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Biology Class 9 — Punjab Board (PECTAA)

CHAPTER 7

Enzymes

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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Chapter 7: Enzymes

Chapter 7 is about enzymes, the biological catalysts that make the chemical reactions of life fast enough to keep an organism alive. Without enzymes most of these reactions would happen far too slowly.

The notes first separate metabolism into catabolism and anabolism, then describe the characteristics of enzymes, the two models that explain how an enzyme binds its substrate, the effect of temperature, pH and substrate concentration on enzyme activity, and the two kinds of enzyme inhibition.

Learning Objectives

- Define metabolism, catabolism and anabolism with examples.
- Define enzymes and describe their main characteristics, including cofactors.
- Explain the lock and key model and the induced fit model of enzyme action.
- Describe how temperature, pH and substrate concentration affect enzyme activity.
- Distinguish competitive and non-competitive inhibition.

Key Concepts

7.1 Metabolism

Metabolism is the total of all chemical reactions that keep an organism alive. It has two parts. Catabolism breaks large molecules into smaller ones and releases energy; examples are cellular respiration, in which glucose is broken into carbon dioxide and water, and lipolysis, in which fats are broken into fatty acids and glycerol.

Anabolism builds large molecules from smaller ones and uses energy; examples are photosynthesis, in which carbon dioxide and water form glucose using light energy, and protein synthesis, in which amino acids are joined into proteins.

7.2 Enzymes and Their Characteristics

Enzymes are biological catalysts: they speed up reactions in living things without being used up. The molecule an enzyme acts on is its substrate. Enzymes can make reactions millions of times faster than they would be without a catalyst.

Nature and shape: almost all enzymes are proteins, usually of 100 to 1,000 amino acids, folded into a three-dimensional globular shape. This shape creates the active site. A few RNA molecules, called ribozymes, also work as catalysts, mainly in ribosomes.

Specificity: each enzyme acts on a particular substrate and catalyses a particular reaction; for example, amylase breaks starch into sugars but does not act on proteins.

Location: intracellular enzymes work inside cells (such as respiratory enzymes), while extracellular enzymes are released outside cells (such as digestive enzymes secreted into the stomach cavity).

Cofactors: many enzymes need a non-protein helper. Inorganic cofactors are metal ions such as iron and magnesium. Organic cofactors are either prosthetic groups, which are tightly bound (for example biotin and the haem group), or coenzymes, which are loosely bound and may leave after the reaction (for example many vitamins and NAD, NADP).

Enzymes often work in sequences, the product of one enzyme becoming the substrate of the next. They are also used widely in industry: in baking (breaking starch into sugars), cheese making, paper making, biological detergents (proteases remove protein stains, amylases remove starch) and fermentation.

7.3 Mechanism of Enzyme Action

The active site is a pocket or groove on the enzyme surface where the substrate binds and the reaction takes place. Binding forms an enzyme-substrate complex; the substrate is changed into product(s), which are then released, leaving the enzyme free to work again.

Lock and key model (Emil Fischer, 1894): the active site has a fixed, rigid shape, and only a substrate of exactly matching shape fits into it, like a key in a lock.

Induced fit model (Daniel Koshland, 1958): the active site is flexible. When the substrate binds, the active site changes shape slightly to fit it more closely, which helps the reaction. This model explains enzyme action better because it allows for the flexibility of protein molecules.

7.4 Factors Affecting Enzyme Activity

Temperature: as temperature rises, molecules move faster and collide more, so the rate increases up to the optimum temperature, which is about 37°C for most human enzymes. Above the optimum, heat breaks the bonds that hold the enzyme's shape; the active site is destroyed and the enzyme is denatured, so the rate falls rapidly.

pH: each enzyme works best at its optimum pH. A change in pH alters the charges on amino acids in the active site, slowing or stopping the enzyme. Pepsin in the stomach works best in strongly acidic conditions (pH about 1.5 to 2), while trypsin in the small intestine works best in alkaline conditions (pH about 7 to 8).

Substrate concentration: with a fixed amount of enzyme, adding more substrate raises the rate because more active sites are occupied. Eventually all active sites are busy (saturation), and adding more substrate no longer increases the rate.

7.5 Enzyme Inhibition

An inhibitor is a substance that binds to an enzyme and reduces its activity.

Competitive inhibitors resemble the substrate and compete with it for the active site. While the inhibitor occupies the active site, the substrate cannot bind. Some antibiotics work in this way by blocking bacterial enzymes.

Non-competitive inhibitors do not resemble the substrate and bind to another part of the enzyme. This changes the overall shape of the enzyme, including the active site, so the substrate no longer fits. Heavy metals such as mercury and some anticancer drugs act like this.

Important Definitions

Metabolism
The sum of all chemical reactions in an organism.

Catabolism
Breakdown of complex molecules into simpler ones, releasing energy.

Anabolism
Building of complex molecules from simpler ones, using energy.

Enzyme
A biological catalyst, usually a protein, that speeds up a reaction without being used up.

Substrate
The molecule on which an enzyme acts.

Active site
The region of an enzyme where the substrate binds and the reaction occurs.

Enzyme-substrate complex
The temporary combination of an enzyme with its substrate.

Ribozyme
An RNA molecule that acts as a catalyst.

Cofactor
A non-protein substance needed by an enzyme to be fully active.

Prosthetic group
An organic cofactor tightly bound to an enzyme.

Coenzyme
An organic cofactor loosely bound to an enzyme, such as NAD.

Optimum temperature
The temperature at which an enzyme works fastest.

Optimum pH
The pH at which an enzyme works fastest.

Denaturation
Permanent loss of an enzyme's shape, and so its activity, due to heat or extreme pH.

Saturation

The state in which all active sites are occupied, so extra substrate does not raise the rate.

Competitive inhibitor
An inhibitor that resembles the substrate and blocks the active site.

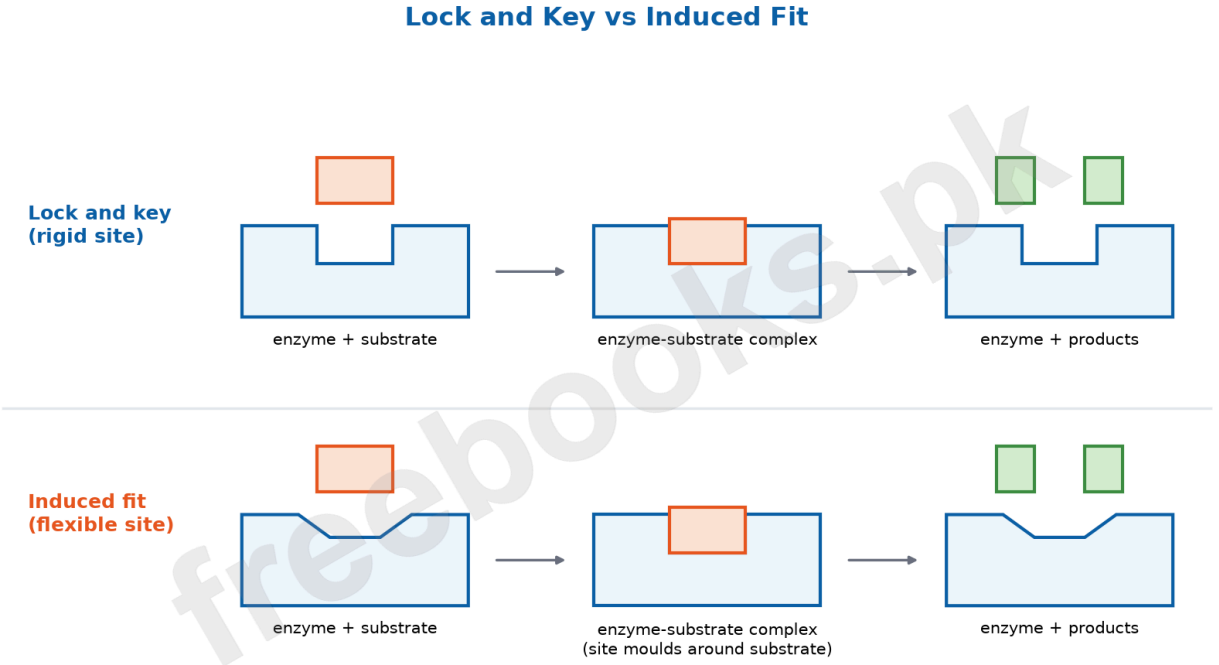
Non-competitive inhibitor
An inhibitor that binds elsewhere on the enzyme and changes the active site's shape.

Key Facts at a Glance

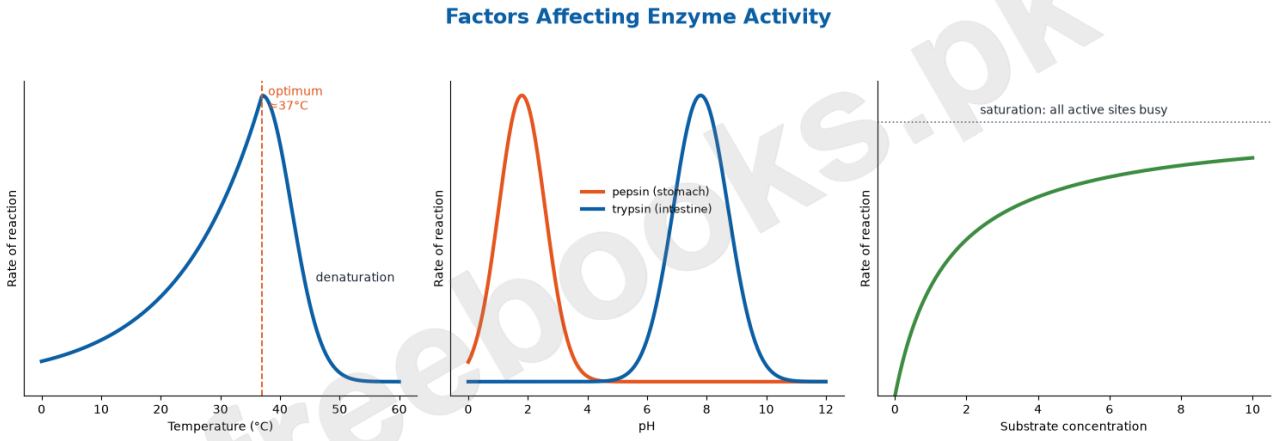
Topic	Key point
Catabolism examples	Cellular respiration, lipolysis
Anabolism examples	Photosynthesis, protein synthesis
Size of most enzymes	100–1,000 amino acids
Lock and key model	Emil Fischer, 1894 — rigid active site
Induced fit model	Daniel Koshland, 1958 — flexible active site
Optimum temperature (human)	About 37°C
Pepsin optimum pH	About 1.5–2 (acidic, stomach)
Trypsin optimum pH	About 7–8 (alkaline, small intestine)
Inorganic cofactors	Metal ions, e.g. Fe, Mg
Prosthetic groups	Tightly bound, e.g. biotin, haem
Coenzymes	Loosely bound, e.g. NAD, NADP, many vitamins
Competitive inhibition	Binds active site; e.g. some antibiotics
Non-competitive inhibition	Binds elsewhere; e.g. mercury, some anticancer drugs

Diagrams

Lock and key vs induced fit: Two simplified sequences showing the substrate fitting a rigid active site and a flexible active site moulding around the substrate.



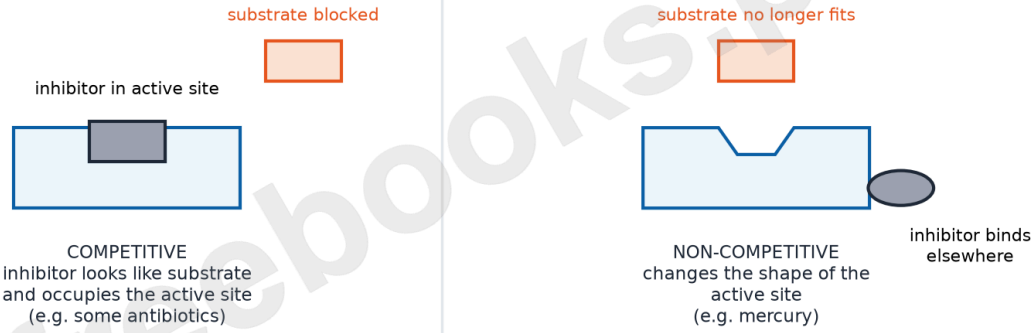
Factors affecting enzyme activity: Three graphs showing the effect of temperature, pH (pepsin and trypsin) and substrate concentration on reaction rate.



Types of enzyme inhibition: A competitive inhibitor blocking the active site and a non-competitive inhibitor binding elsewhere and changing the active site.

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Types of Enzyme Inhibition



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Short Questions and Answers

Why is photosynthesis called an anabolic process?
Because small molecules, carbon dioxide and water, are built into a larger molecule, glucose, and energy (light) is used in the process.

What is meant by enzyme specificity?
Each enzyme acts only on a particular substrate, because only that substrate fits the shape of its active site.

Why are enzymes said not to be used up?
After the product is released, the enzyme returns to its original form and can catalyse the same reaction again and again.

Distinguish a prosthetic group from a coenzyme.
Both are organic cofactors; a prosthetic group is tightly and permanently bound to the enzyme, while a coenzyme binds loosely and may leave after the reaction.

Give one example each of an intracellular and an extracellular enzyme.
Enzymes of cellular respiration act inside cells; pepsin is secreted into the stomach cavity and acts outside cells.

How are enzymes useful in washing powders?
Proteases digest protein stains such as blood and egg, and amylases remove starchy food residues, even at lower washing temperatures.

Why does boiling an enzyme stop its activity permanently?

High heat breaks the bonds holding the enzyme's folded shape, so the active site is destroyed (denatured) and cannot return to its original form.

Why does pepsin stop working when it reaches the small intestine?
The small intestine is alkaline, while pepsin works best at a very acidic pH; the change in pH alters its active site.

Why does the rate of reaction level off at high substrate concentration?
All the enzyme's active sites are already occupied, so extra substrate molecules have to wait; the enzyme is saturated.

How does the induced fit model improve on the lock and key model?
It treats the active site as flexible, changing shape slightly to fit the substrate, which matches the behaviour of real protein molecules.

Why is a competitive inhibitor able to block the active site?
It has a shape similar to the substrate, so it fits into the active site and keeps the real substrate out.

Where does a non-competitive inhibitor bind?
At a site other than the active site; this binding changes the enzyme's shape so the active site no longer fits the substrate.

Long Questions and Answers

Describe the characteristics of enzymes.

What is the chemical nature of enzymes?

Most enzymes are globular proteins of about 100 to 1,000 amino acids whose folded shape forms an active site. A few RNA molecules (ribozymes) also act as catalysts.

Why are enzymes specific?

The active site fits only one kind of substrate, so each enzyme catalyses one particular reaction, such as amylase breaking down starch.

What are cofactors?

Non-protein helpers needed by many enzymes: metal ions such as iron and magnesium, tightly bound prosthetic groups such as haem, and loosely bound coenzymes such as NAD.

Where do enzymes work and how are they used by humans?

Intracellular enzymes work inside cells and extracellular enzymes outside them. Industries use enzymes in baking, cheese making, paper making, detergents and fermentation.

Compare the lock and key model and the induced fit model.

What is the active site?

A pocket or groove on the enzyme surface where the substrate binds and forms an enzyme-substrate complex before being changed into product.

What does the lock and key model state?

Proposed by Emil Fischer in 1894, it states that the active site has a fixed shape into which only the exactly matching substrate fits, like a key into a lock.

What does the induced fit model state?

Proposed by Daniel Koshland in 1958, it states that the active site is flexible and changes shape when the substrate binds, gripping it more closely.

Which model is more accepted and why?

The induced fit model, because protein molecules are flexible and the change in shape helps explain how the enzyme strains bonds in the substrate to speed the reaction.

Explain the factors that affect enzyme activity.

How does temperature affect enzymes?

Rising temperature increases molecular movement and the rate, up to the optimum (about 37°C in humans). Above this the enzyme is denatured and the rate falls sharply.

How does pH affect enzymes?

Each enzyme has an optimum pH. Moving away from it changes the charges in the active site and reduces activity; pepsin works best at pH 1.5–2, trypsin at pH 7–8.

How does substrate concentration affect enzymes?

More substrate increases the rate until all active sites are occupied. At this saturation point the rate stays constant even if more substrate is added.

Why does the enzyme concentration matter at saturation?

At saturation the enzyme is the limiting factor, so only adding more enzyme, which provides more active sites, can raise the rate further.

Describe competitive and non-competitive inhibition.

What is enzyme inhibition?

The reduction of an enzyme's activity by a substance, called an inhibitor, that binds to the enzyme.

How does competitive inhibition work?

The inhibitor resembles the substrate and occupies the active site, so the substrate cannot bind. Some antibiotics block bacterial enzymes this way.

How does non-competitive inhibition work?

The inhibitor binds to another part of the enzyme and changes its overall shape, including the active site, so the substrate no longer fits. Mercury acts this way.

How can the two types be told apart?

Competitive inhibition can be reduced by adding a lot more substrate, which out-competes the inhibitor; non-competitive inhibition is not overcome by extra substrate because the active site itself has changed.

Multiple Choice Questions (MCQs)

Which of these is a catabolic process? (A) Photosynthesis (B) Protein synthesis (C) Cellular respiration (D) DNA replication
Correct answer: (C) Cellular respiration. Respiration breaks glucose down.

Most enzymes are chemically: (A) Lipids (B) Proteins (C) Carbohydrates (D) Nucleic acids
Correct answer: (B) Proteins. Enzymes are mainly globular proteins.

RNA molecules that act as catalysts are called: (A) Coenzymes (B) Ribozymes (C) Hormones (D) Antibodies
Correct answer: (B) Ribozymes. Ribozymes are catalytic RNA.

The haem group of an enzyme is an example of a: (A) Coenzyme (B) Prosthetic group (C) Substrate (D) Inhibitor
Correct answer: (B) Prosthetic group. Haem is tightly bound.

NAD is an example of a: (A) Coenzyme (B) Prosthetic group (C) Metal ion (D) Substrate
Correct answer: (A) Coenzyme. NAD binds loosely.

The lock and key model was proposed by: (A) Koshland (B) Fischer (C) Krebs (D) Calvin
Correct answer: (B) Fischer. Emil Fischer, 1894.

According to the induced fit model, the active site: (A) Is rigid (B) Changes shape when substrate binds (C) Is absent (D) Binds any molecule
Correct answer: (B) Changes shape when substrate binds. The active site is flexible.

Most human enzymes work best at: (A) 20°C (B) 37°C (C) 60°C (D) 100°C
Correct answer: (B) 37°C. Body temperature is about 37°C.

An enzyme heated to 80°C stops working because it is: (A) Saturated (B) Denatured (C) Inhibited competitively (D) Activated
Correct answer: (B) Denatured. Heat destroys its shape.

Trypsin works best in: (A) Strongly acidic medium (B) Alkaline medium (C) Neutral water only (D) Any pH
Correct answer: (B) Alkaline medium. Trypsin's optimum pH is about 7–8.

Adding more substrate does not raise the rate when: (A) Enzymes are saturated (B)

Temperature is low (C) pH is optimum (D) No inhibitor is present
Correct answer: (A) Enzymes are saturated. All active sites are occupied.

A competitive inhibitor: (A) Binds away from the active site (B) Resembles the substrate (C) Is always a metal (D) Increases enzyme activity
Correct answer: (B) Resembles the substrate. It competes for the active site.

Mercury inhibits enzymes by: (A) Competitive inhibition (B) Non-competitive inhibition (C) Acting as a coenzyme (D) Lowering temperature
Correct answer: (B) Non-competitive inhibition. It binds elsewhere and changes shape.

Protease enzymes in detergents remove: (A) Grease stains (B) Protein stains (C) Ink (D) Rust
Correct answer: (B) Protein stains. Proteases digest proteins.

Quick Revision Summary

- Metabolism = catabolism (breakdown, releases energy: respiration, lipolysis) + anabolism (build-up, uses energy: photosynthesis, protein synthesis).
- Enzymes: biological catalysts, mostly globular proteins (100–1,000 amino acids); specific; not used up; some RNA catalysts (ribozymes).
- Cofactors: metal ions (Fe, Mg); prosthetic groups (tight: biotin, haem); coenzymes (loose: NAD, NADP, vitamins).
- Active site → enzyme-substrate complex → product. Lock and key (Fischer 1894, rigid) vs induced fit (Koshland 1958, flexible).
- Temperature: rate rises to optimum (≈37°C) then denaturation. pH: optimum differs (pepsin 1.5–2, trypsin 7–8). Substrate: rate rises then saturation.
- Competitive inhibitor: substrate look-alike, blocks active site. Non-competitive: binds elsewhere, changes active site (e.g. mercury).

Exam Tips

- Learn the two models with their scientist and year: Fischer 1894 (lock and key), Koshland 1958 (induced fit).
- In graph questions, describe the curve in three parts: rising part, peak (optimum) and fall (denaturation).
- Always use the word 'denatured', not 'killed', for enzymes; enzymes are molecules, not living things.
- For inhibition, mention where the inhibitor binds (active site or elsewhere) and give one example of each.
- Practise one-line examples of catabolism and anabolism; they are frequent short questions.

Note on Facts

The textbook gives 'antibiotics' in general as examples of competitive inhibitors. Only some antibiotics act this way (sulfonamides are a classic example); others, such as penicillin, bind to their target enzyme permanently and are not simple competitive inhibitors.

The textbook's key points say enzymes are proteins, while its main text also mentions ribozymes. The accurate statement is that almost all enzymes are proteins and a few catalysts are RNA.