26 Proteins

Key Idea: Protein structure is related to its biological function. Proteins can be classified according to their structure or their function. **Globular proteins** are spherical and soluble in water (e.g. enzymes). **Fibrous proteins** have an elongated structure and are not water soluble. They are often made up of repeating units and provide stiffness and rigidity to the more fluid components of cells and tissues. They have important structural and contractile roles.

Globular Proteins

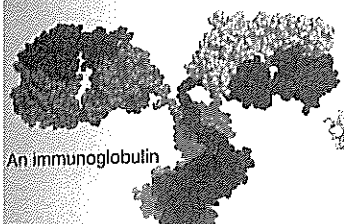
Properties
- Easily water soluble
- Tertiary structure critical to function
- Polypeptide chains folded into a spherical shape

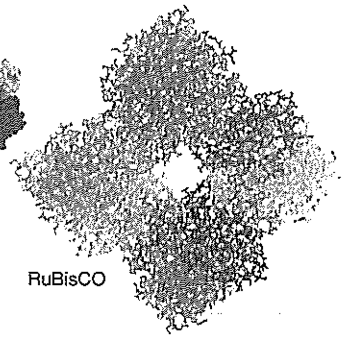
Function
- Catalytic, *e.g. enzymes*
- Regulatory, *e.g. hormones (insulin)*
- Transport, *e.g. haemoglobin*
- Protective, *e.g. immunoglobulins (antibodies)*

Fibrous Proteins

Properties
- Water insoluble
- Very tough physically; may be supple or stretchy
- Parallel polypeptide chains in long fibres or sheets

Function
- Structural role in cells and organisms e.g. *collagen found in connective tissue, cartilage, bones, tendons, and blood vessel walls.*
- Contractile e.g. *myosin, actin*

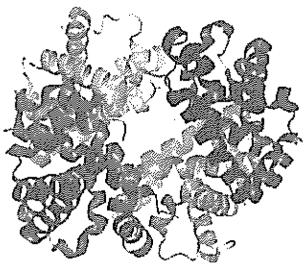


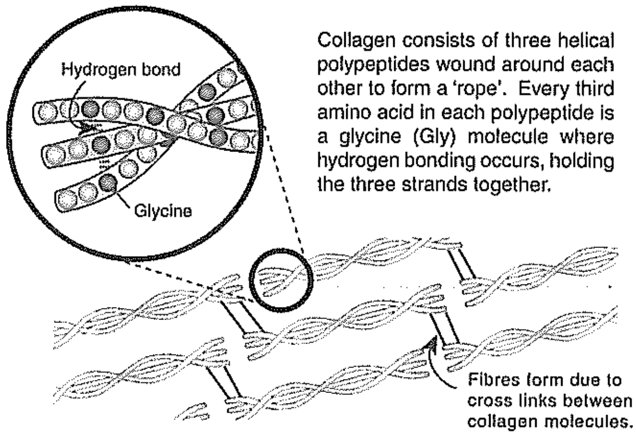


Immunoglobulins
These are large multi-unit Y-shape plasma proteins that recognise, bind to, and help to destroy bacteria and viruses. The tips of the 'Y' form the binding site for specific antigens.

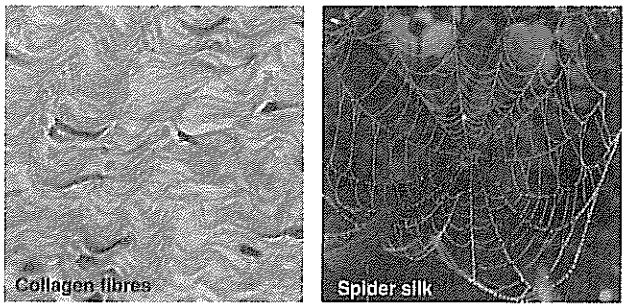
RuBisCo is a large multi-unit enzyme found in green plants and catalyses the first step of carbon fixation in the Calvin cycle. It consists of 8 large (L) and 8 small (S) subunits arranged as 4 dimers. RuBisCO is the most abundant protein in the world.

Haemoglobin is found in red blood cells and is responsible for transporting oxygen. About 80 million of these protein molecules are found in each red blood cell. One haemoglobin molecule (right) consists of 574 amino acids arranged in four polypeptide chains (two identical alpha chains and two identical beta chains).





Collagen consists of three helical polypeptides wound around each other to form a 'rope'. Every third amino acid in each polypeptide is a glycine (Gly) molecule where hydrogen bonding occurs, holding the three strands together.



Collagen is the main component of connective tissue, and is mostly found in fibrous tissues (e.g. tendons, ligaments, and skin). **Spider silk** is a protein spun into a web by spiders to capture prey. Like all fibrous proteins, it is very strong.

1. How are proteins involved in the following roles? Give examples to help illustrate your answer:

   (a) Structural tissues of the body: ______________________

   ____

   ____

   (b) Catalysing metabolic reactions in cells: ______________________

   ____

   ____

2. How does the shape of a fibrous protein relate to its functional role? ______________________

____

3. How does the shape of a catalytic protein (enzyme) relate to its functional role? ______________________

____

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22 Carbohydrates

Key Idea: Carbohydrates are a family of organic molecules made up of carbon, hydrogen, and oxygen atoms only.

Carbohydrates are organic molecules made up of carbon, hydrogen, and oxygen atoms. The simplest carbohydrates are sugars (monosaccharides such as glucose and fructose and disaccharides such as sucrose). These may join together by **condensation** to form polymers called polysaccharides, releasing water in the process. Polysaccharides and disaccharides are broken down into their constituent monosaccharides by the opposite reaction (**hydrolysis**). Sugars play a central role in cells, providing energy for metabolism and joining together to form carbohydrate macromolecules, such as starch and cellulose (in plants) and glycogen (in animals).

Monosaccharides (simple sugars)

Monosaccharides are used as the main energy source for fuelling cell metabolism. The most common ones have a ring structure with either six (hexoses) or five (pentoses) carbon atoms in each molecule. Examples include glucose (grape sugar and blood sugar) and fructose (honey and fruit juices).

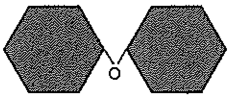
e.g. ribose, deoxyribose

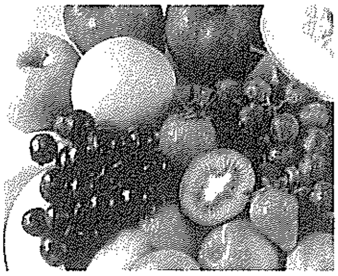
e.g. glucose, fructose, galactose

Disaccharides (compound sugars)

Disaccharides are used as energy sources and as building blocks for larger molecules. They contain two linked monosaccharides, which can either be the same (e.g. maltose) or different (e.g. lactose).

Example	Components	Where found
maltose	glucose + glucose	germinating seeds
lactose	glucose + galactose	milk
sucrose	glucose + fructose	plant sap

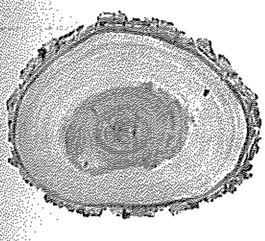




During the fruit ripening process, starch is converted to fructose and/or glucose. This provides the sweetness which attracts animals that might assist in seed dispersal.

Polysaccharides

Cellulose

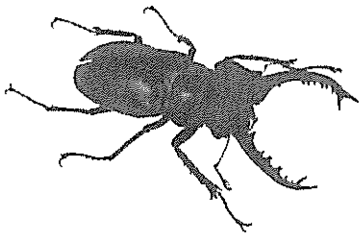


Cellulose comprises unbranched chains of up to 10,000 glucose molecules. Cellulose is a major structural component of plants, forming their **cell walls**, xylem vessel elements and **wood** (photo above). It is the most abundant carbohydrate.

Starch

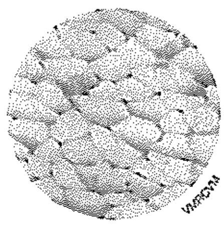
Starch, a branched polysaccharide, is made up of chains of about 1000 glucose molecules. It is an energy storage molecule, concentrated in **starch granules** within the cells of plants (e.g. potatoes, above). It is converted into glucose when required for energy production.

Chitin



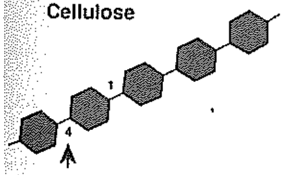
Chitin is made up of unbranched chains of modified glucose molecules. It is chemically similar to cellulose, but each glucose has a nitrogen containing group attached. Chitin occurs in the cell walls of fungi and it makes up the **exoskeleton** of arthropods (above).

Glycogen



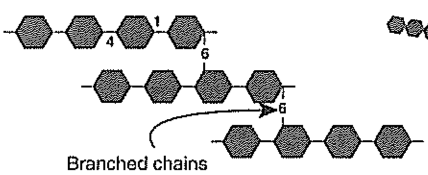
Glycogen, like starch, is a branched polysaccharide. It is composed of 2000 to 60,000 glucose molecules. Glycogen is more highly branched, and is more soluble in water, than starch. It is a storage compound in animal tissues and is found in the cells of liver and **muscle** (above).

Cellulose



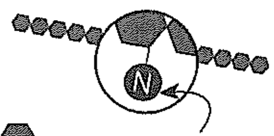
Unbranched chains

Starch

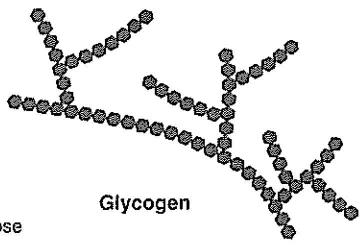


Branched chains

Chitin



Nitrogen containing group on each glucose



Glycogen

1. Name one biological function of monosaccharides, providing an example: ______

2. Describe the structure and biological role of each of the following polysaccharides:

(a) Starch: ______

(b) Glycogen: ______

(c) Cellulose: ______

(d) Chitin: ______

3. (a) What reaction produces polysaccharides from monosaccharides? ______

(b) What reaction breaks down polysaccharides into simple sugars? ______

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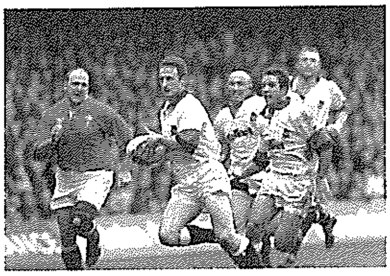
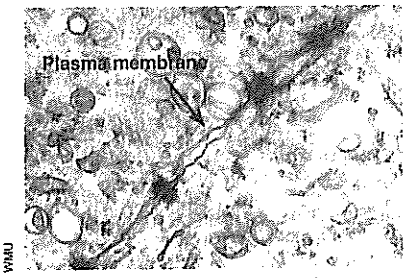
23 Lipids

Key Idea: Lipids are non-polar, hydrophobic organic molecules, which have many important biological functions.

Lipids are a group of organic compounds with an oily, greasy, or waxy consistency. They are relatively insoluble in water and tend to be water-repelling. Fats and oils have a higher proportion of hydrogen than either carbohydrates or protein, making them a more concentrated energy source and important as energy storage molecules. As well as their role as fuels, lipids are important as hormones, as part of plasma membranes, and as a source of fatty acids. Proteins and carbohydrates can be converted into fats by enzymes and stored. When food is short, stored fat can provide energy.

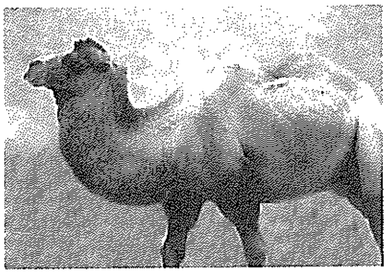


Lipids are concentrated sources of energy and provide fuel for aerobic respiration.

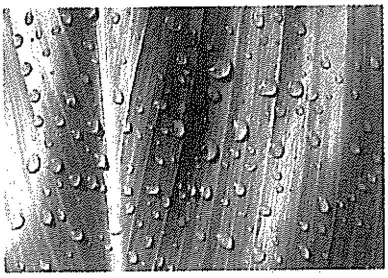


Phospholipids form the structural framework of cellular membranes.

Fat absorbs shocks. Organs that are prone to bumps and shocks (e.g. kidneys) are cushioned with a relatively thick layer of fat.



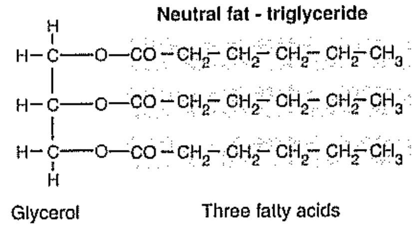
Lipids can provide metabolic water. During respiration, stored lipids are metabolised for energy, producing water and carbon dioxide.



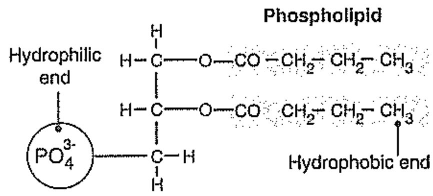
Waxes and oils secreted on to surfaces provide waterproofing in plants and animals.

Stored lipids provide insulation, reducing the amount of heat lost to the environment.

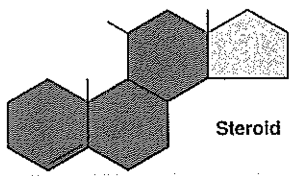
Lipid Structure



Neutral fats and oils are the most abundant lipids in living things. They consist of a glycerol attached to one (mono-), two (di-) or three (tri-) fatty acids. They provide more than twice as much energy as the same quantity of carbohydrate.



Most phospholipids consist of a glycerol attached to two fatty acid chains and a phosphate group. The phosphate end of the molecule is attracted to water while the fatty acid end is water repellent.



Steroids have a basic structure of three 6C rings and a fourth 5C ring.

1. (a) Describe the basic structure of a neutral fat (triglyceride): ___

   (b) How does this structure differ from the structure of a phospholipid: ___

2. Why do lipids have such a high energy content? ___

3. Discuss the various biological roles of lipids: ___

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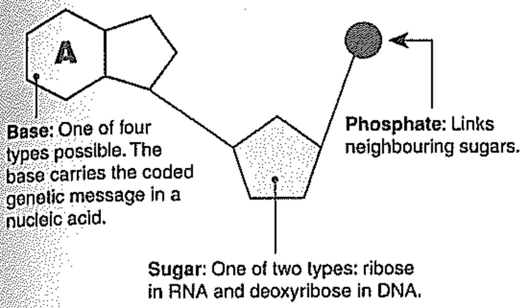
24 Nucleotides and Nucleic Acids

Key Idea: Nucleotides are the building blocks of DNA and RNA. Nucleic acids are long chains of nucleotides, which store and transmit genetic information.

A nucleotide has three components: a base, a sugar, and a phosphate group. They are the building blocks of nucleic acids (DNA and RNA), which are involved in the transmission of inherited information. Nucleic acids such as deoxyribonucleic acid (**DNA**) have the capacity to store the information that controls cellular activity. Ribonucleic acids (**RNA**) are involved in the 'reading' of the DNA information. All nucleic acids are made up of **nucleotides** linked together to form chains or strands. The strands vary in the sequence of the bases found on each nucleotide. It is this sequence which provides the 'genetic code' for the cell.

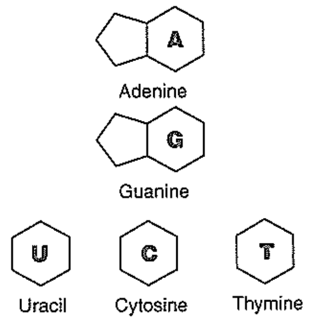
Nucleotide Structure



Nucleotides are the building blocks of DNA. Their precise sequence in a DNA molecule provides the genetic instructions for the organism. Mutations are changes in the nucleotide sequence.

Nucleic Acids

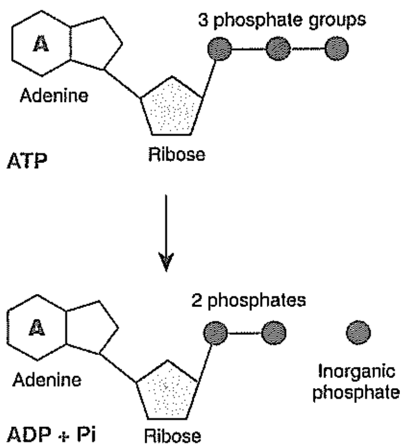
Bases in Nucleotides



Nucleotides have four kinds of bases making up part of their structure. DNA contains A, T, G, and C. RNA contains A, U, G, and C (U replaces T).

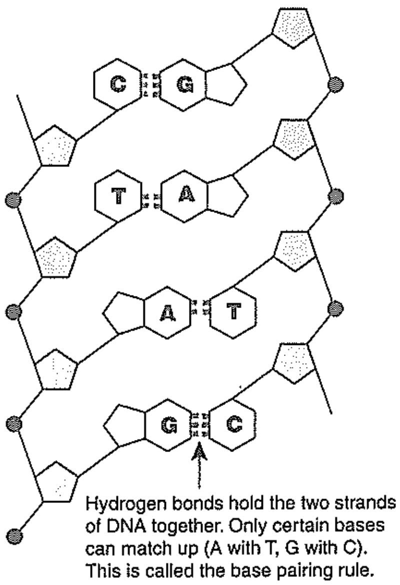
Individual chromosomes (above) are visible with a light microscope only during cell division when they are condensed.

Nucleotide Derivatives
Adenosine Triphosphate (ATP)



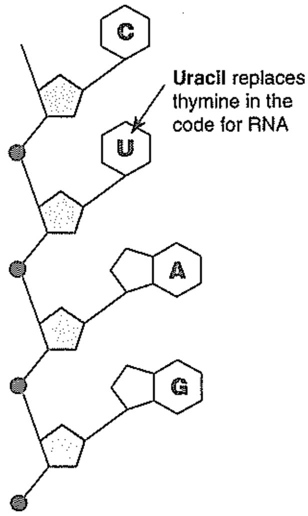
ATP is a **nucleotide derivative** (a nucleoside triphosphate) used in cells as a coenzyme. ATP transports chemical energy within cells for metabolism. It consists of an adenine linked to a ribose sugar and 3 phosphate groups. It males energy available for work when it transfers a phosphate group to an intermediate.

DNA Molecule



Deoxyribonucleic acid (DNA) consists of a double strand of nucleotides linked together, forming a **double helix.**

RNA Molecule



Ribonucleic acid (RNA) consists of a single strand of nucleotides linked together.

1. (a) What is the basic repeating unit of nucleic acids? ______________________

   (b) Describe the structure of this repeating unit: ______________________

   ____

2. (a) What is the base pairing rule in DNA? ______________________

   (b) How does RNA differ from DNA in this respect? ______________________

3. How is information encoded in DNA? ______________________

   ____

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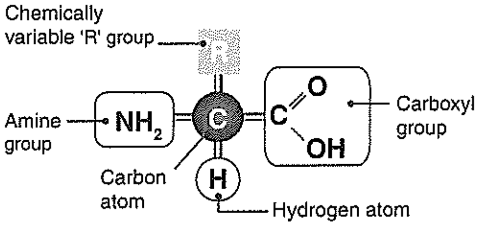
25 Amino Acids

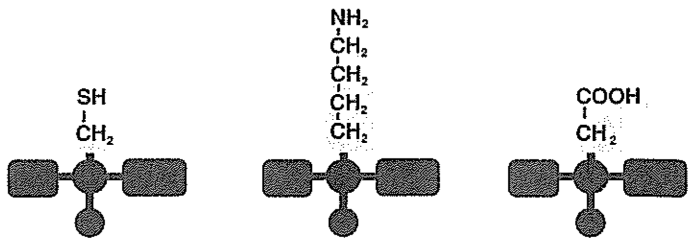
Key Idea: Amino acids can be joined together by condensation reactions to form polypeptides. Proteins are made up of one or more polypeptide molecules.

Amino acids are the basic units from which proteins are made. Twenty amino acids commonly occur in proteins and they can be linked in many different ways by peptide bonds to form a huge variety of polypeptides. Peptide bonds are formed by **condensation reactions** between amino acids.

The Structure and Properties of Amino Acids



All amino acids have a common structure (above), but the R group is different in each kind of amino acid (right). The property of the R group determines how it will interact with other amino acids and ultimately determines how the amino acid chain folds up into a functional protein. For example, the hydrophobic R groups of soluble proteins are folded into the protein's interior, while the hydrophilic groups are arranged on the outside.

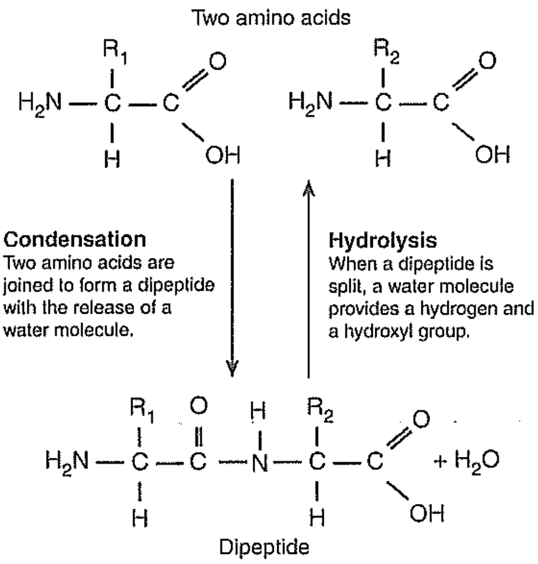


Cysteine
This 'R' group can form **disulfide bridges** with other cysteines to create cross linkages in a polypeptide chain.

Lysine
This 'R' group gives the amino acid an **alkaline** property.

Aspartic acid
This 'R' group gives the amino acid an **acidic** property.

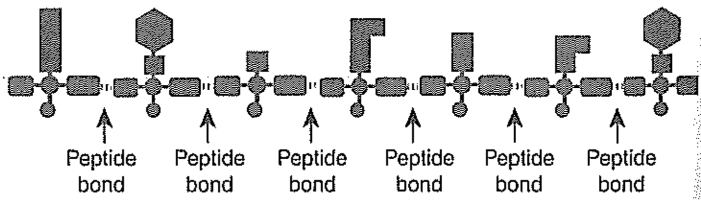
Condensation and Hydrolysis Reactions



Amino acids are linked by **peptide bonds** to form long **polypeptide chains** of up to several thousand amino acids. Peptide bonds form between the carboxyl group of one amino acid and the amine group of another (left). Water is formed as a result of this bond formation.

The sequence of amino acids in a polypeptide is called the **primary structure** and is determined by the order of nucleotides in DNA and mRNA. The linking of amino acids to form a polypeptide occurs on ribosomes in the cytoplasm. Once released from the ribosome, a polypeptide will fold into a secondary structure determined by the composition and position of the amino acids making up the chain.

A Polypeptide Chain



1. (a) What makes each of the amino acids in proteins unique? ______

   (b) What is the primary structure of a protein? ______

   (c) What determines the primary structure? ______

   (d) How do the sequence and composition of amino acids in a protein influence how a protein folds up? ______

2. (a) What type of bond joins neighbouring amino acids together? ______

   (b) How is this bond formed? ______

   (c) Circle this bond in the dipeptide above: ______

   (d) How are di- and polypeptides broken down? ______

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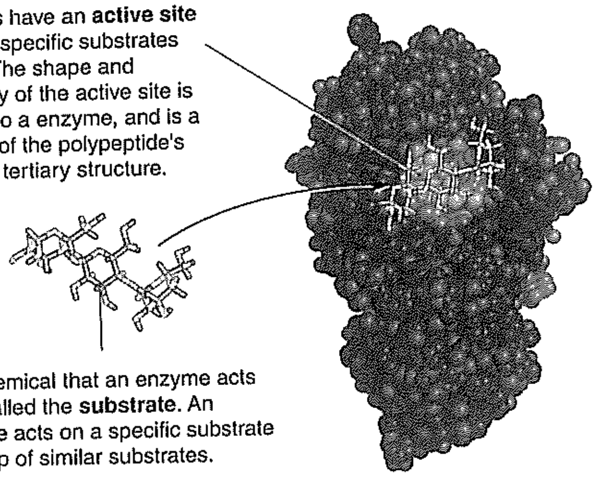
27 Enzymes

Key Idea: Enzymes are biological catalysts. They speed up biological reactions.

All metabolic reactions require the presence of enzymes. **Enzymes** are biological catalysts, that is, they speed up the chemical reactions in cells without being used up. They are unchanged at the end of a reaction and, because each enzyme molecule can be reused many times over, enzymes are effective in low concentrations. Enzymes differ from other catalysts in that they work faster, are specific (catalysing only one kind of reaction), are inactivated (**denatured**) by extremes of heat or pH which disrupt the active site and prevent the enzyme from functioning.

The Active Site

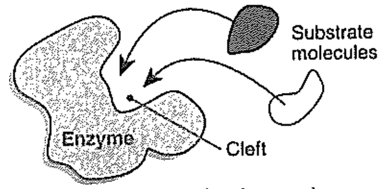


Enzymes have an **active site** to which specific substrates bind to. The shape and chemistry of the active site is specific to a enzyme, and is a function of the polypeptide's complex tertiary structure.

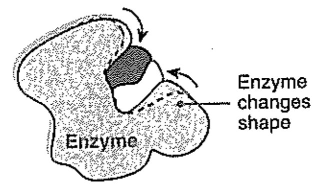
The chemical that an enzyme acts on is called the **substrate.** An **enzyme** acts on a specific substrate or group of similar substrates.

A Model of Enzyme Activity

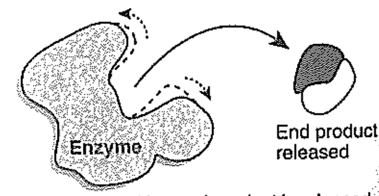
An enzyme fits to its substrate somewhat like a lock and key. The shape of the enzyme changes when the substrate fits into the cleft (called the **induced fit**):



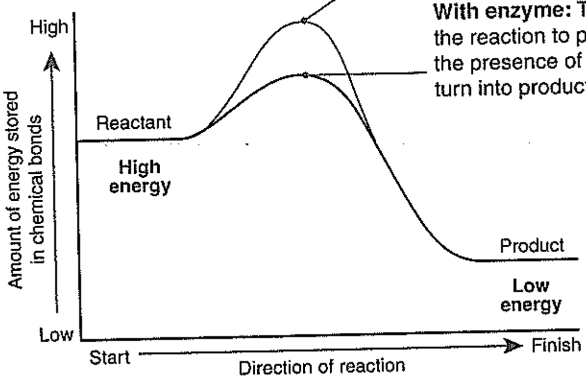
1. Two substrate molecules are drawn into the cleft of the enzyme.



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.



Without enzyme: The activation energy needed to make the reaction proceed in the forward direction is high without the enzyme present.

With enzyme: The energy required for the reaction to proceed is reduced by the presence of the enzyme. Reactants turn into products more readily.

How Enzymes Work

Enzyme are biological catalysts. They speed up reactions by influencing the **stability of bonds** in the reactants, lowering the **activation energy** needed for a reaction to occur (left). The reactants bind to the enzyme, usually by weak chemical bonds. The binding can weaken bonds within the reactants themselves, allowing the reaction to proceed more readily. Various factors, including temperature, substrate concentration, and pH may affect an enzyme's activity.

1. Name three ways in which enzymes differ from other catalysts:

   (a) ______

   (b) ______

   (c) ______

2. Why are enzymes so effective at low concentrations? ______

3. How do enzymes catalyse reactions? ______

4. How does heat denature enzymes? ______

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