Enzymes
Enzymes

Contents

- What are enzymes?
- How do enzymes work?
- Enzymes in life
- Enzymes in industry
- Summary activities
What’s the missing link?

What is the link between digestion, photosynthesis, bread, wine and washing powder?

They all depend on enzymes.
What are enzymes?

Enzymes are **biological catalysts** – they speed up the chemical reactions that take place inside all cells, but without being used up in the process.

There are many thousands of different types of enzyme, and each one catalyzes a different reaction.

Enzymes occur naturally in all organisms, but they are increasingly being used in industrial processes.
What are enzymes made of?

Enzymes are protein molecules, and so are made up of amino acids. Most enzymes contain between 100 and 1,000 amino acids.

These amino acids are joined together in a long chain, which is folded to produce a unique 3D structure.
Why is shape important?

The shape of an enzyme is very important because it has a direct effect on how it catalyzes a reaction.

Why do enzymes have different shapes?

An enzyme’s shape is determined by the sequence of amino acids in its structure, and the bonds which form between the atoms of those molecules.

Different types of enzymes have different shapes and functions because the order and type of amino acids in their structure is different.
### Enzymes: true or false?

Are these statements about enzymes true or false?

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Enzymes are proteins.</td>
<td></td>
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<tr>
<td>2.</td>
<td>Enzymes are catalysts.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>The shape of an enzyme is critical to its function.</td>
<td></td>
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<tr>
<td>4.</td>
<td>An enzyme’s shape is determined by the sequence of carbohydrates in its structure.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Enzymes are non-specific.</td>
<td></td>
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</tbody>
</table>

[Buttons: true, false, solve]
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Fussy enzymes?

Why are enzymes so specific in their reactions?
Why are enzymes so specific?

Enzymes are very specific about which reactions they catalyze. Only molecules with exactly the right shape will bind to the enzyme and react. These are the **reactant**, or substrate, molecules.

The part of the enzyme to which the reactant binds is called the **active site**.

This is a very specific shape and the most important part of the enzyme.
In the same way that a key fits into a lock, so a substrate is thought to fit into an enzyme’s active site. The enzyme is the **lock**, and the reactant is the **key**.

\[
\text{enzyme} \ + \text{reactant} \leftrightarrow \text{enzyme-reactant complex} \leftrightarrow \text{enzyme} \ + \text{products}
\]
What is the 'lock and key' model?

Enzymes are very large molecules, but only a small part of their structure, the active site, is directly involved in reactions.

Click "play" to find out more about the 'lock and key' model.
Why do enzymes speed up reactions?

Enzymes speed up reactions by lowering the activation energy \( (E_a) \) of a reaction. The activation energy is the energy needed to start a reaction.

Different reactions have different activation energies.
Factors affecting enzymes

The rate of enzyme–catalyzed reactions depends on several factors. What are some of these?

Factors that affect the rate of a reaction include:
- temperature
- pH
- substrate concentration
- enzyme concentration
- surface area
- pressure.

All enzymes work best at only one particular temperature and pH: this is called the optimum.

Different enzymes have different optimum temperatures and pH values.
Factors affecting enzymes

If the temperature and pH changes sufficiently beyond an enzyme’s optimum, the shape of the enzyme irreversibly changes.

This affects the shape of the active site and means that the enzyme will no longer work.

When this happens the enzyme is **denatured**.
Enzymes and temperature

How does temperature affect catalase activity?

Potatoes contain an enzyme called catalase. Catalase catalyzes the breakdown of hydrogen peroxide into oxygen and water.

Click "start" to find out more.
How do inhibitors work?

Molecules that decrease the rate of enzyme-catalyzed reactions are called inhibitors.

Inhibitors can be competitive or non-competitive.

Click "play" to find out more.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>active site</td>
<td>The part of the enzyme into which the reactant molecule fits.</td>
</tr>
<tr>
<td>amino acid</td>
<td>A molecule that is the basic component of proteins.</td>
</tr>
<tr>
<td>denatured</td>
<td>The temperature and pH at which an enzyme-catalysed reaction proceeds at the fastest rate.</td>
</tr>
<tr>
<td>inhibitor</td>
<td>The state of an enzyme when it has been irreversibly damaged and has changed shape.</td>
</tr>
<tr>
<td>optimum</td>
<td>A molecule that decreases the rate of enzyme-catalyzed reactions.</td>
</tr>
<tr>
<td>reactant</td>
<td>The molecule that binds to and reacts with the enzyme.</td>
</tr>
</tbody>
</table>
Enzymes and cells

Enzymes catalyze the thousands of reactions that need to take place in order to maintain life. What are some of these reactions?

- digestion
- respiration
- photosynthesis (plants and some bacteria)
- protein synthesis.
What are digestive enzymes?

Not all enzymes work inside cells. In what process do enzymes work outside cells?

**Digestive enzymes** are produced by specialized cells in the pancreas and digestive tract.

These enzymes pass out of the cells and into the stomach and small intestine.

Here the enzymes help to break down large food molecules into smaller molecules that are more easily absorbed.
Enzymes of digestion

Which enzymes break down each nutrient?

Carbohydrates, proteins and fats are broken down by different enzymes in the digestive process.

Choose a nutrient to see how each enzyme works.

- starch
- protein
- fat
When food enters the stomach it stimulates the secretion of hydrochloric acid (HCl) from the stomach wall. HCl increases the acidity of the stomach to about pH2 – the optimum pH for stomach enzymes.
Digestion in the small intestine

Digestive enzymes found in the small intestine are damaged by a strongly acidic pH.

How does the body avoid this problem?

The liver produces **bile** (an alkali), which is stored in the gall bladder and released into the small intestine.

Bile neutralizes the acidic contents coming from the stomach, creating the alkaline environment that the intestinal enzymes need to work.
Aerobic respiration is a series of reactions that release energy from glucose using oxygen.

Aerobic respiration can be summarized by this equation:

\[
glucose + oxygen \rightarrow carbon\ dioxide + water + energy
\]

In animals, plants and fungi, most of the reactions in aerobic respiration take place in mitochondria.

Mitochondria are the energy-producing part of the cell.
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Enzymes in the home

How many items are made using enzymes?
How are enzymes used in breadmaking?

Bread is made by mixing flour, water and yeast to create a dough, which is then baked in a hot oven.

Click "play" to find out how the yeast's enzymes are involved.
Which enzymes are used in producing alcohol?

Natural and artificially-engineered enzymes play a widespread role in the production of alcohol.

Click "start" to find out more.
A type of enzyme called **isomerase** converts the sugar glucose into fructose, another type of sugar.

Fructose is sweeter than glucose, so a smaller amount is needed. This makes fructose syrup a useful ingredient in slimming foods.

**Invertase** is used to create soft-centered chocolates. The centre initially contains sucrose (cane sugar) and is hard.

The invertase breaks down the sucrose into the simpler sugars glucose and sucrose, making the centre soft andrunny.
How do enzymes help to clean clothes?

Biological washing powders and liquids contain enzymes that help remove stains.

The enzymes are coated with a special wax that melts in the wash, releasing the enzymes. Once the stains have been broken down, they are easier for the detergent to remove.

- **Proteases** break down proteins in stains such as grass, blood and sweat.
- **Lipases** break down stains containing fat and oil.
- **Carbohydrases** break down carbohydrate-based stains, such as starch.
Producing enzymes

Many of the enzymes used in the home and in industry are naturally produced by micro-organisms such as bacteria and yeast.

These enzymes are very useful in manufacturing processes because they catalyze reactions in a very predictable way and can replace harmful chemical supplements.

Bacteria and yeast can be manipulated and/or genetically engineered to produce these enzymes on an industrial scale. This process is called fermentation.
How are enzymes produced by fermentation?

Enzymes are manufactured by a process of fermentation and downstream processing.

Click "start" to find out how it works.
Enzymes are used in two main types of industrial process:

- **batch production** – reactants are converted into products, and the enzymes are destroyed in the process.

- **continuous production** – a constant stream of reactants is passed over immobilized enzymes so products are continuously formed. The enzymes are not destroyed.

Immobilized enzymes are attached to unreactive materials such as alginate beads (derived from seaweed).

What are the advantages and disadvantages of batch and continuous production?
Are enzymes the future?

Are these statements advantages or disadvantages?

**Advantages**

**Disadvantages**

Enzymes are easily controlled by slight changes in pH or temperature.
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Glossary (1/2)

- **activation energy** – The energy needed to start a chemical reaction.

- **active site** – The part of the enzyme into which the reactant molecule fits.

- **catalyst** – A substance that changes the rate of a reaction without being used up.

- **denatured** – The state of an enzyme when it has been irreversibly damaged and has changed shape.

- **enzyme** – A biological catalyst.

- **fermentation** – The conversion of sugar to ethanol and carbon dioxide by enzymes in yeast.
- **inhibitor** – A molecule that decreases the rate of enzyme-catalysed reactions.

- **lock and key** – A model of how enzymes work and the importance of their shape.

- **optimum** – The temperature and pH at which an enzyme-catalyzed reaction proceeds at the fastest rate.

- **reactant** – The molecule that binds to and reacts with the enzyme.

- **respiration** – The series of reactions that release energy from glucose, in the presence of oxygen.
Anagrams

How quickly can you unscramble anagrams of words about enzymes?

start
Match each enzyme to its reactant

- catalase
- carboxydrase
- protease
- lipase
- amylase
- invertase
- fats
- hydrogen peroxide
- starch
- sucrose
- carbohydrate
- protein

solve
What are the correct labels for each structure?
Do you need a catalyst for this quiz on enzymes?