

Enzymes: Structure, Types, Mechanism, Functions

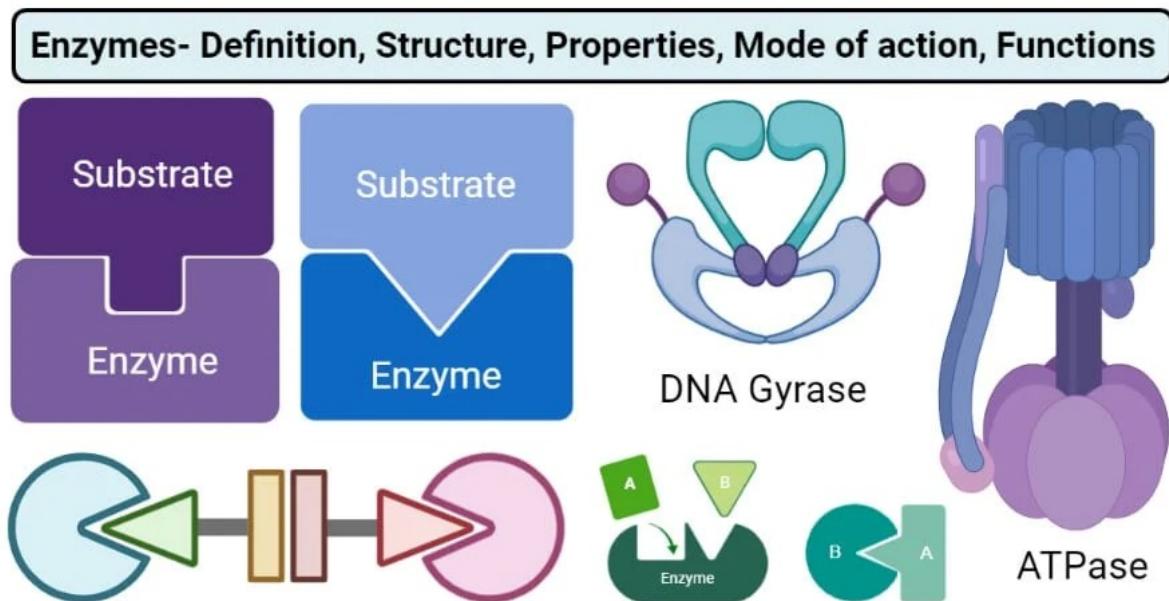
An enzyme is a protein biomolecule that acts as a biocatalyst by regulating the rate of various metabolic reactions without itself being altered in the process.

The name 'enzyme' literally means 'in yeast', and this was referred to denote one of the most important reactions involved in the production of ethyl alcohol and carbon dioxide through the agency of an enzyme zymase, present in yeast.

Enzymes are biological catalysts that catalyze more than 5000 different biochemical reactions taking place in all living organisms.

However, these are different from other catalysts which are chemical and can last indefinitely. Enzymes are proteins that are prone to damage and inactivation.

Enzymes are also highly specific and usually act on a specific substrate of specific reactions.



1. Intracellular enzymes

The enzymes that act within the cells in which they are produced are called intracellular enzymes or endoenzymes.

As these enzymes catalyze most of the metabolic reactions of the cell, they are also referred to as metabolic enzymes.

Most of the enzymes in plants and animals are intracellular enzymes or endoenzymes.

Intracellular enzymes usually break down large polymers into smaller chains of monomers.

All intracellular enzymes undergo intracellular digestion during cell death.

2. Extracellular enzymes

The enzymes which are liberated by living cells and catalyze useful reactions outside the cell but within its environment are known as extracellular enzymes or exoenzymes.

Exoenzymes act chiefly as digestive enzymes, catalyzing the breakdown of complex macromolecules to simpler polymers or monomers, which can then be readily absorbed by the cell.

These mostly act at the end of polymers to break down their monomers one at a time.

Exoenzymes are enzymes found in bacteria, fungi, and some insectivores like *Drosera* and *Nepenthes*.

Extracellular enzymes, unlike intracellular enzymes, undergo external digestion during cell death.

Enzymes and activation energy

According to the transition state theory, for a chemical reaction to occur between two reactant molecules, their free energy level must be raised above a threshold level to take them to a high-energy transition state.

The free energy needed to elevate a molecule from its stable, low-energy ground state to a higher energy unstable state is known as activation energy.

The rate of a reaction depends on the number of reactant molecules that have enough energy to reach the transition state of the slowest step (rate-determining step) in the reaction.

As a rule, very few molecules possess enough energy to reach the transition state.

Enzymes, however, reduce the value of activation energy for a reaction, thereby phenomenally increasing the rate of reactions.

Some enzymes lower the activation energy after the enzyme forms a complex with the substrate which by bending substrate molecules in a way facilitates bond-breaking.

Other enzymes speed up the reaction by bringing the two reactants closer in the right orientation.

Mechanism of Action of Enzymes

The mechanism of action of enzymes in a chemical reaction can occur by several modes; substrate binding, catalysis, substrate presentation, and allosteric modulation.

But the most common mode of action of enzymes is by the binding of the substrate.

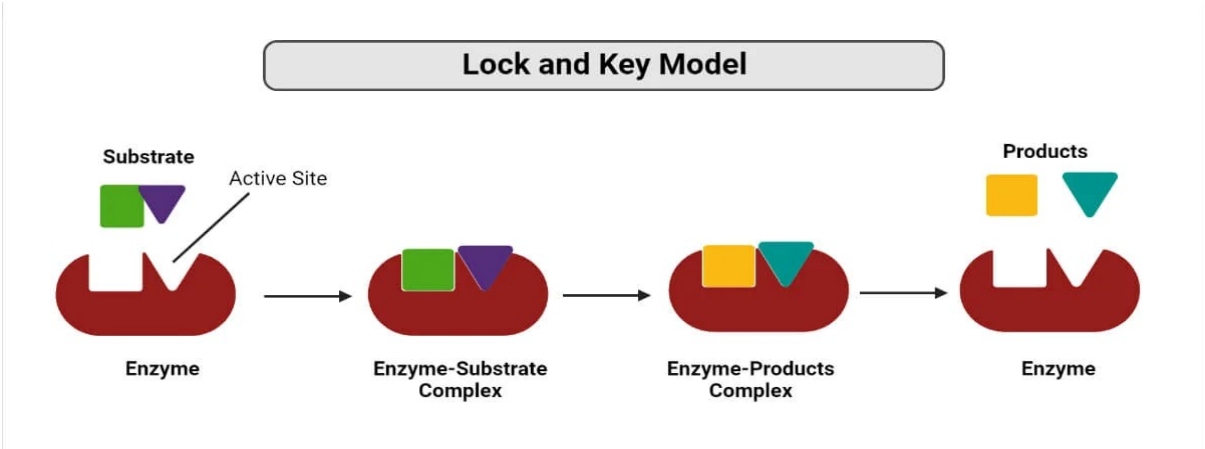
An enzyme molecule has a specific active site to which its substrate binds and produces an enzyme-substrate complex.

The reaction proceeds at the binding site to produce the products which remain associated briefly with the enzyme.

The product is then liberated, and the enzyme molecule is freed in an active state to initiate another round of catalysis.

To describe the mechanism of action of enzymes to different models have been proposed;

1. Lock and key hypothesis



The lock and key model was proposed by Emil Fischer in 1898 and is also known as the template model.

According to this model, the binding of the substrate and the enzyme takes place at the active site in a manner similar to the one where a key fits a lock and results in the formation of an enzyme-substrate complex.

In fact, the enzyme-substrate binding depends on a reciprocal fit between the molecular structure of the enzyme and the substrate.

The enzyme-substrate complex formed is highly unstable and almost immediately decomposes to produce the end products of the reaction and to regenerate the free enzyme.

This process results in the release of energy which, in turn, raises the energy level of the substrate molecule, thus inducing the activated or transition state.

In this activated state, some bonds of the substrate molecule are made susceptible to cleavage.

This model, however, has few drawbacks as it cannot explain the stability of the transitional state of the enzyme and also the concept of the rigidity of the active site.

2. Induced fit hypothesis

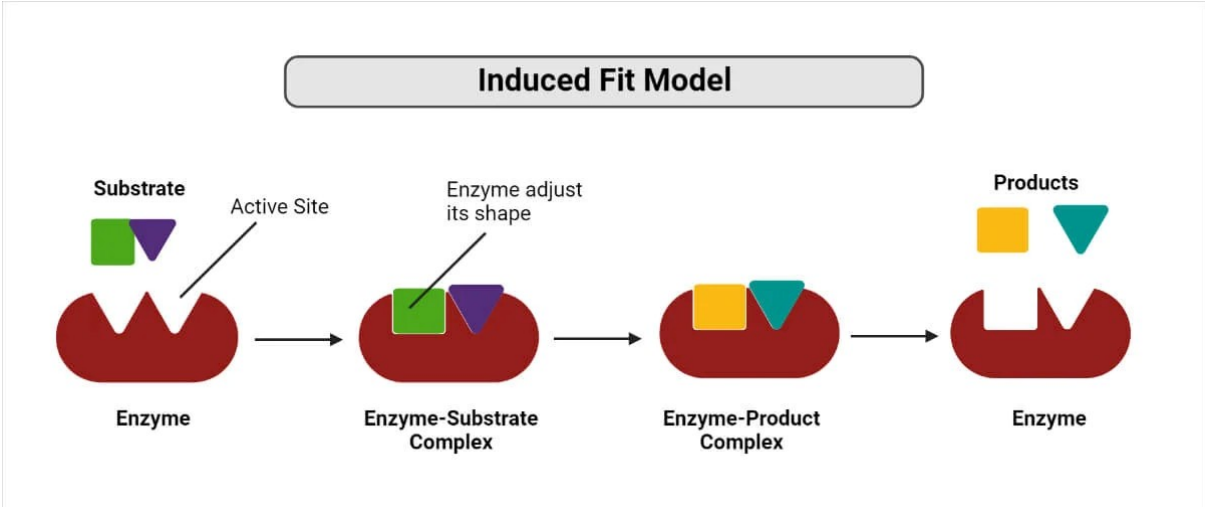


Figure: Induced fit model of Enzymes

The induced fit hypothesis is a modified form of the lock and key hypothesis proposed by Koshland in 1958.

According to this hypothesis, the enzyme molecule does not retain its original shape and structure.

Instead, the contact of the substrate induces some configurational or geometrical changes in the active site of the enzyme molecule.

As a result, the enzyme molecule is made to fit the configuration and active centers of the substrate completely.

Meanwhile, other amino acid residues remain buried in the interior of the molecule.

However, the sequence of events resulting in the conformational change might be different.

Some enzymes might first undergo a conformational change, then bind the substrate.

In an alternative pathway, the substrate may first be bound, and then a conformational change may occur in the active site.

Thirdly, both the processes may co-occur with further isomerization to the final confirmation.

Properties of Enzymes

Enzyme molecules are large, and because of their large size, the enzyme molecules possess meager rates of diffusion. As a result, enzymes form colloidal systems in water.

Enzymes act catalytically and accelerate the rate of chemical reactions occurring in biological systems and involving biological substrate.

Most enzymes also do not participate in the reactions they catalyze. Similarly, some enzymes that are involved in the reaction are recovered without undergoing any qualitative or quantitative change at the end of the reaction.

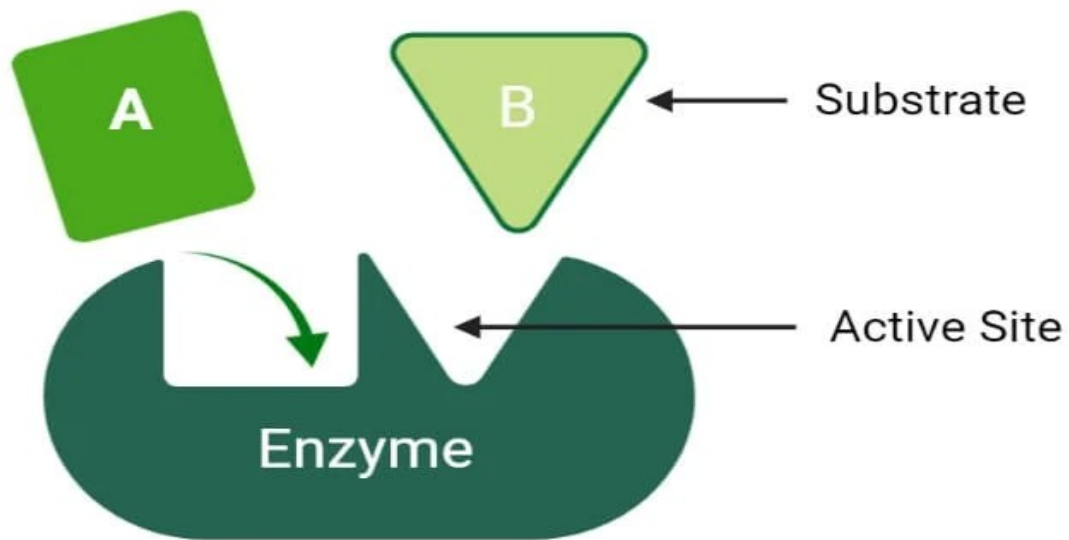
Most enzymes are highly specific in their action.

Being proteinaceous in nature, the enzymes are susceptible to heat. The rate of an enzyme action increases with the rise in temperature; the rate being frequently increased 2 to 3 times for a rise in temperature of 10°C.

The enzymes catalyze the reversion of the reactions they catalyze.

Enzymes are also pH sensitive as the pH of a medium will affect the efficiency of an enzyme and their activity is maximum at a specific pH.

Active site of enzymes



Enzymes are much larger than the substrate they act on, and thus there are some specific regions or sites on the enzyme for binding with the substrate, called active sites. Even in enzymes that differ widely in their properties, the active site present in their molecule possesses some common features;

The active site of an enzyme is a relatively small portion within an enzyme molecule.

The active site is a 3-dimensional entity made up of groups that come from different parts of the linear amino acid sequence.

The arrangement and orientation of atoms in the active site are well defined and highly specific, which is the cause of the marked specificity of the enzymes. However, in some cases, the active site changes its configuration in order to bind a substance.

The interactions or forces between the active site and the substrate molecule are relatively weak.

The active sites in the enzyme molecules are mostly present in grooves or crevices from where large quantities of water are excluded.