Lecture 15

ENZYMES

One of the **unique characteristics** of a living cell is its **ability to permit complex reactions** to proceed rapidly at the temperature of the surrounding environment.

- The **principal agents** which participate in the remarkable transformations in the cell belong to **a group of proteins named enzymes**. In the absence of enzymes in the cell, these reactions would proceed too slowly.
- **Enzymes are proteins specialised to catalyse biological reactions** with the following characteristics.

Characteristics of enzymes

- Enzymes being proteins **exhibit all properties of proteins**.
- They have their **specific isoelectric points** at which they **are least soluble**.
- Like proteins, they can be **denatured by changes in pH and temperature**.
- The enzyme-catalysed reactions occur below $100^{o}C$, at atmospheric pressure and nearby **neutral pH.**
- Enzymes **undergo physical changes during the reaction** but **revert to their original form at the end of the reaction.**
- Enzymes exhibit **enormous catalytic power**.The rates of enzymatically catalysed reactions are **10^{6} - 10^{12} times greater** than those of the corresponding uncatalysed reactions and several times greater than those of the corresponding chemically catalysed reactions.
- For example the **carbonic anhydrase enzyme** catalyses the conversion of **carbondioxide to carbonic acid.**

$$CO_2 + H_2O \; . \; H_2CO_3$$

- In this reaction, each enzyme molecule can hydrate 10^{5} molecules of CO_2 per second.
- **Enzyme activity is regulated** in a variety of ways, ranging from controls over the **amount of enzyme protein synthesised by the cell** or **modulation of activity** through reversible interaction with **metabolic inhibitors and activators** or through **isoenzymes.**

Specificity of the enzymes

- One of the characteristic feature which distinguishes enzymes from catalysts is their **specificity.**

- Enzymes are specific in the **reaction catalysed** and in their **choice of substrates**.
- It usually catalyses a single chemical reaction or a set of closely related reactions

Three kinds of specificities are observed.

i. Absolute specificity

- When enzymes **catalyse only one particular reaction** they are said to exhibit **absolute specificity.**
- e.g. **Urease** acts only on urea.

ii. Group specificity

- Enzymes acting on a **group of substances** that **possess a particular type of linkage** common to that group of substances are said to exhibit group specificity.
- **Amylase** hydrolyses the group of substances like starch, dextrin and glycogen, which have the same type of glycosidic linkages (α1,4).

iii. Optical specificity

- Almost all enzymes show a high degree of optical specificity.
- There are certain enzymes which catalyse the **hydrolysis of same group of substances possessing same optical activity**
- **Eg. D-amino acid oxidase acts on D-amino acid and L-amino acid oxidase acts on L-amino acid.**
- **Maltase** catalyses the **hydrolysis of α**-but not β- glycosides.

Classification of enzymes

- In **olden days** enzymes have been named by **adding the suffix -ase** to the name of
  the substrate (the molecule on which the enzyme acts).
- **Ex. Urease (**Substrate urea**) Arginase (**Substrate arginine**)**
- Recent studies on the **mechanism of enzyme catalysed reactions** have led to a more rational classification of enzymes.
- **The International Union of Biochemistry (IUB)** established a commission on enzyme nomenclature to adopt a systematic classification and nomenclature of all the existing and yet to be discovered enzymes.
- This system is **based on the substrate and reaction specificity**.
- Although, this **International Union of Biochemistry** system is complex, **it is precise, descriptive and informative.**

- IUB system classifies enzymes into **six major classes** (should be written in specific order only)

  1. Oxidoreductases

  2. Transferases

  3. Hydrolases

  4. Lyases

  5. Isomerases

  6. Ligases
- Again each class is divided into subclasses according to the **type of reaction catalysed.**
- Each enzyme is assigned a **recommended name** usually a short for everyday use, a **systematic name** which identify the reaction it catalyses and a **classification number** which is used where accurate and unambiguous identification of an enzyme is required.

I. Oxidoreductases

- Enzymes **catalysing oxido-reductions between two substrates, S and S'.**

$$S_{reduced} + S'_{oxidised} \rightarrow S_{oxidised} + S'_{reduced}$$

Example:

$$CH_3\text{-}CH_2\text{-}OH + NAD^+ \xrightarrow{\text{--------}} CH_3\text{-}CHO + NADH + H^+$$

(reduced) (oxidised) (oxidised) (reduced)

Enzyme: Recommended name **Alcohol dehydrogenase**

Systematic name **Alcohol:NAD^+ oxido-reductase**

Enzyme Commission number **E.C.1.1.1.1**

First digit 1 indicates **oxido-reductase (Major class)**

Second digit 1 indicates **enzymes acting on CH-OH group of donors (Sub-class)**

Third digit 1 indicates **NAD^+ as the electron acceptor (Sub-sub class)**

Fourth digit 1 indicates the **specific enzyme**

II Transferases

- Enzymes catalysing the **transfer of a functional group (G) other than hydrogen between substrates.**

S - **G** + S' ---------> S' - **G** + S

Example: Phosphorylation of glucose by **hexokinase**

Glucose + ATP -------> Glucose – 6- Phosphate + ADP

Enzyme : Recommended name: **Hexokinase**

Systematic name: **ATP:D-hexose, 6- phosphotransferase**

Enzyme commission No: **2.7.1.1**

2 → Transferase group (major class)

7 → Transfer of phosphate group (sub-class)

1 → Alcohol group as acceptor of phosphate group (Sub-sub-class)

1 → Hexokinase

III Hydrolases

- Enzymes **catalysing hydrolysis of ester, peptide or glycosidic bonds.**
- Example

Acetyl choline + H_2O ----------> Acetic acid + Choline

Enzyme: **Acetyl choline esterase**

Systematic name : **Choline:acetyl hydrolase**

E.C : 3.1.1.8

IV Lyases

- Enzymes catalysing the **removal of groups from substrates by mechanism other than hydrolysis leaving a double bond in one of the products**.
- Example: convertion of malic acid to fumaric acid by fumarase

$COOH – CH(OH) – CH_2\text{-}COOH$ --------> $COOH – CH = CH –COOH + H_2O$

Malic acid Fumaric acid

Enzyme : **Fumarase (Fumarate hydratase**)

Systematic name: **L. Malate hydrolyase**

E.C.No.4.2.1.2

V. Isomerases

- Enzymes catalysing **interconversion of optical, geometrical or positional isomers**

Example

All-trans retinal ----------> 11 cis-retinal

Enzyme **Retinene isomerase**

Systematic name : **All-trans retinene:11-cis isomerase**

E.C.No. 5.2.1.3

VI. Ligases

- Enzymes catalysing **the joining together of two compounds with the hydrolysis of a high energy compound.**
- Example

ATP ADP + Pi

Glutamic acid + NH_3 ----------> Glutamine

Enzyme: **Glutamine synthetase**

L.Glutamate: Ammonia ligase

E.C.6.3.1.2