Chapter 1. Introduction

- History
- What is biochemistry
- Biochemistry and life
- Biochemical Energy
- Transfer of Information from DNA to Protein
History

- Life: 150 years ago
- Biochemistry: 60 years ago
What is Biochemistry?
Definition

- The science that is concerned with the **structures**, **interactions**, and **transformations** of biological molecules
- The chemistry of life
Biochemistry can be subdivided into three principal areas:

- Structural chemistry
- Metabolism
- The chemistry of processes and substances that store and transmit biological information (molecular genetics)
Biochemistry and Life

- The cell is the fundamental unit of life
- Prokaryotes and eukaryotes
- Eukaryotic cells
  - animal cells
  - plant cells (chloroplasts and cell walls)
Biochemistry and Life

- Cells are composed of:
  - Small molecules
  - Macromolecules
  - organelles
### The Approximate Chemical Composition of Bacterial Cell

<table>
<thead>
<tr>
<th>Molecular Category</th>
<th>Percent of Total Cell Weight</th>
<th>Number of Types of Each Molecules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>70</td>
<td>1</td>
</tr>
<tr>
<td>Inorganic ions</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Sugars and precursors</td>
<td>3</td>
<td>200</td>
</tr>
<tr>
<td>Amino acids and precursors</td>
<td>0.4</td>
<td>100</td>
</tr>
<tr>
<td>Nucleotides and precursors</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Lipids and precursors</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Other small molecules</td>
<td>0.2</td>
<td>~200</td>
</tr>
<tr>
<td>Macromolecules</td>
<td>22</td>
<td>~5000</td>
</tr>
</tbody>
</table>
Bioenergetics

Structure of biomolecules

Biochemistry—describing the chemistry of the living cell

Function of biomolecules
Biochemistry and Life

- Expect for water, most of the molecules found in the cell are macromolecules, can be classified into four different categories:
  - Lipids
  - Carbohydrates
  - Proteins
  - Nucleic acids
(a) Starch

(b) Cellulose

(c) Protein

(d) Nucleic acid
Biochemistry and Life

- **Lipids** are primarily hydrocarbon structures.
- **Carbohydrates**, like lipids, contain a carbon backbone, but they also contain many polar hydroxyl (-OH) groups and therefore very soluble in water.
- **Proteins** are the most complex macromolecules in the cell. They are composed of linear polymers called polypeptides, which contain amino acids connected by peptide bonds.
Lipid Structure
Carbohydrates Structure

(a) Two common monosaccharides that circularize in aqueous solution

(b) Polysaccharides composed of covalently linked monosaccharides
Biochemistry and Life

- Each **amino acid** contains a central carbon atom attached to four substituents:
  - A carboxyl group
  - An amino group
  - A hydrogen atom
  - An R group

- **Nucleic acids** are the large macromolecules in the cells. They are very long linear polymers, called polynucleotides, composed of nucleotides.
Amino Acids Structures

(a) Generalized structure of amino acid

(b) Different types of side chains (R groups)

(c) Two amino acids reacting to form a peptide bond

(d) Many amino acids reacting to form a polypeptide chain
Biochemistry and Life

- A nucleotide contains:
  - A five-carbon sugar molecules
  - One or more phosphate groups
  - A nitrogenous base

- DNA: A, T, G, C
- RNA: A, U, G, C
DNA Contain Four Bases

- Adenine (A)
- Cytosine (C)
- Guanine (G)
- Thymine (T)

RNA:
- Ribose
- Uracil (U)
Covalent Structure of DNA
Watson-Crick base pairs

[Diagram showing the pairing of Adenine (A) and Thymine (T)]
Watson-Crick base pairs

Guanine (G)      Cytosine (C)
The Double Helix
Biochemical Energy

- All cellular functions require energy.
- The most-important chemical form of energy in most cells is ATP, adenosine 5’-triphosphate.
- ATP \( \rightleftharpoons \) ADP + P_i
- Most ATP synthesis occurs in chloroplasts and mitochondria.
ADT and ATP Structures
Energy Transfer
Transfer of Information from DNA to Protein
1.4 Organelles, Cells, and Organisms

- Virus (病毒)
- Prokaryotic cells (原核細胞)
- Eukaryotic cells (真核細胞)
Virus

- Glycoprotein
- Phospholipid envelope
- RNA
- Capsid

(a) Influenza virus (globular)
Capsomere

(b) Adenovirus (polyhedral)
(c) Tobacco mosaic virus (cylindrical)
(d) Bacteriophage (complex shape)
Prokaryotic cells (原核細胞)

- Cell membrane
- Ribosomes
- Cell wall
- Nucleoid
- Flagella
- Pili
- Mesosome

1 μm
Prokaryotic cells (原核細胞)

- Table 1.1
E. coli

- **a**: cytoplasm
- **b**: cell wall
- **c**: nucleotide

1 μm
# Eukaryotic cells

<table>
<thead>
<tr>
<th>Structural Feature</th>
<th>Molecular Composition</th>
<th>Biological Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell membrane</td>
<td>Bilayer of proteins (50%) and lipids (50%) and some carbohydrate</td>
<td>Selectively permeable boundary for entry and exit of nutrients and waste; some important enzyme activities; location of receptors for signaling</td>
</tr>
<tr>
<td>Nucleus</td>
<td>Contains genomic DNA, and histone proteins as chromatin; RNA</td>
<td>Storage of genetic information; site of DNA replication and transcription to RNA</td>
</tr>
<tr>
<td>Endoplasmic reticulum with</td>
<td>Flat, single-membraned vesicles of lipid and protein; ribosomes consist of RNA and</td>
<td>Surfaces on which ribosomes bind for protein synthesis</td>
</tr>
<tr>
<td>ribosomes</td>
<td>proteins</td>
<td></td>
</tr>
<tr>
<td>Golgi apparatus</td>
<td>Flattened vesicles of lipid, protein, and polysaccharide</td>
<td>Secretion of cell waste products; site of protein processing</td>
</tr>
<tr>
<td>Mitochondria</td>
<td>Double-membraned with protein and lipids; interior (matrix) contains soluble and</td>
<td>Site of energy metabolism and synthesis of high-energy ATP</td>
</tr>
<tr>
<td></td>
<td>insoluble enzymes, RNA, and DNA</td>
<td></td>
</tr>
<tr>
<td>Lysosomes (animal)</td>
<td>Single-membraned vesicles containing enzymes for hydrolysis</td>
<td>Metabolism of materials ingested by endocytosis</td>
</tr>
<tr>
<td>Peroxisomes (animal) or</td>
<td>Single-membraned vesicles containing catalase and other oxidase enzymes</td>
<td>Oxidative metabolism of nutrients using O₂ to generate H₂O₂</td>
</tr>
<tr>
<td>glyoxyosomes (plant)</td>
<td></td>
<td>Sites of photosynthesis. Convert light energy into chemical energy (ATP)</td>
</tr>
<tr>
<td>Chloroplasts (plant)</td>
<td>Double-membraned organelles containing protein, lipid, chlorophyll, RNA, DNA, and</td>
<td>Provides shape to cell; region where many metabolic reactions occur</td>
</tr>
<tr>
<td></td>
<td>ribosomes</td>
<td></td>
</tr>
<tr>
<td>Cytoplasm</td>
<td>Cytoskeleton made of proteins; small molecules, soluble proteins, enzymes, nutrients,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>salts in aqueous solution</td>
<td></td>
</tr>
</tbody>
</table>
key:

- Ribosome
- Proteins
- mRNA
- tRNA
- DNA
- Lipopolysaccharide
- Phospholipid
- Lipoprotein
- Peptidoglycan
Typical eukaryotic cells
An animal cell

Golgi complex (Go)
Nucleus (N)
Mitochondrion (M)
Nuclear envelope (NE)
Plasma membrane (PM)
Smooth endoplasmic reticulum (ER)
Ribosomes (R)
Pore complex (PC)
Nucleolus (N)
Rough endoplasmic reticulum (ER)
Vesicle (V)

1 μm
Typical eukaryotic cells
Animal cell
A Plant cell
A Plant cell
Cell homogenate → Nuclei, cell debris → Mitochondria, peroxisomes, lysosomes → Microsomes → Cytosol