Introduction to Biochemistry

Historical perspectives

Biochemistry

1) **Definitions of Biochemistry:The chemistry of life**
   - **"The science concerned with the chemical basis of life".**
   - ***"The science concerned with the study of biomolecules and their chemical reactions that occur in cells of organisms".***
   - **"*Science which deals with the study of chemical nature and chemical behavior of the living matter*".**
   - ***"Science in which biological processes are analyzed in terms of chemistry".***

2) **Historical Perspectives**

1828 **Friedrich Wohler** for the first-time synthesized **urea** from inorganic matter that is ammonia and water. The concept of vitalism (only life can perform the reactions of living material) was then modified.

1877 **Kuhne** introduced the term **"Enzyme**" (in yeast) to ***explain the substances present in the yeast that can convert sugar in to alcohol. Later, Kuhne also discovered the enzyme Trypsin.***

1897 **Eduard Buchner and Hans Buchner** showed conversion of **sugar into alcohol and CO_2** by dead yeast cell extracts. They were awarded Noble Prize in 1907 in chemistry for the discovery

1894 **Emil Fischer** suggested the **key/lock theory to explain the mechanism** of enzyme action

1903 **Carl Alexander Neuberg (German) introduced the term *"Biochemistry" meaning chemistry of life***

1928 **J B Sumner** succeeded in crystallization of **enzyme Urease** for the first time and discovered the proteinaceous **nature of Enzyme.**

1930 **John Howard Northrop and Wendell Meredith Stanley** purified digestive enzymes **pepsin, trypsin and chymotrypsin. They shared Noble Prize with J B Sumner in 1946 in Chemistry for their discoveries.**

1937 **Hans Krebs** discovered the **Citric Acid Cycle and** won the Nobel Prize in Physiology or Medicine in 1953

1944 **Oswald Avery, Colin MacLeod and Maclyn McCarty** proved **DNA as the genetic material in bacterial cells**

1952 **Rosalind Franklin and Maurice Wilkins obtained first X-ray crystallographic pictures of DNA and hinted the double stranded nature of DNA**

1953 **James D Watson & Francis C Crick** proposed **"DNA Double Helix**" model to explain DNA structure. They along with Maurice Wilkins won the Nobel Prize in Physiology or Medicine in 1962 for their discoveries.

1955 **F. Sanger** invented protein sequencing technique and determine the amino acid sequence of insulin sequence for the first time. Sanger won the Nobel Prize in Physiology or Medicine in 1956

1977 **F. Sanger & M. Gilbert** invented independently the enzymatic DNA sequencing and chemical DNA sequencing methods and won the Nobel Prize in Chemistry in 1980

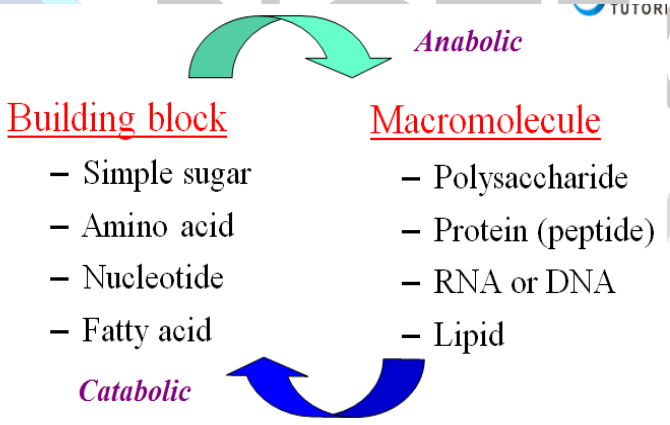
1987 **Kary B. Mullis** invented PCR method for *in vitro* amplification of DNA and won the Nobel Prize in Chemistry in 1993

3) Biochemistry studies include:

- ***Structure and function of cellular components (proteins, carbohydrates, lipids, nucleic acids and other biomolecules)***
- ***Metabolism and Regulation of cellular components***
- ***Energy changes associated with metabolic transformations***
- ***Gene expression and modulation***

4) Polymers and Monomers

1) Protein, carbohydrates and nucleic acid are polymers (macromolecules) that are assembled from single units called monomers (building blocks).
2) Each type of macromolecule is an assemblage of a different types of molecules



5) Principles of Biochemistry

1) Cells (basic structural units of living organisms) are highly organized and ordered structure and constant source of energy is required to maintain the ordered state.
2) All organisms use the same type of molecules: carbohydrates, proteins, lipids & nucleic acids for their living.
3) Living processes contain hundreds of **chemical pathways.** Precise regulation and integration of these pathways are required to maintain life.
4) Instructions for growth, reproduction and developments for each organism is encoded in their DNA

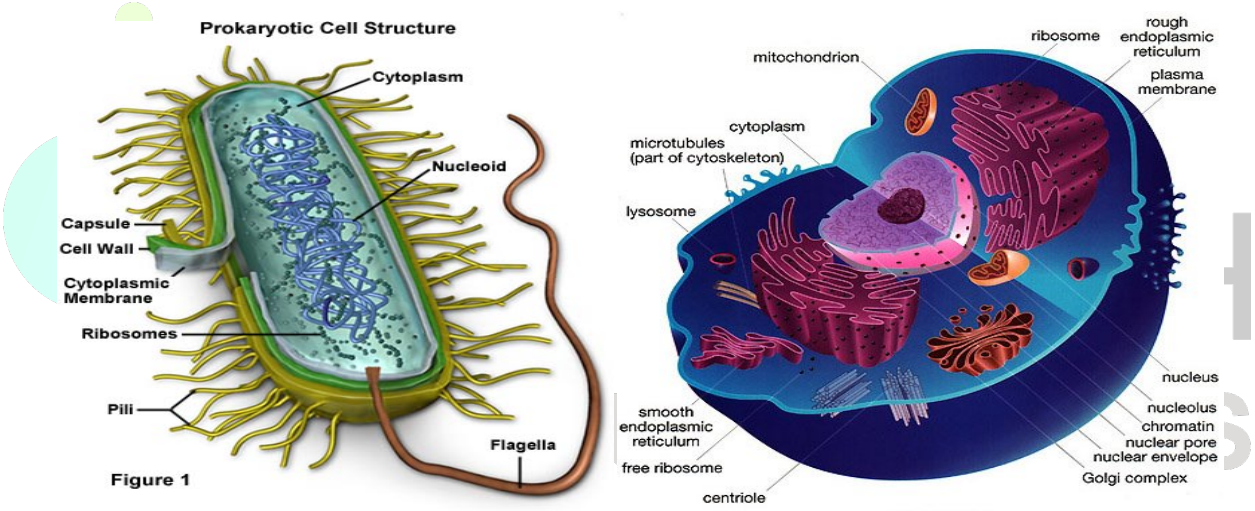
6) Cells

1) Basic building blocks of life
2) Smallest living unit of an organism
3) An organism may be consisting of single cell (unicellular) or it may be consisted of billions of cells (multicellular).
4) Cells grow, reproduce, use energy, adapt, respond to their environment
5) Majority of the cells cannot be seen with the naked eye. A typical cell size is 10 µm; a typical cell mass is 1 nanogram.

7) Cells May be Prokaryotic or Eukaryotic

1) Prokaryotes (Greek: pro-before; karyon-nucleus) include various bacteria which lack a nucleus or membrane-bound structures called organelles

2) Eukaryotes (Greek: eu-true; karyon-nucleus) include most other cells (plants, fungi, & animals)have a nucleus and membrane-bound organelles



8) Characteristic of Subcellular structures

1) Plasma Membrane-Cell's defining boundary

Providing a barrier and containing transport and signaling systems.

2) Nucleus– Cell's information center

Double membrane surrounding the chromosomes and the nucleolus. The place where DNA replication and RNA synthesis occur. The nucleolus is a site for synthesis of RNA making up the ribosome

3) Mitochondria- the power generators

Mitochondria (Greek: mitos-thread; chondros-granule): Surrounded by a double membrane with a series of folds called cristae. Function in energy production. Contain own DNA.

4) ***Rough endoplasmic reticulum (RER)-stacked membrane fold with ribosomes***

Covered with ribosomes (causing the "rough" appearance) which are in the process of synthesizing proteins for secretion or localization in membrane, Golgi or lysosome

5) ***Ribosome-nucleoprotein complex***
Molecular assembly responsible for protein synthesis

6) ***Smooth endoplasmic reticulum (SER) -stacked membrane fold***
A site for synthesis and metabolism of lipids

7) Golgi apparatus -process and package the macromolecules.
A series of stacked membranes. Vesicles carry materials from the Rough Endoplasmic Reticulum to the Golgi apparatus. Vesicles move between the stacks while the proteins are "processed" to a mature form.

8) Lysosomes-contain digestive enzyme
A membrane bound organelle that is responsible for degrading proteins and membranes in the cell.

9) Cytoplasm
Enclosed by the plasma membrane, liquid portion called cytosol and it houses the membranous organelles.

9) Cell Composition

1) Cells are building blocks of tissues; biomolecules are building blocks of cells.
2) Animal and plant cells contain approximately 10,000 kinds of biomolecules.
3) Water constitutes 50-95% of cells content by weight.
4) Ions like Na^+, K^+ and Ca^{2+} may account for another 1%.
5) Almost all other kinds of biomolecules are organic (C, H, N, O, P, S).
6) Organic compounds are compounds composed primarily of a Carbon skeleton.

Chemical composition of a normal man (weight 65 kg)

Constituent	Percent (%)	Weight (kg)
Water	**61.6**	**40**
Protein	**17.0**	**11**
Lipid	**13.8**	**9**
Carbohydrate	**1.5**	**1**
Minerals	**6.1**	**4**

10) Types of biomolecules

1) Small molecules
- **a) Lipid, phospholipid, glycolipid, sterol,**
- **b) Vitamin**
- **c) Hormone, neurotransmitter**

2) Monomers
- **a) Amino acids**
- **b) Nucleotides**
- **c) Monosaccharides**

d) Fatty acid

3) Polymers
   a) Peptides, oligopeptides, polypeptides, proteins
   b) Nucleic acids, i.e., DNA, RNA
   c) Oligosaccharides, polysaccharides (including cellulose)

Biomolecules

Biomolecules	Building blocks	Major Function	Examples
Carbohydrates			
Monosaccharides		Energy	Glucose,Fructose, galactose
Disaccharides	Monosaccharides	Energy storage	Lactose, maltose, sucrose
Polysaccharides	Monosaccharides	Energy storage, physical structure	Starch, cellulose, chitin, inulin, pectin, glycogen
Proteins	Amino acids	Enzyme, toxins, hormones and physical structures	Antibodies, viral surface, flagella and pili
Lipids			
Triglycerides	Fatty acid, glycerol	Energy	Fat and Oils
Phospholipids	Fatty acid, glycerol, Phosphate group R group (choline, ethanolamine, serine, inositol etc)	Constituent of cell and organelle membrane	Plasma membrane
Steroids	cholesterol	Membrane stability, hormones	Cholesterol, sex and adrenal hormones
Nucleic acids			
RNA	Ribonucleotides (NTP)	Gene expression and regulation	rRNA, mRNA, tRNA etc
DNA	Deoxyribonucleotide (dNTPs)	Storage of gene expression	Chromosome

11) Structural hierarchy in the molecular organization of cells

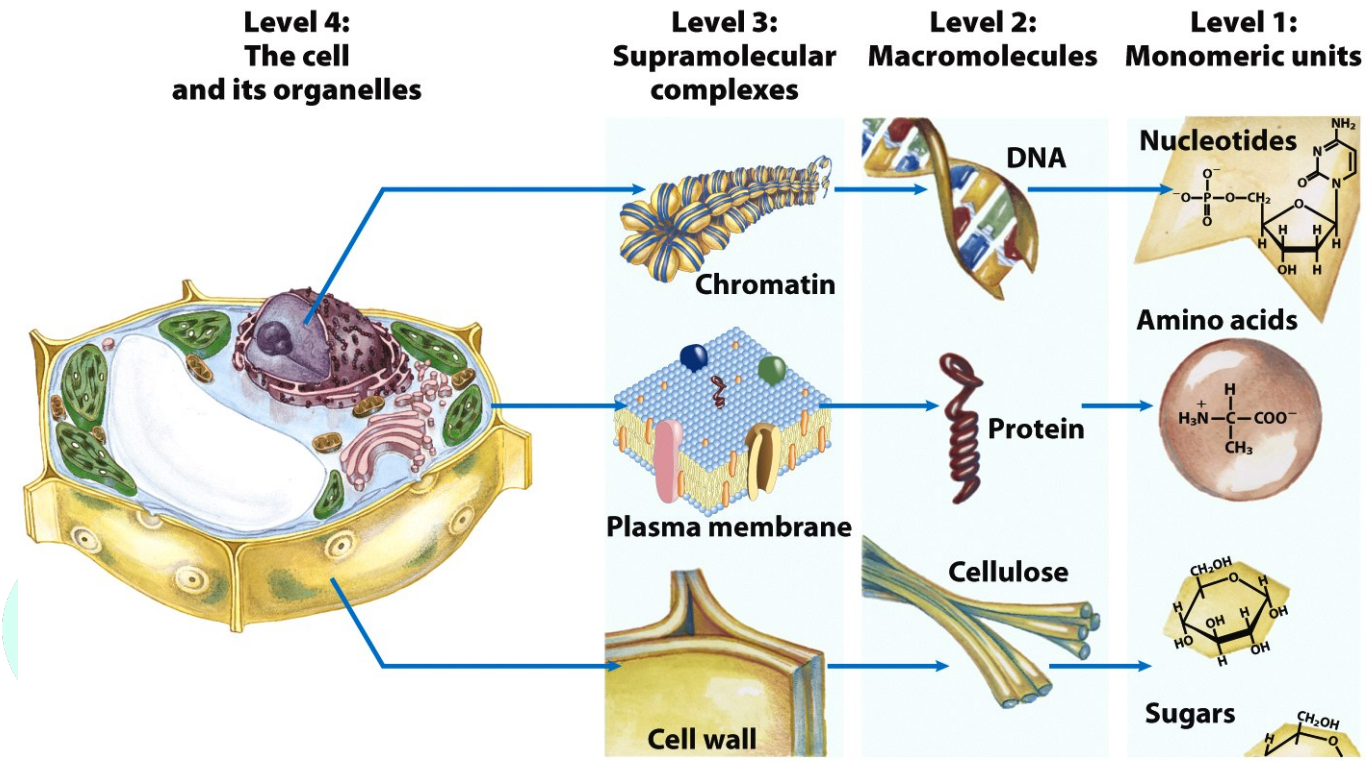


Figure 1-11
Lehninger Principles of Biochemistry, Fifth Edition

The nucleus of this plant cell is an organelle containing several types of supramolecular complexes, including chromatin. Chromatin consists of two types of macromolecules, DNA and many different proteins, each made up of simple subunits.

12) Similarities among all types of cells

1) All cells use DNA to store information
2) Except RNA viruses, but they do not possess cellular organizations (incapable of autonomous replication)
3) All cells use RNA (mRNA, rRNA and tRNA) to access stored information
4) All cells use proteins as catalysts (enzymes) for chemical reactions
5) A few examples of RNA based enzymes, which may reflect primordial use of RNA
6) All cells use lipids for membrane components
7) Different types of lipids in different types of cells
8) All cells use carbohydrates for cell walls (if present), recognition, and energy generation

13) References

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6) **Jain and Jain Principles of Biochemistry 6th Edition, S. Chand and Company Ltd, New Delhi, India**
7) **Wikipedia for various information**