Enzymes

- Enzymes are biological catalysts.
- There are about 40,000 different enzymes in human cells, each controlling a different chemical reaction.
- They increase the rate of reactions by a factor of between 106 to 1012 times, allowing the chemical reactions that make life possible to take place at normal temperatures.
- As well as catalysing all the metabolic reactions of cells (such as respiration, photosynthesis and digestion), they may also act as motors, membrane pumps and receptors.

Enzyme Structure:

- Enzymes are proteins, and their function is determined by their complex structure.
- The reaction takes place in a small part of the enzyme called the **active site**, while the rest of the protein acts as "scaffolding".
- The amino acids around the active site attach to the substrate molecule and hold it in position while the reaction takes place.
- This makes the enzyme specific for one reaction only, as other molecules won't fit into the active site – their shape is wrong.
- Many enzymes need cofactors (or coenzymes) to work properly. These can be metal ions (such as Fe^{2+}, Mg^{2+}, Cu^{2+}) or organic molecules (such as haem, biotin, FAD, NAD or coenzyme A).
- Many of these are derived from dietary vitamins, which is why they are so important. The complete active enzyme with its cofactor is called a **holoenzyme**, while just the protein part without its cofactor is called the **apoenzyme**.

How do enzymes work?

There are three parts to our thinking about enzyme catalysis.

1. Reaction Mechanism:

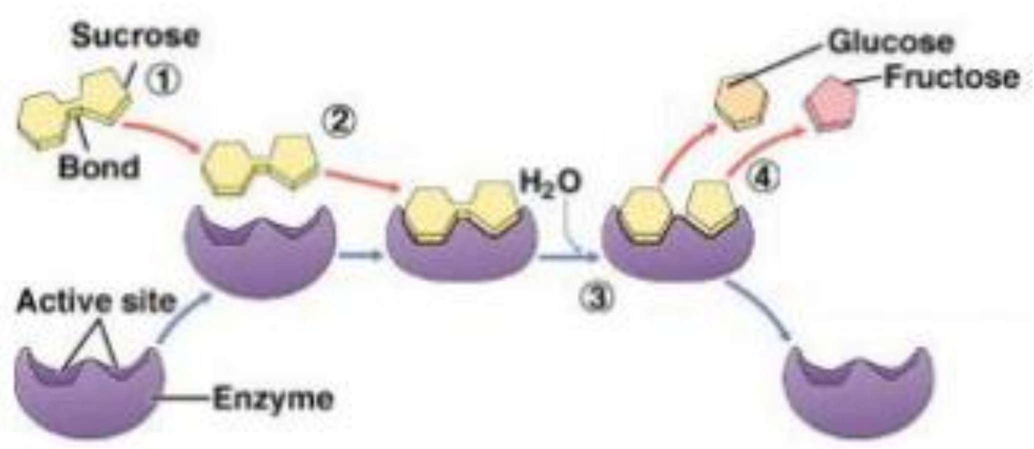
In any chemical reaction, a substrate (S) is converted into a product (P):

In an enzyme-catalysed reaction, the substrate first binds to the active site of the enzyme to form an enzyme-substrate (ES) complex, then the substrate is converted into product whilst attached to the enzyme, and finally the product is released.

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_2} E + P$$

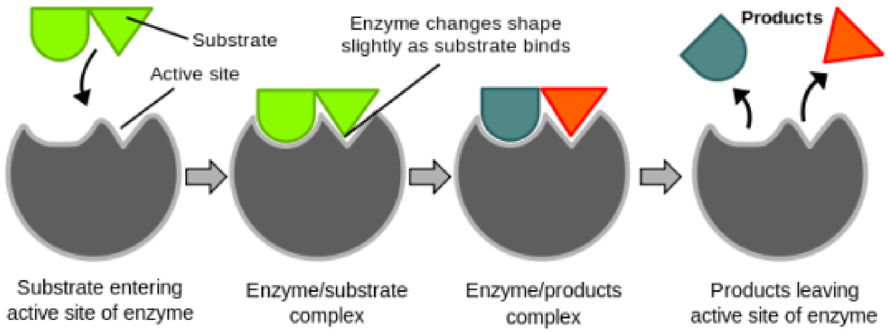
Where E = Enzyme
S = Substrate
P = Products

For example: the action of the enzyme sucrose hydrolysing sucrose into glucose and fructose



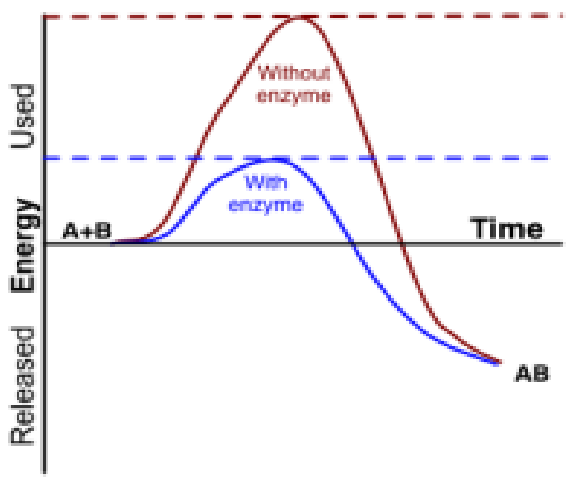
2. Molecular Geometry

- The substrate molecule is complementary in shape to that of the active site.
- It was thought that the substrate exactly fitted into the active site of the enzyme molecule like a key fitting into a lock (the now discredited 'lock and key' theory).



3. Energy Changes

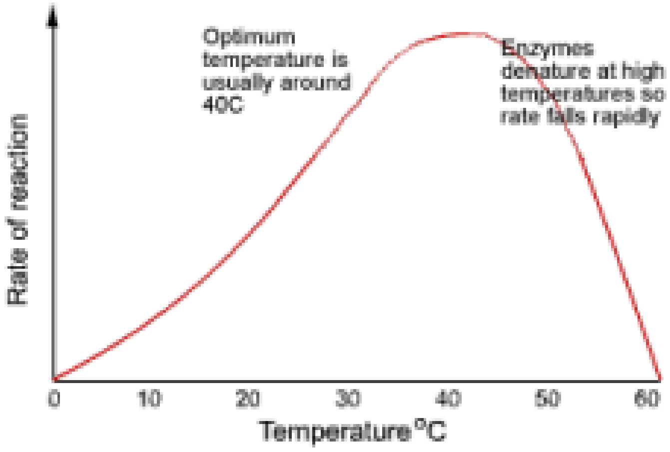
- The way enzymes work can also be shown by looking at the energy changes during a chemical reaction.
- In a reaction where the product has a lower energy than the substrate, the substrate naturally turns into product (i.e. the equilibrium lies in the direction of the product).
- Before it can change into product, the substrate must overcome an "energy barrier" called the activation energy.



Factors that Affect the Rate of Enzyme Reactions

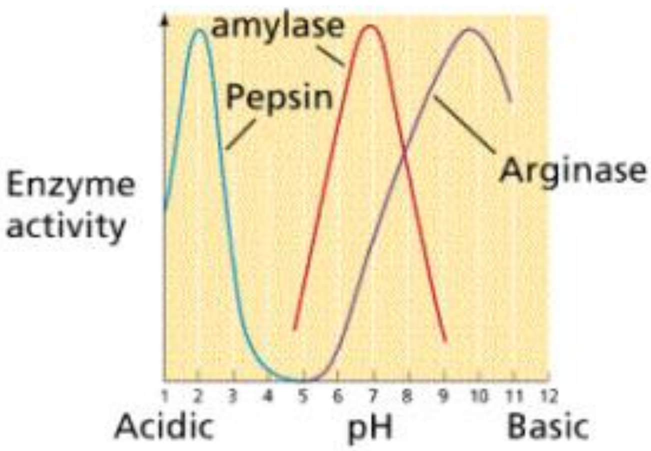
1. **Temperature**:

Enzymes have an optimum temperature at which they work fastest. For mammalian enzymes this is about 40°C, but there are enzymes that work best at very different temperatures, e.g. enzymes from the arctic snow flea work at -10°C, and enzymes from thermophilic bacteria work at 90°C.



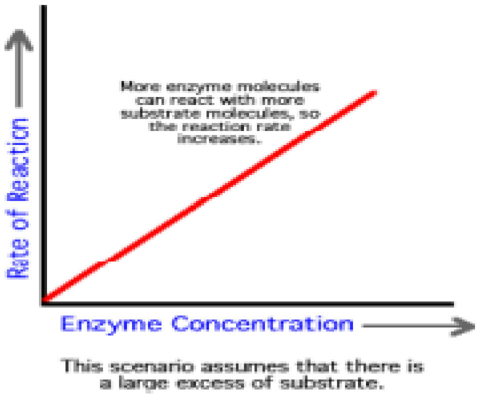
2. pH:

Enzymes have an optimum pH at which they work fastest. For most enzymes this is about pH 7-8 (normal body pH), but a few enzymes can work at extreme pH, such as gastric protease (pepsin) in our stomach, which has an optimum of pH 1.



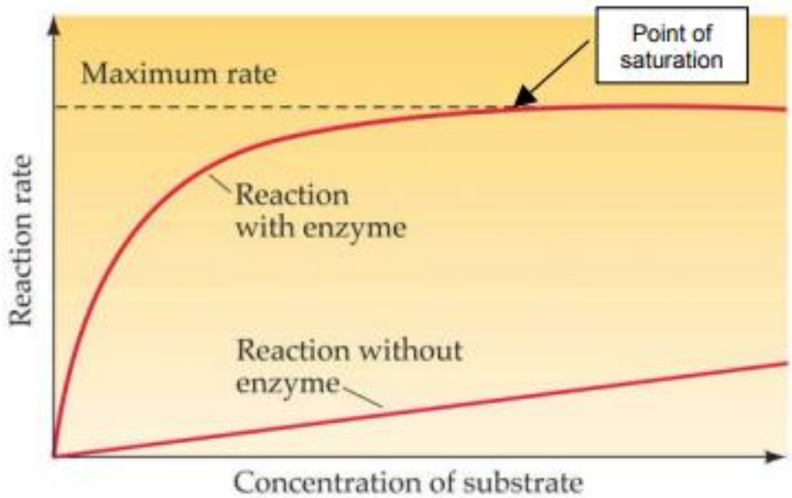
3. Enzyme concentration:

As the enzyme concentration increases the rate of the reaction also increases, because there are more enzyme molecules (and so more active sites), available to catalyse the reaction therefore more enzyme-substrate complexes form.



4. Substrate concentration:

The rate of an enzyme-catalysed reaction is also affected by substrate concentration. As the substrate concentration increases, the rate increases because more substrate molecules can collide with active sites, so more enzyme-substrate complexes form.



5. **Covalent modification** :

- The activity of some enzymes is controlled by other enzymes, which modify the protein chain by cutting it, or adding a phosphate or methyl group.
- This modification can turn an inactive enzyme into an active enzyme (or vice versa), and this is used to control many metabolic enzymes and to switch on enzymes in the gut e.g.

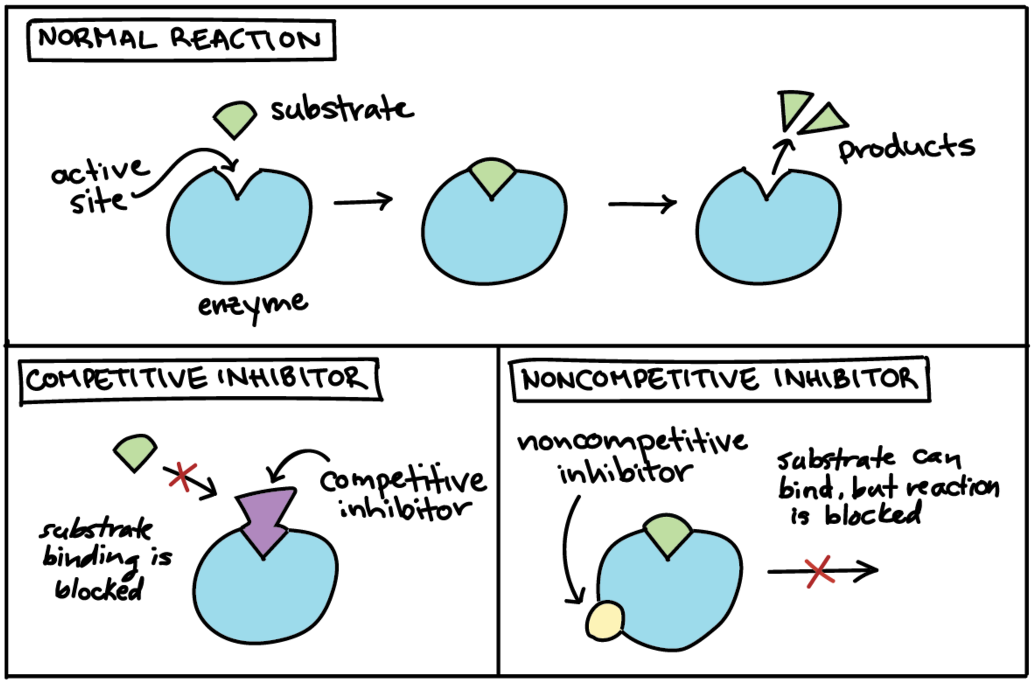
HCl in stomach → activates pepsin → activates rennin.

6. Inhibitors :

Inhibitors inhibit the activity of enzymes, reducing the rate of their reactions. They are found naturally, but are also used artificially as drugs, pesticides and research tools. There are two kinds of inhibitors:

(a) A competitive inhibitor molecule has a similar structure to the substrate molecule, and so it can fit into the active site of the enzyme.

(b) A non-competitive inhibitor molecule is quite different in structure from the substrate and does not fit into the active site.



7. Feedback Inhibition (Allosteric Effectors):

The activity of some enzymes is controlled by certain molecules binding to a specific regulatory (or allosteric) site on the enzyme, distinct from the active site. Different molecules can either inhibit or activate the enzyme, allowing sophisticated control of the rate. They are generally activated by the substrate of the pathway and inhibited by the product of the pathway, thus only turning the pathway on when it is needed. This process is known as feedback inhibition.