc)
  5. Organisms (Human, bovine, etc)

Basic Materials in Cell

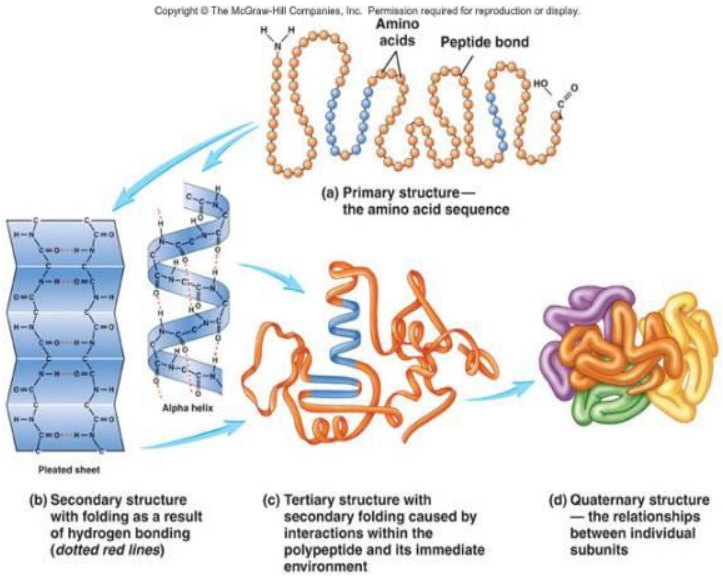
All cells have these basic common materials:

- H_2O: The solvent of life. All cellular reactions are carried out in aqueous environment (about 70% of the cell).
  - All chemical reactions in a cell make up its METABOLISM.
- And 4 Major macromolecules:
  1. Proteins (the cell work horses)
  2. Nucleic Acids (genetic materials)
  3. Carbohydrates (many functions)
  4. Lipids (membrane and energy source and depot)

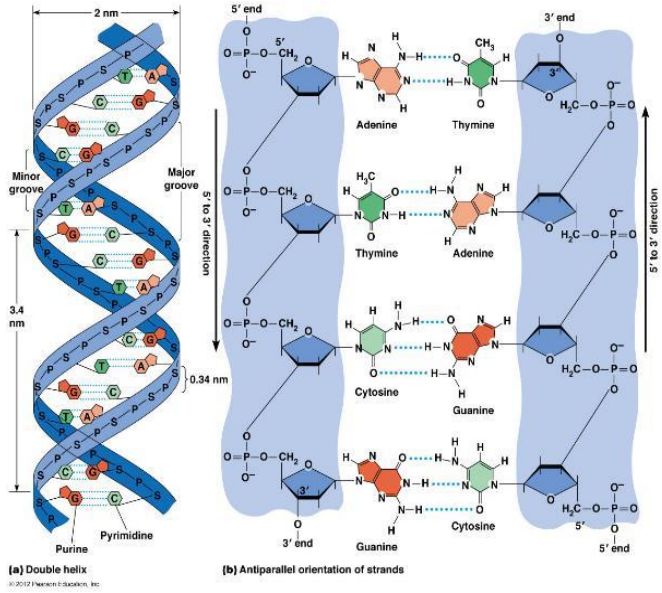
  Notice that all macromolecules are organic compounds (i.e. contain carbon).
- Plus ions & metabolites (small amounts)



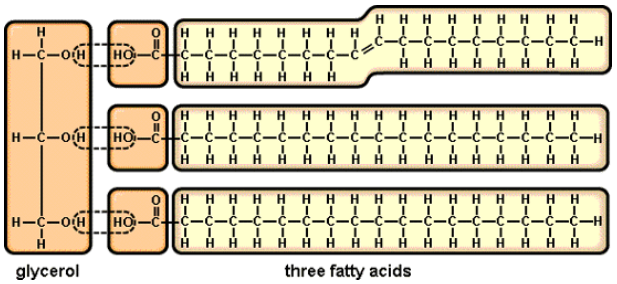
Example of macromolecule having different types of bonds



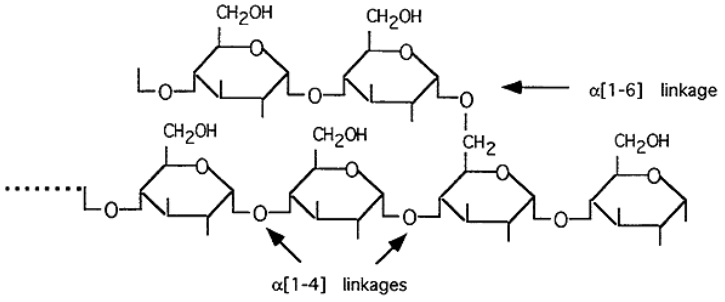
Protein structure



DNA structure



Lipid structure



Carbohydrate structure

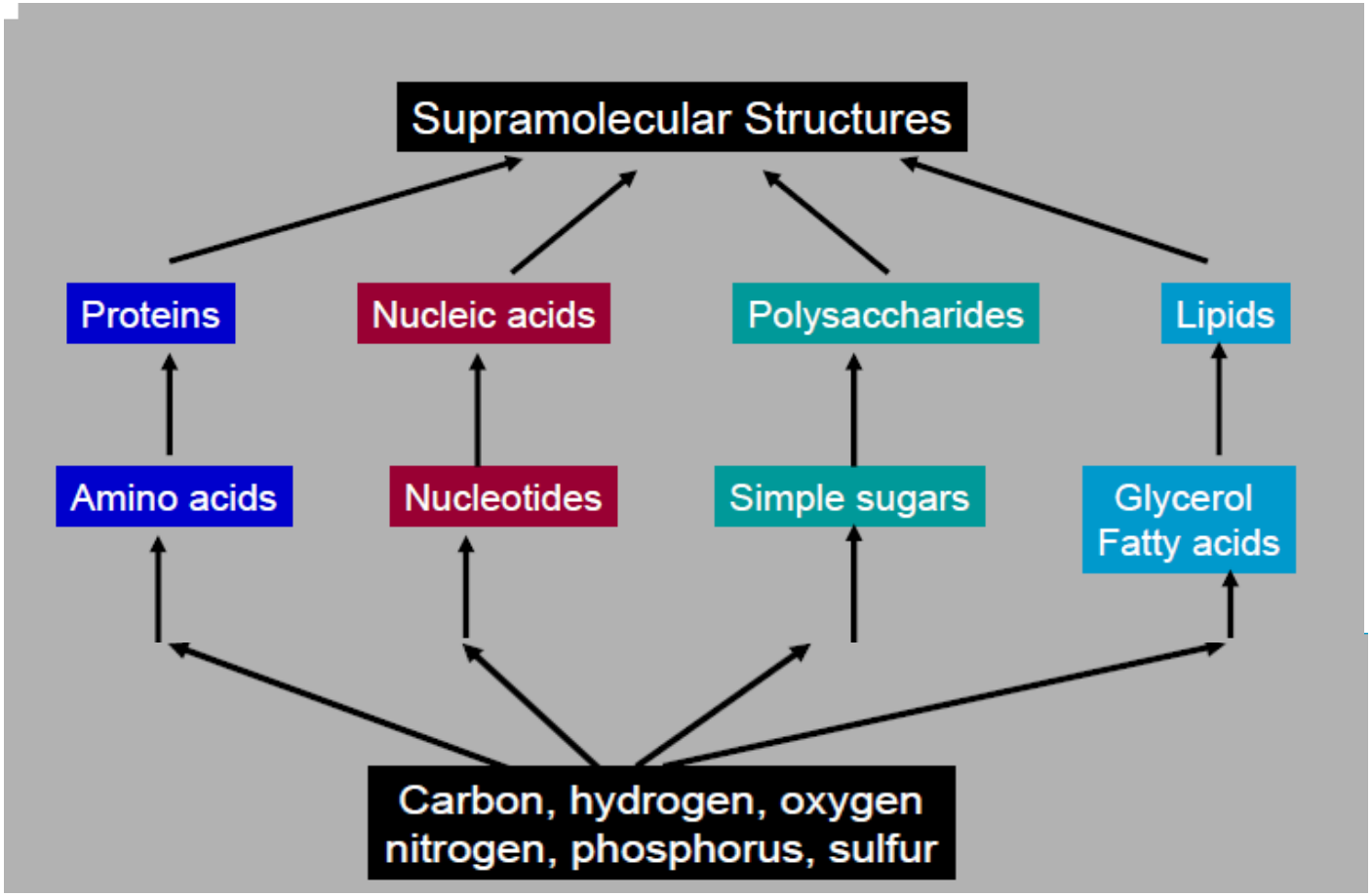
The 4 Major macromolecules

There are 4 major macromolecules in the cell formed by condensation of smaller building blocks (monomers) by the removal of H_2O (dehydration):

Macromolecule	Building blocks (monomers)	Name of bond
Carbohydrate	Monosaccharides	Glycosidic bond
Proteins	Amino acids	Peptide bond
Nucleic acids	Nucleotides	Phospho diester bond
Lipids*	Fatty acids + alcohol	Ester bond

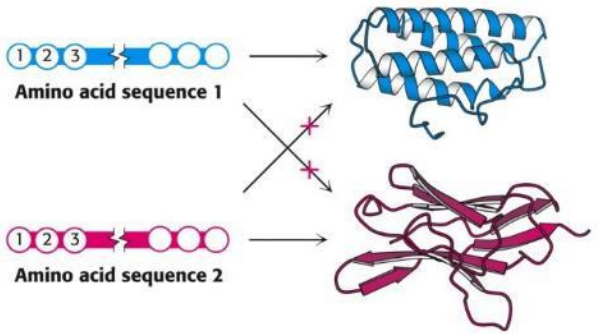
* remember, although F.A. + alcohol are covalently in the building blocks of lipids, the lipids as macromolecules are **NOT** covalently bound polymers

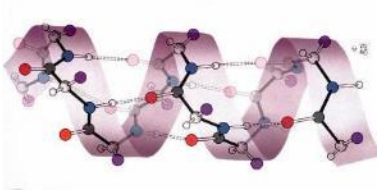
CHNOPS vs monomer vs macromolecules



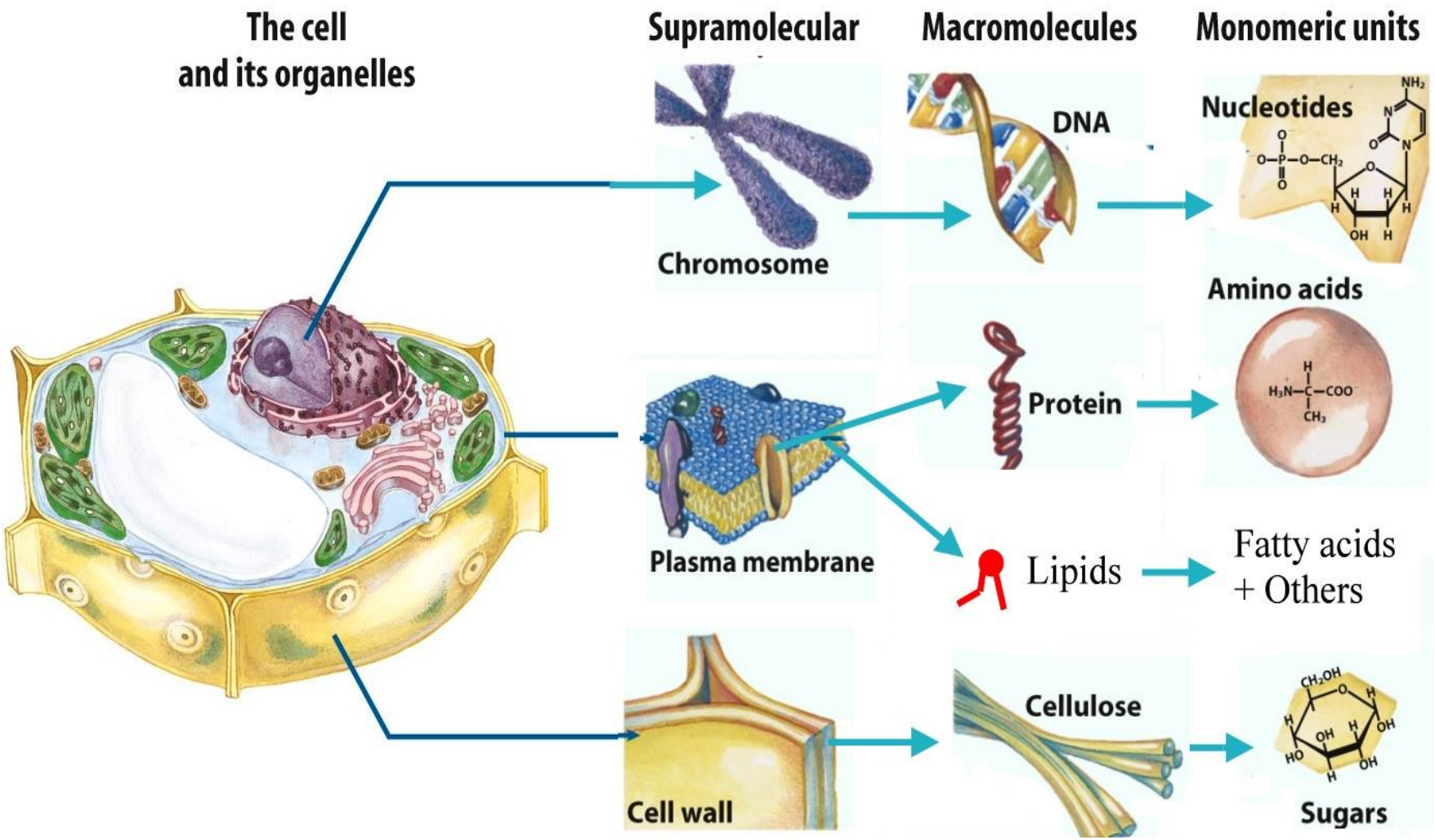
Characteristics of biological molecules

- All macromolecules have a “Sense” or Directionality
  - DNA : -ATC- ≠ -CTA-
  - Protein: -Gly-Ser- ≠ -Ser-Gly-
  - Carbohydrate: -Glu-Gal ≠ -Gal-Glu-
- Macromolecules are Informational:
  - Examples:
    - AUC (codon)=Ile (amino acid);
    - ACU (codon)= Thr (amino acid);
    - UAC (codon)= Tyr (amino acid);
- Macromolecules Have Characteristic Three-Dimensional Architecture
- Weak forces maintain biological structure and determine biomolecular interactions





Structural Levels of Cell Molecules



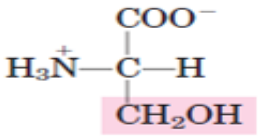
Functional Groups in Biochemistry (Cont.)

Examples from biochemistry

R–OH
Alcohol

—OH
Hydroxyl

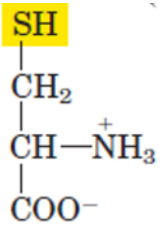
Example:
amino acid
(serine)



R–SH
Thiol

—SH
Sulfahydryl

Example:
amino acid
(cysteine)



Carboxylic acid

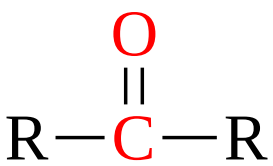
Carboxylate

Example:
All fatty acid
(Palmitic acid)

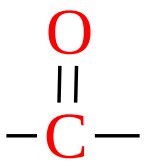
$CH_3(CH_2)_{16}COOH$

Functional Groups in Biochemistry (Cont.)

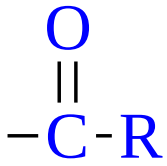
Examples from biochemistry



Ketone

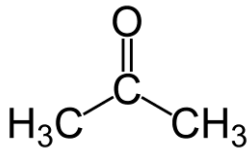


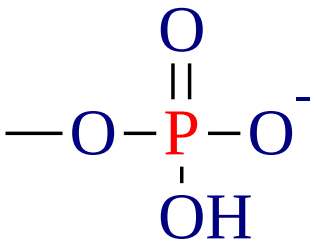
Carbonyl



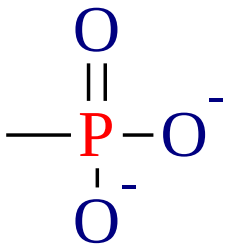
Acyl

Example:
acetone



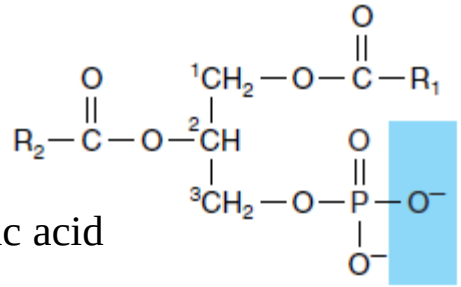


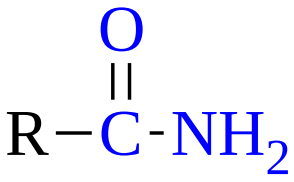
Phosphate



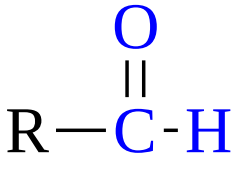
Phosphoryl

Example:
Phosphatetic acid



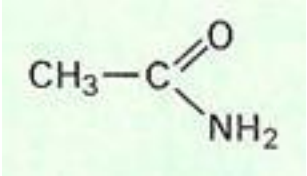


Amide



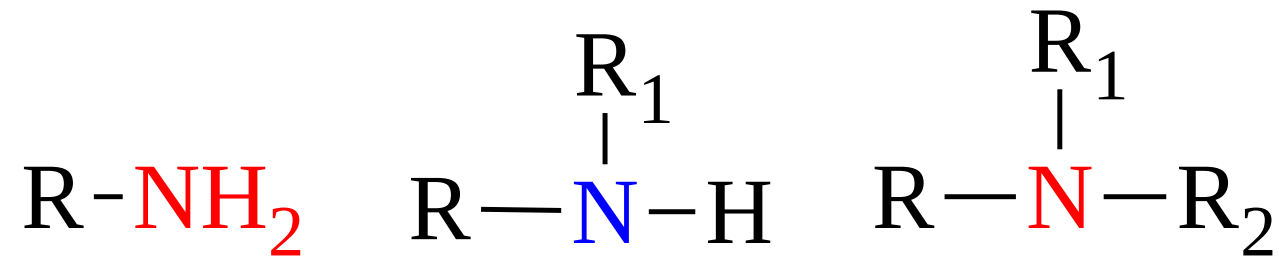
Aldehyde

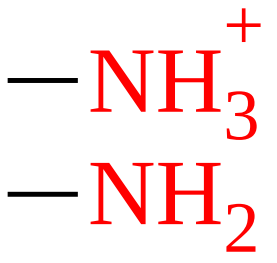
Example:
acetamide



Functional Groups in Biochemistry (Cont.)

Examples from biochemistry





Example:
Urea