Catalysis by Enzymes

- **Enzyme** A protein that acts as a catalyst for a biochemical reaction.
Enzymatic Reaction

1. The substrate, sucrose, consists of glucose and fructose bonded together.

2. The substrate binds to the enzyme, forming an enzyme-substrate complex.

3. The binding of the substrate and enzyme places stress on the glucose-fructose bond, and the bond breaks.

4. Products are released, and the enzyme is free to bind other substrates.
Specificity
The specificity of an enzyme for one of two enantiomers is a matter of fit. One enantiomer fits better into the active site of the enzyme than the other enantiomer. Enzyme catalyzes reaction of the enantiomer that fits better into the active site of the enzyme.
Enzyme Cofactors

- Many enzymes are conjugated proteins that require nonprotein portions known as cofactors.
- Some cofactors are metal ions, others are nonprotein organic molecules called coenzymes.
- An enzyme may require a metal-ion, a coenzyme, or both to function.
Cofactor

 apoenzyme (protein portion) + cofactor (nonprotein portion) → haloenzyme (whole enzyme)

[Chemical structure of heme shown]

[3D structure of a protein with heme bound]
• Cofactors provide additional chemically active functional groups which are not present in the side chains of amino acids that made up the enzyme.

• **Metal ions** may anchor a substrate in the active site or may participate in the catalyzed reaction.
How Enzyme Work

• Two modes are invoked to represent the interaction between substrate and enzymes. These are:
  • *Lock-and-key model*: The substrate is described as fitting into the active site as a key fits into a lock.
  • *Induced-fit-model*: The enzyme has a flexible active site that changes shape to accommodate the substrate and facilitate the reaction.
19.5 Effect of Concentration on Enzyme Activity

• Variation in concentration of enzyme or substrate alters the rate of enzyme catalyzed reactions.

• Substrate concentration: At low substrate concentration, the reaction rate is directly proportional to the substrate concentration. With increasing substrate concentration, the rate drops off as more of the active sites are occupied.
Fig 19.5 Change of reaction rate with substrate concentration when enzyme concentration is constant.
• *Enzyme concentration:* The reaction rate varies directly with the enzyme concentration as long as the substrate concentration does not become a limitation, Fig 19.6 below.
19.6 Effect of Temperature and pH on Enzyme Activity

- Enzymes maximum catalytic activity is highly dependent on temperature and pH.
- Increase in temperature increases the rate of enzyme catalyzed reactions. The rates reach a maximum and then begins to decrease. The decrease in rate at higher temperature is due to denaturation of enzymes.
Fig 19.7 (a) Effect of temperature on reaction rate
• Effect of pH on Enzyme activity: The catalytic activity of enzymes depends on pH and usually has a well defined optimum point for maximum catalytic activity Fig 19.7 (b) below.
19.7 Enzyme Regulation: Feedback and Allosteric Control

• Concentration of thousands of different chemicals vary continuously in living organisms which requires regulation of enzyme activity.
• Any process that starts or increase the activity of an enzyme is activation.
• Any process that stops or slows the activity of an enzyme is inhibition.
Two of the mechanism

- **Feedback control**: Regulation of an enzyme’s activity by the product of a reaction later in a pathway.
- **Allosteric control**: Activity of an enzyme is controlled by the binding of an activator or inhibitor at a location other than the active site. Allosteric controls are further classified as positive or negative.
  - A **positive regulator** changes the activity site so that the enzyme becomes a better catalyst and rate accelerates.
  - A **negative regulator** changes the activity site so that the enzyme becomes less effective catalyst and rate slows down.
A positive regulator changes the activity site so that the enzyme becomes a better catalyst and rate accelerates.

A negative regulator changes the activity site so that the enzyme becomes less effective catalyst and rate slows down.
19.8 Enzyme Regulation: Inhibition

- The inhibition of an enzyme can be *reversible* or *irreversible*.
- In *reversible inhibition*, the inhibitor can leave, restoring the enzyme to its uninhibited level of activity.
- In *irreversible inhibition*, the inhibitor remains permanently bound to the enzyme and the enzyme is permanently inhibited.
• Inhibitions are further classified as:
• *Competitive inhibition if* the inhibitor binds to the active site.
• **Noncompetitive inhibition**, if the inhibitor binds elsewhere and not to the active site.

*Noncompetitive inhibition*
The rates of enzyme catalyzed reactions with or without a competitive inhibitor are shown in the Fig 19.9 below.
(a) Antigenic determinant sites

(b) Antigenic determinant sites

Antigen

Antibodies

Antibody
An Introduction to Carbohydrates

- **Carbohydrates** are a large class of naturally occurring polyhydroxy aldehydes and ketones.
- Monosaccharides also known as simple sugars, are the simplest carbohydrates containing 3-7 carbon atoms.
- Sugar containing an aldehydes is known as an aldose.
- Sugar containing a ketones is known as a ketose.
• The number of carbon atoms in an aldose or ketose may be specified as by tri, tetr, pent, hex, or hept. For example, glucose is aldobexose and fructose is ketohexose.

• Monosaccharides react with each other to form disaccharides and polysaccharides.

• Monosaccharides are chiral molecules and exist mainly in cyclic forms rather than the straight chain.
D-Glyceraldehyde
Right-handed

L-Glyceraldehyde
Left-handed
• **Anomers:** Cyclic sugars that differs only in positions of substituents at the hemiacetal carbon; the \( \alpha \)-form has the \(-\text{OH}\) group on the opposite side from the \(-\text{CH}_2\text{OH}\); the \( \beta \)-form the \(-\text{OH}\) group on the same side as the \(-\text{CH}_2\text{OH}\) group.
Some Important Monosaccharides

Monosaccharides are generally high-melting, white, crystalline solids that are soluble in water and insoluble in nonpolar solvents. Most monosaccharides are sweet tasting, digestible, and nontoxic.

D-glucose
Some Common Disaccharides

Sucrose

Fructose

Galactose

Glucose

Lactose

Glucose

Maltose

Glucose

Isomaltose

Glucose

Cellobiose

Glucose
Polysaccharides

Non-reducing end

Reducing end

Sometimes shown as

GLYCOGEN

Cellulose
Cell-Surface Carbohydrates Involved in Molecular Recognition

- Virus
- Bacterium
- Toxin
- Lectin
- Glycoprotein
- Glycolipid
- Hormone
- Enzyme
- Antibody
- Cancer Cell
Lectins are sugar-binding proteins which are highly specific for their sugar moieties. They typically play a role in biological recognition phenomena involving cells and proteins. For example, some bacteria use lectins to attach themselves to the cells of the host organism during infection.
# Blood Type

<table>
<thead>
<tr>
<th>Red blood cell type</th>
<th>Group A</th>
<th>Group B</th>
<th>Group AB</th>
<th>Group O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antibodies present</td>
<td>Anti-B</td>
<td>Anti-A</td>
<td>None</td>
<td>Anti-A and Anti-B</td>
</tr>
<tr>
<td>Antigens present</td>
<td>A antigen</td>
<td>B antigen</td>
<td>A and B antigens</td>
<td>No antigens</td>
</tr>
</tbody>
</table>

Legend:
- Red blood cell
- N acetyl-galactosamine
- Fucose
- N acetyl-glucosamine
- Galactose
DNA

Nondividing cell

Chromatin in nucleus

Cell prepared for division

Visible chromosome
• In RNA, the sugar is ribose.
• In DNA, the sugar is deoxyribose.
Base

Purines

\[
\begin{align*}
\text{Adenosine} & : \text{ribose} \\
\text{Guanine} & : \text{ribose}
\end{align*}
\]

Pyrimidines

\[
\begin{align*}
\text{Thymine} & : \text{ribose} \\
\text{Cytosine} & : \text{ribose}
\end{align*}
\]

Adenine - Uracil
Adenine → Cytosine → Guanine → Thymine
Bond formation in DNA replication

New strand growing $5' \rightarrow 3'$

Template DNA strand

Bond will form

Bond will break

Incoming nucleoside triphosphate
Virus → Viral RNA

Form complementary strand of DNA using reverse transcriptase

Form double-stranded DNA

Insert into host cell chromosome

One strand of DNA serves as template for synthesis of viral DNA

Replication of viral RNA

Translation of viral RNA: enzymes and capsid proteins

Cell membrane proteins (recognition factors)
• The following three RNA make it possible for the encoded information carried by the DNA to be put to use in the synthesis of proteins.

• **Ribosome RNA**: The granular organelles in the cell where protein synthesis takes place. These organelles are composed of protein and ribosomal RNA (rRNA).

• **Messenger RNA (mRNA)**: The RNA that carries the code transcribed from DNA and directs protein synthesis.

• **Transfer RNA (tRNA)**: The smaller RNA that delivers amino acids one by one to protein chains growing at ribosomes. Each tRNA recognizes and carries only one amino acid.
Initial mRNA → Cut out introns → Final mRNA
Cell nucleus

DNA

Transcription

mRNA

mRNA leaves nucleus

Translation (at ribosome)

tRNAs

Polypeptide

Cytoplasm
Amino acid

NH₃⁺
H−C−R
C=O

O
−O−PO₄

(a)

Anticodon

(b)

Amino acid binding site

(c)

Anticodon
**INITIATION** begins with small ribosomal subunit and the first tRNA arriving at the start codon of the mRNA.

The small and large ribosomal units interlock around the mRNA, with the first tRNA in place at the start codon, completing the initiation stage. The tRNA with amino acid 2 is approaching.

**ELONGATION** begins as the tRNA with amino acid 2 binds to its codon at the second site within the ribosome.

A peptide bond forms between amino acid 1 and 2, the first tRNA is released, the ribosome moves one codon to the right, and the tRNA with amino acid 3 is arriving.

Elongation continues with three amino acids in the growing chain and the fourth one arriving with its tRNA.

**TERMINATION** occurs after the elongation steps have been repeated until the stop codon is reached. The ribosomal units, the mRNA, and the polypeptide separate.