Most enzymes are proteins. They are capable of catalyzing (speeding up) biochemical reactions and are therefore called biological catalysts. Enzymes act on one or more compounds (called the substrate). They may break a single substrate molecule down into simpler substances, or join two or more substrate molecules chemically together. The enzyme itself is unchanged in the reaction; its presence merely allows the reaction to take place more rapidly. When the substrate attains the required activation energy to enable it to change into the product, there is a 50% chance that it will proceed forward to form the product, otherwise it reverts back to a stable form of the reactant again. The part of the enzyme's surface into which the substrate is bound and undergoes reaction is known as the active site. This is made of different parts of polypeptide chain folded in a specific shape so they are closer together. For some enzymes, the complexity of the binding sites can be very precise, allowing only a single kind of substrate to bind to it. Some other enzymes have lower specificity and will accept a wide range of substrates of the same general type (e.g. lipases break up any fatty acid chain length of lipid). This is because the enzyme is specific for the type of chemical bond involved and not an exact substrate.

**Enzyme Structure**

The model on the right is of an enzyme called Ribonuclease S, which breaks up RNA molecules. It is a typical enzyme, being a globular protein and composed of up to several hundred atoms. The darkly shaded areas are called active sites and make up the cleft; the region into which the substrate molecule(s) are drawn. The correct positioning of these sites is critical for the catalytic reaction to occur. The substrate (RNA in this case) is drawn into the cleft by the active sites. By doing so, it puts the substrate molecule under stress, causing the reaction to proceed more readily.

**How Enzymes Work**

The lock and key model proposed earlier this century suggested that the substrate was simply drawn into a closely matching cleft on the enzyme molecule. More recent studies have revealed that the process more likely involves an induced fit (see diagram on the right), where the enzyme or the reactants change their shape slightly. The reactants become bound to enzymes by weak chemical bonds. This binding can weaken bonds within the reactants themselves, allowing the reaction to proceed more readily.

The presence of an enzyme simply makes it easier for a reaction to take place. All catalysts speed up reactions by influencing the stability of bonds in the reactants. They may also provide an alternative reaction pathway, thus lowering the activation energy needed for a reaction to take place (see the graph below).

![Graph showing activation energy before and after enzyme]

**Induced Fit Model**

An enzyme fits to its substrate somewhat like a lock and key. The shape of the enzyme changes when the substrate fits into the cleft (called the induced fit).

1. Two substrate molecules are drawn into the cleft of the enzyme.
2. The enzyme changes shape, forcing the substrate molecules to combine.
3. The resulting end product is released by the enzyme which returns to its normal shape, ready to receive more.
Catabolic reactions
Some enzymes can cause a single substrate molecule to be drawn into the active site. Chemical bonds are broken, causing the substrate molecule to break apart to become two separate molecules. **Examples:** digestion, cellular respiration.

Anabolic reactions
Some enzymes can cause two substrate molecules to be drawn into the active site. Chemical bonds are formed, causing the two substrate molecules to form bonds and become a single molecule. **Examples:** protein synthesis, photosynthesis.

1. Give a brief account of enzymes as biological catalysts, including reference to the role of the active site:

2. Distinguish between catabolism and anabolism, giving an example of each and identifying each reaction as endergonic or exergonic:

3. Outline the key features of the 'lock and key' model of enzyme action:

4. Outline the 'induced fit' model of enzyme action, explaining how it differs from the lock and key model:

5. Identify two factors that could cause enzyme denaturation, explaining how they exert their effects (see the next activity):
   (a)
   (b)

6. Explain what might happen to the functioning of an enzyme if the gene that codes for it was altered by a mutation:
Enzymes are sensitive molecules. They often have a narrow range of conditions under which they operate properly. For most of the enzymes associated with plant and animal metabolism, there is little activity at low temperatures. As the temperature increases, so too does the enzyme activity, until the point is reached where the temperature is high enough to damage the enzyme's structure. At this point, the enzyme ceases to function; a phenomenon called enzyme or protein denaturation.

1. **Enzyme concentration**
   (a) Describe the change in the rate of reaction when the enzyme concentration is increased (assuming that substrate and cofactors are not limiting):

   

   (b) Suggest how a cell may vary the amount of enzyme present in a cell:

   

2. **Substrate concentration**
   (a) Describe the change in the rate of reaction when the substrate concentration is increased (assuming a fixed amount of enzyme and ample cofactors):

   

   (b) Explain why the rate changes the way it does:

   

3. **Temperature**
   Higher temperatures speed up all reactions, but few enzymes can tolerate temperatures higher than 50–60°C. The rate at which enzymes are denatured (change their shape and become inactive) increases with higher temperatures.

   (a) Describe what is meant by an optimum temperature for enzyme activity:

   

   (b) Explain why most enzymes perform poorly at low temperatures:

   

4. **pH (acidity/alkalinity)**
   Like all proteins, enzymes are denatured by extremes of pH (very acid or alkaline). Within these extremes, most enzymes are still influenced by pH. Each enzyme has a preferred pH range for optimum activity.

   (a) State the optimum pH for each of the enzymes:

   Pepsin: ___________ Trypsin: ___________ Urease: ___________

   (b) Pepsin acts on proteins in the stomach. Explain how its optimum pH is suited to its working environment:
Enzyme activity is often influenced by the presence of other chemicals. Some of these may enhance an enzyme's activity. Called **cofactors**, they are a nonprotein component of an enzyme and may be organic molecules (coenzymes) or inorganic ions (e.g., Ca²⁺, Zn²⁺). Enzymes may also be deactivated, temporarily or permanently, by chemicals called enzyme inhibitors.

**Types of Enzyme**

Nearly all enzymes are made of protein, although RNA has been demonstrated to have enzymatic properties. Some enzymes consist of just protein, while others require the addition of extra components to complete their catalytic properties. These may be permanently attached parts called **prosthetic groups**, or temporarily attached pieces (coenzymes) that detach after a reaction, and may participate with another enzyme in other reactions.

**Reversible Enzyme Inhibitors**

Enzyme inhibitors may be reversible or irreversable. **Reversible inhibitors** are used to control enzyme activity. There is often an interaction between the substrate and the enzyme controlling the reaction. Buildup of the end product or a lack of substrate may serve to deactivate the enzyme. This deactivation may take the form of **competitive** (competes for the active site) or **noncompetitive** inhibition. While noncompetitive inhibitors have the effect of slowing down the rate of reaction, **allosteric inhibitors** block the active site altogether and prevent its functioning.

1. Describe the general role of **cofactors** in enzyme activity:

2. (a) List four **heavy metals** that are toxic to humans:

   (b) Explain in general terms why these heavy metals are toxic to life:

3. There are many enzyme inhibitors that are not heavy metals (e.g., those found in some pesticides).

   (a) Name a **common poison** that is an enzyme inhibitor, but not a heavy metal:

   (b) Try to find out how this poison interferes with enzyme function. Briefly describe its effect on a named enzyme:

4. Distinguish between **competitive** and **noncompetitive** inhibition:

5. Explain how **allosteric inhibitors** differ from other noncompetitive inhibitors: