Enzymes

Source: H. Stephen Stoker. Biochemisty, 2nd Edition. (Cengage Learning Asia Pte Ltd:Philippine Branch): 2016, pp. 163-187.

Enzyme

- Enzyme is a compound, usually a protein, that acts as a catalyst for a biochemical reaction.
- The word enzyme comes from the Greek words “en” which means “in”, and “zyme” which means “yeast”.
- Yeast enzymes were used in the production of bread and alcoholic beverages. The action of yeast on sugars produces the carbon dioxide gas that causes bread to rise.
- Fermentation of sugars in fruit juices using the same yeast enzymes produces alcoholic beverages.

Characteristics of Enzymes

- As catalyst, enzymes are not consumed during the reaction but merely help the reaction occur more rapidly.
- Most enzymes are specialized proteins that function as biochemical catalysts. Each cell in the human body contains thousands of different enzymes because almost every reaction in a cell requires its own specific enzymes.
- Enzyme cause cellular reactions to occur millions of times faster than corresponding uncatalyzed reactions.
- Most enzymes are globular proteins. Some are simple proteins, consisting entirely of amino acid chains. Others are conjugated proteins, containing additional chemical components. Few enzymes are made of ribonucleic acids.

Enzyme Structure

Enzymes can be divided into two general structural classes of enzymes:

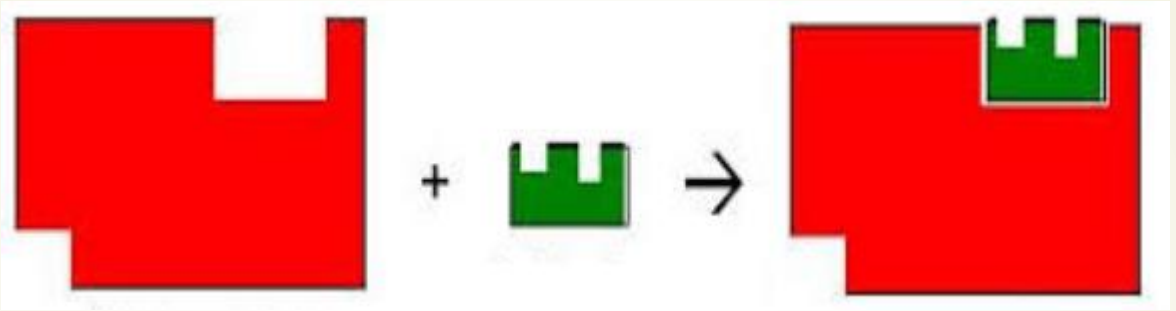
1. Simple enzyme is an enzyme composed only of protein (amino acid chains).
2. Conjugated enzyme is an enzyme that has a nonprotein part in addition to a protein part.

- By itself, neither the portion part nor the nonprotein portion of a conjugated enzyme has catalytic properties.

Enzyme

- An apoenzyme -is the protein part of a conjugated enzyme.
- A cofactor -is the nonprotein part of a conjugated enzyme.
  - Coenzyme is a small organic molecule that serves as a cofactor in a conjugated enzyme.
  - Many vitamins have coenzyme functions in human body.
  - Dietary minerals are an important source of inorganic ion cofactors.
- Haloenzyme is the biochemically active conjugated enzyme produced from an apoenzyme and a cofactor.

Enzyme



apoenzyme (protein part) + cofactor (non-protein part) = holoenzyme (active enzyme)

a. small inorganic ion

(Zn^{2+}, Mg^{2+}, Mn^{2+}, Fe^{2+}, Cl^-)

dietary minerals (Ca, K, I, Se)

b. small organic molecule

(coenzyme: vitamins)

- Cofactors provide additional chemically reactive functional groups besides those present in the amino acid side chains of apoenzymes.

Nomenclature and Classification of Enzymes

a. The type of the substance they act upon.

Substrate is the reactant in an enzyme-catalyzed reaction. The substrate is the substance upon which the enzyme "acts".

1. The suffix "**ase**" identifies a substance as an enzyme.

Substrate	Enzyme
1. Urea	Urease
2. Sucrose	Sucrease
3. Lipids	Lipase
Starch	Amylase

2. The suffix "**in**" is still found in the names of some of the first enzymes studied, many of which are digestive enzymes.

Substrate	Enzyme
1. Pancreatic juice	Trypsin
2. Protein*	Chymotrypsin (Protease)
3. Gastric juice	Pepsin

*Cleaves the peptide chains on Phenylalanine (F), Tryptophan (W), and Tyrosine (Y).

Nomenclature and Classification of Enzymes

b. The type of reaction catalyzed by an enzyme.

1. Oxidase enzyme	Catalyzes an oxidation reaction
2. Hydrolase enzyme	Catalyzes a hydrolysis reaction
3. Decarboxylase enzyme	Catalyzes decarboxylation reaction (removal of carbon dioxide)

c. The identity of the substrate is often noted in the addition of the type of reaction.

(substrate + type of reaction)

1. Glucose oxidase	
2. Pyruvate carboxylase	(Pyruvate is salt or ester of pyruvic acid.)
3. Succinate dehydrogenase	

Six (6) Major Classes of Enzymes

[on the basis of the types of reactions they catalyze]

1. Oxidoreductase -is an enzyme that catalyzes an oxidation-reduction reaction.

Subclasses	Type of reaction catalyzed
oxidases	oxidation of a substrate
reductases	reduction of a substrate
dehydrogenases	introduction of double bond (oxidation)

2. Transferase -is an enzyme that catalyzes the transfer of a functional group from one molecule to another.

Subclasses	Type of reaction catalyzed
transaminases	transfer of an amino group between substrates
kinases	transfer of a phosphate group between substrates

Six Major Classes of Enzymes
[on the basis of the types of reactions they catalyze]

3. Hydrolase -is an enzyme that catalyzes a hydrolysis reaction in which the addition of a water molecule to a bond cause the bond to break.

Subclasses	Type of reaction catalyzed
lipases	hydrolysis of ester linkages in lipids
proteases	hydrolysis of amide linkages in proteins
nucleases	hydrolysis of sugar-phosphate ester bonds in nucleic acids
carbohydrases	hydrolysis of glycoside bonds in carbohydrates
phosphatases	hydrolysis of phosphate-ester bonds

Six Major Classes of Enzymes
[on the basis of the types of reactions they catalyze]

4. Lyase -is an enzyme that catalyzes the addition of a group to a double bond or the removal of a group to form a double bond in a manner that does not involve hydrolysis or oxidation.

Subclasses	Type of reaction catalyzed
dehydratases	removal of H_2O from a substrate
decarboxylases	removal of CO_2 from a substrate
deaminases	removal of NH_3 from a substrate
hydratases	addition of H_2O to a substrate

Six Major Classes of Enzymes
[on the basis of the types of reactions they catalyze]

5. Isomerase -is an enzyme that catalyses the isomerisation (rearrangement of atoms) of a substrate in a reaction, converting it into a molecule isomeric with itself.

Subclasses	Type of reaction catalyzed
racemases	conversion of D isomer to L isomer, or vice-versa
mutases	transfer of a functional group from one position to another in the same molecule

Six Major Classes of Enzymes
[on the basis of the types of reactions they catalyze]

6. Ligase -is an enzyme that catalyzes the bonding together of two molecules into one with the participation of ATP.

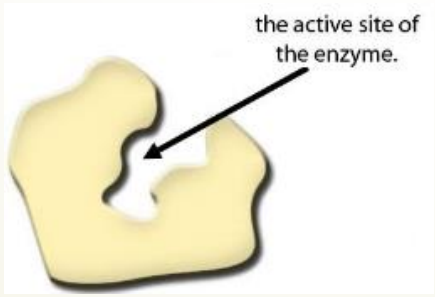
Subclasses	Type of reaction catalyzed
synthetases	formation of new bond between two substrates
carboxylases	formation of new bond between a substrate and CO_2

A commonly observed enzyme-influenced phenomenon that occurs outside the body is the discoloration (browning) that occurs when freshly cut fruits (apples, pears, etc.) and vegetables (potatoes) are exposed to air for a short period of time. The enzyme involved, which is present in the food, is an oxidoreductase enzyme called phenolase.

Models of Enzyme Action

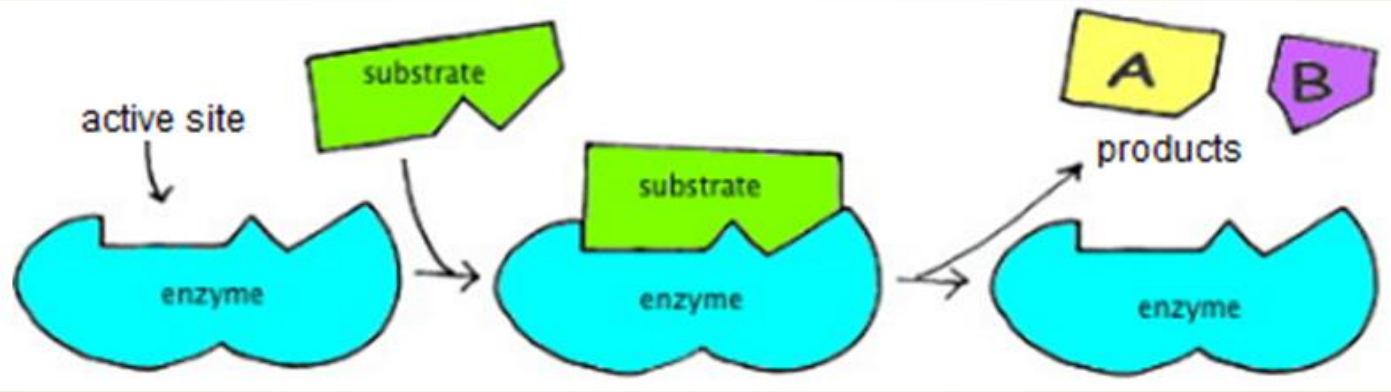
- Explanation of how enzyme function as catalysts in biochemical systems is based on the concepts of an enzyme active site and enzyme-substrate complex formation.
- Studies show that only a small portion of an enzyme molecule called the active site participates in the interaction with a substrate or substrates during a reaction.

1. Enzyme Active Site
   - The active site is the relatively small part of an enzyme's structure that is actually involved in the catalysis. The active site is usually a "crevicelike" location in the enzyme.



Models of Enzyme Action

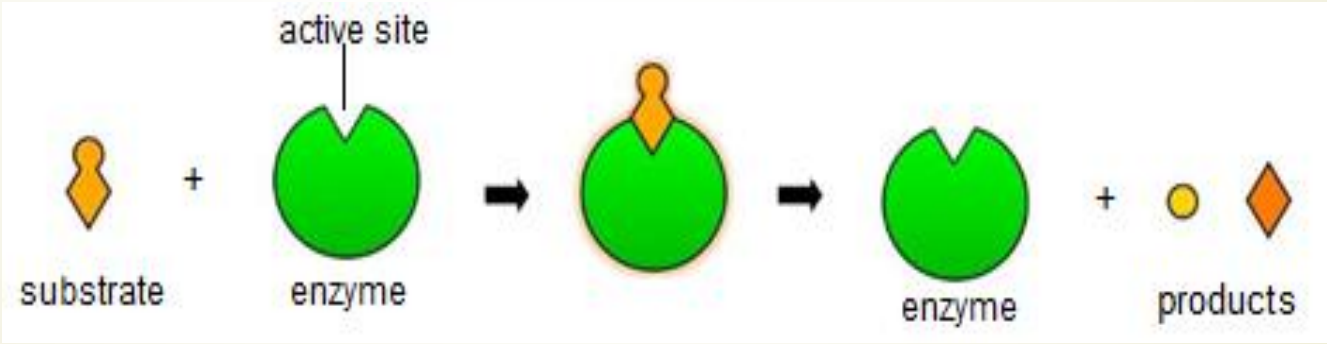
2. Enzyme-Substrate Complex
   - An enzyme-substrate complex is the intermediate reaction species that is formed when a substrate binds to the active site of an enzyme. Within the enzyme-substrate complex, the substrate encounters more favorable conditions than if it was free (or substrate can normally bind to active site of enzyme). The result is faster formation of product.



Models of Enzyme Action

3. Lock-and-Key Model

In the *lock-and-key model*, the active site in the enzyme has a fixed, rigid geometrical conformation. Only substrates with complementary geometry can be accommodated at such a site, much as a lock accepts only certain keys.



Models of Enzyme Action

4. Induced-Fit Model

- The induced-fit model allows a small change in the shape or geometry of the active site of an enzyme to accommodate a substrate. A good analogy is the changes that occur in the shape of a glove when a hand is inserted into it.
- The enzyme active site, although not exactly complementary in shape to that of the substrate, is flexible enough that it can adapt to the shape of the substrate.

1. Two substrate molecules are drawn into the cleft of the enzyme.

2. The enzymes changes shape forcing the substrate molecules to combine

3. The resulting end product is released by the enzyme which returns to the normal shape, ready to undergo more reactions.

Enzyme Specificity

- Enzyme specificity is the extent which an enzyme's activity is restricted to a specific substrate, a specific group of substrates, a specific type of chemical bond, or a specific type of chemical reaction.
- The degree of enzyme specificity is determined by the active site.

Types of Enzyme Specificity

1. Absolute specificity
   - The enzyme will catalyze only one reaction. This most restrictive of all specificities is not common. Catalase is an enzyme with absolute specificity. It catalyzes the conversion of Hydrogen peroxide (H_2O_2) to O_2 and H_2O. H_2O_2 is the only substrate it will accept.
2. Group specificity
   - The enzyme will act only on molecules that have specific functional group, such as hydroxyl, amino, or phosphate groups. Carboxyl-peptidase is group-specific; it cleaves amino acids, one at a time, from the carboxyl end of a peptide chain.

Types of Enzyme Specificity

3. Linkage specificity
   - The enzyme will act on a particular type of chemical bond, irrespective of the rest of the molecular structure. Phosphatases hydrolyze phosphate-ester bonds in all types of phosphate esters. Linkage specificity is the most general of the common specificities.
4. Stereochemical specificity.
   - The enzyme will act on a particular stereoisomer. Chirality is inherent in an enzyme active site because amino acids are chiral compounds. An L-amino acid oxidase will catalyze the oxidation of the L-form of an amino acid but not the D-form of the same amino acid.

4 Factors That Affect Enzyme Activity

Enzyme activity is a measure of the rate at which an enzyme converts substrate to products in a biochemical reaction.

1. Temperature is a measure of kinetic energy (energy of motion) of molecules.
    a. Reaction rate increases with temperature until the point at which the protein is denatured and activity drops sharply.
    b. Higher temperatures mean molecules are moving faster and colliding more frequently. This concept applies to collisions between substrate molecules and enzymes. However, when the temperature increases beyond a certain point, the increased energy begins to cause disruptions in the tertiary structure of the enzyme: denaturation is occurring.

Factors That Affect Enzyme Activity

Temperature

c. Optimum temperature is the temperature at which an enzyme exhibits maximum activity.

d. For human enzymes, the optimum temperature is around 37°C, normal body temperature. Body core temperature exceeds 40°C can be a life threatening situation because such a temperature is sufficient to initiate enzyme denaturation.

e. In hospital setting, the "*destroying*" effect of temperature on bacterial enzymes is used to sterilize medical instruments and laundry. In high temperature, high pressure vessels called "*autoclaves*", super-heated steam is used to produce a temperature sufficient to denature bacterial enzymes.

Factors That Affect Enzyme Activity

2. pH (Power of Hydrogen)

pH is a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline.

a. Maximum enzymatic activity is possible only within narrow pH range. Outside this pH range, the protein is denatured and activity drops sharply.

b. The pH of an enzyme's environment can affect its activity. A small change in pH (less than one unit) can result in enzyme denaturation and subsequent loss of catalytic activity.

c. Optimum pH is the pH at which an enzyme exhibits maximum activity.

Factors That Affect Enzyme Activity

pH

d. Each enzyme has a characteristic optimum pH, which usually falls within the physiological pH range of 7.0-7.5.

- Notable exceptions are the digestive enzymes pepsin and trypsin. Pepsin, which is active in the stomach, function best at a pH of 2.0. Trypsin, which operates in the small intestine, functions best at pH of 8.0.
- The reason that pickles and other pickled foods do not readily undergo spoilage is due to acidic conditions associated with their preparation. These acidic conditions significantly reduce the enzymatic activity of any microorganisms present.

Factors That Affect Enzyme Activity

3. Substrate Concentration

Substrate concentration -is the amount of substrate present that can be turned into product.

a. Reaction rate increases with substrate concentration until full saturation occurs, then the rate levels off.

b. It is used to measure enzyme activity, which is based on the rate of a reaction (product formed over time).

c. Increasing substrate concentration increases the rate of reaction to a certain point. Once all the enzymes have bound, any substrate increase will have no effect on the rate of reaction, as the available enzymes are used to their maximum extent (saturated).

Factors That Affect Enzyme Activity

Substrate Concentration

d. The incoming substrate molecules must "*wait their turn*" for an empty active site, where the product must leave the site before the cycle can be repeated. At this point, the rate of reaction remains constant and the enzyme is said to be under saturation condition.

e. The rate at which an enzyme accepts substrate molecules and releases product molecules at substrate saturation is given by its *turnover number*.

f. Turnover number is the number of substrate molecules transformed per minute by one molecule of enzyme under optimum conditions of temperature, pH and saturation.

Factors That Affect Enzyme Activity

4. Enzyme Concentration

   Enzyme concentration refers to the amount of enzyme present in a reaction and is measured by the activity it catalyzes.

   a. The relationship between activity and concentration is affected by many factors such as temperature, pH, etc.

   b. Enzymes are not consumed in the reactions they catalyze. In general, the concentration of substrate in a reaction is much higher than that of the enzyme.

   c. If the amount of substrate present is kept constant and the enzyme concentration is increased, the reaction rate increases because more substrate molecules can be accommodated in a given amount of time. The greater the enzyme concentration, the greater the reaction rate.

Extremozymes

An extremophile –is a microorganism that thrives in extreme environments, environments in which humans and most other forms of life could not survive.

- Types of Extremophile

  a. acidophiles, optimal growth at pH levels of ≤ 3.0.

  b. alkaliphiles, optimal growth at pH levels of ≥ 9.0.

  c. halophiles, salinity that exceeds 0.2 M NaCl needed for growth.

  d. hypothermophiles, temperature between 80°C and 122°C needed to thrive.

  e. piezophiles, high hydrostatic pressure needed for growth.

  f. cryophiles, temperature of 15°C or lower needed for growth.

- The enzymes present in extremophiles are called extremozymes.
- Extremozyme is a microbial enzyme active at conditions that would inactivate human enzymes as well as enzymes present in other types of higher organisms.

Enzyme Inhibition

The rates of enzyme-catalyzed reactions can be decreased by a group of substances called inhibitors.

- Enzyme inhibitor is a substance that slows down or stops the normal catalytic function of an enzyme by binding to it.

Three Modes of Inhibition

1. Reversible Competitive Inhibition
2. Reversible Noncompetitive Inhibition
3. Irreversible Inhibition

Mode of Inhibition

1. Reversible Competitive Inhibition
   - Reversible Competitive Inhibitor is a molecule that sufficiently resembles an enzyme substrate shape and charge distribution that it can compete with the substrate for occupancy of the enzyme's active site (or competitive inhibitor mimics substrate and competes for active site).

Mode of Inhibition

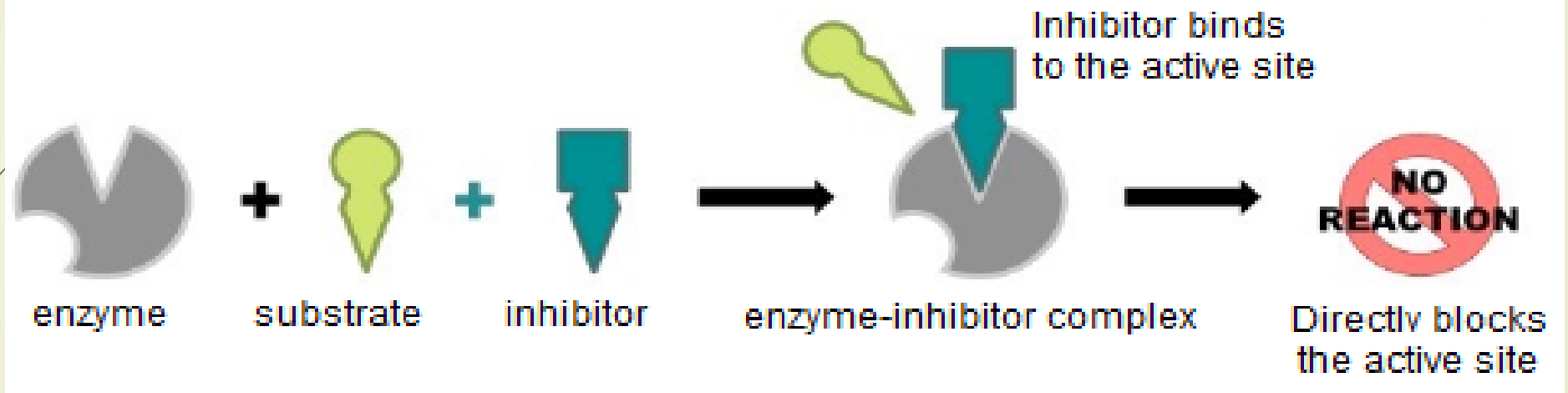
- Reversible Competitive Inhibition

  Numerous drugs act by means of competitive inhibition.

  - For example, antihistamines are competitive inhibitors of histidine decarboxylation, the enzymatic reaction that converts histidine to histamine.
  - Histamine causes the usual allergy and cold symptoms: watery eyes and runny nose.

Mode of Inhibition

- Reversible Competitive Inhibition



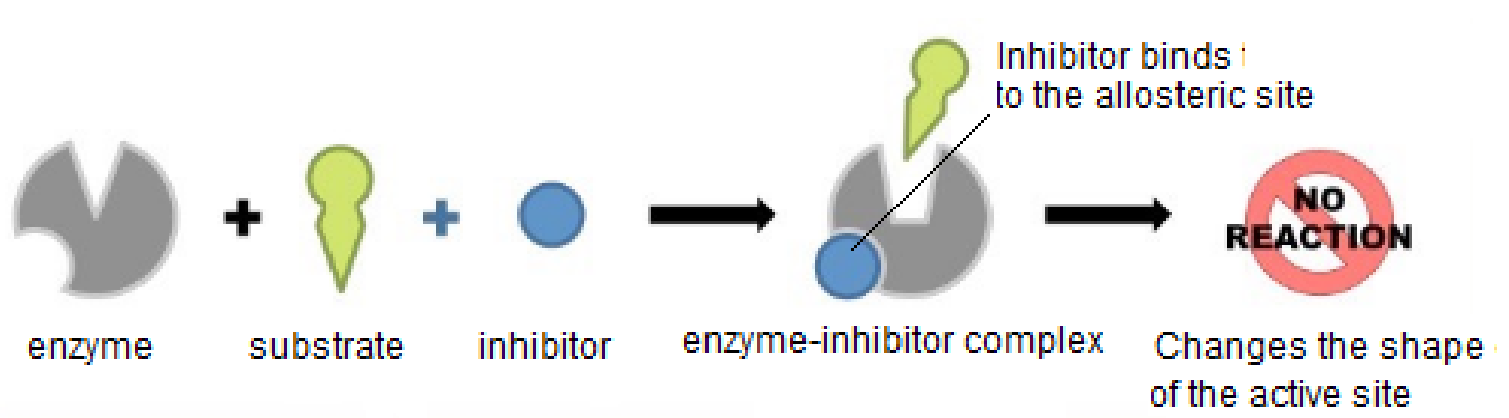
If inhibitor concentration is greater than the substrate concentration, the inhibitor dominates the occupancy process. The reverse is also true.

Mode of Inhibition

2. Reversible Noncompetitive Inhibition
   - Reversible Noncompetitive enzyme inhibitor is a molecule that decreases enzyme activity by binding to a site on an enzyme other than the active site.
     - The substrate can still occupy the active site, but the presence of the inhibitor causes a change in the structure of the enzyme sufficient to prevent the catalytic groups at the active site from properly effecting their catalyzing action (or noncompetitive inhibitor alters conformation of enzyme so active site is no longer fully functional).

Mode of Inhibition

- Reversible Noncompetitive Inhibition



  - Competitive inhibitor sufficiently does free up many enzymes, which then return to normal activity.
  - Examples of noncompetitive inhibitors include the heavy metals ions Pb^{2+}, Ag^{+}, and Hg^{2+}. The binding sites for these ions are sulfhydryl (-SH) groups located away from the active site. Metal sulfide linkage is formed, an effect that disrupts secondary and tertiary structure.

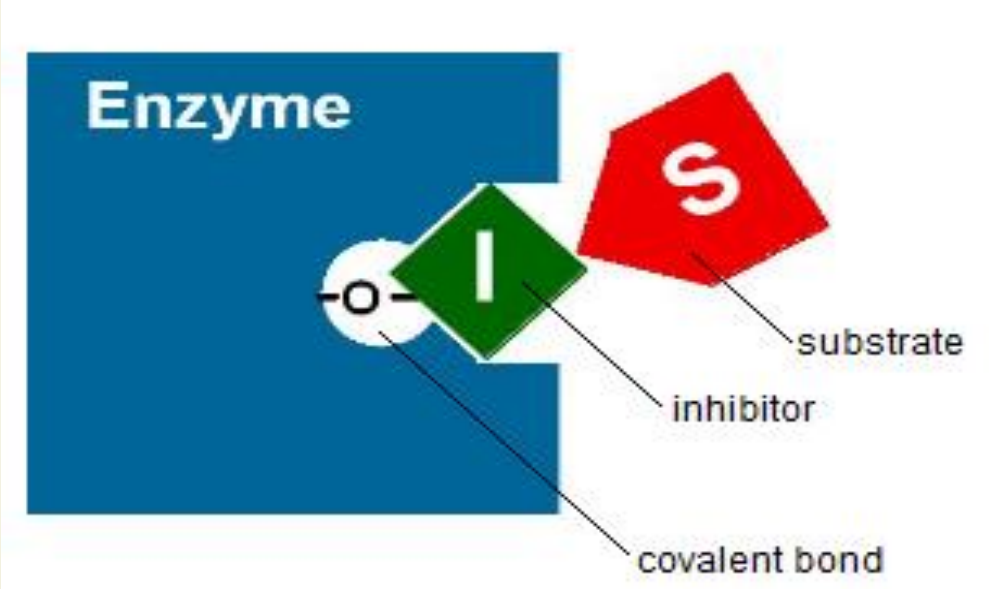
Mode of Inhibition

3. Irreversible Inhibition

- Irreversible Inhibitor is a molecule that inactivates enzymes by forming a strong covalent bond to an amino acid side-chain group at the enzyme's active site.
  - In general, such inhibitors do not have structures similar to that of the enzyme's normal substrate. The inhibitor active site bond is sufficiently strong that addition of excess substrate does not reverse the inhibition process. Thus, the enzyme is permanently deactivated.

Mode of Inhibition

- Irreversible Inhibition



The inhibitor binds to the enzyme irreversibly through formation of a covalent bond with the enzyme.

  - The actions of chemical warfare agents (nerve gas) and organophosphate insecticides are based on irreversible inhibition.

Regulation of Enzyme Activity

Many mechanisms exist by which enzymes within a cell can be "*turned on*" and "*turned-off*".

Three mechanisms are considered:

1. Feedback Control associated with allosteric enzymes
2. Proteolytic Enzymes and Zymogens
3. Covalent Modification of Enzymes

Mechanisms of Enzyme Activity

1. Feedback Control associated with allosteric enzymes

   Allosteric enzyme is an enzyme with two or more protein chains (quarternary structure) and two kinds of binding sites (substrate and regulator).

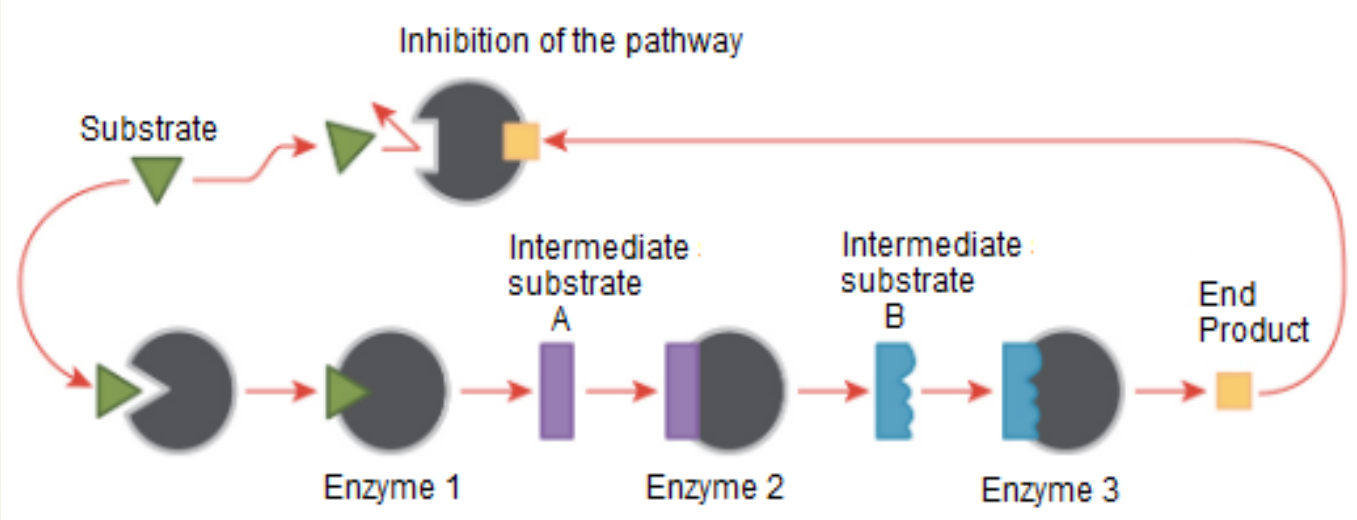
   Regulators are substances that bind at regulatory sites of allosteric enzymes.

   1.a. Positive regulator. The binding of a positive regulator increases enzyme activity; the shape of the active site is changed such that it can more readily accept substrate.

   1.b. Negative regulator (a noncompetitive inhibitor). The binding site of negative regulator decreases enzyme activity; changes to the active site are such that substrate is less readily accepted.

Mechanisms of Enzyme Activity

- Feedback Control is a process in which activation or inhibition of the first reaction sequence is controlled by a product of the last reaction sequence.



Mechanisms of Enzyme Activity

2. Proteolytic Enzymes and Zymogens
   - The second mechanism for regulating cellular enzyme activity is based on the production of enzymes in an inactive form.

These inactive enzyme precursors are then “turned on” at the appropriate time. Such a mechanism for control is often encountered in the production of proteolytic enzymes. Because they would otherwise destroy the tissues that produce them, proteolytic enzymes are generated in an inactive form, and then later, when they are needed, are converted to their active form.

Mechanisms of Enzyme Activity

- Proteolytic Enzymes and Zymogens
  - Proteolytic Enzyme is an enzyme that catalyzes the breaking of peptide bonds that maintain the primary structure of protein.
  - Zymogen is the inactive precursor of proteolytic enzymes (Apoenzyme is the alternative for zymogen)
  - Most digestive and blood-clotting enzymes are preoteolytic enzymes.

Mechanisms of Enzyme Activity

3. Covalent Modification of Enzymes
   - Covalent modification is a process in which enzymes activity is altered by covalent modifying the structure of the enzyme through attachment of a chemical group to or removal of a chemical group from a particular amino acid within the enzyme's structure.
     - Phosphate group involves in the most commonly encountered type of covalent modification by which the group is added or removed from an enzyme. The source of the added phosphate group is often an ATP molecule.

Mechanisms of Enzyme Activity

- Covalent Modification of Enzymes
  - Phosphorylation is the process of addition of the phosphate group to the enzyme. Protein kinases effect the addition of phosphate groups. Dephosphorylation is the process of removing the phosphate group from the enzyme.
  - Phosphatases catalyze removal of the phosphate group.

Mechanisms of Enzyme Activity

- Covalent Modification of Enzymes
  - Usually, the phosphate group is added to (or removed from) the **R** group of Serine, Tyrosine, or Threonine amino acid residue present in the protein (enzyme). The R groups of these three amino acids have a common structural feature, the presence of a free -OH group. The hydroxyl group is the site where phosphorylation or dephosphorylation occurs.
  - Glycogen phosphorylase is an enzyme involved in the breakdown of glycogen to glucose, is activated by the addition of phosphate group.
  - Glycogen synthase is an enzyme involved in the synthesis of glycogen, is deactivated by phosphorylation.

Prescription Drugs that Inhibit Enzyme Activity

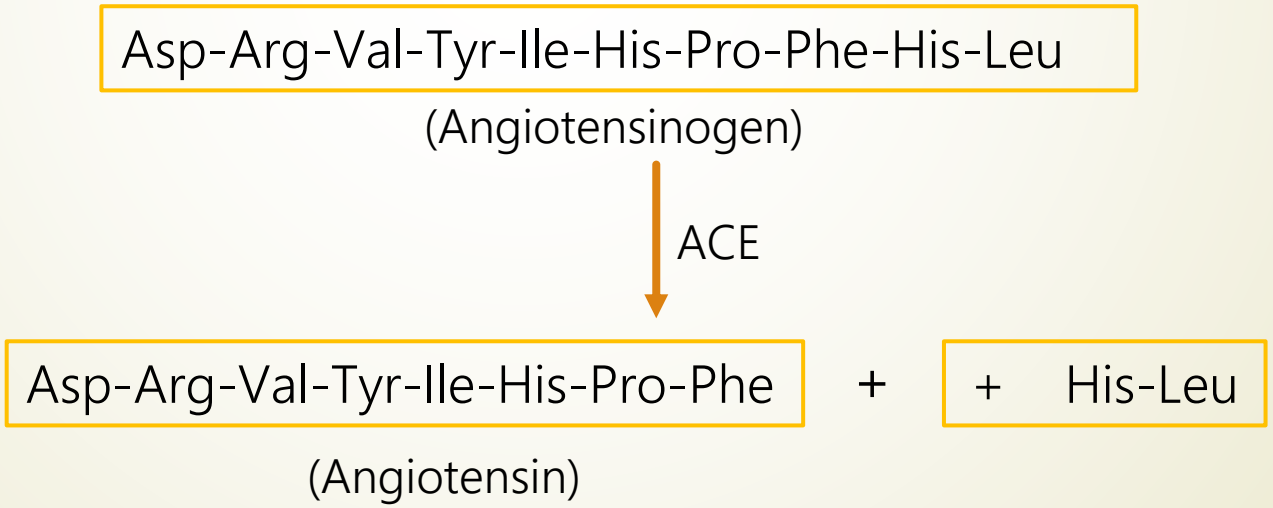
Several common types of prescription drugs have modes of action that involve enzyme inhibition. Among them are:

1. ACE inhibitors (Angiostensin-Converting Enzyme)
   - used to treat high blood pressure conditions as well as several heart conditions.
   - converts the inactive decapeptide zymogen to the active octapeptide form (angiotensin) by cleaving two amino acids from the zymogen structure.

Prescription Drugs that Inhibit Enzyme Activity

- ACE inhibitors

  Angiotensin is an octapeptide hormone involved in blood pressure regulation. It increases blood pressure by narrowing blood vessels. Until needed, angiotensin is present in the body in an inactive form as the zymogen angiotensinogen, which is a decapeptide.



Prescription Drugs that Inhibit Enzyme Activity

- ACE inhibitors
  - Example of ACE Inhibitors used today is Lisinopryl, a compound heavily prescribed for the treatment of moderately elevated blood pressure conditions.
  - It is not metabolized (broken down) by liver enzymes
  - It is excreted unchanged in the urine.
  - It was first obtained from snake venom of the jararaca (a Brazilian pit viper).

Prescription Drugs that Inhibit Enzyme Activity

2. Sulfa Drugs and Penicillins are two well-known families of antibiotics.

2.a. Sulfa drug is the first antibiotic in the medical field.

- The 1932 discovery of the antibacterial activity of the compound sulfanilamide by the German bacteriologist, Gerhard Domagk led to the characterization of a whole family of sulfanilamide derivatives.
- Antibiotic*s* is a substance that kills bacteria or inhibits its growth. Antibiotics exert their action selectively on bacteria and do not affect the normal metabolism of the host organism. Antibiotics usually inhibit specific enzymes essential to the life processes of the bacteria.

Prescription Drugs that Inhibit Enzyme Activity

- Sulfanilamide inhibits bacteria growth because it is structurally similar to PABA (p-aminobenzoic acid). Many bacteria need PABA in order to produce an important coenzyme, *folic acid*.
- Sulfanilamide acts as a competitive inhibitor to enzymes in the biosynthetic pathway for converting PABA into folic acid in these bacteria. Folic acid deficiency retards the growth of the bacteria and can eventually kill them. Human absorbs folic acid from their diet and thus do not use PABA for its synthesis.

Prescription Drugs that Inhibit Enzyme Activity

2.b. Penicillin is one of the most widely used antibiotics, was accidentally discovered by Alexander Fleming in 1928 while he was working with cultures of an infectious staphylococcus bacterium. A decade later, the scientists Howard Flory and Ernst Chain isolated penicillin in pure form and proved its effectiveness as an antibiotic.

- Penicillins inhibit transpeptidase, an enzyme that catalyzes the formation of peptide cross links between polysaccharide strands in bacterial cell wall. These cross links strengthen cell walls. A strong cell wall is necessary to protect the bacterium from lysis (breaking down). By inhibiting transpeptidase, penicillin prevents the formation of cell wall.

Any osmotic pressure or mechanical shock then causes lysis, killing the bacterium.

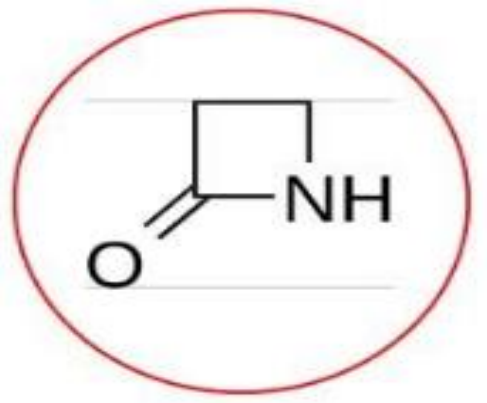
Prescription Drugs that Inhibit Enzyme Activity

- Some bacteria produce the enzyme penicillase, which protects them from penicillin.
- Penicillase selectively binds penicillin and catalyzes the opening of the β-lactam ring before penicillin can form a covalent bond to the enzyme. Once the ring is opened, penicillin is no longer capable of inactivating transpeptidase enzyme.

- Penicillin does not usually interfere with normal metabolism in humans because of its highly selective binding to bacterial transpeptidase. This selectivity makes penicillin an extremely useful antibiotic.

Prescription Drugs that Inhibit Enzyme Activity

- Lactam –is a cyclic amide.



β-lactam ring is a four membered lactam. It is named as such because the Nitrogen atom is attached to the β-carbon relative to the carbonylβ-lactam ring is a four membered lactam. It is named as such because the Nitrogen atom is attached to the β-carbon relative to the carbonyl

Food-Enzyme Interactions that affect Prescription Medication

- Liver enzymes known as Cytochrome P450s are involved in the processes by which many prescription medications are metabolized in the body.
  - It is now known that several foods and herbal remedies contain compounds that decrease (inhibit) the activity of these Cytochrome P450s enzymes, thus decreasing the rate at which affected drugs are metabolized (deactivated and eliminated from the body).
  - The net result of this slowing enzyme action for affected drugs is that drug concentration in the bloodstream increases, sometimes to the levels considered dangerous.

Medical Uses of Enzymes

1. Enzyme can be used to diagnose certain diseases. Although blood serum contains many enzymes, some enzymes are not normally found in the blood but are produced only inside the cells of certain organs and tissues.
   - The appearance of these enzymes in the blood often indicates that there is tissue damage in an organ and that cellular contents are spilling out (*leaking*) into the bloodstream.
   - Assay of abnormal enzyme activity in blood serum can be used to diagnose many disease states.
   - The enzymes aspartate transaminase (AST) and alanine transaminase (ALT) at abnormal level indicate heart disease, liver disease and muscle damage.

Medical Uses of Enzymes

2. Enzymes can also be used in the treatment of diseases.
   - A recent advance in treating heart attacks is the use of tissue plasminogen *activator* (TPA), which activates the enzyme plasminogen.
   - When so activated, this enzyme dissolved blood clots in the heart and often provides immediate relief.

Medical Uses of Enzymes

3. Another medical use for enzymes is in clinical laboratory chemical analysis.
   - For example, no simple direct test for the measurement of urea in the blood is available. However, if the urea in the blood is converted to ammonia via the enzyme urease, the ammonia produced, which is easily measured, becomes an indicator of urea.
   - This *blood urea nitrogen (BUN) tes*t is a common clinical laboratory procedure. High urea levels in the blood indicate kidney malfunction.

Thank You for Watching

What is Assay?

- An assay is an investigative (analytic) procedure in laboratory medicine, pharmacology, environmental biology, and molecular biology for qualitative assessing or quantitatively measuring the presence or amount or the functional activity of a target entity (the analyte) which can be a drug or biochemical substance or organic sample.