Biocatalysis is catalysis in living (biological) systems. In biocatalytic processes, natural catalysts, such as protein enzymes, perform chemical transformations on organic compounds. Both enzymes that have been more or less isolated and enzymes still residing inside living cells are employed for this task.

Biocatalysis—the use of enzymes to catalyze a chemical reaction—has become a scientific buzz word. To be clear, a biocatalyst can be one or more enzymes or cells—living, dormant, or dead—and the reaction can be a single chemical reaction or series of reactions. Thus, biocatalysis includes the one-step enzymatic production of aspartic acid (a component of the non-caloric sweetener aspartame), the two-step oxidation of ethanol to acetic acid (vinegar can be made this way, and if it is, it is called natural), and the multi-step brewing of beer (quite likely the oldest example of biocatalysis, with historical records dating back 6000 years!). Proponents say biocatalysis is green and sustainable. Critics will tell you that it is often costly and requires a development timeline that is too long to meet the needs of real world industrial manufacturing.

One of the most important advantages of biocatalysts is high selectivity, manifested as stereo-selectivity (for chiral synthesis or separation, often used for the synthesis of pharmaceutical intermediates in which only one stereoisomer possesses the desired biological activity), positional selectivity (also known as regio-selectivity, allowing selective modification of a specific site in a molecule), and functional group selectivity (i.e. chemo-selectivity, allowing one type of chemical functional group to be modified in the presence of another, sometimes more reactive functional group). Such selectivity is highly desirable in chemical synthesis, offering benefits such as higher yields, fewer side reactions, elimination of protection and de-protection steps, purer products, easier recovery and separation, and reduced environmental waste. There are also operational advantages, including the ability to carry out reactions under mild operational conditions, avoiding extremes of pH, temperature, and pressure that often require the use of expensive equipment or energy intensive processing. Biocatalytic processes also rely on catalysts that are biodegradable and are produced from renewable resources, meaning the processes are typically “greener” and more sustainable. Since there is an enzymatic counterpart to most known chemical reactions, the potential scope for the application of biocatalysis is broad.

Table: Advantages and disadvantages of biocatalysis in comparison with chemical catalysis

Advantages	Disadvantages
Generally more efficient (lower	Susceptible to substrate or product inhibition

concentration of enzyme needed)	
Can be modified to increase selectivity, stability, and activity	Solvent usually water (high boiling point and heat of vaporization)
More selective (types of selectivity: chemo-selectivity, regio-selectivity, diastereo-selectivity, and enantio-selectivity)	Enzymes found in nature in only one enantiomeric form
Milder reaction conditions (typically in a pH range of 5–8 and temperature range of 20^0–40^0C)	Limiting operating region (enzymes typically denatured at high temperature and pH)
Environment friendly (completely degraded in the environment)	Enzymes can cause allergic reactions

Mechanism of Enzyme Action:

Enzyme is active in catalytic action of biochemical reaction. They act on substrate and forms a complex after interactions with the enzyme is called active center. The enzyme and substrate forms a complex at the active centre.

This binding action makes both enzyme and substrate stable. The interaction between substrate and enzyme may be either ionic bonds and hydrogen bonds or Van der Waal forces. The active sites of enzyme have some special groups such as NH_2 COOH, -SH etc. which bind the substrate though above bonds to form a transitional (intermediate) compound called enzyme-substrate complex (ES).

This reaction is exergonic and releases some energy which raises energy level of the substrate molecule.

Thus, activating the substrate molecule and the phenomenon is known as activation energy or energy of activation as shown in Fig.

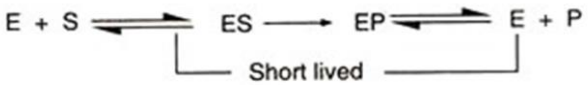

Fig: ES complex

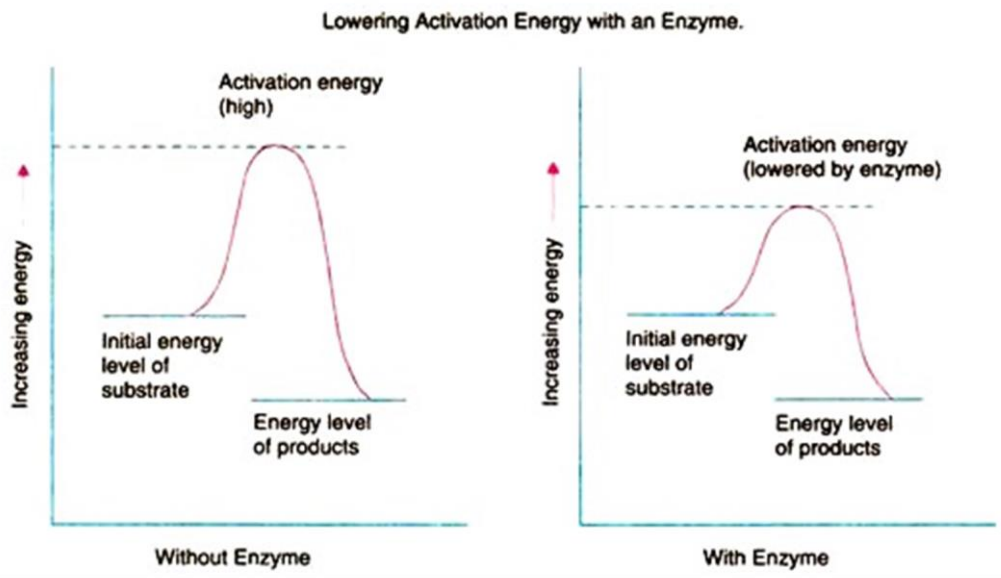

Fig: Mode of enzyme action

Types of Mechanisms of Enzymes:

There are two types of mechanisms involved to explain substrate-enzyme complex formation; lock and key theory (template model), and induced-fit theory.

LOCK AND KEY THEORY:

Emil Fischer (1894) explained the specific action of an enzyme with a single substrate using a theory of Lock and Key analogue (Fig-below). According to this theory, reaction of sub-state and enzyme is analogous to lock and key.

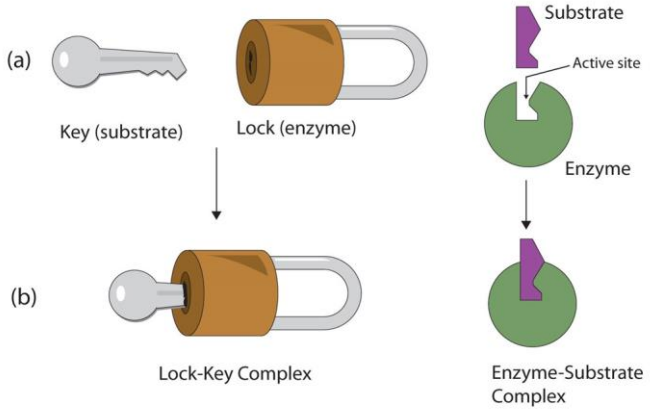

Fig: Lock and Key theory

Enzyme is analogous to key, where the geometrical configuration of socket is fixed. Similarly substrate has also got fixed geometrical configuration like that of key. A particular lock can be opened or closed by a particular key. According to the particular substrate can be found at active site of particular enzyme forming substrate-enzyme complex.

Enzyme-substrate complex remains in tight fitting and active sites of enzymes are complementary to substrate molecules. Subsequently, enzyme-substrate complexes result in the transformation of substrate into the product formation due to activity of reaction sites.

Since product has lower free energy, it is released. Enzymes are fixed to receive another molecule of substrate and thus enzyme activity continues. In this analogy, the lock is the substrate and the key is the enzyme. Only the correctly sized key (substrate) fits into the key whole (active site) of the lock (enzyme).

Smaller keys, larger keys, or incorrectly positioned teeth on keys (incorrectly shaped or sized substrate molecules) do not fit into the lock (enzyme).

INDUCED FIT THEORY:

In 1958, Koshland modified the Fischer's model for the formation of an enzyme-substrate complex to explain the enzyme property more efficiently. According the Fischer's model the nature of the active site of enzyme is rigid, but it is able to be pre-shaped to fit the substrate.

Koshland explains that the enzyme molecule does not retain its original shape and structure, but the contact of the substrate induces some geometrical changes in the active site of the enzyme molecule. The enzyme molecule is made to fit completely the configuration and active centres of the substrate. At the same time, other amino acid residues may become buried in the interior of the molecule.

This theory can be explained by a hypothetical illustration as shown in Fig-below. The hydrophobic and charged group both are involved in substrate binding. A phosphoserine (-P) and SH group of cysteine residue are involved in catalysis.

Residue of the other amino acid such as lysine (Lys) and methionine (Met) are not involved in either binding or catalysis. In the absence of substrate, the substrate binding group and catalytic group are far apart from each other.

But the contact of the substrate induces a conformational change in the enzyme molecule and aligns both the groups for substrate binding and catalysis. Simultaneously, the spatial orientation of the other region also changed. This causes the lysine and methionine much closer.

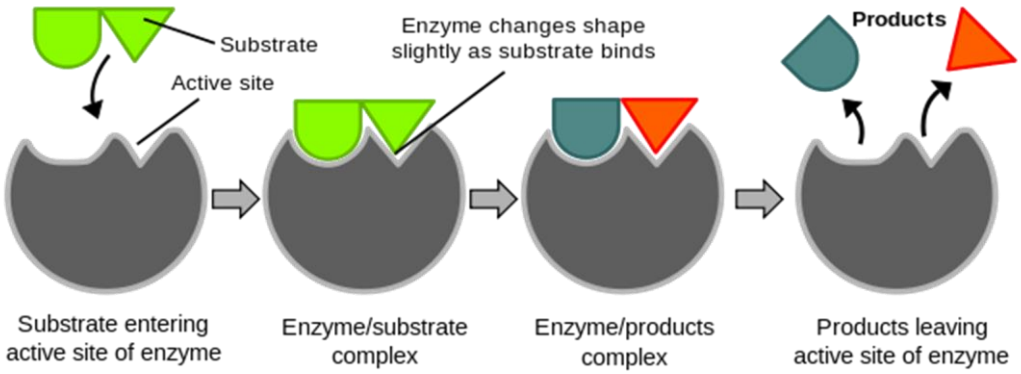

Fig: Induced fit theory

Difference between Lock-Key Theory and Induced Fit Theory

S.No.	Lock-Key Theory	Induced Fit Theory
1.	Active site is a single entity	Active site is made of two components
2.	There is no separate catalytic group	A separate catalytic group is visualized
3.	Active site is static	In contact with substratum, the buttressing group undergoes conformational change
4.	Development of transition state is not considered	It considers the development of transition state before the reactants undergo change
5.	It does not visualize the weakening of substrate bonds	Catalytic group is believed to weaken the substrate bonds by nucleophile and electrophilic attack
6.	It does not explain the mechanism of non- activity in case of competitive inhibitor	It gives a mechanism for non-action over competitive inhibitor