WJEC (England) Biology AS-level

1.4: Biological reactions are regulated by enzymes

Notes

Enzymes are globular proteins which increase the **rate of reaction** by lowering the **activation energy** of the reaction they catalyse. **Active site** is the area of the enzyme where the reaction with the **substrate** takes place. Enzymes are **specific to substrates** they bind to meaning that only one type of substrate fits into the active site of the enzyme. When the enzyme and substrate form a **complex**, the structure of the enzyme is altered so that the active site of the enzyme fits around the substrate. This is called the **induced fit model**. The lock and key model of enzyme activity is based on the idea that the substrate fits into the enzyme the way a key fits into the lock due to the complementarity in shape between the two structures.

Enzymes can be **intracellular** and catalyse reactions inside of cells, for instance ATP synthase, DNA helicase which unwinds the helix, DNA polymerase involved in catalysing the formation of phosphodiester bonds as well as lysosome which carries hydrolytic enzymes. Examples of **extracellular** enzymes are digestive enzymes secreted by the cell.

Enzymes can be **immobilised** for the use in industrial processes with the purpose of making the enzyme more stable and reusable.

Factors affecting the rate of enzyme-controlled reactions:

- **Enzyme concentration** – the rate of reaction increases as enzyme concentration increases as there are more active sites for substrates to bind to, however increasing the enzyme concentration beyond a certain point has no effect on the rate of reaction as there are more active sites than substrates so substrate concentration becomes the limiting factor.

- **Substrate concentration** – as concentration of substrate increases, rate of reaction increases as more enzyme-substrate complexes are formed. However, beyond a certain point the rate of reaction no longer increases as enzyme concentration becomes the limiting factor.

- **Temperature** – rate of reaction increases up to the optimum temperature which is the temperature enzymes work best at, rate of reaction decreases beyond the optimum temperature.

- **pH** – in the case where the pH is more acidic than the optimum pH, H^+ ions disrupt the enzyme-substrate binding and decrease the rate of reaction. In the case where the pH is more alkaline than the optimum, the OH^- ions disrupt the binding, also leading to a decrease in product formation.

Inhibitors

An **inhibitor** is a substance which slows down or stops a reaction by affecting the binding of substrate to the enzymes. Inhibitors can either be **reversible and irreversible.**

Examples of irreversible inhibitors include **heavy metal ions** such as mercury and silver which cause disulphide bonds within the protein structure to break, as a result causing the shape of the active site to change, thus affecting protein activity. Other examples include cyanide which is a nerve gas that covalently binds to the active site, therefore preventing the binding of the substrate.

Reversible inhibitors bind to the active site through hydrogen bonds and weak ionic interactions therefore they do not bind permanently. Reversible inhibitors can either be **competitive or non-competitive.**

Competitive inhibitors are similar in structure to the substrate molecule therefore they bind to the active site of the enzyme, decreasing its activity as they compete with substrate for the enzyme. The amount of product formed remains the same, however the rate at which product formation occurs decreases. The higher the concentration of competitive inhibitor the lower the reaction rate. Increasing the substrate reverses the effect of competitive inhibitors by outcompeting them.

Non-competitive inhibitor does not bind to the active site, it binds at another site on the enzyme known as the allosteric site. Binding of the non-competitive inhibitors changes the shape of the active site therefore preventing the binding of the substrate. As a result, the enzyme-substrate complex does not form. Increasing the concentration of substrate has no effect on non-competitive inhibition.

Many drugs are inhibitors. Examples include **penicillin** which is used to fight bacterial infections, it is an inhibitor of enzyme transpeptidase which plays an important role in cell wall formation.

Other examples include **Ritonavir** which is an antiretroviral drug used to treat HIV which inhibits HIV protease which is responsible for assembly of new viral particles and spread of infection.

Digitalis, a chemical extracted from foxglove which can be used to treat arrhythmia is a non-competitive inhibitor which binds to an enzyme involved in restricting contraction of the cardiac muscle.