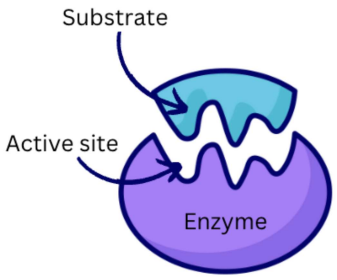
INTRODUCTION



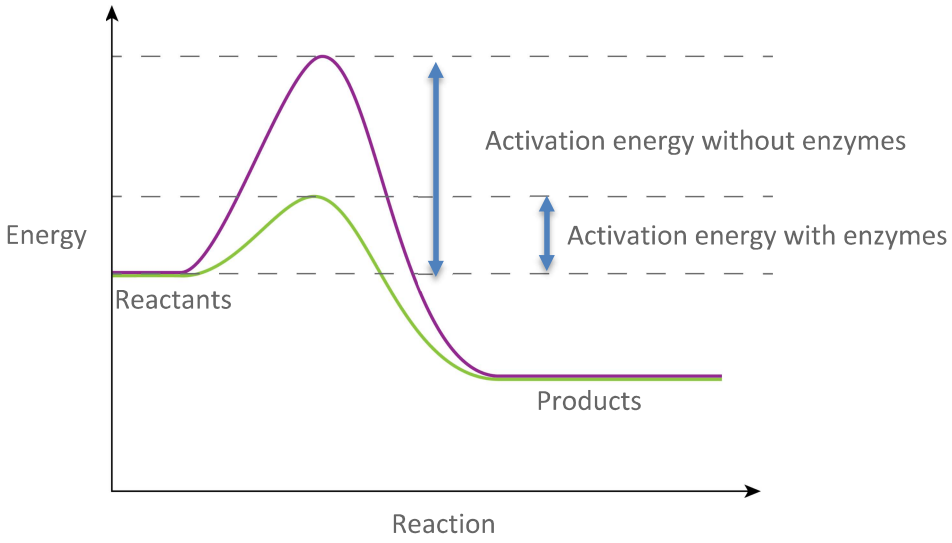
- Enzyme is a protein that is a biological catalyst. It can change or **speed up a chemical reaction** while **remaining chemically unchanged** at the end of a reaction.
- They have an **active site**, which is a hole that is specific to the molecule they work on, for a substrate to bind to.
    - Substrates have a **specific shape** that complements to the active site, to form an **enzyme-substrate complex**
    - Products will then be formed after this chemical reaction and detach from the active site of the enzyme

WHEN ARE ENZYMES USED?

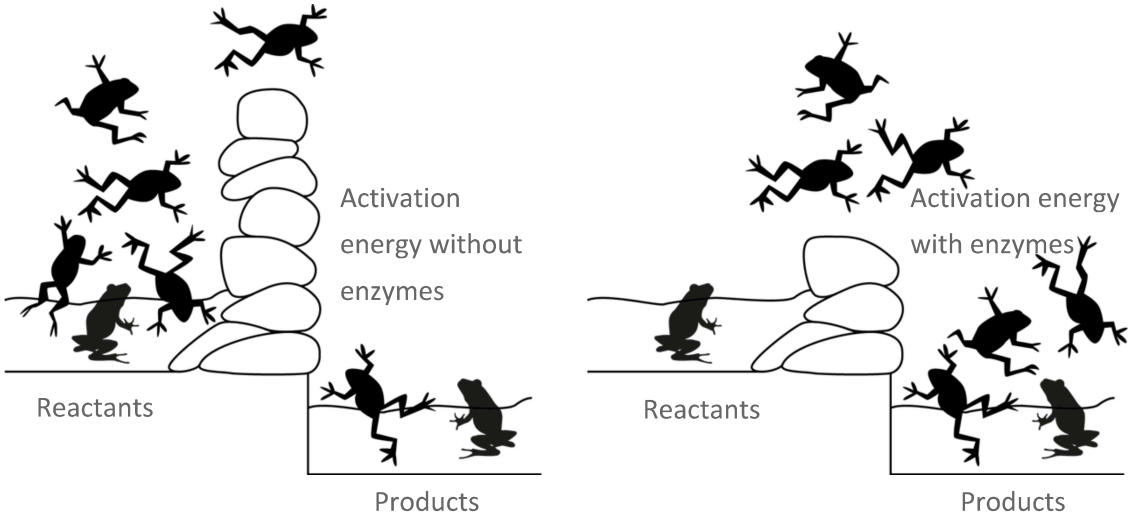
- Enzymes can be involved in anabolic (building up) or a catabolic (breaking down) reaction
    - Anabolic: building up of complex substances from simpler ones
        - Eg amino acids forming a polypeptide chain to form proteins
        - Eg glucose is oxidised to release water and carbon dioxide during respiration
    - Catabolic: breaking down of complex substances into simpler ones
        - Eg starch breaking down into glucose monomers during digestion
        - Eg breaking down of alcohol in liver
- Enzymes are **only produced when they are needed**

WHAT ARE THE CHARACTERISTICS OF ENZYMES?

1. **Speed up** chemical reactions
    - Increase rate of reactions by providing an alternative pathway with a lower activation energy, allowing more molecules to have sufficient energy for reaction to occur

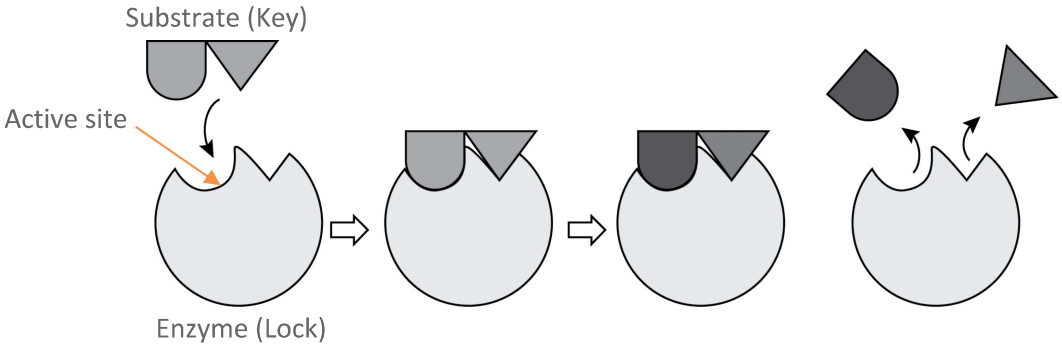


- Imagine the activation energy as a pile of pebbles, enzymes lower the height of the pebbles, making it easier for the frogs to climb to get to the other side.



2. Required in **small/minute amounts**
    - Enzymes remain unchanged at the end of a chemical reaction
    - Hence they can be reused continuously for large amount of substrates
3. Catalyse **reversible** reactions
    - Enzymes can build up or break down substances
4. Highly **specific**
    - Only substrates with a shape that is 100% complementary to the shape of the active site can fit and cause a chemical reaction
5. Works best at on **optimum temperature and pH**

LOCK AND KEY HYPOTHESIS

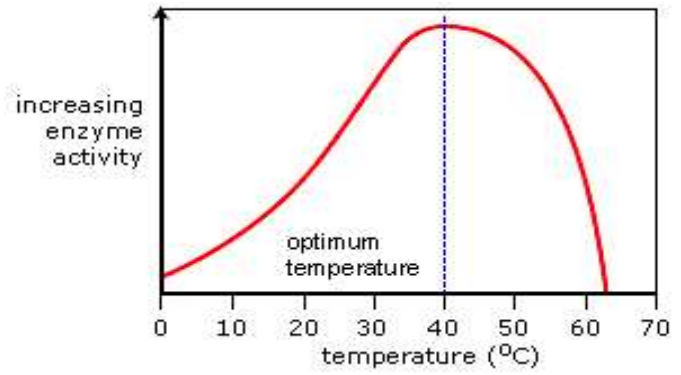


- Imagine the enzyme as a lock, and the substrate as a key. Only when the right key (substrate) fits into the lock (enzyme's active site) can the reaction occur.
- Substrate has to have a **specific three-dimensional conformation**, complementary to the active site to bind and form an **enzyme-substrate complex**.

- Reaction occurs and **product** molecules are then released from the enzyme
- Enzyme molecule **remain unchanged at the end** of the reaction and has its active site available to catalyse more reactions

FACTORS AFFECTING ENZYMATIC ACTIVITY

- **Temperature**:



At **low temperature**, enzymes and substrates have l**ow kinetic energy**.

Hence there is a l**ow rate of effective collisions** between enzyme and substrate molecules to form enzyme-substrate complexes.

Rate of reaction is **slow**.

As temperature increases towards optimum temperature, the kinetic energy of molecules increase.

Hence there is an increasing rate of effective collisions between enzyme and substrate molecules to form enzyme-substrate complexes.

At **optimum temperature**, the rate of effective collisions between enzyme and substrate molecules to form enzyme-substrate complexes is at **maximum**.

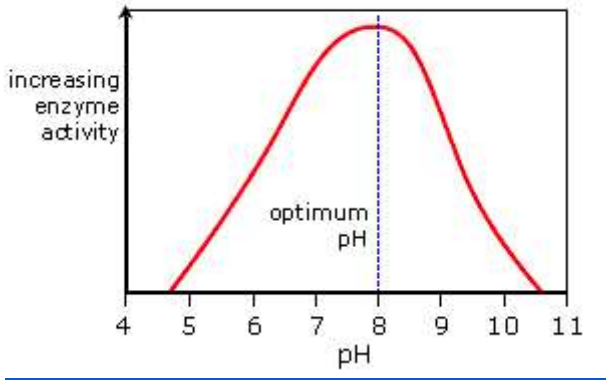
As temperature increases beyond optimum, **high temperature** causes enzymes to **denature**.

They **lose their 3D shapes** and substrate molecules can no longer fit in the active sites.

Rate of reaction decreases.

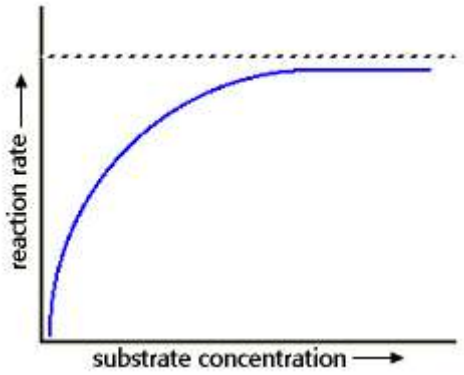
- Denaturation is the alteration in 3D structure of an enzyme, caused by heat or chemicals.

- **pH:**



  - At the optimum pH, activity of enzyme molecules is maximum
  - As pH decreases or increases from optimum, enzyme activity decreases as the ions in the solution disrupts the bonds holding the 3D confirmation of the active site of the enzyme.
  - Hence there is a **low rate of effective collisions** between enzyme and substrate molecules to form enzyme-substrate complexes.
  - Optimum pH varies for different enzymes.

- **Substrate concentration:**



  - As substrate concentration increases, the rate of effective collisions between enzyme and substrate molecules to form enzyme-substrate complexes increases until it reaches

a maximum.

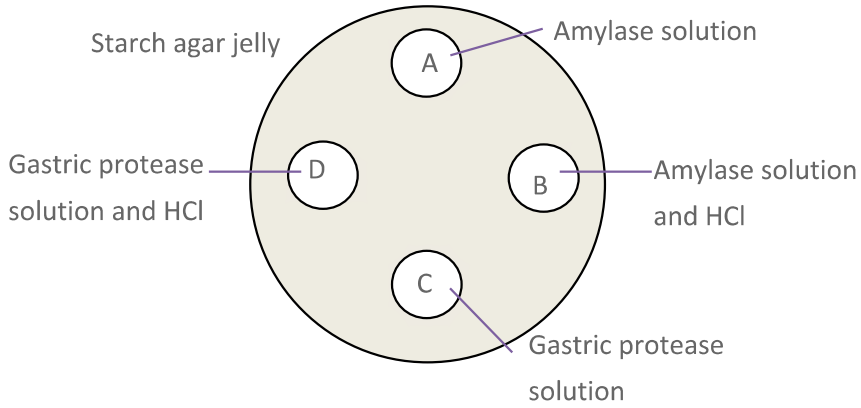
- Graph plateaus and further increase in concentration no longer increases the rate of enzymatic activity as **all enzyme molecules are occupied**.

Example question:	Describe the role of enzymes in digestion. Explain how pepsin and amylase function in the digestive process.
Answer:	• Enzymes play a crucial role in breaking down food in the digestive system. They facilitate the hydrolysis of large macromolecules (e.g., proteins, carbohydrates) into smaller, absorbable molecules. • Pepsin is an enzyme found in the stomach that is responsible for breaking down proteins into peptides through proteolysis. It works optimally in the acidic environment of the stomach. • Amylase is an enzyme found in saliva and pancreatic secretions. It breaks down starch (a polysaccharide) into maltose (a disaccharide) by catalysing the hydrolysis of glycosidic bonds.
Pitfalls:	• Students may overlook the importance of pH in the activity of digestive enzymes. • Pepsin requires an acidic pH, while amylase functions optimally in a more neutral pH environment. • Failure to consider pH differences can lead to misunderstandings about enzyme function in digestion.

Example question:

A dish is filled with agar jelly containing starch. Four holes were cut in the agar jelly and filled with different solutions as shown below.

After half an hour, which hole will show the largest area with no starch?



Answer: **B**

Explanation:

- Amylase is an enzyme that breaks down starch into simpler sugars. When you add amylase solution to the agar jelly containing starch, it will start to break down the starch molecules around the hole filled with amylase solution.
- Hydrochloric acid (HCl) creates an acidic environment. In this context, it simulates the acidic conditions of the stomach. Amylase works optimally in a slightly acidic environment. Therefore, when you add hydrochloric acid to the amylase solution, it creates an environment that is even more favourable for amylase activity.
- So, the combination of amylase solution and hydrochloric acid will result in the largest area without starch because the amylase will break down the starch more effectively in the acidic environment.

Example question:	The diagram shows how an enzyme molecule changed its shape.  What explains this change? A) It has been cooled to 5°C B) It has been heated to 70°C C) It has been placed in a concentrated salt solution D) It has been placed in a dilute salt solution
Answer:	**B**
Pitfalls:	• Enzymes are highly sensitive to temperature, and their activity is influenced by temperature changes. When an enzyme is heated to a high temperature, such as 70°C, it undergoes a process called denaturation. Denaturation involves the disruption of the enzyme's three-dimensional structure, including the active site. • This change in shape makes the enzyme non-functional and unable to catalyse reactions effectively.

Example question:

Cubes of egg white are placed in test-tubes containing $5cm^3$ of water. Other substances are added to each tube as shown in the chart. The tubes are left for 8 hours and then tested for amino acids.

Tube	Solution added	Results of amino acids test
1	Pepsin	Absent
2	Pepsin + alkali	Absent
3	None	Absent
4	Pepsin + acid	Large amount
5	Boiled pepsin + acid	Traces
6	Acid	Absent
7	Alkali	Absent

Which tubes show that pepsin is an enzyme?

A. 1 and 6
B. 2 and 7
C. 4 and 5
D. 5 and 6

Answer: **C**

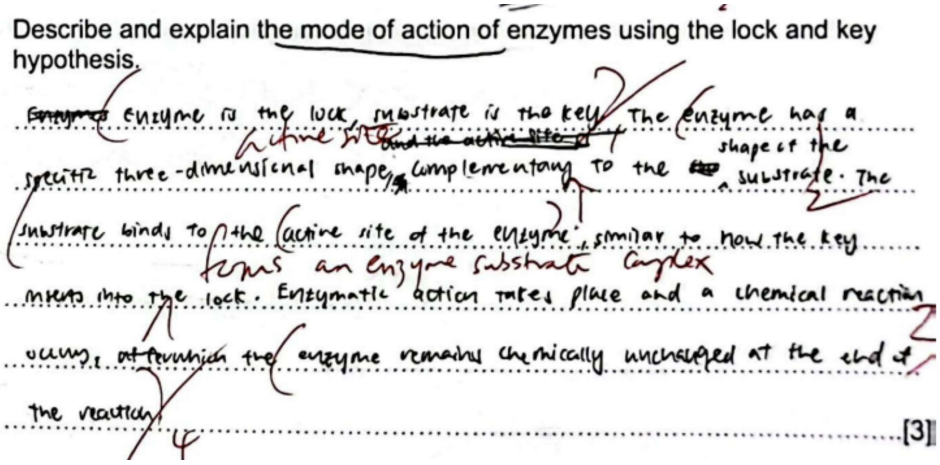
Pitfalls:

- Pepsin is an enzyme responsible for the digestion of proteins in the stomach. It works optimally in an acidic environment, which is why the stomach's acidic conditions are suitable for its activity.
- Tube 4 contains pepsin + acid, and it shows a large amount as a result for the test of amino acids. This indicates that pepsin, in the presence of an acidic environment, is active and capable of breaking down proteins (amino acids are the building blocks of proteins). This result supports that pepsin is an enzyme.
- Tube 5 contains boiled pepsin + acid and shows traces as a result for the test of amino acids. Boiling pepsin denatures the enzyme, rendering it inactive. However, the presence of acid alone in the tube (Tube 6) also shows traces of amino acids, suggesting that the acid alone does not have

the same protein-digesting capacity as active pepsin. Therefore, Tube 5 confirms that the activity observed in Tube 4 is due to the presence of active pepsin

Example of an exam question:

Describe and explain the mode of action of enzymes using the lock and key hypothesis.



Points required in answer:

1. **Identify the lock and the key.**
2. **Specificity of the active site that complements to a specific substrate.**
3. **When the substrate fits into the active site, an enzyme-substrate complex is formed.**
4. **Chemical reaction takes place, to produce the products.**
5. **Enzymes remain chemically unchanged.**

Summary

Topic	Key Points
Introduction	• Enzymes are biological catalysts made of proteins. • They have an active site for substrates to bind to. • Enzymes can be involved in anabolic or catabolic reactions. • Enzymes are only produced when needed.
Characteristics of Enzymes	• Speed up chemical reactions. • Require small amounts. • Remain unchanged at the end of reactions and can be reused. • Catalyze reversible reactions. • Highly specific, only compatible substrates can bind. • Work best at optimal temperature and pH.
Lock and Key Hypothesis	• Enzymes act like locks, and substrates are keys. • Substrates must fit the active site for a reaction to occur.

Factors Affecting Enzymatic Activity	• Temperature:
	  ○ Low temperature leads to slow reactions.
	  ○ Optimal temperature maximizes enzyme activity.
	  ○ High temperature causes denaturation and reduces activity.
	• pH:
	  ○ Optimal pH varies for different enzymes.
	  ○ Deviations from optimal pH reduce enzyme activity.
	• Substrate Concentration:
	  ○ Increasing substrate concentration increases enzyme activity until saturation.

What are some common pitfalls?

1. Misunderstanding the Role of Enzymes

Pitfall: Some students may mistakenly think that enzymes are consumed or used up during chemical reactions.

Elaboration: Enzymes are catalysts, which means they remain unchanged and can be reused after catalyzing a reaction. They lower the activation energy required for a reaction but are not part of the reaction's final products.

2. Confusion between Substrate and Enzyme

Pitfall: Students might mix up the substrate and the enzyme in a reaction.

Elaboration: The substrate is the molecule that the enzyme acts upon, while the enzyme is the biological molecule (usually a protein) that facilitates the reaction. Enzymes bind to substrates to form enzyme-substrate complexes.

3. Overlooking Specificity

Pitfall: Some students generalize enzyme functions or assume that one enzyme can work on any substrate.

Elaboration: Enzymes are highly specific in their actions. Each enzyme typically catalyzes a specific reaction or a group of closely related reactions.

4. Misconceptions about Active Sites

Pitfall: Some students may have misconceptions about the active site of an enzyme.

Elaboration: The active site is a region on the enzyme's surface where the substrate binds, and the catalytic reaction occurs. It's not a physical hole or tunnel but rather a specific molecular structure that accommodates the substrate.

5. Lack of Consideration for Factors Affecting Enzyme Activity

Pitfall: Students might overlook the influence of factors such as temperature and pH on enzyme activity.

Elaboration: Enzymes have optimal conditions under which they function most efficiently. Deviating from these conditions can lead to reduced enzyme activity or denaturation.

6. Assuming That the Optimum pH for All Enzymes Is the Same

Pitfall: Some students may mistakenly believe that enzymes have a uniform optimum pH at which they function optimally.

Elaboration: Optimum pH values of enzymes vary. Eg amylase in saliva has an optimum pH of 7 while protease in the stomach has an optimum pH of 2. Protease in the small intestine has an optimum pH of 8.

7. Believing Enzymes Are Produced All the Time

Pitfall: Some students may mistakenly think that enzymes are continually produced by cells, regardless of whether they are needed.

Elaboration: In reality, cells regulate enzyme production based on the demand for specific reactions. Enzymes are synthesized when required to catalyze specific biochemical processes. Cells have mechanisms to control enzyme production, ensuring that resources are not wasted on unnecessary enzyme synthesis.

Here are some specific study tips relevant to the topic of enzymes:

1. Focus on Key Enzymes:

   Start by understanding the key enzymes you need to know for your syllabus. These might include enzymes involved in digestion (e.g., amylase, pepsin), cellular respiration (e.g., ATP synthase), or other important biological processes.

2. Learn Enzyme-Substrate Specificity:

Pay close attention to how enzymes are specific to their substrates. Understand that enzymes have active sites with specific shapes that only fit particular substrates. Think of it as a lock-and-key mechanism.

3. Memorize Enzyme Names and Functions:

   Enzymes often have names that reflect their functions. For example, lipase breaks down lipids, and sucrase acts on sucrose. Try to connect the enzyme names with their functions to make memorization easier.

4. Understand Activation Energy:

   Enzymes lower the activation energy required for a chemical reaction to occur. Visualize the activation energy barrier as a hill that enzymes help molecules overcome. This concept is crucial for explaining enzyme function.

5. Practice Enzyme Reaction Mechanisms:

   Break down enzyme-catalyzed reactions step by step. Understand how substrates bind to the active site, what happens during the reaction, and how products are released. Practice writing out these reaction mechanisms.

6. Explore Factors Affecting Enzyme Activity:

   Study how factors like temperature and pH affect enzyme activity. Remember that enzymes have optimal conditions at which they work best, and deviations from these conditions can impact their effectiveness.

7. Use Mnemonics and Acronyms:

   Create mnemonics or acronyms to remember lists of enzymes or factors affecting enzyme activity. Mnemonics can make complex information more memorable.

8. Analyze Enzyme Graphs:

   When studying factors like temperature and pH, analyze enzyme activity graphs. Understand the patterns of enzyme activity concerning different conditions. Practice interpreting these graphs.

9. Practice with Sample Questions:

Find practice questions related to enzymes, especially those that require you to explain enzyme mechanisms or predict enzyme activity under specific conditions. This will help reinforce your understanding.

10. Connect Enzymes to Real-Life Examples:

    Relate enzyme concepts to real-life examples, such as digestion, photosynthesis, or cellular respiration. Understanding how enzymes function in everyday processes can make the topic more relatable.

11. Review and Practice Regularly:

    Consistent review and practice are essential for mastering enzyme topics. Regularly revisit enzyme concepts to reinforce your knowledge.

Remember that enzymes are a fundamental part of biology, and understanding their functions and mechanisms is crucial for success in your exams. Use these study tips to approach the topic systematically and confidently! You can do it! :)