Hello, this is my summary of IGCSE Biology (Cambridge) for 2014 exam. As a student, I have always enjoyed learning Biology and want to make it a fascinating subject for others as well!

As references, I am using the following books:

IGCSE Biology textbook by Mary Jones & Geoff Jones
IGCSE Study guide for Biology by Dave Hayward
Biology IGCSE Revision guide by Ron Pickering

and other resources from Internet, including:

e-socrates.org Science Aid

Credits to authors of pictures used for illustration purpose in this blog.

I'm no expert on Biology so just feel free to leave a comment or any suggestions that could help me improve this blog.

I hope you will enjoy Biology as much as I do!

Cheers,
Emma Le

Please visit my blog:

Biology Notes on weebly

Biology Notes on Blogspot
The 7 characteristics that distinguish living things from non-living objects are: **Nutrition, Excretion, Respiration, Sensitivity, Reproduction, Growth and Movement.**

### 7 characteristics of living organisms

<table>
<thead>
<tr>
<th>1. Nutrition</th>
<th>Take in</th>
<th>Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorb</td>
<td>Organic substances</td>
<td></td>
</tr>
<tr>
<td>Assimilate</td>
<td>Mineral ions</td>
<td></td>
</tr>
<tr>
<td>Plants make their own food</td>
<td>containing <strong>raw materials/energy</strong></td>
<td></td>
</tr>
<tr>
<td>Photo-synthesis</td>
<td>for: <strong>Growth + Tissue repair</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>H₂O, CO₂, Light</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Excretion</th>
<th>Removal</th>
<th>Toxic Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Break down</td>
<td>Waste Products of metabolism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>By chemical reactions in cells (respiration...)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Respiration</th>
<th>Break down</th>
<th>Food in cells</th>
<th>Release Energy</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>4. Sensitivity</th>
<th>Sense</th>
<th>Respond</th>
<th>Changes in the environment (Stimuli)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>5. Reproduction</th>
<th>Produce</th>
<th>Offspring</th>
<th>Prevent extinction of species</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>6. Growth</th>
<th>Increase</th>
<th>Size</th>
<th>Mass of an organism</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>By increasing cell number and/or cell size</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Movement</th>
<th>Change</th>
<th>Position or Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex: Parts of plants move very slowly to obtain more light for photosynthesis.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Common misconceptions

- Don’t confuse respiration with breathing.

- Don’t use faeces or defecation as an example of excretion (faeces is indigested food - it has not been formed through metabolic processes).

- Some non-living things, such as a car, may appear to show some of the characteristics - but not all of them.

* Characteristics of living organisms Quiz
# 2: Classification of living organisms

Classification: The scientific method of dividing organisms into smaller and larger groups, on basis of their similarities.

Swedish botanist Carolus Linnaeus is the Father of Systematic Biology. He believed he could:

- Put every organism into a group (the science of TAXONOMY)
- Give every organism a name (the science of NOMENCLATURE).

Carolus Linnaeus organized **taxonomy** (1735).

In his **BINOMIAL SYSTEM**, every living organism has a unique, two-part name:

- The first name is **Genus**, the second name is **species**.
- Names are written in Latin, printed in *italics*.
- The genus always has a **capital** letter, and the species always has a **small** letter.

For examples:

<table>
<thead>
<tr>
<th></th>
<th>Genus</th>
<th>Species</th>
<th>Abreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td><em>Homo</em></td>
<td><em>sapiens</em></td>
<td><em>H. sapiens</em></td>
</tr>
<tr>
<td>Lion</td>
<td><em>Panthera</em></td>
<td><em>leo</em></td>
<td><em>P. leo</em></td>
</tr>
<tr>
<td>Wolf</td>
<td><em>Canis</em></td>
<td><em>lupus</em></td>
<td><em>C. lupus</em></td>
</tr>
</tbody>
</table>
All life forms are categorized into a scheme that had 7 categorical terms. The biggest group are **Kingdom**, the smallest one is **Species**.

Each kingdom is divided into smaller group, which include genus and species. Organisms can exist in only one group at each level of classification. For example, an organism can only belong to one kingdom or one genus.
All living things are divided into 5 kingdoms. Each kingdom has certain characteristics that all members of that group shared. They are:

- Animals
- Plants
- Fungi
- Protoctists
- Bacteria (Prokaryotes)

The characteristics that Linnaeus used to divide all organisms into one of the five groups included:

- How many cells made up their bodies, if their cells were very simple or had complex parts
• If they can move on their own
• If they could make their own food, or had to eat other creatures to survive ...

**Mnemonic**

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Protoctists</th>
<th>Fungi</th>
<th>Plants</th>
<th>Animals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>mnemonic:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bees Prefer Finding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poohbear Alive</td>
</tr>
</tbody>
</table>

---

If they can move on their own
If they could make their own food, or had to eat other creatures to survive ...
The animal kingdom contains many phyla. Some of them are:

**Vertebrates, Arthropods, Annelids, Molluscs, Nematodes.**

It is not always easy to recognise an animal. For a very long time, people thought that’s sea anemones were plants, because they tend to stay in one place and their tentacles look rather kike petals. Now we know that they are animals.
One of the best way to tell if an organism is an animal is to look at its cells under the microscope. **Animal cells never have cell walls.**

Animals are classified into many phyla. Here are just some of these phyla:

**Classes** in two of these phyla:

Details of each phylum and class are given in the next topics.
Vertebrates are animals with backbones. They are divided into 5 groups called classes:

**Fish, Amphibians, Reptiles, Birds and Mammals.**

Details of each group are given in the table below. You only need to be able to describe visible external features, but other details can be helpful.
<table>
<thead>
<tr>
<th>CLASS</th>
<th>EXTERNAL FEATURES</th>
<th>OTHER FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish (all aquatic)</td>
<td>Scales</td>
<td>Jelly-covered eggs; usually use external fertilisation</td>
</tr>
<tr>
<td></td>
<td>Fins</td>
<td>Ectothermic</td>
</tr>
<tr>
<td></td>
<td>Eyes and lateral line</td>
<td>Gills for gas exchange</td>
</tr>
<tr>
<td>Amphibians (always breed in water)</td>
<td>Moist skin</td>
<td>Jelly-covered eggs; external fertilisation</td>
</tr>
<tr>
<td></td>
<td>Four limbs</td>
<td>Ectothermic</td>
</tr>
<tr>
<td></td>
<td>Eyes and ears</td>
<td>Lungs/skin for gas exchange</td>
</tr>
<tr>
<td>Reptiles (lay eggs on land)</td>
<td>Dry, scaly skin</td>
<td>Soft-shelled eggs; internal fertilisation</td>
</tr>
<tr>
<td></td>
<td>Four limbs (not in snakes)</td>
<td>Ectothermic</td>
</tr>
<tr>
<td></td>
<td>Eyes and ears</td>
<td>Lungs for gas exchange</td>
</tr>
<tr>
<td>Birds (very few are aquatic)</td>
<td>Feathers (scales on legs)</td>
<td>Hard-shelled eggs; internal fertilisation</td>
</tr>
<tr>
<td></td>
<td>Two wings, two legs</td>
<td>Endothermic</td>
</tr>
<tr>
<td></td>
<td>Eyes and ears</td>
<td>Lungs for gas exchange</td>
</tr>
<tr>
<td>Mammals (very few are aquatic)</td>
<td>Fur or hair</td>
<td>Live young (a few lay eggs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Endothermic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lungs for gas exchange</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feed young with milk from mammary glands</td>
</tr>
</tbody>
</table>

You could be asked to directly describe these in exam questions

You could use these features in questions on other topics
### Classification of Vertebrates

Vertebrates are animals with backbones (part of an internal skeleton). Vertebrates are divided into five groups called classes. Details of each group are given in the table below.

<table>
<thead>
<tr>
<th>Vertebrate class</th>
<th>Body covering</th>
<th>Movement</th>
<th>Reproduction</th>
<th>Sense organs</th>
<th>Other details</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>Scales</td>
<td>Fins (also used for balance)</td>
<td>Usually produces jelly-covered eggs in water</td>
<td>Eyes but no ears, lateral line along body for detecting vibrations in water</td>
<td>Cold-blooded, gills for breathing</td>
<td>Herring, perch, shark</td>
</tr>
<tr>
<td>Amphibians</td>
<td>Moist skin</td>
<td>Four limbs, back feet often webbed to make swimming more efficient</td>
<td>Produces jelly-covered eggs in water</td>
<td>Eyes and ears</td>
<td>Cold-blooded, lungs and skin for breathing</td>
<td>Frog, toad, salamander</td>
</tr>
<tr>
<td>Reptiles</td>
<td>Dry, with scales</td>
<td>Four legs (apart from snakes)</td>
<td>Eggs with rubbery, waterproof shell — laid on land</td>
<td>Eyes and ears</td>
<td>Cold-blooded, lungs for breathing</td>
<td>Crocodile, python</td>
</tr>
<tr>
<td>Birds</td>
<td>Feathers, scales on legs</td>
<td>Wings, two legs</td>
<td>Eggs with hard shell</td>
<td>Eyes and ears</td>
<td>Warm-blooded, lungs for breathing, beak</td>
<td>Flamingo, pigeon</td>
</tr>
<tr>
<td>Mammals</td>
<td>Fur</td>
<td>Four limbs</td>
<td>Live young</td>
<td>Eyes, ears with pinna (external flap)</td>
<td>Warm-blooded, lungs for breathing, females have mammary glands to produce milk to feed young, four types of teeth</td>
<td>Elephant, mouse</td>
</tr>
</tbody>
</table>

#### 1. Fish

![Fish Diagram]

Scales - Fins - Eyes & lateral Lines - Gills.
2. Amphibians

Moist scaleless skin - Eye & Ears - 4 limbs.

3. Reptiles

Dry scaly skin - Eyes & Ears - 4 legs (apart from snakes).

4. Birds
Beak - Feathers - Scales on legs - Wings - 2 legs.

5. Mammals

Fur - 4 limbs.
There are more arthropods than any other group of animals, so they are divided into classes:

**Insects, Crustaceans, Arachnids and Myriapods.**

### Special features of Arthropods:

- Invertebrates (**no backbone**)
- Waterproof **Exoskeleton** ----> Exist in very dry places, not confined to water or moist places like most invertebrates.
- **Segmented body**
- **Jointed legs** (exoskeleton prevents movement)

### 4 classes of Arthropods

#### 1. Insects

Insects are a very successful group, due to their exoskeleton and **tracheae**, which are very good at stopping water from evaporating from insects’s body, so they can live in **very dry** places.
2. Crustaceans

These are the crabs, lobsters and woodlice. They breath through gills, so most of them live in wet places and many are aquatic.

3. Arachnids

These are spiders, ticks and scorpions. They are land-dwelling organisms.
Key features of Arachnids

- 4 pairs of legs
- **no wings**
- 2 pairs of antennae
- 2 body parts: **Cephalothorax, Abdomen**
- several pairs of simple eyes
- all have **piercing jaws** since all are predator
- chelicerae (pointed mouthparts) for biting and poisoning prey
4. **Myriapods**

These are the centipedes and millipedes.

**Key features of Myriapods**

- long, thin body with **many segments** for moving easily through soil and leaf litter
- no obvious thorax and abdomen
- each segment has **jointed legs** (>9 pairs)
- 1 pair of antennae as sense organs in dark habitats
- simple eyes
# 7 Other groups of invertebrates

Details about some more phyla of invertebrates:

**Annelids, Nematodes, Molluscs.**

1. **Phylum Annelids**

Annelids are worms, with bodies made up of ring-like segments. Most of them live in water, some like the earthworm live in moist soil.

![Diagram of earthworm](image)

**Key features of Annelids**

- **many segments** on long body
- body covered with **mucus** to conserve water
- mouth and anus present
- **bristles** (stiff hair) usually present for movement
- many are hermaphrodite (intersex)

2. **Phylum Nematodes**

Nematodes are worms, but unlike annelids their bodies are not divided into segments. They are usually white, long and thin. They live in many different habitats. Many nematodes live in the soil.
3. Phylum Molluscs

Molluscs are soft-bodies animals, sometimes with a shell (snails) or without (slugs).

**Key features of Nematodes**

- no segments
- long cylindrical body
- body pointed at both ends
Key features of Molluscs

- soft, unsegmented body
- muscular foot for movement or burrowing
- most have a shelf made of calcium carbonate (protection from predators/drying out)
- often have eyes on retractable tentacles

Common misconceptions

Students are often confused by the different numbers of legs in insects, arachnids and crustaceans.

They often lose the mark by stating that insects have 3 legs instead of 3 pairs of legs.
#8: Plant Kingdom

Plants are multicellular organisms, with cell wall made of cellulose. They include small organisms such as mosses, ferns and flowering plants.

At least some parts of a plant are green, thanks to pigment chlorophyll. Chlorophyll absorbs energy from sunlight for plant to make glucose, using $\text{CO}_2$ and $\text{H}_2\text{O}$ from environment. This is called photosynthesis.
Phylum Flowering Plants

- have roots, stems and leaves
- have xylem and phloem
- reproduce by producing seeds
- seeds produced inside ovary, inside flower
- asexual reproduction is possible

They are divided into 2 groups, depending on number of seed leaves (Cotyledon):

1. Monocotyledonous (Monocots)
2. Dicotyledonous (Dicots)
## Differences between Monocot and Dicot leaves

<table>
<thead>
<tr>
<th>Feature</th>
<th>Monocot</th>
<th>Dicot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf shape</td>
<td>long, thin</td>
<td>broad</td>
</tr>
<tr>
<td>Leaf veins</td>
<td>parallel</td>
<td>branching (network of veins)</td>
</tr>
<tr>
<td>Seed leaf</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Example</td>
<td>Grasses</td>
<td>Trees</td>
</tr>
</tbody>
</table>

![Monocot and Dicot leaves comparison](image)
Viruses are not true living things. They are not considered to be alive, because on their own they can do nothing until they enter a living cell.

Viruses are complicated assemblies of molecules including proteins, nucleic acids, lipids, carbohydrates...

When viruses encounter a cell, they take over cell’s machinery. A series of chemical reactions occur that lead to the production of new viruses. These new viruses burst out of the cell and invade others, where the process is repeated. The host cell is usually killed when this happens.

These steps are completely passive, that is, they are predefined by the nature of the molecules that comprise the virus particle. Viruses don’t actually ‘do’ anything. Without cells, viruses would not be able to multiply.
Scientists do not classify a virus as a living thing. This is because:

- it does not show all seven processes for life
- when it enters a cell it changes the way a cell works so it can make copies of the virus.

**Key features of Viruses**

- very **small** (100 times smaller than bacteria)
- **no typical cell structure**
- contain a strand of **DNA** or **RNA**
- surrounded by a protein coat called a **capsid**
- the only life process they show is **reproduction** (inside host cell)
Bacteria cells are very different from the cells of all other organisms: they do not have a nucleus.

Some bacteria can carry out photosynthesis. The oldest fossils belong to this kingdom, so we think that they were the first kinds of organisms to evolve.
For a very long time, fungi were classified as plants. However, they are very different from plants and belong to their own kingdom. Fungi do not have chlorophyll and do not photosynthesise.

They feed saprophiytically, or parasitically, on organic material like faeces, human foods and dead plants or animals.
A fungus is made of **hyphae**, which are long tubes, collectively they are called **mycelium** and form branches that can cover many acres.

The hypha is a long tube and effectively one cell with many nuclei. It could be divided into compartments by **septa**; The tip is tapered, this is where it is growing outwards and is known as the extension zone.
Fungi grow specialised areas for reproduction called **fruiting bodies**. These can grow very large and be visible to the naked eye where they are known as **mushrooms**. It is from these that spores are produced.
The identification of biological organisms can be greatly simplified using tools such as dichotomous keys. It is a written set of choices, each involving two statements, that leads to the name of an organism. Scientists use these to identify unknown organisms.

Consider the following animals. They are all related, but each is a separate species. Use the dichotomous key below to determine the species of each.
As seen above:

- the keys are **mutually exclusive characteristics** of biological organisms.
- they often begin with **general** characteristics and lead to more **specific** characteristics.
- you simply compare the characteristics of an unknown organism against an appropriate dichotomous key.
- if the organism falls into one category, you go to the next indicated couplet.

By following the key and making the correct choices, you should be able to identify your specimen to the indicated taxonomic level.
Try this

Figure above shows single leaves from six different trees. Use the key below to identify which tree each leaf comes from.

Make a table similar to the one below and put a tick in the correct box to show how you identify each leaf. Give the name of the tree. Leaf A has been identified for you as an example.

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leaf with smooth outline</td>
<td>Leaf with jagged outline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Leaf about the same length as width</td>
<td>Leaf about twice as long as it is wide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Leaf divided into more than two distinct parts</td>
<td>Leaf not divide into more than two distinct parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Leaf divided into five parts</td>
<td>Leaf divided into ten or more parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Leaf with pointed spines along its edge</td>
<td>Leaf with rounded lobes along its edge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leaf</th>
<th>1a</th>
<th>1b</th>
<th>2a</th>
<th>2b</th>
<th>3a</th>
<th>3b</th>
<th>4a</th>
<th>4b</th>
<th>5a</th>
<th>5b</th>
<th>Name of tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Cydonia</strong></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[ 4 marks]
### Answers

<table>
<thead>
<tr>
<th>Leaf</th>
<th>1a</th>
<th>1b</th>
<th>2a</th>
<th>2b</th>
<th>3a</th>
<th>3b</th>
<th>4a</th>
<th>4b</th>
<th>5a</th>
<th>5b</th>
<th>Name of tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td><em>Quercus</em></td>
</tr>
<tr>
<td>C</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td><em>Ilex</em></td>
</tr>
<tr>
<td>D</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td><em>Fraxinus</em></td>
</tr>
<tr>
<td>E</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td><em>Aesculus</em></td>
</tr>
<tr>
<td>F</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td><em>Magnolia</em></td>
</tr>
</tbody>
</table>

Additional sources:
- [http://biology.clemson.edu/bpc/bp/Lab/104/Labmanual/LabEx/09Keys.pdf](http://biology.clemson.edu/bpc/bp/Lab/104/Labmanual/LabEx/09Keys.pdf)
- [http://www.biologyjunction.com/dichotomous_keying.htm](http://www.biologyjunction.com/dichotomous_keying.htm)
#13 Summary of Classification of Living things

- All living things have **7 characteristics**: Nutrition, Respiration, Growth, Excretion, Movement, Reproduction and Sensitivity.

- Living organisms are classified into groups according to how closely related they are. Each species of organism is given a unique two-word Latin name called a **binomial**. The first word of the binomial is the **genus** and the second word is the **species**.

- **Vertebrates** are classified into **5 classes**: fish, amphibians, reptiles, birds and mammals. They each have their own distinctive set of features. E.g. amphibians have a smooth skin, fish and reptiles have scales, birds have feathers and scales, and mammals have hair.

- **Arthropods** are invertebrates with joined legs and segmented bodies. They can be further classified into insects, arachnids, crustaceans and myriapods.

- **Annelids** are worm with **segmented** bodies but no legs.

- **Nematodes** are worms with **unsegmented** bodies.

- **Molluscs** have unsegmented bodies, and often have a **shell**.

- **Bacteria** are single-celled organisms whose cells do **not** have nuclei.

- **Fungi** include moulds, mushrooms and toadstools. They have cells with **cell walls** but do **not** photosynthesise.

- **Viruses** are **not** generally considered to be **alive** at all. They are not made of cells and cannot carry out any of the characteristics of living things on their own.

- **Flowering plants** can be classified in to **monocotyledonous** plants and **dicotyledonous** plants. **Monocots** have seeds with one cotyledon, and their leaves often have **parallel veins**. **Dicots** have seeds with two cotyledons, and their leaves generally have branching veins.

- A **dichotomous key** is a set of **paired contrasting descriptions** which lead you through to the identification of an unknown organism.
Most living things are made of cells. Cell shape varies according to its function. Plant and animal cells differ in size, shape and structure (plants cells are usually larger than animal cells).

**Similarities and differences between animal cell and plant cell**
**Tips for drawing**

**A plant cell**

- To *label* parts of a plant cell, start from the *outside* and work inwards. The correct order: *cell wall, membrane, cytoplasm, chloroplast, nucleus, vacuole*.
- Draw the cell wall as a *double line* to show its thickness.
- Make the *cell wall* label line touche the *outer* line, and the *membrane* label line touche the *inner* line.

**An animal cell**

- Contains only *3 main parts*: Membrane, Nucleus, Cytoplasm.

---

**Mnemonic**

**Animal cell**

- Membrane
- Nucleus
- Cytoplasm

**mnemonic:**

- *Mice Nibble Cheese*
Animal cell features

1. **Irregular** shape as does not have a **rigid cell wall**.

2. **Vacuoles**: may have several **small, temporary** vacuoles, for **digestion** or the **excretion** of excess water.

3. **Denser cytoplasm**: contain more **dissolved substances** and **organelles** (e.g. more mitochondria where respiration take place to release more energy for fast movement).

4. **Store food** (carbohydrates) in the form of **glycogen**

---

Plant cell features

1. **Regular** shape as **cell wall** (made of cellulose) is **rigid** (stiff).

2. **Vacuoles**: **large, permanent** vacuoles, contains H₂O and dissolved substances (**cell sap**). Helps to maintain pressure in the cell.

3. **Chloroplasts**: contain **chlorophyll** and **enzymes** for photosynthesis.

4. **Store food**: Glucose produced by photosynthesis is converted into **starch** and stored in the cytoplasm.
Common misconceptions

- Animal cells **never** have a cell wall, chloroplast or sap vacuole (they may have temporary vacuoles where food is stored.
- **Not all** cells have all cell **parts** when matured, e.g. red blood cell do not have nucleus, xylem cells do not have a nucleus or cytoplasm.
- **Not all** plant cells contain **chloroplasts**, e.g. epidermis cells and root cells do not.
- Chloroplasts (organelle) are **different** from chlorophyll (the chemical found in them)
Multicellular plants and animals contain many different types of cell. Each type of cell is designed for a particular function.

Here are examples of cells and their functions in tissues

1. **Ciliated cells** in *respiratory tract*

   **Features**: tiny hairs called *cilia* which can move mucus.
   **Function**: waft mucus with bacteria and dust away from the lungs.

2. **Muscle cells**

   **Features**: cells merge together to form fibres that can *contract*.
   **Function**: cause movement

3. **Red blood cells**
Features: have no nucleus, contain hemoglobin
Function: transport oxygen around the body

4. Root hair cell (plants)

Features: the hair gives a large surface area
Function: absorb water and mineral ions; anchor the plant firmly in the soil

5. Xylem cells
**Features**: long, thin cells arranged end-to-end to form vessels (tubes). The cells lack end wall and cell contents such as cytoplasm and nucleus. The walls become lignified (woody).

**Function**: conduction (transport water and mineral ions from roots to leaves)

support (Ligmin provides strength for the stem).

**Common misconceptions**

Xylem and phloem tissue are often confused. **Xylem** carries water and mineral salts, while **Phloem** transports sugars and amino acids. In a vascular bundle in a stem, **Phloem** is on the outside and **Xylem** is on the inside.
Examiner's tips

1. You need to be able to give examples of tissues, organs and organ systems in both plants and animals. A leaf is an organ made up of a number of tissues, e.g. upper epidermis, palisade, mesophyll.
2. If you draw a diagram to support an exam answer, make sure you refer to its in your written answer. Annotation is more likely to help you gain extra mark.

Example of annotation

Action of phagocyte

lobed nucleus

bacterium

cytoplasm forms pseudopodia to surround and engulf bacteria - enzymes are released to digest and kill bacteria
Cells are organized to form tissue, organs, and organ systems. In a healthy organism, all the systems work together.

**SPECIALIZED CELLS**

- A specialized cell is designed to do a particular job.
- Nerve cells have long fibres to carry massages.
- Muscle cells can contract and relax.
- White blood cells attack bacteria.
- Platelets help clotting.

**TISSUES**

- Large numbers of specialized cells make up tissue.
- Muscles, blood and nerves are all tissues.
- Blood tissue contains red cells for carrying oxygen, white cells for destroying harmful bacteria, and platelets to cause clotting in cuts

**ORGANS**

- Various tissues together make up an organ.
- Each organ has its own specific job.
- The heart, the stomach and the brain are all organs.
- The heart has to pump blood around the body. It is made up of muscle tissue, blood vessels and nerves.
- Arteries and veins are usually thought of as organ as they consist of several tissue layers.

**ORGAN SYSTEMS**
Various organs together make up an **organ system**. E.g. the **circulatory system** carries blood to all parts of the body. It is made up of heart, arteries, veins, capillaries and blood.

**ORGANISM**
Various organ systems together make up an **organism**. An human organism has:

- Respiratory system
- Digestive system
- Circulatory system
- Nervous system
- Endocrine system

---

**Levels of organisations**

<table>
<thead>
<tr>
<th>Organism</th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organ Systems</td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>Digestive</td>
</tr>
<tr>
<td>Organs</td>
<td></td>
</tr>
<tr>
<td>Arteries</td>
<td>Heart</td>
</tr>
<tr>
<td>Tissues</td>
<td></td>
</tr>
<tr>
<td>Muscles</td>
<td>Blood</td>
</tr>
<tr>
<td>Cells</td>
<td></td>
</tr>
<tr>
<td>Red cells</td>
<td>White cells</td>
</tr>
</tbody>
</table>

**Key definitions**
- **Organells**: a structure within a cell (e.g. nucleus, vacuole, cytoplasm and chloroplast are all organelles of a plant cell).
- **Tissue**: a group of cells with similar structures, working together to perform a shared function.
- **Organ**: a structure made up of a group of tissues, working together to perform specific functions.
- **Organ system**: a group of organs with related functions, working together to perform body functions.
Diffusion is the net movement of molecules from a region of its higher concentration to a region of its lower concentration. Molecules move down a concentration gradient, as a result of their random movement.

For living cells, the principle of the movement down a concentration gradient is the same, but there is one problem:

The cell is surrounded by a cell membrane, which can restrict the free movement of the molecules. This is a selective permeable membrane: the composition of the membrane (lipid and protein) allows some molecules to cross with ease, but others with difficulty or not at all. The simplest sort of selection is based on the size of the molecules.
**Importance of gaseous and solute diffusion**

Diffusion helps living organisms to:

- **obtain** many of their **requirements**
- **get rid** of many of their **waste products**
- **gas exchange** for respiration

**Examples**

- CO$_2$ uses by plants for photosynthesis is diffuses from the air into the leaves, through the stomata (pores at the surface of leaves). There is a lower concentration of CO$_2$ inside the leaf, as the cells are using it up. O$_2$ (waste product of photosynthesis diffuses out in the same way).
- Flowering plants use diffusion to attract pollinators like bees.
- Some of the products of digestion are absorbed from the ileum of mammals by diffusion.

<table>
<thead>
<tr>
<th>Site of diffusion</th>
<th>Substance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alveoli of lungs</td>
<td>O$_2$</td>
<td>Alveoli à Blood capillaries</td>
</tr>
<tr>
<td></td>
<td>CO$_2$</td>
<td>Blood capillaries à Alveoli</td>
</tr>
<tr>
<td>Stomata of leaf</td>
<td>O$_2$</td>
<td>Air spaces of leaf à Atmosphere</td>
</tr>
</tbody>
</table>

**Factors favoring diffusion**

- **Distance** (the shorter the better), e.g. thin walls of alveoli and capillaries.
- **Concentration gradient** (the bigger the better). This can be maintained by removing the substance as it passes across the diffusion surface. (Think about oxygenated blood being carried away from the surface of alveoli).
- **Size** of the **molecules** (the smaller the better).
- **Surface area** for diffusion (the larger the better).
- **Temperature** (molecules have more kinetic energy at higher temperature).

**Importance of water as a solvent**

- Most cells contain about **75%** of **wate**.
- Many **substances** move around a cell **dissolved** in water.
- Many important **reactions** take place in water.
**What is a concentration gradient?**

![Diagram showing concentration gradient]

The gas particles are more concentrated in the blood than in the lungs. Thus there is a concentration difference between these 2 points. If you join the concentrations in the blood and in the lungs (their points on the graph), you get a straight line which is sloped or has a gradient. This line is the **concentration gradient** between the 2 points.

The difference in concentration between 2 regions is known as the concentration gradient.

The particles of fluids (liquids and gases) possess kinetic energy. They are continually moving about. As their movement is random, the particles will move (diffuse) down the concentration gradient and become evenly spread out after some time. (So if you spray perfume in one corner of your room, eventually you can smell it from the other side of the room.)

The steeper the concentration gradient, the faster the particles will move. The steeper the concentration gradient for a substance, the faster the rate of diffusion is for that substance!

*From http://askmichellebiology.blogspot.com*

Additional resource: [http://askmichellebiology.blogspot.com](http://askmichellebiology.blogspot.com)
Osmosis is the diffusion of water molecules from a region of their higher concentration to a region of their lower concentration, through a partially permeable membrane.

Osmosis is a special form of diffusion and always involves the movement of H$_2$O across a membrane. Osmosis is:

- the movement of H$_2$O
- across a selectively permeable membrane
- down a water potential gradient.

In the picture below

- The concentration of sugar molecules is higher on the concentrated solution (L) and lower on the diluted one (R).

- The concentration of water molecules is higher on the (R) and lower on the (L) (a lot of place is taken up by sugar molecules).
It is confusing to talk about the 'concentration of water', so we can say that a diluted solution (R) has a **high water potential** and a concentrated solution (L) has a **low water potential**.

There is a water **potential gradient** between the 2 sides. The water molecules diffuse **down** this **gradient**, from a high water potential (R) to a low water potential (L).
Cell membranes

- partially permeable (let some substances pass through, but not others).
- separate 2 solutions: cytoplasm and solution around the cell.
- If the solutions are of different concentrations, osmosis will occur.

Effect of Osmosis on plant and animal cells

1. When placed in \( \text{H}_2\text{O} \):

Concentration of \( \text{H}_2\text{O} \) outside the cell is higher than inside it. Cells will take in \( \text{H}_2\text{O} \) by osmosis:

- **plant** cells become turgid (swollen) but do not burst (have tough **cell wall** which is fully permeable).

- **animal** cells will burst (no cell wall).
2. **When placed in concentrated sugar or salt solutions:**

Concentration of $H_2O$ inside the cell is **higher** than outside it. $H_2O$ get **out** of the cells by osmosis:

- **plant** cells become **flaccid** (soft and limp), cytoplasm is no longer pressed against the cell wall. The plant loses it firmness and begin to **wilt**.
- **animal** cells shrink, become **crenated**.

### Importance of $H_2O$ potential gradient in the uptake of $H_2O$ by plants:

Enables $H_2O$ movement by **osmosis**

- from **soil** to **root** hairs
- from **tissue fluid** to **cells**
- from **xylem** to leaf **mesophyll** cells.

### Common misconceptions

Sugar and salt do **not** move by osmosis. Cell membranes prevent them entering or leaving the cell.
Try this

A potato was set up as shown in the figure below (left-hand side). The investigation was left for several hours. The results are shown on the right-hand side of the figure.

1. Describe what happened to
   a. the water in the disk
   b. the salt solution in the hollow in the potato.  [2 marks]

2. a. Name the process that is responsible for the changes that have occurred.  [1 mark]
   b. Explain why these changes have occurred.  [3 marks]
   c. Where does this process occur in a plant?  [1 mark]
   d. What is the importance to the plant of this process?  [1 mark]

Answers

1.  a. The volume of water in the dish decreased.
    b. The volume of salt solution in the potato increased.

2.  a. Osmosis
    b. 3 points from:
        - there was a higher concentration of water in the dish than in the potato
        - so water moved into the potato.
        - from a high concentration of water to a lower concentration of water
        - by osmosis.
    c. Root hairs, or in the roots.
    d. Osmosis enables the plant to absorb water to maintain cell turgidity (or to replace water lost by transpiration).
Sometimes substances are required to be move against the Concentration Gradient, or faster than they would by Passive Transport. In these cases, Active Processes are used, which require energy.

There are many occasions when cells need to take in substances which are only present in small quantities around them.

E.g. root hair cells in plants take in nitrate ions from the soil. Their concentration are often higher inside the root hair cell than in the soil, so the diffusion gradient is from the root hair à the soil. Despite this, the root hair cells still can take nitrate ions in, by active transport.
The importance of active transport: energy-consuming process by which substances are transported against a concentration gradient, e.g. ion uptake by root hairs and glucose uptake by epithelial cells of villi.

<table>
<thead>
<tr>
<th>Site</th>
<th>Substance</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root hair cells</td>
<td>Mineral salts (phosphate...)</td>
<td>Soil → roots</td>
</tr>
<tr>
<td>Wall of small intestine (villi)</td>
<td>Glucose</td>
<td>Small intestine → blood plasma</td>
</tr>
</tbody>
</table>

Two big differences between diffusion and active transport:
- direction of movement (down or up a gradient)
- use of energy for movement

The active transport is carried out by ‘carrier proteins’ in the membrane, which bind to the solute molecule, change shape and carry the molecule across the membrane.
Try this

Figure above shows root hair cells.

1. Explain how the presence of root hair cells on roots enables the efficient absorption of water and minerals. [2 marks]
2. Root hair cells can absorb mineral ions by diffusion and active transport.
   a) Define the term active transport [2 marks]
   b) Explain why respiration rates may increase in root hair cells during the uptake of mineral ions [1 mark]

Answers

1. - Large number of root hair cells give a large surface area to the root.
   - Mitochondria are present to provide energy for active transport.
2. a) active transport is absorption of a substance into a cell or across a membrane
   - against (up) a concentration gradient.
   - using energy
   b) active transport requires energy
# 20 Summary of Cells

Structure

- **Cells** are the smallest units of living things. They are too small to be seen with the naked eye, so we need to use microscopes to see their structures.

- Cells have a cell membrane, cytoplasm and a nucleus. Plant cells also have a cell wall, and often have chloroplasts and a large vacuole containing cell sap.

- The cell membrane is partially permeable, and it controls what enters and leaves the cell.

- The cytoplasm is a jelly-like solution of many different substances in water. It is the site of many different metabolic reactions.

- The nucleus contains the chromosomes, which are made of DNA. This is the genetic information and it controls the activities of the cell.

- The cell wall of a plant cell is made of criss-crossing fibres of cellulose. It is fully permeable. It helps to support the cell, and prevents the cell bursting if it absorbs a lot of water.

- The vacuole of a plant cell contains cell sap, which is a solution of sugars and other substances in water.

- Chloroplasts contain the green pigment chlorophyll, which absorbs sunlight for photosynthesis. There may be starch grains inside the
chloroplasts, which are the form in which plants store the **food** that they make in photosynthesis.

- **A tissue** is a group of **similar cells** which work together to carry out a particular function. Tissues are grouped into **organs**, and organs are grouped into organ **systems**.

**Movement in and out of cells**

- **Particles in gases, liquids and solutions are in constant random motion.** As a result of this, there is a net movement from where they are in a **high concentration** to where they are in a **low concentration**. This is **diffusion**.

- **Diffusion** is important to cells. For example, **oxygen** enters a respiring cell by diffusion, and **carbon dioxide** diffuses out of it.

- **Water molecules are small and can diffuse through a **partially permeable membrane**. Larger molecules dissolved in the water cannot do this. The diffusion of water through a partially permeable membrane is called **osmosis**.

- Osmosis is important to cells. In a **dilute solution**, water passes into a cell through its partially permeable cell membrane. The cell gets bigger. **Animal cells** may **burst**, but **plant cells** do not because of their **strong cell wall**.

- In a **concentrated solution**, water passes out of a cell by osmosis through its partially permeable membrane. The cell **shrinks**. Plant cells may become **plasmolysed** – that is, the cell membrane pulls away from the cell wall.

- A solution containing a lot of water is said to have a high water potential. A solution containing only a little water has a low water potential. Water moves by **osmosis down** a **water potential gradient**, from a high water potential to a low water potential.

- Cells can use **energy** to move substances **up** their **concentration gradient**, from a low concentration to a high concentration. This is called **active transport**. It uses energy that the cells release by **respiration**.
Many chemical reactions can be speeded up by substances called **catalysts**. Within living organisms, these reactions (metabolic reactions) are controlled by catalysts called **enzymes**. Enzyme molecules are **proteins**.

### Key definitions

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>substance that speeds up a chemical reaction is not changed by the reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enzyme</td>
<td>protein that functions as <strong>biological catalyst</strong></td>
</tr>
<tr>
<td>Substrate</td>
<td>chemical compound the enzyme work on</td>
</tr>
<tr>
<td>End product</td>
<td>result of the reaction</td>
</tr>
</tbody>
</table>

### Enzymes and reactions

Most enzyme names end in –ase, e.g. lipase, protease.

Enzymes usually speed up reactions, but some slow them down. Some enzymes help to build up molecules (synthesize them), e.g.

- **starch phosphorylase**
  - Maltose $\xrightarrow{\text{starch phosphorylase}}$ Starch

Others are involved in breaking them down, e.g.

- **protease**
  - Protein $\xrightarrow{\text{protease}}$ Amino Acids
- **amylase**
  - Starch $\xrightarrow{\text{amylase}}$ Maltose
**Temperature, pH and enzymes**

The activity of enzymes is affected by temperature and pH.

**Effect of temperature on enzymes**

The **optimum** (best) temperature for enzyme-controlled reactions is 37°C (body temperature).

As the temperature increases, the rate of reaction increases. But very **high** temperatures **denature** enzymes.

The graph shows the typical change in an enzyme’s activity with increasing temperature.

The enzyme activity gradually increases with temperature up to around 37°C, or body temperature. Then, as the **temperature** continues to **rise**, the rate of reaction falls rapidly as heat energy **denatures** the enzyme. Most enzymes are denatured above 50°C.

**Effect of pH on enzymes**

- The pH of a solution is how acidic or alkaline it is.
- Different enzymes work best at different pH values.
- The optimum pH for an enzyme depends on where it normally works.
- It is around neutral (pH= 7) for most enzymes but there are some exceptions.
Changes in pH also alter an enzyme’s shape and slow down its activity, but this can usually be reversed if the optimum pH is restored.

An extreme pH can denature enzymes – the active site is deformed permanently.
Enzymes are very specific, each kind of enzyme catalyse one kind of reaction only. To catalyse a reaction, enzyme molecule and substrate molecule need to meet and joint together by a temporary bond.

Each molecule has a special shape and an active site into which its substrate molecule fits exactly.

This enzyme is amylase, and its active site is just the right size and shape for a substrate molecule (starch in this case).

The starch slots into the active site.

The starch is split into maltose molecules.

The enzyme is unaltered, and ready to accept another part of the starch molecule.
# 23 Role of enzymes in germinating seeds

- Seeds contain **stored food** in the cotyledons to provide energy and materials for growth. This is usually in the form of **starch** — a large, **insoluble** molecule (long chain of glucose), that keeps the food immobile. The starch needs to be changed into a **soluble** molecule (**sugar**) with help of **enzymes** for the seeds to make use of.

- In the presence of **H₂O**, **Gibberellin** or **gibberellic acid** (GA) stimulates the production of **amylase**.

- **Amylase** breaks down **starch** to **maltose**, allowing for the formation of **ATP** (via glucose).

- The **energy** produced in the embryo is used to facilitate germination.

- The **glucose** produced may also be used to synthesis cellulose - for cell wall formation.

- **Warmth** helps speed up the process.
Biological washing powders contain protease and lipase to remove protein stains and fat/grease from clothes. The enzymes break down proteins or fats on the fabric, forming water-soluble substances that can be washed away.

**Example:** Blood contain the red protein Haemoglobin (Hb). The Proteases in biological washing powder break Hb molecules into smaller molecules, which are not coloured and which dissolve in water and can be washed away.

This makes the washing powder more effective than detergent alone, especially at lower temperatures. This save energy (no need to boil water), but if the temperature is too high, the enzyme will be denatured.

| **The differences between biological and regular washing powders** |
|---|---|---|
| **Detergents** | Biological washing powder | Regular washing powder |
| Mix greasy dirt with H$_2$O so it can be washed away | (+) | (+) |
| **Enzymes** | Proteases → proteins (blood, egg, gravy... ) | (-) |
| Braking down stains and dirt in fabrics | Amylases → starches | |
| Lipases → fats and grease | Cellulase → micro fibrils on cotton, brightening color of washed clothes | |
| They work efficiently at 40°C. | |
| Remove difficult stains (blood, gravy, egg yolk, sweat, fats and grease) | Easily by decomposing the stains. | Difficultly. |
| Heat alone makes stains coagulate and attach more firmly to the clothing. | | |

*Gravy: juices that drip from cooking meat.*
Do it your self

Boil two standard eggs together, and push two teaspoons into the yolks so that there is some yolk left on the spoons.

Dissolve equal amounts of ordinary and 'biological' detergents in two separate glasses of water, and leave a yolk-stained spoon in each glass. After some time you will see that the spoon in the ordinary detergent still has yolk on, but the yolk on the other spoon has been digested by the 'biological' detergent. This will happen if the 'biological' detergent really contains enzymes that break down the proteins in egg yolk.

Try this

Figure above shows a box of biological washing powder.

a) Explain why:
   i) The presence of protease and lipase would make the washing powder more effective than ordinary detergent [3 marks]
   ii) The powder should not be used in boiling water [2 marks]

b) Silk is a material made from protein. Explain why the biological washing powder should not be used to wash silk clothes [2 marks]

Answer:

a)  i) Protease and lipase are enzyme
    They break down stains better than ordinary detergent
    Protease breaks down protein; lipase breaks down fat
   ii) Enzymes are denatured at high temperature
b) There is protease in the biological washing powder
    This would digest the protein in the silk so the clothes would get spoiled.

Benefit from using enzymes in cleaning products, toothpaste and other products in our home.

Additional resources:

- [http://www.saasta.ac.za/biosciences/enzymes.html](http://www.saasta.ac.za/biosciences/enzymes.html)
- [http://isbibbio.wikispaces.com/biological+washing+powders+and+enzymes](http://isbibbio.wikispaces.com/biological+washing+powders+and+enzymes)
Enzymes are an integral component of modern fruit juice manufacturing and are highly suitable for optimising processes. Fruit juices are extracted using an enzyme called pectinase.

Pectin is a substance which helps to stick plant cells together. Fruits like apple or orange contain a lot of pectin. The braking down of pectin makes it much easier to squeeze juice from the fruit.

Pectinase is widely used in order to:

- increase extraction of juice from raw material
- increase processing efficiency (pressing, solid settling or removal)
- generate a final product that is clear and visually attractive

Enzymes are sometimes used when making baby foods. Proteases are used to treat some high-protein foods, they break down proteins to polypeptides and amino acids for young baby to absorb the food easier.

### Use of enzymes in the food industry

<table>
<thead>
<tr>
<th>Process</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baking</td>
<td>Enzymes in yeast convert sugar $\rightarrow$ ethanol and CO₂. CO₂ makes the bread dough rise.</td>
</tr>
<tr>
<td>Brewing</td>
<td>Enzymes in yeast convert sugar $\rightarrow$ ethanol and CO₂. Ethanol makes the drink alcoholic. CO₂ makes the drink fizzy.</td>
</tr>
<tr>
<td>Cheesemaking</td>
<td>Enzyme rennin, extracted from cow’s stomachs, is used to clot milk. Rennin can now be made using genetically engineered bacteria.</td>
</tr>
<tr>
<td>Making baby foods</td>
<td>Trypsin (a protease) is used to predigest baby foods.</td>
</tr>
</tbody>
</table>
We obtain many enzymes from microorganisms. The enzymes that are used in industry are usually obtained from microorganisms. These include bacteria and microscopic fungi, such as yeast. The microorganisms are grown inside large vessels called fermenters.

- Inside the fermenter, the microorganisms are provided with everything they need to grow and reproduce, e.g.: \(O_2\), supply of nutrients, a suitable pH and temperature.
- The microorganisms make the enzymes and release them into the liquid in which they are growing.
- The liquid can then be collected from the fermenter, and the enzymes purified before use.

**Closer look at fermenter**

The fermenter is a large, sterile container with a stirrer, a pipe to add feedstock* (molasses* or corn-steep liquor), and air pipes to blow air into the mixture. The microorganisms are added and the liquid is maintained around 26\(^\circ\)C and a pH of 5-6.
The enzymes produced by the microorganisms may be extracellular or intracellular:

1. **Extracellular** enzymes are extracted from the feedstock by filtering.
2. To extract **intracellular** enzymes the microorganisms are filtered from the feedstock, then crushed and washed with water. The enzymes are now in solution.

**Explain words:**

* **Feedstock**: Raw material (input) fed into a process for conversion into something different (output).

* **Molasses (syrup)**: Thick, dark brown, uncrystallized juice obtained from raw sugar during the refining process.

* **Corn-steep liquor**: a concentrated fluid obtained by soaking corn grains in water (containing 0.2% $\text{SO}_2$) for 36 — 40 hours at 46 — 50°C.
Antibiotics are substances which kill bacteria without harming human cells. They help to cure bacterial infections. Penicillin is made by growing the fungus Penicillium in a large fermenter.

Often, it is easier to use the whole microorganisms rather than extract its enzymes from it. The microorganism is grown in a fermenter, its enzymes convert a substrate to a desired product. The production of antibiotic penicillin is one example.
Fermenter

The fungus is grown in a culture medium containing carbohydrates and amino acid. This looks like watery porridge and is stirred continuously to:

- Keep the fungus in contact with fresh supplies of nutrients.
- Mix O2 into the culture
- Roll the fungus up into little pellets (this facilitates the separating of the liquid part containing penicillin from the fungus lately).

![Fermenter for producing penicillin](image)

For first 15-24 h, the fungus just grows. After that it begins to secret penicillin. Rate of production depends on how much sugar is available:

- A lot of sugar à not much penicillin
- No sugar à no penicillin

So small amount of sugar have to be fed all the time that the fungus is producing penicillin.

The culture is kept going until the rate of production is so slow that it is not worth waiting more (often after a week). Then it is filtered, and the liquid is treated to concentrate the penicillin in it.
History (not included in the syllabus)

Thousands of glass fermentation vessels like this one were used in Glaxo (now GlaxoSmithKline) laboratories to produce penicillin.

![Glass fermentation vessel](image)

*Credits: Science Museum*

The penicillium mould was grown on the surface of a liquid filled with all the nutrients it needed. This approach was replaced by the method of growing the mould within large industrial fermenters. The antibiotic was first used in the early 1940s and saved the lives of many soldiers during the Second World War.

**Discovering of Penicillin**

![Sir Alexander Fleming](image)

Sir Alexander Fleming, 1952 (photo AP)
Penicillin was discovered by chance. Alexander Fleming - the Scottish bacteriologist - accidentally left a dish of staphylococcus bacteria uncovered for a few days. He returned to find the dish dotted with bacterial growth, apart from one area where a patch of mould (Penicillin notatum) was growing. The mould produced a substance, named penicillin by Fleming, which inhibited bacterial growth and was later found to be effective against a wide range of harmful bacteria.

However, it was not until World War II that penicillin, the first antibiotic, was finally isolated by Howard Florey and Ernst Chain. Fleming, Florey and Chain received a Nobel prize in 1945, for their discovery which revolutionised medicine and led to the development of lifesaving antibiotics.

Additional sources: Royal Society of Chemistry
                     sciencemuseum
Enzymes are specialized protein molecules facilitating most of the body’s metabolic processes – such as, supplying energy, digesting foods, purifying your blood, ridding the body of waste products. Enzymes are vital to our health and change the rate at which chemical reactions happen, but without any external energy source added or by being changed themselves.

- Enzymes are proteins that work as biological catalysts.
- Enzymes are named according to the substrate on which they act. Proteases act on proteins, carbohydrases on carbohydrates and lipases on fats (lipids). The substance that is produced by the reaction is called the product.
- An enzyme molecule has a depression called its active site, which is exactly the right shape for the substrate to fit into. The enzyme can be thought of as a lock, and the substrate as the key.
- Reactions catalysed by enzymes work faster at higher temperatures, up to an optimum that differs for different enzymes. Above the optimum temperature, reaction rate rapidly decreases.
- At low temperatures, molecules have low kinetic energy, so collisions between enzyme and substrate molecules are infrequent. As temperature rises they collide more frequently, increasing reaction rate.
- Above the optimum temperature, the vibrations within the enzyme molecule are so great that it begins to lose its shape. The enzyme is said to be denatured. The substrate no longer fits into the active site and the reaction stops.
- Reactions catalysed by enzymes work fastest at a particular pH. The optimum pH for most enzymes is around pH7 (neutral), but some have an optimum pH much higher or lower than this.

- Extremes of pH cause enzyme molecules to lose their shape, so they no longer bind with their substrate.

- Amylase is found in seeds. When the seed begins to germinate, the amylase is activated and catalyses the breakdown of insoluble starch to soluble maltose in the seed. The maltose is used by the growing embryo as an energy source and to make cellulose for new cell walls.

- Biological washing powders contain enzymes, often obtained from microorganisms such as bacteria or fungi. The enzymes break down proteins or fats on the fabric, forming watersoluble substances that can be washed away.

- Pectinase is used to break down cell walls in fruits, making it easier to extract juice from them.

- The antibiotic penicillin is made by cultivating the fungus Penicillium in a fermenter. The fermenter is kept at the correct pH and temperature for the enzymes of the fungus to work well.
Photosynthesis is the fundamental process by which plants manufacture food molecules (carbohydrates) from raw materials CO₂ and H₂O using energy from light.

1. The equation for photosynthesis

- The raw materials are CO₂, H₂O and light energy.
- The products are glucose (starch) and O₂

2. The process of photosynthesis

- Green plants take in CO₂ through their leaves (by diffusion).
- H₂O is absorbed through plants’ roots (by osmosis), and transported to the leaf through xylem vessels.
- Chlorophyll traps light energy and absorbs it.
- This energy is used to break up H₂O molecules, than to bond hydrogen and CO₂ to form glucose.
- Glucose is usually changed to sucrose for transport around the plant, or to starch for storage.
- O₂ is released as a waste product, or used by plant for respiration.
- In this process, light energy is converted to chemical energy for the formation of glucose and its subsequent storage.

Video: What is photosynthesis?
https://www.youtube.com/watch?v=WHMLq3bqGwk
Experiments can be used to find out what factors (CO₂, light, chlorophyll) are needed for photosynthesis. But first of all you need to **destarch** the plants. To be certain that they are thoroughly destarched, **test** a leaf for **starch** before you begin your investigation.

**Principles of investigations**

1. **Investigations need controls**
   - **Control** plant (or leave) has all substances it needs.
   - **Test** plant lacks one substance (light/chlorophyll/CO₂)

2. **Plants must be destarched**
   - It is very important that the leaves you are testing should **not** have any **starch** in them at the beginning of the experiment.
   - So, first of all, you must destarch the plants. Leave them in the **dark** for 48 hours. The plants use up all stores of starch in its leaves.

3. **Starch test with Iodine solution**
   - After a few hours, carry out the starch test on both plants: **Iodine solution** is used; a blue-black colour on the leave is positive.
   - **Boil the leaf in water** for 30 second. This kill the cells in the leaf à break down the membrane à iodine solution gets through cell membrane to reach **starch** inside the chloroplasts and react with them.
Boil the leaf in water.

- **Boil the leaf in alcohol** (ethanol) in a water bath: The green colour of the leaf and the brown iodine solution can look black together, so you need to remove chlorophyll by dissolving it out with alcohol. Leave it until all the chlorophyll has come out of the leaf.

  ![Boil the leaf in alcohol](image)

  Boil the leaf in alcohol.

- **Rinse the leaf in water**: Boiling the leaf in ethanol makes it brittle, the water softens it.
- Spread the leaf out on a **white** tile à easy to see the result.
- **Add iodine solution** to the leaf à blue- black colour is positive, starch is present.

A leaf before (on the left) and after (on the right) starch test.

Additional resource: [sjiiscience.blogspot.com](http://sjiiscience.blogspot.com)
#40 Photosynthesis investigations – chlorophyll, CO2, light tests

![Photosynthesis diagram](image)

Investigations to see if chlorophyll, light and CO2 are needed for photosynthesis.

1. **Chlorophyll is necessary for photosynthesis**

**Process**

- Take a potted plant with **variegated** (green and white) leaves.
- **Destarch** the plant by keeping it in complete darkness for about 48 hours.
- Expose the plant to the **sunlight** for a few days.
- Test one of the leaves for **starch** with iodine solution.

**Observations**

- Areas with previously **green** patches test **positive** (turn blue black).
- Areas with previously pale **yellow** patches test **negative** (remain brown).

**Conclusion**

- Photosynthesis takes place only in green patches because of the presence of **chlorophyll**.
- The pale yellow patches do not perform photosynthesis because of the absence of chlorophyll.
2. Light is essential for photosynthesis

Process

- Take a potted plant.
- **Destarch** the plant by keeping it in complete darkness for about 48 hours.
- Test one of it leaves for starch, to check that is does not contain any.
- Fix a leaf of this plant in between two strips of a thick paper on leaf.
- Place the plant in light for a few days.
- Remove the cover from the leaf and test it for starch.

Observations

Positive starch test will be obtained only in the portion of the leaf exposed to light and negative test in parts with paper strip.

Conclusion

Light is necessary for photosynthesis.

3. Carbon dioxide is essential for photosynthesis

Process

- Take two destarched potted plants.
- Cover both the plants with bell jars and label them as A and B.
- Inside Set-up A, keep **NaHCO₃** (sodium bicarbonate). It produces CO₂.
- Inside Set-up B, keep **NaOH** (Sodium hydroxide). It absorbs CO₂.
- Keep both the set-ups in the sunlight at least for 6 hours.
- Perform the starch test on both of the plants.
**Observations**

Leaf from the plant in which NaHCO$_3$ has been placed gives positive test. Leaf from the plant in which NaOH has been kept give negative test.

**Conclusion**

Plant in Set up A gets CO$_2$ whereas plant in Set-up B does not get CO$_2$. It means CO$_2$ is must for photosynthesis.

**Source:** [mastermindtutor.com](http://mastermindtutor.com)
#41  Effect of Light intensity on the rate of Photosynthesis

Plants need light energy to make the chemical energy needed to create carbohydrates. Increasing the light intensity will boost the speed of photosynthesis. However, at high light intensities the rate becomes constant.

![Graph showing the effect of light intensity on the rate of photosynthesis.](image)

**Experiment**

- Place a pond weed Elodea upside in a test tube containing water.
- Place the tube in a beaker of fresh water at 25°C. This helps to maintain a constant temperature around the pond weed.
- Place excess sodium bicarbonate (NaHCO₃) in the water to give a constant saturated solution of CO₂.
- Place the lamp (the only light source) at distance from the plant.
- Count the number of oxygen bubbles given off by the plant in 1 minute period. This is the rate of photosynthesis at that particular light intensity.
- The gas should be checked to prove that it is indeed oxygen - relights a glowing splint.
• Repeat at different light intensities by moving the lamp to different distances.

Photo from passmyexams.co.uk

• Graph the results placing light intensity on the x-axis.

Explanation

• **Light energy** absorbed by chlorophyll is converted to ATP and H+
• At very low light levels the plant will be respiring only not photosynthesising.
• As the **light intensity increases**, the **rate** of photosynthesis **increases**. However, the rate will not increase beyond a certain level of light intensity.
- At high light intensities the rate becomes **constant**, even with further increases in light intensity, there are no increases in the rate.
- The plant is unable to harvest the light at these high intensities and the chlorophyll system can be damaged by very intense light levels.

Additional sources:  
[skool.ie](http://skool.ie)  
[passmyexams.co.uk](http://passmyexams.co.uk)
#42 Effect of Temperature on the Rate of Photosynthesis

When the **temperature** rises the rate of photosynthesis rises also. There is an **optimum** temperature at which the rate of photosynthesis is maximum. Beyond this temperature, the reaction quickly comes to a halt.

![Graph showing the effect of temperature on the rate of photosynthesis](image)

**Experiment**

- Place a pond weed Elodea upside in a test tube containing water at 25°C.
- Place the tube in a beaker of fresh water.
- Place excess sodium bicarbonate (NaHCO₃) in the water to give a constant saturated solution of CO₂.
- Place the lamp (the only light source) at a fixed distance from the plant.
- Maintain the room temperature at 20°C.

- Count the number of oxygen bubbles given off by the plant in a one-minute period. This is the rate of photosynthesis at that particular temperature.
- The gas should be checked to prove that it is indeed oxygen - relights a glowing splint.
- Repeat at different temperatures: 0°C - surround the beaker with an ice jacket; greater than room temperature (25°C, 30°C, 35°C, 40°C, 45°C, etc.) by using a hot plate.
- Graph the results placing temperature on the x-axis.

**Explanation**

- At low temperature, the enzyme does not have enough energy to meet many substrate molecules, so the reaction is slowed.
- When the temperature rises, the particles in the reaction move quicker and collide more, so the rate of photosynthesis rises also.

![Graph showing rate of photosynthesis vs temperature with an optimum temperature peak.](image)

- At the optimum temperature, the enzyme is most efficient and the rate is maximum.

![Graph showing rate of photosynthesis vs temperature with an optimum temperature peak.](image)
- At temperatures above 40°C the rate slows down. This is because the enzymes involved in the chemical reactions of photosynthesis are temperature sensitive and destroyed (denatured) at higher temperatures.

Additional sources:  
- skool.ie  
- passmyexams.co.uk  
- woisd.net
# 43 Effect of Carbon Dioxide on the Rate of Photosynthesis

When the concentration of CO₂ is low the rate of photosynthesis is also low. (the plant has to spend time waiting for more CO₂ to arrive). Increasing the concentration of CO₂ increases the rate of photosynthesis.

![Graph showing the effect of CO₂ concentration on the rate of photosynthesis]

**Experiment**

- Place a pond weed Elodea upside in a test tube containing water at 25°C.
- Place the tube in a beaker of fresh water.
- Place excess sodium bicarbonate (NaHCO₃) in the water to give a constant saturated solution of CO₂.
- Place the lamp (the only light source) at a fixed distance from the plant.
- Maintain the room temperature at 20°C.

- Count the number of oxygen bubbles given off by the plant in a one-minute period. This is the rate of photosynthesis at that particular concentration of CO₂.
- The gas should be checked to prove that it is indeed oxygen - relights a glowing splint.
- Repeat at different lower CO₂ concentrations by using different dilutions of a saturated solution.
- Graph the results placing CO₂ concentration on the x-axis.
Explanation

- The rate of photosynthesis increases linearly with increasing CO₂ concentration (from point A to B).
- The rate falls gradually, and at a certain CO₂ concentration it stays constant (from point B to C). Here a rise in CO₂ levels has no effect as the other factors such as light intensity become limiting.
Limiting factor is something present in the environment in such short supply that it restricts life processes. Three factors can limit the speed of photosynthesis - light intensity, carbon dioxide concentration and temperature.

If a component is in low supply then productivity is prevented from reaching maximum.

Sunlight

- Light energy is vital to the process of photosynthesis. It is severely limiting at times of partial light conditions, e.g. dawn or dusk.
- As light intensity increases, the rate of photosynthesis will increase, until the plant is photosynthesising as fast as it can. At this point, even if light becomes brighter, the plant cannot photosynthesise any faster.

- Over the first part of the curve (between A and B), light is a limiting factor. The plant is limited in how fast it can photosynthesise because it does not have enough light.
- Between B and C, light is not a limiting factor. Even if more light is shone on the plant, it still cannot photosynthesise any faster.
Carbon dioxide

- In photosynthesis CO$_2$ is a key limiting factor. The usual atmospheric level of CO$_2$ is 0.03%. In perfect conditions of water availability, light and temperature this low CO$_2$ level holds back the photosynthetic potential.
- The more CO$_2$ a plant is given, the faster it can photosynthesise up to a point, but then a maximum is reached.

Temperature

The chemical reactions of photosynthesis can only take place very slowly at low temperature, so a plant can photosynthesise faster on a warm day than on a cold one.
When plants are growing outside, we can not do much about changing the conditions that they need for photosynthesis. But if crops are grown in glasshouses, then it is possible to control conditions so that they are photosynthesising as fast as possible.

**CO₂ enrichment**

CO₂ concentration can be controlled. CO₂ is often a limiting factor for photosynthesis, because its natural concentration in the air is so very low (0.04%). In a closed glasshouse, it is possible to provide extra CO₂ for the plants, e.g. by burning fossil fuels or releasing pure CO₂ from a gas cylinder.

**Optimum light**

Light also can be controlled. In cloudy or dark conditions, extra artificial lighting can be provided, so that light is not limiting the rate of photosynthesis. The kind of lights that are used can be chosen carefully so that they provide just the right wavelengths that the plants need.

**Optimum temperature**

In some countries where it is too cold for good growth of some crop plants, the heated greenhouses can be used. This is done, for example, with tomatoes. The temperature in the glasshouse can be kept at the optimum level to encourage the tomatoes to grow fast and strongly, and to produce a large yield of fruit that ripens quickly.

The temperature can be raised by using a heating system. If fossil fuels are burned, there is also a benefit from the CO₂ produced.
The leaf consists of a broad, flat part called the **lamina**, which is joined to the rest of the plant by a leaf stalk or **petiole**. Running through the petiole are **vascular bundles**, which then form the **veins** in the leaf.

Although a leaf looks thin, it is made up of **several layers** of cells. You can see these if you look at a transverse section (cross-section) of a leaf under a microscope.

1. **Cuticle:**
   - made of **wax** – waterproofing the leaf
   - secreted by cells of the upper epidermis

2. **Upper epidermis**
   - thin and transparent – allows **light** to pass through
   - **no chloroplasts** are present
   - act as a **barrier** to disease organisms
3. **Palisade mesophyll**

- main region for **photosynthesis**
- cells are **columnar** (quite long) and packed with **chloroplasts** to trap light energy
- receive CO₂ by diffusion from air spaces in the spongy mesophyll

4. **Spongy mesophyll**

- cells are more **spherical** and loosely packed
- contain chloroplasts, but not as many as in palisade cells
- **air spaces** between cells allow gaseous exchange – CO₂ to the cells, O₂ from the cells during photosynthesis

5. **Vascular bundle**

- this is a leaf **vein**, made up of xylem and phloem
- **xylem** vessels bring **water** and **minerals** to the leaf
- **phloem** vessels transport **sugars** and **amino acids** away (translocation)

6. **Lower epidermis**

- acts as a **protective** layer
- **stomata** are present to regulate the loss of **water vapour** (transpiration)
- site of **gaseous exchange** into and out of the leaf

7. **Stomata**

- each stomata is surrounded by a pair of **guard cells**
- guard cells – control whether the stoma is **open** or **closed**
- **water vapour** passes out during **transpiration**
- CO₂ diffuses in and O₂ diffuses out during **photosynthesis**
#47 Plant's mineral requirements and fertilisers

Plants need minerals for healthy growth.

Plant is in need for **mineral ions** to control chemical activities, grow, and produce materials. The most important minerals are **Magnesium ions** and **Nitrates**.

1. Importance of nitrate and magnesium ions

<table>
<thead>
<tr>
<th>Mineral salt</th>
<th>Nitrogen</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrates (NO₃⁻) or Ammonium (NH₄⁺)</td>
<td>Magnesium (Mg²⁺) ions</td>
</tr>
<tr>
<td>Why needed</td>
<td>To make proteins</td>
<td>To make chlorophyll</td>
</tr>
<tr>
<td>Deficiency</td>
<td>Weak growth, yellow leaves</td>
<td>Yellowing between the veins of leaves</td>
</tr>
</tbody>
</table>

a. Nitrates

- plants absorb nitrate ions from the soil, through their root hairs
- nitrate ions combine with glucose -----→ **amino acids**
- amino acids bond together -----→ **protein**
- **deficiency** causes poor growth, especially of leaves. The stem becomes weak, lower leaves become yellow and die, while upper leaves turn pale green

*Nitrates deficiency: Growth severely restricted, few stems; yellowing of older foliage.*
b. Magnesium

- plants absorb magnesium ions from the soil solution
- used for the manufacture of **chlorophyll**
- each chlorophyll contains one magnesium atom
- **deficiency** makes leaves turn yellow from the bottom of the stem upwards and eventually stops photosynthesis

![Magnesium deficiency in potato plant.](image)

*(Growth fairly normal; foliage slightly pale; older leaflets develop central necrosis, turn yellow or brown and wither prematurely).*

![Magnesium deficiency: yellowing between the veins of leaves.](image)

2. Nitrogen fertilisers

Sometimes the soil is lacking of the mineral ions needed, this problem can be solved by adding fertilisers to the soil. Fertilisers are chemical compounds rich in the mineral ions needed by the plants. They help the plants grow faster, increase in size and become greener, they simply make them healthier and **increase** the **crop yield**.
Intensive farming (repeatedly using the same land for crops) removes nitrates from the soil. These need to be replaced to prevent a drop in yield. Nitrates can be replaced in 3 ways:

- applying animal manure
- **crop rotation** – growing leguminous plants such as peas, beans and clover every 2 or 3 years: these plants develop root nodules containing nitrogen-fixing bacteria, and the roots are ploughed into the soil, boosting nitrate levels
- adding artificial fertilisers such as ammonium nitrate

**Danger of overuse**

Apply too much nitrogen fertiliser ----> **water** is drawn out of plant roots (osmosis) ----> plant wilt/die.

**Eutrophication:**
Nitrates can be **leached** out of the soil and enter a nearby river polluting it, creating a layer of green algae on the **surface** of it causing lack of **light** in the river thus preventing the aqua plants photosynthesising ----> **death** of algae ----> decomposers (bacteria) multiply and decay, respire using **O₂** ----> death of **aquatic animals** from lack of **O₂** = Eutrophication.

**Overuse of nitrogen fertiliser can have nasty environmental consequences.**

Additional resource: [xtremepapers.com](http://xtremepapers.com)
Photosynthesis takes place in chloroplasts in the leaves of plants.
The word equation for photosynthesis is:

**Word equation**

Carbon dioxide + Water $\xrightarrow{\text{Light}}$ Glucose + Oxygen

Chlorophyll

The balanced equation is:

**Symbol equation**

$6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{Light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

Chlorophyll

Chlorophyll traps energy from light. In photosynthesis, this energy is converted to chemical energy in carbohydrates.
Photosynthesis takes place in the cells of the mesophyll layer, especially the palisade mesophyll. Leaves are thin and have a large surface area, to speed up the supply of carbon dioxide to the palisade cells and to maximise the amount of sunlight that hits the leaf and can be absorbed by chlorophyll. Stomata and air spaces allow carbon dioxide to diffuse quickly from the air to the chloroplasts. Xylem vessels bring water, and phloem tubes take away the products of photosynthesis.

Some of the glucose that is made is used in respiration, to provide energy to the plant cells. Some is stored as starch. Some is used to make cellulose for cell walls. Some is transported around the plant in the form of sucrose, in the phloem tubes. Some is combined with nitrate or ammonium ions to make proteins. Some is used to make other substances such as fats. With the addition of magnesium ions, chlorophyll can be made.

When testing a leaf for starch, it must first be boiled to break down cell membranes and allow iodine solution to make contact with any starch inside the cells. Hot alcohol will remove chlorophyll from the leaf, making it easier to see any colour changes.

Plants need light and carbon dioxide for photosynthesis.

If either light or carbon dioxide are in short supply, they limit the rate of photosynthesis and are said to be limiting factors. The rate of photosynthesis is also affected by temperature.
The food an animal eat everyday is called **diet**. Most animals need 7 types of nutrients in their diet: **carbohydrates, proteins, fats** + **water, fibre, vitamins, minerals**.

The amount of **energy** needed is provided mainly by our carbohydrate and fat intake. Your dietary requirements depend on your **age, sex** and **activity**.

- **Age**: The energy demand increases until we stop growing. While children are growing they need more protein per kilogram of body weight than adults do.
- **Sex**: Generally, males use up more energy than females.
- **Pregnant women** need extra nutrients for the development of the fetus.
A. A balanced diet is a diet that contains all the main nutrients in the correct amounts and proportions to maintain good health.

B. Malnutrition is the result of not eating a balanced diet. There may be:

- wrong amount of food: too little or too much
- incorrect proportion of main nutrients
- lacking in one or more key nutrients
Effects of malnutrition

1. Obesity - Too much food (carbohydrate, fat or protein)

```
 too much food → obesity
        coronary heart disease

 too much food → diabetes → blindness
```

2. Coronary heart disease

- Too much saturated/animal fat in the diet results in high cholesterol levels.
- Cholesterol can stick to the walls of arteries, gradually blocking them.
- If coronary arteries become blocked, the results can be angina and coronary heart disease.
3. Starvation

- **Too little** food can result in starvation.
- Extreme slimming diets, such as those that avoid carbohydrate foods, can result in the disease anorexia nervosa.

4. **Childhood protein-energy malnutrition (Kwashiakor)**

Wrong proportion of nutrients e.g. too much carbohydrates (starchy foods) and a lack of protein can lead to Kwashiakor in young children.

Kwashiakor characterized by edema, anorexia, ulcerating dermatoses.
5. Vitamin, mineral and fiber deficiency diseases - Lacking key nutrients.

**Vitamin, minerals, fibre and water**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Function</th>
<th>Deficiency</th>
<th>Food sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C</td>
<td>Maintain healthy skin and gums</td>
<td>Scurvy - bleeding under skin, bleeding gums</td>
<td>Citrus fruits, cabbage, blackcurrants, guava, mango, tomato</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>- Maintain hard bones - Help to absorb calcium from small intestine</td>
<td>Rickets - soft bones that become deformed (e.g. bow legs)</td>
<td>- Milk, butter, cheese, egg yolk, fish-liver oil - Made by skin when exposed to sunlight</td>
</tr>
<tr>
<td>Calcium</td>
<td>- Formation of healthy bones and teeth - Normal blood clotting</td>
<td>- Rickets, brittle bones and teeth - Slow blood clotting</td>
<td>Milk, cheese, fish</td>
</tr>
<tr>
<td>Iron</td>
<td>- Formation of haemoglobin in red blood cells</td>
<td>Anaemia (not enough red blood cells → not enough O₂ delivered to tissues): constant tiredness, lack of energy</td>
<td>Red meat, liver, kidney, eggs, vegetables (spinach, cabbage...), chocolate</td>
</tr>
<tr>
<td>Fibre</td>
<td>Cellulose adds bulk (mass) to undigested food passing through the intestines, maintaining peristalsis (constriction and relaxation)</td>
<td>- Constipation - Long-term deficiency leads to bowel cancer</td>
<td>Vegetables, fruit, whole meal bread</td>
</tr>
<tr>
<td>Water</td>
<td>- Formation of blood, cytoplasm - Solvent for transport of nutrients and removal of wastes (urine) - Enzymes only work in solution</td>
<td>Dehydration</td>
<td>Drinks, fruit, vegetables</td>
</tr>
</tbody>
</table>
Modern technology such as chemical fertilisers, pesticides, herbicides, modern agricultural machinery, artificial selection... have been used to increase food production.

- Development and use of chemical fertilisers on farm land boots levels of nutrients in the soil, increasing crop yields.
- Development and use of pesticides such as insecticides and fungicides kill pests that feed on or damage crops to increase crop yields.
- Development and use of herbicides kill weeds that compete with crops for nutrients, light, water and space to increase crop yields.
- Use of modern machinery, such as tractors and combine harvesters enables land and crops to be managed more efficiently.
- Artificial selection to produce varieties of plants that are suited to particular climates and soil types, and breeds of animal for specific purpose such as optimum meat, milk, and wool production.
- Development of **biological control** methods for pest control as an alternative to pesticides.

- Use of **yeast and bacteria** in the large-scale production of bread, beer and wine, youghurt and cheese. Single-cell protein and fungi are use to produce meat substitutes.

- Use of **medicines** such as antibiotics, hormones and artificial insemination techniques in intensive animal rearing.

- Use of **plant hormones** in plant growing and fruit production.

- Use of **genetic engineering** and cloning techniques to produce organisms to produce hormones, etc.
- Development of systems to **water plants** in **greenhouses** automatically and to grow plants in nutrient solutions (a process called hydroponics).

- Use of **satellites** to monitor crop development, observe crop diseases and assess the need for additional fertiliser.

- Development of **intensive farming** and automated feeding mechanisms.
#51 Problems of world food supplies and the causes of famine

There is **not** always **enough food** available in a country to feed the people living there. A severe food shortage can lead to **famine**.

It has been calculated that more than enough food is produced on Earth to provide every single person with more than enough for their needs. Yet many people do not get enough food. Each year, many people die because they have an inadequate diet.

The fundamental problem is that **food is distributed unequally** on our planet: while some parts of the world produce more than enough food for the people that live there, in other part of the world not enough food is produced.

- Although large amounts of food are transported from one area to another, this is still not sufficient to supply enough food to everybody.
- If food prices rise too high, many people may not be able to afford to buy it.
Famine can occur for many different reasons:

- Climate change and natural disaster such as drought and flooding that prevent crops from growing.

- Increasing population: population may grow so large that the land on which they live can no longer provide enough food for them.

- Unequal distribution of food.
The **alimentary canal** is a long tube which stars at the mouth, runs through the stomach and intestines and finishes at the anus. It is part of the digestive system. The **digestive system** also includes the **accessory organs** (teeth, tongue, gallbladder, salivary glands, liver, the pancreas).

Main regions of the alimentary canal and associated organs are:

- Mouth, salivary glands
- Oesophagus
- Stomach
- Pancreas, liver, gall bladder
- Small intestine (duodenum + ileum)
- Large intestine (colon + rectum)
- Anus.
Food is broken down with the help of digestive juices, which contain special chemicals called enzymes.

Dealing with food

- **Ingestion**: Taking food into the body through the mouth ('eating')
- **Digestion**: The break-down of large, insoluble food molecules into small, water-soluble molecules using mechanical and chemical processes.
- **Absorption**: Moving digested food molecules across the wall of the intestine into the bloodstream or the lymph so they can be transported around the body.
- **Assimilation**: Movement of digested food molecules into the cells where they are used, becoming part of the cells (uptake and use of food molecules by cells).
- **Egestion**: Passing out of undigested food as faeces, through the anus.
Functions of the regions of the digestive system:

<table>
<thead>
<tr>
<th>Organ</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>Digestion starts here! The teeth cut and grind the food, which is mixed with saliva. This contains amylase to break starch down into maltose (sugar).</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>Boluses (balls) of food pass through by peristalsis, from mouth to stomach.</td>
</tr>
</tbody>
</table>
| Stomach       | Muscular walls squeeze on food to make it semi-liquid. Gastric juice contains:  
|               |   - Pepsin (a protease) to break big proteins down into small protein (polypeptides)  
|               |   - Hydrochloric acid (HCl) to maintain an optimum pH (1-2.5). The acid also kills bacteria. |
| Gall bladder  | Stores bile used to help in the digestion of fats.                       |
| Pancreas      | Secretes pancreatic juice into the duodenum, also makes the hormones insulin and glucagon. |
| Liver         | Makes bile, which is stored on the gall bladder. Bile contains salts that emulsify fats, forming droplets with a large surface area to make digestion by lipase more efficient. Digested foods are assimilated here. For example, glucose is stored as glycogen, surplus amino acids are deaminated. |
| Small intestine | Duodenum + Ilium                                                          |
| Duodenum      | The first part of the small intestine. It receives pancreatic juice containing protease, lipase and amylase. Proteins, fats, starches and complex sugars are broken down into small soluble molecules. The juice also contains sodium hydrogen carbonate, which neutralises acid from the stomach, producing a pH of 7.8. |
| Ileum         | The second part of the small intestine. Enzymes in the epithelial lining break down lactose and peptides. Its surface area is increased by the presence of villi which allow the efficient absorption of fully digested food molecules into the bloodstream. |
| Large intestine | Colon + Rectum                                                         |
| Colon         | Only undigested food reaches here. Water absorbed.                      |
| Rectum        | This stores faeces until it is egested.                                 |
| Anus          | This has muscles to control when faeces is egested from the body.       |

Common misconceptions
The liver does not make digestive enzymes- bile is not an enzyme. It breaks fat down into smaller droplets, but does not change them chemically. The fat molecules stay the same size, it is just the droplet size that changes from large to small due to the action of bile.
Additional resource: classes.midlandstech.com
# 53  Human teeth and dental decay

There are four types of teeth in human (incisors, canines, premolars and molars), each specialised for different functions.

**Position of teeth in the mouth**

![Diagram of tooth positions in the mouth]

**Types of human teeth**

<table>
<thead>
<tr>
<th>Incisor</th>
<th>Canine</th>
<th>Premolar</th>
<th>Molar</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Incisor image]</td>
<td>![Canine image]</td>
<td>![Premolar image]</td>
<td>![Molar image]</td>
</tr>
<tr>
<td>Position in mouth</td>
<td>Front</td>
<td>Either side of incisors</td>
<td>Behind canine</td>
</tr>
<tr>
<td>Description</td>
<td>Chisel-shaped (sharp edge)</td>
<td>Slightly more pointed than incisors</td>
<td>2 points (cusps), 1 or 2 roots</td>
</tr>
<tr>
<td>Function</td>
<td>Biting of pieces of food</td>
<td>Similar function to incisors</td>
<td>Tearing and grinding food</td>
</tr>
</tbody>
</table>
Structure of tooth

Causes of dental decay
- Bacteria are present on the surface of our teeth. Food deposits and bacteria form a layer called plaque. Bacteria on the plaque feed on sugars, producing acid. This acid dissolves enamel, forming a hole.

- Dentine underneath the enamel is softer – it dissolves more rapidly.

- If the hole reaches the pulp cavity, bacterial infection can get to the nerve. This results in toothache and possibly, an abscess (an infection in the jaw).

**Common misconceptions:**

Do not say that sugar causes decay. It only causes problems because of the activity of bacteria feeding on it and producing acids.

**Try this**

The outer layer of the crown of a tooth is resistant to attack by bacteria

1. Name this outer layer. (1 mark)
2. State the mineral and the vitamin needed in the diet for the healthy development of this layer. (2 mark)
3. Explain how bacteria can gain entry through this layer into the tooth and cause dental decay. (3 mark)

**Answers**

1. Enamel
2. Mineral: calcium; vitamin: D
3. Three points from:

   • bacteria feed on sugar from food left on the teeth
   • bacteria produce acid
   • acid attacks or dissolves the enamel
   • dentine if softer, so it breaks down more quickly
   • this results in a hole in the enamel, exposing the pulp cavity.
Fluoride helps prevent **destruction** of the tooth surface caused by **acids** produced by bacteria. It forms a **reservoir** on the teeth from which fluoride is released during attack. It reduces the **loss of minerals** from the tooth and promotes **repair** of early tooth decay.

Growing children can absorb fluoride in their diet (from toothpaste of fluoridated water). It becomes part of the enamel of their developing teeth, and the enamel; is then more resistant to tooth decay.

**Arguments for and against the addition of fluoride to public water supplies**

**For:**

- Tooth decay in the local population of children decreases.
- There is no need to buy fluoridated toothpaste.

**Against:**

- It is form of mass medication – people have no choice about whether or not they want the treatment.
- Fluoride is a benefit only to growing children – adults do not benefit.
- If people take proper care of their teeth, fluoridation is unnecessary.
- Fluoride may have side effects, such as an increase in risk of bone cancer (but this is unlikely).
Proper care of teeth

- Avoid sugary food, especially between meals, so bacteria cannot make acid and clean teeth regularly to remove plaque.
- Use dental floss or a toothpick to remove pieces of food and plaque trapped between them.
- Use fluoride toothpaste (or drink fluoridated water) – fluoride hardens tooth enamel.
- Visit a dentist regularly to make sure tooth decay is reacted early and any stubborn plaque (called calculus) is removed.

Common misconceptions

There is a big difference between fluoride and fluorine. Fluorine is a very toxic gas, while fluoride is a mineral that helps to strengthen teeth. Make sure do not use the term fluorine in an exam answer about teeth.
Food that we ingest is mainly made up of large, insoluble molecules that can not be absorbed through the gut wall. It needs to be changed into small, soluble molecules.

1. **Mechanical digestion** is the physical process of preparing the food for chemical digestion.

   - It involves **chewing** (in the mouth), **mixing, churning** (in the stomach and intestine) and **segmentation** (in the intestine).

   - Large pieces of food are breaking down into smaller pieces à increases the surface area of the food.

   - **Bile** physically digests **fats** by emulsifying them – turning them into small droplets with a large surface area.

**Chewing**

**Mechanical** digestion, performed bye the teeth à pieces of food are mixed with saliva and become smaller à easier to swallow and have a larger surface area.
Peristalsis

- The walls of the alimentary canal have an **inner, circular muscle** fibre coat and an **outer, longitudinal muscle** fibre coat.

- As the ball of food (bolus) formed in the mouth enters the pharynx, a reflex action is initiated.

- This produces slow, wave-like contractions in the walls of the esophagus and later along the whole length of the tract (**peristalsis**).

- Peristaltic waves involve the **contraction** of the **circular muscle** fibres **behind** the bolus (A) and their **relaxation in front** of the bolus.

- Longitudinal muscles provide the **wave-like action**. The two functions together push the ball down the tract (B).

![Diagram of peristalsis]

**Misconceptions:** Chewing food does not involve breaking down large molecules into small molecules; it only breaks down large pieces into smaller pieces, giving a larger surface area for enzymes to work on.

**Video Peristalsis**

**2. Chemical digestion**

- Involves breaking down large, insoluble molecules into small, soluble ones.

- Enzymes speed up the process. They work efficiently at body temperature ($37^0C$) and at suitable pH.

- The main places where chemical digestion happens are the mouth, stomach and small intestine.
Absorption is the movement of digested food molecules through the wall of the intestine into the blood or lymph.

Digestion is completed in the small intestine. By now, most carbohydrates have been broken down to simple sugar, proteins to amino acids, and fats to fatty acids and glycerol. These molecules are small enough to pass through the wall of the small intestine and into the blood. This is called absorption. The small intestine is especially adapted to allow absorption to take place very efficiently.

It has a very rich blood supply. Digested food molecules are small enough to pass through the wall of the intestine into the bloodstream. Water, mineral salts and vitamins are also absorbed in the small intestine. The small intestine absorbs 5-10 dm$^3$ of water each day. However, the colon absorbs much less water and salt than the small intestine, generally around 0.3–0.5 dm$^3$ per day.
The adaptation of the small intestine for absorbing digested nutrients

<table>
<thead>
<tr>
<th>Features</th>
<th>How this helps absorption take place</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is very long, about 5 m in an adult human</td>
<td>This gives plenty of time for digestion to be completed, and for digested food to be absorbed as it slowly passes through.</td>
</tr>
<tr>
<td>It has villi, each villus is covered with cells which have even smaller projections on them, called microvilli.</td>
<td>This gives the inner surface of the small intestine a very large surface area. The larger the surface area, the faster nutrients can be absorbed.</td>
</tr>
<tr>
<td>Villi contain blood capillaries</td>
<td>Monosaccharides, amino acids, water, minerals and vitamins, and some fats, pass into the blood, to be taken to the liver and then round the body.</td>
</tr>
<tr>
<td>Villi contain lacteals, which are part of the lymphatic system.</td>
<td>Fats are absorbed into lacteals.</td>
</tr>
<tr>
<td>Villi have walls only one cell thick</td>
<td>The digested nutrients can easily cross the wall to reach the blood capillaries and lacteals.</td>
</tr>
</tbody>
</table>
Significance of Villi

Villi are finger-like projections that increase the surface area for absorption. If a section of small intestine was turned inside out, its surface would be like a carpet. Inside each **villus** are:

- Blood capillaries: absorb amino acids and glucose.
- Lacteals: absorb fatty acids and glycerol.

Food molecules are absorbed:
- mainly by **diffusion**.
- or by **active transport**.

Epithelial cells contain mitochondria to provide energy for absorption against the concentration gradient.
Role of the hepatic portal vein

The hepatic portal vein transports absorbed food from the small intestine to the liver. After a meal, the blood in this vein contains very high concentrations of glucose and amino acids, as well as vitamins and minerals. The liver reduces levels backs to normal.
Assimilation is the movement of digested food molecules into the cells of the body where they are used, becoming part of the cells.

Role of liver in the metabolism of glucose and amino acids

- **Excess glucose** in the blood arriving at the liver is converted into glycogen (animal starch) for storage, or broken down through respiration, producing energy for other purposes.

- Amino acids cannot be stored in our body, so any that is excess has to be dealt with in the liver.
  - Some amino acids are transaminated to produce a different amino acid.
  - The rest are deaminated to produce ammonia \((\text{NH}_3)\) and a keto acid.

  + \(\text{NH}_3\) is converted into urea, which is transported to the kidneys and excreted.
  + The keto acid is used primarily as energy for liver cells
So **Deamination** is the removing of **nitrogen-containing** part of amino acids to form **urea** and using of the remainder of amino acid to provide **energy** to the liver cells.

**Role of liver in the breaking down of alcohol and other toxins**

- Breaking down any toxins absorbed from the alimentary canal, including drugs such as alcohol. Cells in the liver are able to convert many toxins to harmless substances that can be transported in the blood and excreted from the body.

**Role of fat as an energy storage substance**

- **Fatty acids** and **glycerol** pass into the lymphatic system and then the bloodstream. Once in the blood nutrients are carried to all cells of the body. Some are oxidised to produce **energy** and others are used to repair the cell, build new cells.

- Fat is a good storage compound – it releases twice as much energy as carbohydrates when respired, and act as insulation in the skin. Some nerve cells form a **myelin sheath** from fat, to prevent electrical impulses from leaking out.
A **balanced diet** contains suitable proportions of each group of nutrients – carbohydrates, fats, proteins, minerals, vitamins, water and fibre – and the correct amount of energy.

- Eating food containing more energy than you can use up causes weight increase, which can lead to obesity. Children who do not get enough food may suffer from energy protein malnutrition, in which they do not grow properly and have little energy.

- Digestion is the breakdown of large molecules of food into small ones, so that they can be absorbed through the wall of the alimentary canal.
• Mechanical digestion breaks down large pieces of food to small ones. It is done by the teeth, the muscles in the wall of the alimentary canal and bile salts. Chemical digestion breaks down large molecules to small ones. It is done by enzymes.

• Mammals have four types of teeth – incisors, canines, premolars and molars – each with their own functions.

• Digestion begins in the mouth, as teeth grind food into smaller pieces, and amylase digests starch to maltose.

• Protein digestion begins in the stomach, where pepsin digests proteins to polypeptides. Rennin is present in young mammals, and clots milk protein. Hydrochloric acid kills bacteria and provides a low pH for the action of pepsin.

• Pancreatic juice flows into the duodenum. It contains enzymes that digest starch, proteins and lipids, and also sodium hydrogencarbonate to partly neutralise the acidity of food coming from the stomach.

• Bile also flows into the duodenum. It contains bile salts, which emulsify fats, making it easier for lipase to digest them.

• The lining of the small intestine is covered with villi, giving it a very large surface area, which helps to speed up absorption. Cells on the surface of the villi make enzymes, which complete the digestion of food. The villi contain blood capillaries to absorb glucose, amino acids, water, vitamins and minerals, and lacteals to absorb fatty acids and glycerol.
The absorbed nutrients are carried to the liver in the hepatic portal vein. Some are used in the liver, some are stored, and some are sent on in the blood to be delivered to cells all over the body.

The colon absorbs more water from the food. In the rectum, the undigested food is formed into faeces, which are eventually egested through the anus.
Plants have transport systems to move food, water and minerals around. These systems use continuous tubes called xylem and phloem:

- **Xylem vessels** carry **water** and minerals from the **roots** to the leaves.
- **Phloem tubes** carry **sugar** & other **organic nutrients** made by plant from the **leaves** to the rest of the plant.

**Structure of the phloem tissue**

This is a long tube that runs alongside the xylem tissue. They are made of long narrow tubes with **perforated sieve plates** along the thin length.

The function of the phloem tissue is to **transport** food nutrients such as **glucose** and **amino acids** from the leaves and to all other cells of the plant, this is called translocation.

Unlike the xylem, the phloem tissue is made of columns of **living cells**, which contains a cytoplasm but no nucleus, and its activities are controlled by a **companion cell** next to it which has a nucleus, but companion cells have no function in translocation.
**Structure of the xylem tissue**

Xylem vessels consist of **dead cells**. They have a thick, strengthened cellulose cell wall with a hollow lumen. The end walls of the cells have disappeared, so a long, open tube is formed. The walls of the xylem vessel contains holes called **pits** which water enters through.

The xylem vessel is specialised to **transport water** and dissolved **minerals** from the root up to all the other parts of the plant, and also to helps **supporting** the stem and strengthening it.
Additional resource: xtremepapers.com
acceleratedstudynotes.com

Related post: Cell functions
In the **roots** xylem and phloem are in the **centre** to withstand stretching forces.

In the **stems**, they are arranged in bundles near the **edge** to resist compression and bending.
They are grouped together into **veins** and **vascular bundles** as they pass through **leaves**.

The positions of xylem and phloem tissues as seen in transverse sections of unthickened, herbaceous, dicotyledonous roots, stems and leaves:
Plants take in **water** from the soil, through their **root hairs**:

- At the very tip is a **root cap**. This is a layer of cells which protects the root as it grows through the soil.

- The rest of the root is covered by a layer of cells called the **epidermis**.

- The **root hairs** are a little way up from the root tip. Each root hair is a **long epidermal cell**. Root hairs do not live for very long. As the root grows, they are replaced by new ones.
**Root hair cells**, as seen under the light microscope:

![Image of root hair cells](image)

*The hair is an extension of the cell and not a separate cellular structure.*

**Functions of root hair cells**

- **Increase** the external **surface area** of the root for **absorption** of **water** and **mineral ions** (the hair increases the surface area of the cell to make it more efficient in absorbing materials).

- Provide **anchorage** for the plant.

**Video**
#62 Passage of water through root, stem and leaf

Water enters root hair cells by osmosis. This happens when the water potential in the soil surrounding the root is higher than in the cell à water diffuses from the soil into the root hair, down its concentration gradient.

- As the water enters the cell, its water potential becomes higher than in the cell next to it, e.g. in the cortex. So water moves, by osmosis, into the next cell. Some of water may also just seep through the spaces between the cells, or through the cell walls, never actually entering a cell.

- Water vapour evaporating from a leaf creates a kind of suction, its pressure at the top of the vessels is lower than that at the bottom à water move up the stem in the xylem, more water is drawn into the leaf from the xylem. This creates a traspiration stream,
pulling water up from the root. Mature xylems cells have no cell contents, so they act like open-ended tubes allowing free movement of water through them. Roots also produce a root pressure, forcing water up xylem vessels.

- Water moves from xylem to enter leaf tissues down water potential gradient. In the leaves, water passes out of the xylem vessels into the surrounding cells.

Common misconceptions

Water does not travel through xylem vessels by osmosis. Osmosis involves the movement of water across cell membranes – xylem cells do not have living contents when mature, so there will be no membranes.

Try this

Describe how the structure of xylem tissue is adapted to its functions.
The cells join together to make a long tubular structure. There are no cross-wall and no living contents so the water and mineral salts can pass through freely.

Describe the mechanism of water movement through the xylem.
Water moves by the pull from the leaves caused by the transpiration. Xylem vessels are very thin, so they act like a capillary tube helping to withdraw water upward.

1. a) Labell all parts of the root hair cell (5 mark)

   ![Root Hair Cell Diagram]

   b) Which plant cell part is missing from this cell? (1 mark)

   c) Name the process by which the cell absorbs:

   i)Water (1 mark)

   ii)Minerals (1 mark)
Answer:

a)

b) Chloroplast

c) i) osmosis
   ii) diffusion or active transport (or active uptake)
# 63 Transpiration in plants and factors affecting transpiration rate

In the leaves, water molecules leave the xylem vessels and move from cell to cell. They move through the spongy mesophyll layer by osmosis along a concentration gradient. Water then evaporates into spaces behind the stomata and diffuses through the stomata into the surrounding air.

Transpiration is the evaporation of water at the surfaces of the mesophyll cells, followed by loss of water vapour from plant leaves, through the stomata.

Water in the leaf cells forms a thin layer on their surface. The water evaporates into the air spaces in the spongy mesophyll. This creates a high concentration of water molecules. They diffuse out of the leaf into the surrounding air, through the stomata, by diffusion.
Mechanism of water movement through a plant

Water molecules are attracted to each other (cohesion) à water vapour evaporating from a leaf creates a kind of suction, pressure of water at the top of the vessels is lower than that of the bottom à water move up the stem in the xylem, more water is drawn into the leaf from the xylem. This creates a transpiration stream, pulling water up from the root.

**The rate of transpiration can be affected by several factors:**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ temperature</td>
<td>↑ the kinetic (movement) energy of water molecules à they diffuse faster.</td>
</tr>
<tr>
<td>↑ air movement</td>
<td>Removes water molecules as they pass out of the leaf à maintaining a steep concentration gradient for diffusion.</td>
</tr>
<tr>
<td>↓ humidity</td>
<td>↓ the concentration of water molecules outside the leaf à steeper concentration gradient for diffusion.</td>
</tr>
<tr>
<td>↑ light intensity</td>
<td>Stomata open to allow gas exchange for photosynthesis à water vapour can diffuse out of the leaf.</td>
</tr>
</tbody>
</table>

The opening and closing of the stomata is controlled by the guard cells.

- In light, guard cells take up water by osmosis and become turgid. Because their inner walls are rigid they are pulled apart, opening the pore.
- In darkness water is lost and the inner walls move together closing the pore.
Because of this, the transpiration rate is increased by an increase in light intensity.

* Most of the factors that result in a change in transpiration rate are linked to diffusion. When writing explanation, try to include references to the concentration gradient caused by a change in the factor.

**How wilting occurs**

Young plant stems and leaves rely on their cells being turgid to keep them rigid. If the amount of water lost from the leaves of a plant is > than the amount taken into the roots à the plant will have a water shortage à cells become flaccid (soft) and will no longer press against each other à Stems and leaves lose their rigidity, and wilt.
#64 Adaptations of the leaf, stem and root to different environments

Plants which live in extreme environments have adaptations to control their transpiration rate. Most modifications are adaptations to very dry (arid) environments.

**Water plants** have no problems of water shortage. They do not need adaptations to conserve water as desert plants.

Plants modified to cope with a lack of water are called xerophytes. Living in deserts where water is scarce and evaporation is rapid, or in windy habitats where evaporation can also be rapid, they have to cut down water loss.

1. **Marram grass** (Ammophila)

- Very **long roots** to search for water deep down in sand dunes.
- **Leaves** that roll up in dry weather to increase humidity around stomata, reducing transpiration.
- **Sunken stomata** to create high humidity and reduce transpiration.
- **Fine hairs** around stomata, reducing air movement so humidity builds up and transpiration is reduced.
2. Prickly pear cactus (Opuntia)

- **Leaves** reduced to spines – this reduces the surface area for transpiration and also acts as a defence against herbivores.
- **Reduces** number of stomata.
- Stomata **closed** during the **day** - when conditions for transpiration are most favourable.
- **Fleshy stem** - to store water.

3. Pine tree (Pinus)

- **Leaves needles-shaped** to reduce surface area for transpiration and to resist wind damage.
- **Sunken stomata** to create high humidity and reduce transpiration.
- **Thick waxy cuticle** on the epidermis to prevent evaporation from leaf surface.
Water plants may have stomata on the tops of their leaves

**Water hyacinth** (Eichhornia cassipes)

- **Roots** do not attach to the bed of the river or pond where they grow, but just float freely in the water.
- The **stems** and **leaf stalks** have hollow spaces in them, filled with air to help to float on the top of the water where they can get plenty of light for photosynthesis.
- **Leaves** and **stomata** are on **both surfaces**, not just on the underside as in most plants to allow to absorb CO₂ from the air, for photosynthesis.
- The **cuticle** on the upper and lower surfaces of the leaves is much **thinner** than in plants that don't live in water, there is no need to prevent water loss from the leaves.
Translocation is the movement of organic food such as sucrose and amino acids in phloem; from regions of production to regions of storage or regions of utilisation in respiration or growth.

1. **Glucose** the product of **photosynthesis** is very important as it makes many other important nutrients, e.g. sucrose.
   - Sucrose in the leaves then enters the phloem vessels.
   - The phloem transports the sucrose all **across the leaf** where it can be made used of.

2. **Amino acids** are also transported in the phloem.

Sucrose and amino acids are transported to every tissue of the plant, each cell use it in a different way.

- **Root cells** convert sucrose into glucose for respiration and store it.
- **Growing cells** make cellulose for cell walls from sucrose and use the amino acids to make proteins for growth.
- And **fruits** use the sucrose to make the attractive scent and tasty nectar to attract insects.

The areas of the plant where sucrose is made, are called sources, and where they are delivered to and made use of are called sinks.
**Ringing Experiment**

The **phloem** vessels are situated nearer to the bark in comparison with xylem; they can be selectively removed by cutting a **ring** in a stem just deep enough to cut the phloem but not the xylem.

After a week there is:

- a **swelling above** the ring
- **reduced growth below** the ring
- the **leaves** are unaffected.

This was early evidence that **sugars** were transported downwards in the phloem.

Grey squirrels and other small mammals gnaw the bark and destroy the phloem that is in the inner bark region.
People who grow crops for food sometimes need to use chemicals called **pesticides**. Pets such as **insects** that eat the crop plants, or **fungi** that grow on them, can greatly reduce the yield of the crop. Pesticides are use to kill the insects or fungi.

Some pesticides kill only the insects or fungus that the spray touches. They are called **contact pesticides**. They can be very effective if they are applied properly, but they also kill insects and pests that are useful to the plant.

**Systemic pesticides** are more effective because when sprayed onto the leaves of the plant, they are absorbed by it through the **cuticle** or **stomata** and into the phloem tubes. They move through the plant in the **phloem (translocation)** and are taken in by any insect eating the plant or sucking up phloem sap.

So any insect feeding on the plant, even if it was hidden under the leaf where the spray could not reach it, will eventually end up feeding on pesticide. The same is true for fungi; no matter where they are growing on
the plant, the pesticide will eventually reach them. Once an insect has ingested enough pesticide it will die, meanwhile the harmless insects remain safe.

The disadvantages of systemic pesticides are that they may accumulate in the food chain.

Systemic pesticides may need to be taken up by roots or through the leaves.
#67 Transport of materials from sources to sinks at different seasons

'Source' is the part of a plant where substances are **produced** (e.g. leaves for sucrose, amino acids) or **enter the plant**.

'Sink' refers to the part of the plant where the substrate can be **stored** (e.g. roots or stem for starch).

**Examples:**

**Sources:**

- **Leaves** - sucrose is produced here.
- **Root hairs** - Nitrates are absorbed here.

**Sinks:**

- **Roots/Stems** - starch is stored here.
- **Root tips** - amino acids are stored here.

When a plant is actively photosynthesising and growing, the **leaves** are generally the major **sources** of translocated materials. They are constantly **producing sucrose**, which is carried in the phloem to all other parts of the plant.

'Source' is the part of a plant where substances enter the plant, whereas 'Sink' refers to the part of the plant where the substrate is stored.
These parts - the sinks - include the roots, the flowers and the fruits:

- The roots may change some of the sucrose to starch and store it.
- The flowers use the sucrose to make fructose.
- Later, when the fruits are developing, quite large amounts of sucrose may be used to produce sweet, juicy fruit ready to attract animals.

But many plants have a time of year when they become dormant. During this stage, they wait out harsh conditions in a state of reduced activity.

Dormant plants do not photosynthesise, but survive on their stored starch, oils and other materials. When the seasons change, they begin to grow again. Now the stored materials are converted to sucrose and transported to the growing region.

For example, potato plants are not able to survive the cold frost of winter.

- During the summer, the leaves photosynthesise and send sucrose down into underground stems. Here, swellings called tubers develop. The cells in the root tubers change the sucrose to starch and store it.

- In winter, the leaves die. Nothing is left of the potato plant above ground - just the stem tubers beneath the soil.
• In spring, they begin to grow new shoots and leaves. The starch in the tubers is changed back to the sucrose, and transported in the phloem to the growing stems and leaves. This will continue until the leaves are above ground and photosynthesise.

So in summer, the leaves are sources and the growing stem tubers are sinks. In spring, the stem tubers are sources and the growing leaves are sinks.

Conclusion:

Phloem can transfer sucrose in either direction - up or down the plant. This isn't true for the transport of water in the xylem vessels. That can only go upwards, because transpiration always happens at the leaf surface, and it is this that provides the 'pull' to draw water up the plant.

<table>
<thead>
<tr>
<th>Transport</th>
<th>From</th>
<th>To</th>
<th>Mechanism</th>
<th>High rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transpiration</td>
<td>H₂O, Mineral Ions</td>
<td>Soil</td>
<td>Leaves, Flowers, Fruits</td>
<td>Passive process using a tension in the xylem produce by evaporation of water.</td>
</tr>
<tr>
<td>Translocation</td>
<td>Sucrose, Amino acids</td>
<td>Leaves</td>
<td>Shoot, root tips, root cortex, seeds, flowers, fruits</td>
<td>Active process, the water enters the tubes to build up a head of pressure that forces the phloem sap to the sinks.</td>
</tr>
</tbody>
</table>
In plants, **xylem** vessels transport **water** and **mineral** ions from the roots upwards to the leaves. **Phloem** tubes transport **sucrose** and other organic nutrients, from the leaves where they are made to all parts of the plant. This is called **translocation**.

**Xylem** vessels are made of **dead**, empty **cells** with strong lignin in their walls. As well as transporting water, they help to **support** the plant.

Water is drawn up xylem vessels by the evaporation of water from the leaves, called **transpiration**. Transpiration happens fastest when it is hot, dry, windy and sunny.

Water enters root hairs by **osmosis**, and then moves across the cortex of the root into the xylem.

Root hairs take up mineral ions by **active transport**, using energy supplied by respiration to move them against their concentration gradient.

**Phloem** is made of **living cells** with sieve plates at their ends. A companion cell is associated with each phloem sieve tube element.

**Systemic pesticides** are translocated in phloem.

**Sucrose** is translocated from sources to sinks. Different parts of a plant may become sources and sinks in different seasons.
The main transport system of human is the **circulatory system**, a system of tubes (**blood vessels**) with a pump (the **heart**) and **valves** to ensure **one-way** flow of blood.

Its functions:

- To transport **nutrients** and **oxygen** to the cells.
- To remove **waste** and **carbon dioxide** from the cells.
- To provide for efficient **gas exchange**.

The **right** side of the heart collects **deoxygenated** blood from the body and pumps it to the **lungs**.

The **left** side collects **oxygenated** blood from the lungs and pumps it to the **body**.
The double circulation

Beginning at the lungs, blood flows into the left-hand side of the heart, and then out to the rest of the body. It is brought back to the right-side of the heart, before going back to the lungs again.

This is call a double circulation system, because the blood travels through the heart twice on one complete journey around the body:

- one circuit links the heart and lungs (low pressure circulation)
- the other circuit links the heart with the rest of the body (high pressure circulation).

The importance of a double circulation

- **Oxygenated** blood is kept separate from **deoxygenated** blood. The septum in the heart ensures this complete separation. Oxygenated blood flows through the left side of the heart while deoxygenated blood flows through the right.

- The **blood pressure** in the **systemic circulation** is kept higher than that in the pulmonary circulation. The left ventricle, with a thicker wall, pumps blood under higher pressure to the body and delivers oxygenated blood effectively to all parts of the body. The right ventricle has a thinner wall and pumps blood to the lungs under lower pressure, thereby avoiding any lung damage.

Video
The function of the **heart** is to pump blood around the body. The **right** side pumps blood to the **lungs** and the **left** side pumps blood to the rest of the **body**.

### Structure of the heart

<table>
<thead>
<tr>
<th>Muscular wall</th>
<th>Septum</th>
<th>Chambers</th>
<th>Valves</th>
<th>Associated blood vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>The wall of the LV is much thicker than the RV because it needs to build up enough pressure to move the blood to all the main organs.</td>
<td>Completely separated the chambers on the left-hand side and the ones on the right-hand side.</td>
<td>2 atria: <strong>right atrium</strong> (RA) and <strong>left atrium</strong> (LA), receiving blood from veins and squeeze it into the ventricles. 2 ventricles: <strong>right ventricle</strong> (RV) and <strong>left ventricle</strong> (LV), receiving blood from the atria and squeeze it into arteries.</td>
<td>Semilunar Tricuspid Bicuspid</td>
<td>Vena cava Pulmonary artery Pulmonary Aorta</td>
</tr>
</tbody>
</table>
Heart's function

- **Blood circulation**

1. Blood in the **right ventricle** (RV) is pump to the **lungs**
2. Blood from the **lungs** flows back into the **left atrium** (LA) and then into the **left ventricle** (LV).
3. Blood in the LV is pumped through the **body** (except for the lungs)
4. Blood returns to the heart where it enters the **right atrium** (RA).
• **Muscular contraction**

The heart is made of a special type of muscle called **cardiac muscle** which contracts and relaxes regularly, throughout life.

The heart’s muscle is constantly active, so it needs its own blood supply, through the **coronary artery**, to provide it with **oxygen** and **glucose**.

• **Working of the valves**

Valves in the heart prevent blood from being pushed backwards up into the atria when the heart ‘beats’.

**Animation:** [Heart Contraction and Blood Flow](#)  
[How the heart pumps blood](#)
Try this

1. On a copy of the diagram of the double circulatory system, label:
   i) The 4 main blood vessels (4 marks)
   ii) The chambers of the heart (4 marks)
   iii) The 2 valves shown (2 marks)

2. State 2 differences in composition between blood leaving the right ventricle and blood entering the left atrium. (2 marks)

**Answers:**
1.

2. Blood leaving the right ventricle has more CO₂ and less O₂ than blood entering the left atrium.

**Common misconceptions**

Remember that blood passing through the chambers of the heart does **not** supply the heart muscle with oxygen or glucose. The heart muscles has its own blood supply - via the coronary arteries - to do this.
#71 Effect of exercise on heartbeat and causes of coronary heart disease

A heartbeat is a contraction. Each contraction squeezes blood to the lungs and body. The heart beats about 70 times a minute, more if you are younger, and the rate becomes lower the fitter you are.

- During exercise the heart rate increases to supply the muscles with more oxygen and glucose to allow the muscles to respire aerobically, thus they have sufficient energy to contract.

- Regular exercise is important to keep the heart muscle in good tone, so it is more efficient in maintaining blood pressure and reduces the risk of coronary heart disease and stroke.

Coronary arteries

The muscles of the heart are so thick that the nutrients and oxygen in the blood inside the heart would not be able to diffuse to all the muscles quickly enough. The heart muscles need a constant supply of nutrients so that it can keep contracting and relaxing. The coronary arteries supply this.

If a coronary artery gets blocked – e.g. by a blood clot – the cardiac muscles run short of oxygen, so they can not respire, can not obtain energy to contract, so the heart stops beating. This is called a heart attack or cardiac arrest.

Main causes of a coronary heart disease and preventive measures

<table>
<thead>
<tr>
<th>Cause</th>
<th>Explanation</th>
<th>Preventive measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor diet with too much saturated (animal) fat</td>
<td>Cholesterol building up in arteries block the blood vessels/ form a blood clot.</td>
<td>Cholesterol-free diet</td>
</tr>
<tr>
<td>Smoking</td>
<td>Nicotine damages the heart and blood vessels</td>
<td>Stop smoking</td>
</tr>
<tr>
<td>Stress</td>
<td>Tends to raise blood pressure, collect fatty materials in the arteries.</td>
<td>Relaxing, Avoid the causes of stress</td>
</tr>
<tr>
<td>Obesity</td>
<td>Put extra strain on the heart, makes it more difficult for the person to exercise.</td>
<td>Controlled diet, Regular exercise</td>
</tr>
<tr>
<td>Lack of exercise</td>
<td>The heart muscle loses its tone and becomes less efficient in pumping blood.</td>
<td>Regular exercise</td>
</tr>
<tr>
<td>Inherited factors</td>
<td>Heart disease can pass from one generation to the next in some families.</td>
<td>Reduce the other risk factors by a healthy life-style.</td>
</tr>
</tbody>
</table>
Blockage of the coronary arteries is called **coronary heart disease**.
There are 3 main kinds of blood vessels – arteries, veins and capillaries.

- **Arteries** carry blood away from the heart. They divide again and again, and eventually form very tiny vessels called capillaries.
- The **capillaries** gradually join up with one another to form large vessels called veins.
- **Veins** carry blood towards the heart.

**The comparison of blood vessels structure and functions**

![Diagram showing the structure of arteries, veins, and capillaries.](image)
The transfer of materials between capillaries and tissue fluid

<table>
<thead>
<tr>
<th>Function</th>
<th>Arteries</th>
<th>Capillaries</th>
<th>Veins</th>
</tr>
</thead>
</table>
| Carry blood away from the heart at **high** pressure | -Supply all cells with their **requirements**  
-Take away **waste** products | **Return** blood to the heart at **low** pressure |
| **Structure of wall**                 | -**Thick**, strong  
-Contain **muscles**, **elastic** fibres and **fibrous** tissue | **Very thin**, only one cell thick | -**Thin**  
-**Mainly fibrous** tissue  
-Contain far **less** muscle and **elastic** tissue than arteries |
| **Lumen**                             | -**Narrow**  
-Varies with heartbeat (increases as a pulse of blood passes through) | -**Very narrow**  
-Just wide enough for a red blood cell to pass through | **Wide** |
| **Valves**                            | (-)                       | (-)                                                   | (+)  
Prevent backflow |
| **How structure fits function**       | -Strength and elasticity needed to withstand the pulsing of the blood, prevent bursting and maintain pressure wave  
-Heels to maintain **high blood pressure**, preventing blood flowing backwards | -No need for strong walls, as most of the blood pressure has been lost  
-**Thin walls** and narrow lumen bring blood into close contact with body tissue, allowing **diffusion** of materials between capillary and surrounding tissues.  
-White blood cells can squeeze between cells of the wall | -No need for strong walls, as most of the blood pressure has been lost  
-Wide lumen offers **less resistance** to blood flow |
As blood enters capillaries from arterioles (small arteries), it slows down. This allows **substances** in the plasma, as well as **O$_2$** from red blood cells, to **diffuse** through the capillary wall into the surrounding tissues (the capillary wall is thin and permeable).

**Liquid** in the **plasma** also passes out. This forms **tissue fluid**, bathing the cells. **Waste products** from the cells, e.g. CO$_2$, **diffuse** back through the capillary walls into the plasma. Some of the tissue fluid also passes back.

**Diffusion** is responsible for the **transfer of materials between capillaries and tissue fluid.**

**Plan of the main blood vessels in the human body**
Sample questions

Figure above shows a section through the heart

i) Name the two blood vessels A and B       [2 marks]
ii) Which of blood vessels A, B, C or D carry oxygenated blood   [1 mark]
iii) Name valve E and state its function       [3 marks]

Student's answer

i) A, vena cava (√)       B, pulmonary vein (∗)
ii) C (∗)

iii) name: semilunar valve (√)       function: to stop blood going backwards (√)

Examiner's comments

Blood vessels B is the pulmonary artery. Arteries of the heart always carry blood from a ventricle.

Part ii) needs two answers (blood vessels C and D) to gain the mark.

D is the pulmonary vein, which carries oxygenated blood to the heart from the lung.

C is the aorta, which carries oxygenated blood from the heart to the body.

In part iii) the name of the valve is correct, but there are two marks for its functions. This candidate has given only one statement: a second mark was available for stating that the valve prevents blood from going back into the left ventricle.
If blood is allowed to stand without clotting, it separates out into 4 components: plasma, red blood cells, white blood cells and platelets.

The plasma and red blood cells play an important role in the transportation of substances, around the body.

White blood cells and platelets are part of the body's immune system.

55% of the blood is plasma. This straw-coloured liquid contain water with many important dissolved substances which must be carried around the body. Most materials are carried by the blood plasma, except for oxygen.
Plasma transports:

- **blood cells**
- soluble **nutrients** e.g. **glucose** (products of digestion) from the small intestine to the organs
- **amino acids** (plasma acts as a pool for amino acids for these cannot be stored in the body)
- **plasma proteins** that are important in blood **clotting** (e.g. fibrinogen).
- **CO₂** (waste gas produced by respiration in cells) from the organs to lungs
- Other wastes of digestion (e.g. **urea**) from the liver to the kidneys.
- **Antibodies** and **antitoxins**
- **Hormones**
- **Ions**
- **Heat** from the liver and muscles to all parts of the body.

Credit: [moodle](https://moodle.com)
Blood consists of **cells** floating in **plasma**. Most of the cells are **red blood cells**. A much smaller number are **white blood cells**. There are also fragments formed from special cells in the bone marrow, called **platelets**.

**Red** and **white** blood cells as seen under a light microscope.

Blood as seen through a microscope:

- The largest cells are **white cells**.
- The others are all **red cells**.
- There are also a few **platelets**.
Functions of blood cells

- Red blood cells transport oxygen.
- White blood cells protect against disease.
- Blood platelets help the blood to clot.

1. Red blood cells (erythrocytes)

- Made in the bone marrow of some bones, including ribs, vertebrae and some limb bones. Produced at a very fast rate – about 9000 million per hour!

- Transport O₂ from lungs to all respiring tissues. Prepare CO₂ for transport from all respiring tissues to lungs.

- Contain haemoglobin (Hb), a red iron-containing pigment which can carry O₂. In the lungs, Hb combines with O₂ to form oxyhaemoglobin. In other organs, oxyhaemoglobin splits up into Hb and O₂

- Have no nucleus à can fit more Hb inside the cytoplasm, but can lives only for about 4 months.

- Have a special biconcave disc shape à increases the surface area and makes the diffusion of oxygen into & out of the cell easier.

- Old red blood cells are broken down in the liver, spleen and bone marrow. Some of the iron from the Hb is stored, and used for making new Hb, some of it is turned into bile pigment and excreted.
2. White blood cells (leukocytes)

- Made in the bone marrow and in the lymph nodes.
- Have a nucleus, often large and lobed.
- Can move around and squeeze out through the walls of blood capillaries into all parts of the body.
- There are many different kinds of white blood cells. They all have the function of fighting pathogens (disease-causing bacteria and viruses) and to clear up any dead body cells in your body:

a. Phagocytes:

- Have lobed nuclei and granular cytoplasm.
- Can move out of capillaries to the site of an infection.
- Remove any microorganisms that invade the body and might cause infection, engulf (ingest) and kill them by digesting them.

b. Lymphocytes: produce antibodies to fight bacteria and foreign materials.

- Have large nuclei
- Responsible for immunity
- There are two different types of lymphocytes:

  B-lymphocytes: secrete special proteins called antibodies in response to contact with their particular antigen, which may be an invading pathogen or a foreign tissue that has been transplanted.

  T-lymphocytes attack foreign or infected cells and kill them.
3. Platelets (thrombocytes)

- Small fragments of cells, with **no nucleus**.
- Made in the red **bone marrow**.
- Involve in **blood clotting**: form blood clot, which **stop blood loss** at a wound and **prevent** the entry of **germs** into the body.

![Diagram of blood cells]

**Functions of the blood**

- Transportation of R.B.C’s, W.B.C’s, oxygen, food nutrients, hormones, and waste products.
- Defence against disease, by white blood cells phagocytosis and production of antibodies.
- Supplying cells with glucose to respire and keep a constant temperature.
#75 Blood clotting

When an injury causes a blood vessel wall to break, platelets are **activated**. They change shape from round to **spiny**, stick to the broken vessel wall and each other, and begin to **plug** the break.

The platelets also interact with **fibrinogen**, a **soluble** plasma **protein**, to form **insoluble fibrin**. **Calcium** is required for that.

Fibrin strands form a **net** that entraps more platelets and other blood cells (red cells and white cells), producing a **clot** that plugs the break.

**Necessity for blood clotting**

- Prevent excessive blood loss from the body when there is a damage of the blood vessel.
- Maintain the blood pressure.
- Prevent the entry of microorganism and foreign particles into the body.
- Promote wound healing.
#76 Immune system - antibody production, tissue rejection & phagocytosis

The **immune system** is the body's defence against disease and foreign bodies, under the form of **antibody production**, **tissue rejection** and **phagocytosis**.

---

**Antibody production**

Antibodies are produced by **lymphocytes**, which are formed in lymph nodes. Lymphocytes produced **antibodies** in response to the presence of **pathogens** such as bacteria. This is because **alien cells** have chemicals called **antigen** on their surface. A different antibody is produced for each antigen.

The antibodies make bacteria **clump** together in preparation for action by **phagocytes**, or neutralise **toxins** produced by the bacteria. Once antibodies have been made, they remain in the blood to provide long-term protection.

Some lymphocytes **memorise** the antigens the body has been exposed to. They can rapidly reproduce and produce antibodies to respond to further infections by the same pathogen (disease-causing organism).
Tissue rejection

**Transplants** involve replacing a damaged organ with a donor organ. Unfortunately, lymphocytes and phagocytes will respond to any foreign cells in your body, even if they are not pathogens.

If a person's kidneys fail, they can be given a new kidney taken from another person. However the recipient's immune system will recognise the cells in the new kidney as 'foreign', and will attack and destroy them.

The transplanted organ triggers an immune response, antibodies are secreted and the organ may be rejected. This is called **tissue rejection**.

To prevent this happening:

- The donor organ needs to be a **similar** tissue type to that of the patient e.g. from a close **relative**.

- **Immunosuppressive** drugs are used, which switch off the body's immune response. While recovering, transplant patients are at risk of dying from any disease they are exposed to, so they need to be kept in **isolation**.
**Phagocytosis**

**Phagocytes** have the ability to move out of capillaries to the site of an infection. They then engulf (ingest) the infecting pathogens and kill them by digesting them.

Video: Phagocytosis of a Paramecium (unicellular ciliate protozoa)
The lymphatic system is a collection of lymph vessels and glands. It has 3 main roles:

- **Fluid balance**: return tissue fluid to the blood
- **Protection from infection**: produce white blood cells lymphocytes
- **Absorption of fats**: transport digested fats from villi to blood stream

1. **Lymph and Tissue Fluid**

Tissue fluid is a fluid surrounding the cells of a tissue. It is leaked plasma - Plasma from the blood capillaries move to the tissue through gaps in the walls and become tissue fluid.
Tissue fluid play an important role in substance exchange between blood and cells. It supplies cells with O$_2$ and nutrients and takes away waste products including CO$_2$.

At the end of the capillary bed, the tissue fluid leaks back into the blood, and becomes plasma again, but not all of it. A little of it is absorbed by the lymphatic vessel and becomes lymph.

The lymphatic vessel takes the lymph to the blood stream by secreting them in a vein near the heart, called subclavian vein. The lymph in the lymphatic vessels are moved along by the squeeze of muscles against the vessel, just like some veins.

The return of tissue fluid to the blood in the form of lymph fluid prevents fluid built up in the tissue.

2. Production of lymphocytes

The lymphatic system is an important component of the immune system, which fights infection. One group of white blood cells, the lymphocytes, are made in lymph glands such as the tonsils, adenoids and spleen. The glands become more active during an infection because they are producing and releasing large numbers of lymphocytes.

The lymphocytes can live and multiply in the lymphatic system, where they attack and destroy foreign organisms. Lymphoid tissue scattered throughout the body filters out pathogens, other foreign matter and cellular debris in body fluids.
3. The absorption of fatty acids and glycerol from the small intestine

Following the chemical and mechanical breakdown of food in the digestive tract, most nutrients are absorbed into the blood through intestinal capillaries. Many digested fats, however, are too large to enter the blood capillaries and are instead absorbed into lymphatic capillaries by intestinal lacteals. Fats are added to the blood when lymph joins the bloodstream.

Each villus contains a lacteal - a blind ending lymph vessel.

Additional source: [lubopitko-bg](#)  [Xtremepapers](#)

Related topic: Absorbtion – function of the small intestine and significance of villi

Video
Mammals have a double circulatory system, in which blood is moved through vessels by the regular contraction and relaxation of cardiac muscles in the wall or the heart.

Blood enters the atria of the heart, flows through open valves into the ventricles, and is then forced out into the arteries during systole.

The ventricles have thicker walls than the atria, and the left ventricle has a thicker wall than the right ventricle, to allow them to produce a greater force when the muscles contract, necessary so that they can push the blood further.

In coronary heart disease, the coronary arteries become blocked, so oxygen is not delivered to the heart muscles and they stop contracting. Smoking, stress and a diet high in saturated fats increase the risk.

Arteries are thick-walled, elastic vessels that carry pulsing, high-pressure blood away from the heart. They split into capillaries, which are tiny vessels with walls only one cell thick. Capillaries take blood close to every cell to the body, so that the cells are supplied with oxygen and nutrients and have their waste products removed. Capillaries join up to form veins. Veins are thin-walled vessels with valves, which carry low-pressure blood back to the heart.

Blood contains red cells, white cells and platelets floating in plasma. Plasma transports many different substances in solution. Red cells contain the iron-containing protein haemoglobin, which transports oxygen. White cells fight against bacteria and viruses. Platelets help the blood to clot.

Fluid leaks out of capillaries to fill the spaces between all the body cells, where it is called tissue fluid. It is collected into lymph vessels which carry it back to the bloodstream.
Respiration is the chemical reactions that break down nutrient molecules in living cells to release energy.

In humans, our cells need energy (ATP) for:

- muscle contraction
- making protein molecules: linking together amino acids into long chains
- cell division: to repair damaged tissues and so that we can grow
- active transport
- transmitting nerve impulses
- maintenance of constant body $t^\circ$

All this energy comes from the food we eat. Water soluble molecules are absorbed from the intestine into the blood.

The main energy–providing nutrient: glucose (contains a lot of chemical energy).

There are 2 types of respiration:

- Aerobic (with O$_2$)
- Anaerobic (without O$_2$)

Video
Respiration releases energy from food.

There are 2 kinds of respiration: **Aerobic** and **Anaerobic**. The main difference between them is that aerobic respiration involves **oxygen** and anaerobic respiration does not!

**A. Aerobic respiration**

The release of a relatively **large amount of energy** in cells by the breakdown of food substances in the **presence of O₂**.

\[
\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} \\
C_6H_{12}O_6 + 6O_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}
\]

**B. Anaerobic respiration**

Anaerobic respiration: the release of a relatively **small amount of energy** by the breakdown of food substances in the **absence of O₂**.

**Anaerobic respiration in muscles during exercise:**

\[
\text{glucose} \rightarrow \text{lactic acid} + \text{energy} \\
C_6H_{12}O_6 \rightarrow 2\text{C}_3\text{H}_6\text{O}_3 + \text{energy}
\]

**Anaerobic respiration in yeast:**

\[
\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide} + \text{energy} \\
C_6H_{12}O_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 + \text{energy}
\]

Muscles respire anaerobically when exercising vigorously, because the blood cannot supply enough oxygen to maintain aerobic respiration. However, the formation and build-up of lactic acid in muscles causes cramp (muscle fatigue).
The lactic acid that is made is transported to the liver, and later is broken down by combining it with O$_2$. This extra O$_2$ is breathed in after the exercise has stopped, and it is known as the **oxygen debt**.

**Bread making**

- yeast is mixed with water to activate it then added to flour to make dough

- mixture -------> warm place -------> rise

- yeast releases CO$_2$ -------> dough rises

* a warm $t^o$ is important because fermentation is controlled by enzymes

- when dough is cooked, high $t^o$ kills yeast and evaporates any formed ethanol
- air spaces are left where CO$_2$ was trapped

**Brewing**

- yeast is added to a source of sugar (fruit juice or germinated barley grains) and kept in warm conditions

- fermentation (yeast respires the sugar) occurs -------> ethanol is formed making the drink alcoholic

- CO$_2$ makes the drink fizzy + sharp flavour
Gas exchange usually involves **2 or more gases** transferred in **opposite** directions across a **respiratory surface**.

**1. Structure of the breathing system**: the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries.

*Credit: biology-forums.com*
2. Gaseous exchange relies on diffusion. To be efficient, the **gaseous exchange surface** must:

- **thin** – shorter distance to diffuse
- **moist** – allow gases to dissolve
- **large surface area**
- have a **concentration gradient** across surface – maintained by movement of air and transport/use of gas.

These features are present in gills (fish) and alveoli (lungs).

3. The role of mucus and cilia
- Inside the nose, thin turbinal bones are covered with a layer of cells. Some of which are **goblet cells**.

- Goblet cells produce a **liquid** (water + **mucus**) ---› evaporate ---› moisten nose.

- Cilia: tiny hair-like projections; constantly moving

- Bacteria + dust particles are **trapped** by cilia and mucus as to not move further inside the gas exchange system.

**Try this**

State how each feature labeled on the diagram of an alveolus makes the process of gaseous exchange efficient. [5 marks]

**Answer**

Wall of alveolus – one cell thick (or very thin) so that diffusion happens quickly.

Moist surface- allow O\textsubscript{2} to dissolve making diffusion faster.

Blood is moving – so that’s concentration gradient is maintained for O\textsubscript{2} and CO\textsubscript{2}

Wall of capillary – one cell thick (or very thin) so that’s diffusion happens quickly.

Red blood cells – contain haemoglobin to transport O\textsubscript{2} away from the lungs.

**Video: Gas exchange**

**Video: Functions of Cilia and Goblet Cells**
#81 Inspired and expired air, blood pH and breath rate

* inspired air: air we breath in
* expired air: air we breath out

The composition of inspired and expired air

**Testing for CO₂**

To investigate the differences in composition between inspired and expired air, we use *limewater* because it *change colour* when the gas is bubbled through, from colourless to *milky*.

There is more CO₂ present in *expired air* ----> it makes limewater change colour more *quickly* (than inspired air).

**Effects of physical activity on breathing**

* tidal volume: amount of air during normal, relaxed breathing
  * vital capacity: maximum amount of air breathed in or out in one breath

**During normal breathing:**
- depth (tidal volume) : ≈ 0.5ℓ
- rate: 12 breaths/ minute

**During exercise:**
- depth: ≈ 5ℓ (depending on age, sex, size & fitness of person)
- rate: over 20 breaths/ minute

*The total lung volume is greater than vital capacity (some air always remains in the lungs). If not, alveoli walls would stick together, the lung would collapse.*
Link between physical activity and rate and depth of breathing

- when you run, muscles in your legs use up a lot of energy.
- cells in the muscles need a lot of O\(_2\) very quickly.
- they combine O\(_2\) + glucose as fast as they can, to release energy for muscle construction --- > a lot of O\(_2\) is needed
- you breath deeper and faster to get more O\(_2\) into your blood.
- your heart beast faster to get O\(_2\) to the leg muscles as quickly as possible.
- a limit is reached - the heart and the lung can not supply O\(_2\) to the muscles any faster.
- some extra energy (not much) is produced by anaerobic respiration: some glucose is broken down without combing with O\(_2\): 

\[
\text{Glucose} \rightarrow \text{lactic acid} + \text{energy.}
\]

- CO\(_2\) and lactic acid concentration in tissue and in the blood ↑ --- > blood pH ↓
- Brain sens the change --- > nerve impulses sent to the diaphragm and the intercostal muscles, stimulating them to contract harder and more often --- > faster and deeper breathing.

Try this

a) The composition of the air inside the lungs changes during breathing.

i) State three differences between inspired and expired air. [3 marks]

ii) Gaseous exchange in the alveoli causes some of the changes to the inspired air. Describe three features of the alveoli which assist gaseous exchange. [3 marks]

b) i) State what is meant by anaerobic respiration [2 marks]

ii) Where does anaerobic respiration occur in human? [1mark]

Answer

a) i) Inspired air contains more O\(_2\), less CO\(_2\), and less water vapor then expired air.

   ii) Three features from:

   - the wall of the alveolus is one cell thick (or very thin)
   - there is a moist surface to the alveoli
   - there are large number of alveoli
   - the air in the alveoli is constantly being replaced.

b) i) The release of energy by cells without the use of oxygen.

   ii) In muscle cells.
Tobacco smoke contains irritants and carcinogens. Its 4 main toxic chemicals: carbon monoxide, nicotine, smoke particles and tar.

**Carbon monoxide:**
- combines with haemoglobin in RBC ---> prevents them transporting O₂.

**Nicotine:**
- addictive ---> continual smoking

**Smoke particles:**
- irritate air passages ---> inflammation + increase mucus production ---> chronic bronchitis.
- presence of smoke particles in alveoli + coughing = emphysema (breathlessness)

**Tar:**
- a carcinogen: increase risk of lung cancer (cell division out of control)
- lines air passages:
  - increase mucus production
  - paralysing + damaging cilia
  ---> bronchitis
Common misconceptions

*Remember that only nicotine and carbon monoxide enter the blood. Tar and smoke particles do not – they stay in the lungs.*

Sample question

The table shows the percentage of haemoglobin which is inactivated by CO present in the blood of taxi drivers in a city.

<table>
<thead>
<tr>
<th>City taxi drivers</th>
<th>Percentage of Hb inactivated by CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime drivers</td>
<td></td>
</tr>
<tr>
<td>Non-smokers</td>
<td>2.3</td>
</tr>
<tr>
<td>Smokers</td>
<td>5.8</td>
</tr>
<tr>
<td>Night-time drivers</td>
<td></td>
</tr>
<tr>
<td>Non-smokers</td>
<td>1.0</td>
</tr>
<tr>
<td>Smokers</td>
<td>4.4</td>
</tr>
</tbody>
</table>

i) Suggest two sources of the CO inhaled by these taxidrivers [2 marks]

ii) Some daytime drivers have 5.8% of their Hb affected. Using information from the table, explain which source contributes most to this effect. [2 marks]

iii) Suggest a reason for the differences, shown in the table, between daytime and night-time drivers. [1 mark]

Student’s answer

i) 1. cigarette smoke √
   2. breathing by passengers ×

ii) It must be cigarette smoking because non-smokers have less of their Hb affected. √

iii) There could be less car exhaust fumes, containing CO, at night. √

Examiner’s comments

*In part (i), the second answer is biologically incorrect (we breath out CO₂, not CO. The other correct answer was car exhaust gases.*

*In part (ii), the answer and the explanation were correct.*

*Part (iii) was a good answer.*
#83 Ventilation, role of intercostal muscles and diaphragm

There are 2 sets of muscles which help you to breath:
- **intercostal**: between the ribs
- **diaphragm**: a large sheet of muscle and elastic tissue, underneath the lungs and heart.

Figure below shows the relationship between intercostal muscles, diaphragm and ribcage to achieve ventilation of the lungs.

*Two set of intercostal muscles are attached to the ribes. They are antagonistic.*
1. Breathing in (inhaling)

- The **external intercostal muscles** contract, they move the ribcage upward and outward ---> ↑ volume of the thorax.
- The diaphragm muscles **contracts** ---> diaphragm moves **down**
- ↑ volume of the thorax
- ↓ air pressure in the thoracic cavity
- air rush **into** the lungs through the mouth or nose.

2. Breathing out (exhaling)

The opposite happens:

- The **internal intercostal muscles** contract
- The diaphragm muscles **relax** ---> diaphragm moves **up**
- ↓ volume of the thorax
- ↑ air pressure in the thoracic cavity
- air rush **out** of the lungs.

<table>
<thead>
<tr>
<th>Features</th>
<th>Inspiration</th>
<th>Expiration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intercostal muscles</strong></td>
<td><strong>external</strong> muscles contract</td>
<td><strong>internal</strong> muscles contract</td>
</tr>
<tr>
<td><strong>Ribcage moving</strong></td>
<td><strong>upward</strong> outward</td>
<td><strong>downward</strong></td>
</tr>
<tr>
<td><strong>Diaphragm muscles</strong></td>
<td><strong>contract</strong></td>
<td><strong>relax</strong></td>
</tr>
<tr>
<td><strong>Diaphragm</strong></td>
<td>move ↓</td>
<td>move ↑</td>
</tr>
<tr>
<td><strong>Thorax volume</strong></td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td><strong>Air pressure in thorax cavity</strong></td>
<td>↓ lower than air pressure outside</td>
<td>↑ higher than air pressure outside</td>
</tr>
<tr>
<td><strong>air rushes</strong></td>
<td><strong>into</strong> the lungs</td>
<td><strong>out</strong> of the lungs</td>
</tr>
</tbody>
</table>
Respiration is a series of metabolic reactions that takes place in every living cell. The purpose of respiration is to release energy from glucose, so that the cell can make use of the energy.

In aerobic respiration, the glucose is combined with $O_2$, forming $CO_2$ and $H_2O$.

In anaerobic respiration, the glucose is broken down without being combined with $O_2$. In plants and fungi, this produces alcohol and $CO_2$. In animals (including human) it produces lactic acid.

Muscles respire aerobically when they are working so fast that they cannot be supplied with $O_2$ quickly enough. The lactic acid that is made is transported to the liver, and later is broken down by combining it with $O_2$. This extra $O_2$ is breathed in after the exercise has stopped, and it is known as the oxygen debt.

All gas exchange surfaces need to be thin, have a large surface area, be kept moist, and have a good supply of $O_2$. In larger animals, a transport system is needed to carry away the $CO_2$ and bring $O_2$.

The air we breath in travels down the trachea and bronchi, through the bronchioles and into the alveoli.

Some of these tubes are lined with goblet cells which make mucus, and ciliated cells. The mucus traps dirt, bacteria and other particles and the cilia sweep the mucus up and away from the lungs.

Air is drawn into the lungs by the contraction of the external intercostal muscles and the muscles in the diaphragm. These muscle contractions increase the volume of the thorax, which decreases the pressure. Air flows down the pressure gradient and into the lungs.

Tobacco smoke contains many different substances that harm health. Nicotine is an addictive stimulant, and its intake increases the risk of developing heart diseases. Tar causes lungs and other cancers. $CO_2$ reduces the ability of red blood cells to transport $O_2$. Smoke particles irritate the lungs and can contribute to the development of emphysema.
The human nervous system is made up of two parts:

- **Central nervous system (CNS)** - brain and spinal cord: role of coordination
- **Peripheral nervous system** - nerves: connect all parts of the body to the CNS.

Together, they coordinate and regulate body functions.

Sense organs are linked to the peripheral nervous system. They are groups of receptor cells responding to specific stimuli: light, sound, touch, temperature and chemicals. When exposed to a stimulus they generate an electrical impulse which passes along peripheral nerves to the CNS, triggering a response.
Peripheral nerves contain sensory and motor neurones (nerve cells).

<table>
<thead>
<tr>
<th></th>
<th>Sensory neurone</th>
<th>Motor neurone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>transmit nerve impulses</strong></td>
<td>sense organs $\rightarrow$ CNS</td>
<td>CNS $\rightarrow$ effectors (muscles or glands)</td>
</tr>
</tbody>
</table>

Motor and sensory neurones are covered with a myelin sheath, which insulates the neurone to make transmission of the impulse more efficient.

The cytoplasm (mainly axon and dendron) is elongated to transmit the impulse for long distances.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Sensory neurone</th>
<th>Motor neurone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell body</td>
<td>Near end of neurone, in a ganglion (swelling) just outside the spinal cord</td>
<td>At start of neurone, inside the grey matter of the spinal cord</td>
</tr>
<tr>
<td>Dendrites</td>
<td>Present at end of neurone</td>
<td>Attached to cell body</td>
</tr>
<tr>
<td>Axon</td>
<td>Very short</td>
<td>Very long</td>
</tr>
<tr>
<td>Dendron</td>
<td>Very long</td>
<td>None</td>
</tr>
</tbody>
</table>

**Fun fact:** The human nervous system runs on electrical impulses that travel close to the speed of light.

**Sample question and answer**

**Question** Figure above shows a type of neurone. Name this type of neurone and state a reason for your choice. [2 marks]

**Answer** Name: motor neurone.

Reason: It has a cell body, the cell body is at the end of the cell.
A reflex action is an automatic response to a stimulus.

A reflex arc describes the pathway of an electrical impulse in response to a stimulus.

Relay neurones are found in the spinal cord, connecting sensory neurones to motor neurones.
On the picture below, the stimulus is a drawing-pin sticking in the finger. The response is the withdrawal of the arm due to contraction of the biceps.

The sequence of events is:

1. **Stimulus** (sharp pin in the finger)
2. **Receptor** (pain receptor in skin)
3. **Coordinator** (spinal cord)
4. **Effector** (biceps muscle)
Reflex: automatically and rapidly integrating and coordinating stimuli with responses

Neurones do not connect directly with each other: there is a gap called a synapse. The impulse is 'transmitted' across the synapse by means of a chemical called acetylcholine.

**Try this**

Figure below shows a nerve cell.

[Diagram of a neuron with labels: cytoplasm, myelin sheath]

a. i) Name the type of nerve cell shown in the figure [1 mark]

   ii) State two features that distinguish it from other types of nerve cell [2 mark]

   iii) Where, in the nervous system, is this cell located? [1 mark]

b. Nerve cells are specialised cells. Suggest how the following parts of the nerve cell, labelled in the figure, enable the nerve cell to function successfully: cytoplasm; myelin sheath. [4 mark]

c. Reflex involve a response to a stimulus.

   i) Copy and completes the flowchart by putting the following terms in the boxes to show the correct sequence in a reflex. [2 marks]
ii) For the pupil reflex, identify each of the parts of the sequence by copying and completing the table below. The first has been done for you. [4 marks]

<table>
<thead>
<tr>
<th>Part of sequence</th>
<th>Part in pupil reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator</td>
<td>Brain</td>
</tr>
<tr>
<td>Effector</td>
<td></td>
</tr>
<tr>
<td>Receptor</td>
<td></td>
</tr>
<tr>
<td>Response</td>
<td></td>
</tr>
<tr>
<td>Stimulus</td>
<td></td>
</tr>
</tbody>
</table>

**Answer**

a. i) Motor neurone
   ii) Two features from:
       - presence of motor end plates
       - the cell body is at the beginning of the cell
       - the cell body has dendrites on
       - there is no dendron (only on axon).
   iii) Peripheral nervous system.

b. Cytoplasm: two suggestions from:
   - is elongated
   - passes electrical signals along
   - connects different parts of the body
   - is modified to form dendrites.
Myelin sheath: two suggestions from:
   - acts as insulating material
   - so prevents leakage of electrical signal from axon
   - allows faster transmission of impulses.

c. i) flowchart

![Flowchart](image)

ii) For the pupil reflex, identify each of the parts of the sequence by copying and completing the table below. The first has been done for you. [4 marks]

<table>
<thead>
<tr>
<th>Part of sequence</th>
<th>Part in pupil reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator</td>
<td>Brain</td>
</tr>
<tr>
<td>Effector</td>
<td>Iris (muscle)</td>
</tr>
<tr>
<td>Receptor</td>
<td>Retina or rods or cones</td>
</tr>
<tr>
<td>Response</td>
<td>Pupil changes diameter or iris muscles contract</td>
</tr>
<tr>
<td>Stimulus</td>
<td>Bright light or change in light intensity</td>
</tr>
</tbody>
</table>

**Video: Reflex Arc**
Effectors are muscles or glands which respond when they receive impulses from motor neurones. Examples of effectors are the biceps and triceps muscles in the arm.

Structure of the human arm
When stimulated, muscles contract and get shorter. The biceps and triceps are antagonistic muscles - they have opposite effects when they contract.

The biceps is attached to the scapula (shoulder blade) and the radius. Contraction of the biceps pulls on the radius, moving the lower arm toward the scapula. This results in the arm bending (flexing) at the elbow - the arm is raised.

The triceps is attached to the scapula, humerus and ulna. Contractions of the triceps pull on the ulna, straightening (extending) the arm. In doing so, the triceps pulls the biceps back to its original lengths.

**Try this**

Figure below is a simplified diagram of the muscles and bones of the human leg.

![Muscles and bones diagram](image)

a) Complete the following sentences.

Muscles are formed from cells which have a special property of being able to _____. Because of this, muscles can not push, they can only _____. [2 marks]

b) Muscles operate as antagonistic pairs. With reference to figure above, explain what is mean by this statement. [2 marks]
c) i) Which muscles A, B, C or D, must contraction in order to raise the heel to stand on tiptoe? [1 mark]

   ii) Which muscles A, B, C or D, must contract to bend the leg at the knee? [1 mark]

d) When running very quickly, the muscles of the leg may not receive sufficient oxygen to supply all their energy requirements.

   i) Name the type of respiration these muscle cells carry out to release additional energy. [ 1 mark]

   ii) Name the waste product produced by this process. [1 mark]

Answer

a) Contract; pull

b) Muscles A and B; and C and D are antagonistic pairs. They have opposite effects when they contract.

c) i) C
   ii) B

d) i) Anaerobic respiration.
   ii) Lactic acid (or lactate).
#88 Structure and function of the eye, rods and cones

You need to be able to label parts of the eye on diagrams.

- The eyebrow stops sweat running down into the eye.
- Eyelashes help to stop dust blowing on to the eye.
- Eyelids can close automatically (blinking is a reflex) to prevent dust and other particles getting on to the surface of the cornea.
- Blinking also helps to keep the surface moist by moving liquid secretions (tears) over the exposed surface. Tears also contain enzymes that have an antibacterial function.

* Try this

Trace or copy both diagrams of the eyes. Practice adding the labels. [8 marks]
Distinguishing between rods and cones

Rods and cones are light-sensitive cells in the retina. When stimulated they generate electrical impulses, which pass to the brain along the optic nerve.

<table>
<thead>
<tr>
<th>Function</th>
<th>Distribution</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rods</td>
<td>Sensitive to low light intensity. Detect shades of grey</td>
<td>Found through the retina, but none in the centre of the fovea or in the blind spot</td>
</tr>
<tr>
<td>Cones</td>
<td>Sensitive only to high light intensity. Detect colour (don’t operate in poor light)</td>
<td>Concentrated in the fovea</td>
</tr>
</tbody>
</table>

The normal retina has rods that see only black, white, and shades of grey and tones and three forms of color cones, red, green, and blue.
Photos of rods and cones.
# 89 Accommodation - focusing on objects far and near

The amount of focusing needed by the lens depends on the distance of the object being viewed – light from near objects requires a more convex lens than light from a distant objects.

The shape of the lens needed to accommodate the image is controlled by the ciliary body - this contains a ring of muscle around the lens.

**Distance objects**

The ciliary muscles relax, giving them a larger diameter. This pulls on the suspensory ligaments which, in turn, pull on the lens. This makes the lens thinner (less convex). As the ciliary muscles are relaxed, there is no strain on the eye.

**Near objects**

The ciliary muscles contract, giving them a smaller diameter. This removes the tension on the suspensory ligaments which, in turn, stop pulling on the lens. The lens becomes thicker (more convex). As the ciliary muscles are contracted, there is strain on the eye, which can cause a headache if a near object (book, microscope, computer screen etc.) is viewed for too long.
The pupil reflex changes the size of the pupil to control the amount of light entering the eye. In bright light, pupil size is reduced as too much light falling on the retina could damage it. In dim light, pupil size is increased to allow as much light as possible to enter the eye.

The retina detects the brightness of light entering the eye. An impulse passes to the brain along sensory neurones and travels back to the muscles of the iris along motor neurones, triggering a response - the change in size of the pupil due to contraction of radial or circular muscles.
Video: BBC Eye pupil reflex

**Common misconceptions**

Students often confuse circular muscles and ciliary muscles. Remember that circular muscles affect the size of the iris, ciliary muscles affect the shape of the lens.

**Try this**

Describe and explain how the eye changes its focus from a distant object to a near object.

**Answer**

- ciliary muscle contract
- the suspensory ligaments become relaxed
- so tension is removed from the lens
- the lens becomes more convex
- so light is focused more strongly.

Video: Human eye structure, accommodation
**Hormone** is a *chemical* substance, secreted by *endocrine gland*, carried by the *blood*, which alters the activity of one or more specific *target organs* and is then destroyed by the *liver*.

### 1. Chemical control of metabolic activity by adrenaline

**Adrenaline** is a hormone secreted by *adrenal glands*. When you are frightened, excited, your brain sends impulses along a nerve to your adrenal glands. This makes them secrete adrenaline into the blood.

*Adrenal gland is situated above each kidney.*
Adrenaline helps you to cope with danger:

1. ↑ **heart rate** → supply $O_2$ to brain and muscle more **quickly** →↑ energy for action (fighting, running...).

Contrast blood vessels in skin and digestive system → they carry very little blood → supplies blood back to vital organs (brain and muscles).

2. Stimulate **liver** to convert glycogen to glucose, ↑ **glucose** release into the blood by liver → extra glucose for muscle → help muscle to contract.

**Examples of situations in which adrenaline secretion increases**

Adrenaline is needed and secreted in a “fright, fight or flight” situation.

*E.g.: When you are facing danger, for example, a masked man with a gun is approaching you.*

- Your brain sends a signal to the adrenal glands, to start secreting and pumping adrenaline into the bloodstream.

- the actions of the adrenaline is listed above

- this gets you ready to either stand and fight or run away from the man.

2. **Comparison of nervous and hormonal control systems**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Nervous</th>
<th>Hormonal (endocrine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made up of</td>
<td>Neurones</td>
<td>Secretory cells</td>
</tr>
<tr>
<td>Form of transmission</td>
<td>Electrical impulses</td>
<td>Chemical (hormones)</td>
</tr>
<tr>
<td>Transmission pathway</td>
<td>Nerves fibres (axons and dendrons)</td>
<td>Blood plasma</td>
</tr>
<tr>
<td>Speed of transmission</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Duration of effect</td>
<td>Short term</td>
<td>Long term</td>
</tr>
<tr>
<td>Response</td>
<td>Localised</td>
<td>Widespread (although there may be a specific target organ)</td>
</tr>
</tbody>
</table>
Farmer sometimes use hormones to make their animals grow faster, or to produce more of a particular product. One hormone used in this way is called bovine somatotropin, or BST.

BST is a hormone which is naturally produced by cattle. However, if cows are given extra BS, they make more milk. Some people think it would be a good idea to give cow BST, to get higher milk yields. You would need fewer cows to get the same amount of milk.

Here are arguments against it.

- Some people are worried about drinking milk from cows treated with BST. They think BST might damage their health. This is very unlikely, because the hormone does not get into the milk in any significant quantity.

- It is difficult to see why we need BST. For example, the European Union already produces more milk than it needs, so milk quotas have to be imposed, to stop farmer from producing too much milk.

- There are concerns that the BST might harm the cows. Cows treated with BST make very large amounts of milk, far beyond the ‘natural’ levels which they produce. This make them more likely to get infections of their udders (breast), and may make them feel less comfortable.

Mammary infections in BST treated cows require treatment with antibiotics.

Read more on this topic:
Recombinant bovine somatotropin
#92 Voluntary and involuntary actions

Knee jerk is an involuntary reflex

Two types of action controlled by the human nervous system are: **voluntary** and **involuntary** actions. The peripheral nerves transmit both of them.

**Comparison of voluntary and involuntary actions**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Voluntary action</th>
<th>Involuntary action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nature</strong></td>
<td>- Conscious thought (make decision about making action).</td>
<td>- Does not involve thought</td>
</tr>
<tr>
<td></td>
<td>- Free will</td>
<td>- Not under the control of the will</td>
</tr>
<tr>
<td></td>
<td>- Consciously control skeletal muscles</td>
<td>- Cannot control the activities.</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>If we want to ask question, we raise our hands</td>
<td>Involving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- skeletal muscle (e.g. knee jerk)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- smooth muscles (e.g. peristalsis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- cardiac muscles (e.g. pumping of the heart)</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td>Respond with the benefit of experience</td>
<td>Respond quickly to avoid danger</td>
</tr>
<tr>
<td><strong>Controlled by</strong></td>
<td>Forebrain (Cerebrum): - coordinates incoming information, initiates impulses sent to the effectors. - may spontaneously initiates actions without any sensory stimulation.</td>
<td>- Hind-brain (cranial reflex action)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Spinal cord (spinal reflex action), e.g. blinking of the eyes</td>
</tr>
<tr>
<td>Speed of action</td>
<td>Slow response, as the cerebrum needs time to “think” before an action is carried out.</td>
<td>Rapid response, as the cerebrum is not involved.</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Response to the same stimulus</td>
<td>The same stimulus may produce various responses. E.g. when you are hungry, you may decide to eat or not to eat, or just need to drink water.</td>
<td>The same stimulus always results in the same response (stereotyped response), e.g. the knee jerk reflex.</td>
</tr>
</tbody>
</table>

*Forebrain is responsible for voluntary actions, hindbrain is responsible for involuntary actions*

Source: [Voluntary and Involuntary Actions](http://example.com/voluntary_and_involuntary_actions)
Coordination in plants – tropism

Tropism are responses by part of a plant toward or away from a stimulus coming from one direction.

The movement is always a growth movement.

Like animals, plants are able to respond to their environment, although usually with much slower responses than those of animals.

Tropic responses can be:

Positive – if growth is towards the stimulus
Negative – if growth is away from the stimulus

Two important stimuli for plants are light and gravity.

Phototropism

➢ is a growth response to light

Geotropism

➢ is a growth response to gravity
Shoots normally grow towards light. Roots do not usually respond to light, but a few grow away from it.

Shoots tend to grow away from the pull of gravity, while roots normally grow towards it.

### Plant tropism

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Light</th>
<th>Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot</td>
<td>(+)</td>
<td>(-)</td>
</tr>
<tr>
<td>Root</td>
<td>(-)</td>
<td>(+)</td>
</tr>
</tbody>
</table>

(+) Grow towards the stimulus  
(-) Grow away from the stimulus

---

**A shoot is:**

- **Negatively geotropic**
- **Positively phototropic**

**A root is:**

- **Positively geotropic**
- **Negatively phototropic**

Pictures are taken from: **Tropism slideshow**
Auxins are plant **growth substances**, produced by the shoot and root tips of growing plants.

- Auxins in the **shoot** → **stimulate** cell growth, by the absorption of water.
- Auxins in the **root** → **slow down** the cell growth.

**Auxin in phototropism**

1. *If a shoot is exposed to light from one side*

   - More auxins are moving in the **shaded** side (from the tip of the shoot)
   - On this side, cells are stimulated to absorb **more** water, plant grows more
   - Shoot bends **toward** the light.
   - This is called **positive phototropism**.
2. If a root is exposed to light in the absence of gravity

- More auxins are moving in the shaded side (from the tip of the root) →
- On this side, cells are stimulated to absorb less water, plant grows less
- Root bends away from the light.
- This is called negative phototropism.

When exposed to light from one side

<table>
<thead>
<tr>
<th>Features</th>
<th>Shoot</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>More auxins are moving in the shaded side</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Cell are stimulated to absorb (on the shaded side)</td>
<td>more water</td>
<td>less water</td>
</tr>
<tr>
<td>Stem bends</td>
<td>toward the light</td>
<td>away from the light</td>
</tr>
<tr>
<td>Process</td>
<td>Positive phototropism</td>
<td>Negative phototropism</td>
</tr>
</tbody>
</table>

Auxin in geotropism

1. If a shoot is placed horizontally in the absence of light:

- Auxins accumulate on the lower side of the shoot, due to gravity.
- Cells on the lower side grow more quickly
- The shoot bends upwards.
- This is called negative geotropism.

2. If a root is placed horizontally in the absence of light:

- Auxins accumulate on the lower side of the shoot, due to gravity.
- Cells on the lower side grow more slowly
- The shoot bends downwards.
- This is called positive geotropism.

When is placed horizontally in the absence of light

<table>
<thead>
<tr>
<th>Features</th>
<th>Shoot</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>More auxins are moving in the lower side</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Cell growth (on the lower side)</td>
<td>more quickly</td>
<td>more slowly</td>
</tr>
<tr>
<td>Bending</td>
<td>upwards</td>
<td>downwards</td>
</tr>
<tr>
<td>Process</td>
<td>Negative geotropism</td>
<td>Positive phototropism</td>
</tr>
</tbody>
</table>
Darwin did the first experiments to study the effects of Auxin

- Shoots and roots that have their tips removed will not respond to light or gravity because the part that produces auxins has been cut off.

- Shoots that have their tips covered with opaque material grow straight upwards when exposed to one-sided light, because the auxin distribution is not influenced by the light.

**Effects of weedkillers**

Weedkillers (herbicide) are synthetic plant hormones, similar to auxins. If these chemicals are sprayed on to plants they can cause rapid, uncontrolled growth and respiration, resulting in the death of the plant.
Some plant species are more sensitive than others to synthetic plant hormones, so weedkillers can be selective.

Many weedkillers kill only broad-leaved plants (dicotyledons), leaving grasses (monocotyledons) unharmed.

**Try this**

In figure above, the left-hand side shows an experiment in which the coleoptiles (shoots) of similar seedlings have been treated in different ways, and the right-hand side shows the result in shoot D 24 hours later.

a) i) Name the response shown by shoot D. [2 marks]
   ii) Explain what has caused this response. [3 marks]

b) Copy and complete the right-hand side figure to show the likely results for shoots A, B and C. [3 marks]

**Answer**

a) i) Positive phototropism
   ii) Three points from:
   - the coleoptiles have been exposed to one-sided light
   - auxins have been produced by the tip
   - and have passed into the block
   - auxins have passed from the block to the cut coleoptile
   - more auxins accumulates on the shaded side of the coleoptile
   - causing more growth on the shaded side.

b) **A**, taller and growing vertically upwards;
   **B**, taller and bending towards the light;
   **C**, taller and growing vertically upwards.
All organisms are able to sense changes in their environment, called **stimuli**, and respond to them. The part of the body that senses the stimulus is a **receptor**, and the part that responds is an **effector**.

The **human nervous system** contains specialized cells called neurons. The brain and spinal cord make up the central nervous system (CNS), which coordinates responses to stimuli.

**Reflex actions** are fast, automatic responses to a stimulus. They involve a series of neurons making up a reflex arc. A sensory neurone takes the impulse to the CNS and a motor neurone takes it from the CNS to an effector.

Receptors are generally found within **sense organs**.

The receptors in the eye are **rod** and **cone cells**, found in the retina. Rods respond to dim light and cones to bright light. Cones give colour vision.

The cornea and lens focus light rays onto the **fovea**, the part of the eye where cone cells are most densely packed.

The shape of the lens is changed by the contraction or relaxation of the **ciliary muscle**. When focusing on a distance subject, the muscle relaxes so that the suspensory ligament are pulled taut and the lens is pulled into a thin shape. When focusing on a near object, the muscle contracts and the lens falls into its natural, more rounded shape.

Muscles can pull when they contracts, but they cannot push. A pair of muscles is therefore needed to pull in different directions, e.g. at the elbow joint. They are **antagonistic muscles**.

**Hormones** are chemicals made in endocrine glands and carried in the blood plasma. **Adrenaline** is secreted by the adrenal glands, and bring about changes that supply the muscles with extra glucose. This gives the energy for contraction for ‘fight or flight’.

Plant response to some stimuli by growing towards or away from them. These responses are **tropism**.

**Auxins** are mostly made in the tips of the shoots and roots, and can diffuse to other parts of the shoots or roots. It collects in the shady side of the shoot, making the side grow faster so the shoot bends towards the light. Auxins are used as selective weedkillers.
10. Excretion

#96 Structure of the kidney, the nephron

Excretion is the removal from organisms of toxic materials, the waste products of metabolism and substances in excess of requirements (carbon dioxide, urea, salts...).

Common misconceptions

Remember that faeces is not an example of excretion – it is mainly undigested material that has passed through the gut, but which has not been made in the body. The only excretory materials in it are bile pigments.

The relative position of the ureters, bladder and urethra in the body

Examiner’s tip

Make sure you can label the diagram showing the relative positions of the kidneys, ureters, bladder and urethra. The spellings of the ureter and urethra are really important.
Structure of a kidney

The kidney has 3 main parts: the cortex, medulla, and pelvis. Leading form the pelvis is a tube, called the ureter. The ureter carries urine that the kidney has made to the bladder.

Kidneys are made up of thousands of tiny tubules, or nephrons. Each nephron begins in the cortex, loops down into the medulla, back into the cortex, and then goes down again through the medulla to the pelvis. In the pelvis, the nephrons join up with the ureter.

Sample question and answer

Figure on the right shows the human urinary system

a) Name parts X,Y and Z. [3 marks]

b) Name the blood vessel that carries blood from the aorta to the kidneys. [1 mark]

c) Suggest two differences between the composition of the blood flowing to the kidneys and the blood flowing away from the kidneys. [2 marks]

Student’s answer

a) X ureta × Y Bladder ✓ Z vagina ×
b) renal artery
c) 1. Blood going to the kidneys contains more urea.
   2. Blood going to the kidney contains oxygen.

Examiner’s comments

The spelling of X (ureter) must be accurate because this name is so similar to urethra.

Part Z is the urethra, not the vagina (the vagina is attached to the uterus, not the bladder).

In part (c) the second answer given does not make a comparison. If the candidate had stated ‘blood going to the kidney contains more oxygen’, this would have gained the mark.
Video: Urinary system The nephron
The function of the kidney is to filter blood, removing urea and excess H₂O, reabsorbing glucose, some H₂O and some mineral salts.

**Urine is made by filtration and selective reabsorption**

- As blood passes through the kidneys, it is filtered. This removes most of the urea from it, and also excess H₂O and salts.
- As this liquid moves through the kidneys, any glucose in it is reabsorbed back into the blood. Most of the H₂O is also reabsorbed along with some of the salts.

<table>
<thead>
<tr>
<th>Remove from blood</th>
<th>Reabsorb into the blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>most urea</td>
<td>all glucose</td>
</tr>
<tr>
<td>excess H₂O</td>
<td>most H₂O</td>
</tr>
<tr>
<td>excess salts</td>
<td>some salts</td>
</tr>
</tbody>
</table>

The final liquid produced by the kidneys is a solution of urea and salts in water. It is called urine, and it flows out of the kidneys, along the ureters and into the bladder. It is stored in the bladder for a while, before being released from the body through the urethra.
Filtration happens in renal capsules

Blood is brought to the renal capsule in a branch of the renal artery. Small molecules, including water and most of the things dissolved in its, are squeezed out of the blood into the renal capsule.

There are thousands of renal capsules in the cortex of each kidney. Each one is shaped like a cup. It has a tangle of blood capillaries, called a glomerulus, in the middle. The blood vessels bringing blood to each glomerulus is quite wide, but the one taking blood away is narrow. This means that the blood in the glomerulus cannot get away easily. Quite a high pressure builds up, squeezing the blood in the glomerulus against the capillary walls.

These walls have small holes in them. So do the walls of the renal capsules. Any molecules small enough to go through these holes will be squeezed through, into the space in the renal capsule. Only small molecules can go through. These include water, salt, glucose and urea. Most protein molecules are too big, so they stay in the blood, along with the blood cells.
Useful substances are reabsorbed

The fluid in the renal capsule is a solution of glucose, salts and urea dissolved in water. Some of the substances in this fluid are needed by the body. All of the glucose, some of the water and some of the salts need to be kept in the blood.

Wrapped around each kidney tubule are blood capillaries. Useful substances from the fluid in the kidney tubule are reabsorbed, and pass back into the blood in these capillaries.

The remaining fluid continues on its way along the tubule. By the time it gets to the collecting duct, it is mostly water, with urea and salts dissolved in it. It is called urine. The kidneys are extremely efficient at reabsorbing water. Over 99% of the water entering the tubules is reabsorbed.

The relative amount of water reabsorbed depends on the state of hydration of the body (how much water is in the blood), and is controlled by secretion of the hormone ADH.

- On a hot day: we sweat more to cool down, the body needs to conserve water, produce a small amount of concentrated urine.
- On a cold day: little sweat is being produced, we tend to produce a larger volume of dilute urine.

Filtered blood returns to the vena cava (main vein) via a renal vein. The urine formed in the kidney passes down a ureter into the bladder, where it is stored. A sphincter muscle controls the release of urine through urethra.

Video: Nephron function
Surplus amino acids in the bloodstream cannot be stored. They are removed by the liver and broken down into the urea (which is the nitrogen-containing part of the amino acid) and a sugar residue, which can be respired to release energy. The breakdown of amino acids is called deamination.

Urea is returned to the bloodstream (into the hepatic vein) and filtered out when it reaches the kidneys.

The body treats alcohol as a poison. The liver removes poisons, such as alcohol and drugs, from the blood and breaks them down. Prolonged and excessive use of alcohol damages the liver and may cause it to fail. An overdose of drugs, such as paracetamol, can result in death due to liver failure, because the liver cannot cope with breaking down such a high concentration of the chemical.

The liver also converts hormones into inactive compounds. These are filtered out of the blood by the kidneys.
The usual treatment for a person with kidney failure is to have several sessions a week using a dialysis unit (a kidney machine), to maintain the glucose and protein concentration in blood diffusion of urea from blood to dialysis fluid.

Dialysis is a method of removing one or more components from a solution using the process of diffusion. The solution is separated from a bathing liquid contains none of the components that need to be removed from the solution, so these pass from the solution, through the membrane, into the bathing dilution by diffusion. The bathing solution needs to be changed regularly to maintain a concentration gradient.
A patient with kidney failure needs to have toxic chemicals removed from the blood to stay alive. Blood is removed from a vein in the arm, and is kept moving through dialysis tubing in the dialysis machine using a pump. The tubing is very long to provide a large surface area. The dialysis fluid has a composition similar to blood plasma, but with no urea or uric acid. **Urea** or **uric acid** and excess **mineral salts** are removed from the blood, by **diffusion**, into the dialysis fluid. The cleaned blood is then passed through a bubble trap to remove any air bubbles, before being returned to the patient’s vein.

How kidney dialysis works.
Advantages and disadvantages of kidney transplants compared with dialysis.

**Advantages**

- The patients can return to a normal lifestyle – dialysis may require a lengthy session in hospital, 3 times a week, leaving the patient very tired after each session.
- A dialysis machine will be available for other patients to use.
- Dialysis machines are expensive to buy and maintain.

**Disadvantages**

- Transplants require a suitable donor – with a good tissue match. The donor may be a dead person, or a close living relative who is prepared to donate a healthy kidney (we can survive with one kidney).
- The operation is very expensive.
- There is a risk of rejection of the donate kidney – immunosuppressive drugs have to be used.
- Transplantation is not accepted by some religions.

**Video: Hemodialysis and how it works**
Summary of homeostasis, excretion, drugs

- **Homeostasis** is the maintenance of a constant internal environment. It is achieved using **negative feedback**.

- Organisms that can control their internal body temperature are called **homeotherms**. Mammals and birds are homeotherms. All other animals are **poikilotherms**, meaning that they have only limited ways of controlling their temperature.

- The control of body temperature in humans involves the **hypothalamus**, the skin and muscles. When the body becomes too hot, **sweating** and **vasodilatation** increase the rate of heat loss from the skin. When the body becomes too cold, **shivering** increases heat production, and **vasoconstriction** reduces the rate of heat loss from the skin.

- The **pancreas**, working in conjunction with the liver, controls blood glucose concentration. When this rises too high, the pancreas secretes **insulin** which causes the liver to remove glucose from the blood and convert it to **glycogen**. When blood glucose concentration falls to low, the pancreas secretes **glucagon** which causes the liver to convert glycogen to glucose.

- **Excretion** is the removal from the body of waste products of metabolism. The main excretory products of mammals are **CO₂**, **urea**, **salts** and excess **H₂O**.

- Mammals excrete CO₂ from the **lungs** and urea from their **kidneys**.
- **Urea** is produced in the *liver* from excess amino acids. It is transported in solution in blood plasma to the kidneys, where it is excreted in *urine*.

- **Urine** is made in the *nephrons* of each kidney. First, blood is filtered. Then any substances to be retained in the blood are reabsorbed. The fluid that is left in the nephron flows into the *ureters* and then to the *bladder*, before leaving the body as urine through the *urethra*.

- A *drug* is a substance that effects chemical reactions in the body. Many drugs are used in *medicine*. For example, *antibiotics* are used to kill bacteria that are causing disease in the body.

- **Heroin** is a depressant that is often addictive. Use of heroin often leads to crime and misery for the user’s family. People who inject heroin run a high risk of infection with HIV.

- **Alcohol** is also a depressant. Drinking alcohol lengthens reaction time, reduced self-control and may cause aggression, causing serious problems for friends and family. Some people become addicted to alcohol. Over time, the liver is damaged by excessive alcohol intake.
Homeostasis is the maintenance of a constant internal environment, which is vital for an organism to stay healthy. Fluctuations in temperature, water levels and nutrient concentrations ... could lead to death.

Temperature regulation is one homeostatic function. Mammals and birds are warm-blooded – they maintain a constant body temperature despite external environment changes.

Human maintain a body temperature of $37^\circ$C – we have mechanisms to lose heat when we get too hot, and ways of retaining heat when we get too cold.
The hypothalamus coordinates temperature control

The **hypothalamus** (part of brain) acts like a thermostat. It detects $t^\circ$ of the blood running through it.

If $t^\circ >$ or $< 37^\circ C$, it sends electrical impulses, along nerves, to parts of the body which function in regulating body $t^\circ$.

When you are cold, body produces and saves heat

- **shivering**: muscles contract and relax spontaneously --> produces heat --
  --> warms blood
- **vasoconstriction**: arterioles near skin become narrower so little blood can flow through them (the blood flows through the deep-lying capillaries instead)--> conserve heat
- **metabolism may increase** --> release energy
- **hair stands up**. In human, it just produces ‘goose pimples’. But in hair animals (cat), it acts as an **insulator**: trap a thicker layer of warm air next to the skin, prevent skin from loosing more warmth.
When you are hot, the body loses more heat:

- **sweating**: droplets of sweat evaporate, cooling the body
- **vasodilation**: more blood flows near skin surface ---> lose heat
- **hair lies flat**.

**Common misconceptions**

Remember that the process of vasodilatation and vasoconstriction happen only in arterioles – the do **not** happen in capillaries or veins. When writing about the process, make sure you refer to arterioles.
Control of blood glucose content

The control of glucose concentration in the blood is a very important part of homeostasis.

Two hormones insulin and glucagon control blood glucose levels.

Both hormones are secreted by the pancreas and are transported to the liver in the bloodstream.

When blood glucose levels get too high or too low, a person may:

- lose consciousness
- fall into a coma
- die

Too little glucose ---› Cells can not release enough energy they need. Brain cells are especially dependent on glucose for respiration, and die quite quickly if they are deprived of it.

Too much glucose in the blood ---› water moves out of cells and into the blood by osmosis ---› Cell has too little water to carry out normal metabolic process.
The control of blood glucose concentration is carried out by the pancreas and the liver.

Pancreas secretes insulin and glucagon: 2 hormones that work side-by-side.
*Left-side:* When glucose levels drop below normal, glycogen is broken down to glucose, which is released into the bloodstream.

**glucagon:** glycogen $\rightarrow$ glucose

*Right-side:* Excess glucose is stored in the liver and muscles as the polysaccharide glycogen (animal starch).

**insulin:** glucose $\rightarrow$ glycogen

$\uparrow$ respiration rates $\rightarrow$ cells consume more glucose

---

**Try this**

Copy and complete the paragraph using some of the words in the list below.

excretion glucose glycogen insulin liver oestrogen pancreas secretion starch stomach sucrose

The bloodstream transports a sugar called __________. The blood sugar level has to be kept constant in the body. If this level falls below normal, a hormone called glucagon is released into the blood by an endocrine organ called the ______. The release of a substance from a gland is called ____. Glucagon promotes the breakdown of ______ to increase the blood sugar level. If the blood sugar level gets too high, the endocrine organ secretes another hormone called __________ into the blood. This hormone promotes the removal of sugar from the blood and its conversion to glycogen in the ________ [6 marks].

**Answer**

**glucose, pancreas, secretion, glycogen, insulin, liver.**
Temperature and glucose blood levels regulation involve **negative feedback**:  
- a **change** from normal conditions (body temperature, blood glucose levels...)  
- triggers a **sensor**,  
- stimulates a **response** in an **effector**.

**Glucose blood levels regulation**

- If **glucose** levels rise, the sensor will instruct an effector (the **pancreas**) to secret **insulin** --- glucose levels drop below normal.  
- If glucose levels drop, the sensor will instruct the pancreas to stop secreting insulin --- glucose levels rise.  
- This is negative **feedback** – the change is fed back to the effector.
Temperature regulation

- All the time, the hypothalamus is monitoring small changes in the temperature of your blood.
- If temperature rise above normal, actions take place that help to reduce it.
- If temperature is lower than normal, the hypothalamus stops these actions and start actions that help to raise the blood temperature.
- This is negative feedback - the information that the blood has cool down stop the hypothalamus making your skin to increase heat loss.

*Maintaining temperature in steady state.*
Drug is any substance taken into the body that modifies or affects \textit{chemical reactions} in the body. Drug used in \textit{medical care}, or to relieve mild pain, are very helpful to us. However, some people misuse drugs, so that they cause harm to themselves and to others around them.

1. Antibiotics kill bacteria in the body

Antibiotics are substances that \textit{kill bacteria} or prevent their growth, but do not harm other living cells. Most of them are made by fungi. It is thought that the fungi make antibiotics to kill bacteria living near them – bacteria and fungi are both decomposers, so they might compete for food.

The first antibiotic to be discovered was \textit{penicillin}. It is made by the fungus \textit{Penicillium}. Penicillin kills bacteria by:

- \textbf{preventing} the production of peptidoglycan that form the \textbf{cell wall}:
  - the cell continue to grow without dividing or developing new cell wall
  - the wall gets weaker
  - ruptures (lysis).

Since the \textbf{discovery} of penicillin in 1928, many more antibiotics have been developed and used to treat bacterial infections. Some bacteria have mutated and become resistant to antibiotics, but new drugs are constantly being developed and tested.

Antibiotics do \textbf{not} work \textbf{against viruses}. Many antibiotics kill bacteria by damaging their cell walls. Viruses do not have \textbf{cell walls}, so they are unharmed by antibiotics. It is difficult to develop drugs that kill viruses without damaging the body’s tissues.
2. Effects of heroin abuse

- **Heroin** is a powerful **depressant**.

- It is a narcotic, producing a dream-like feeling of relaxation and reducing severe pain.

- It is very **addictive**, leading to dependency (addiction).

- **Withdrawal** symptoms can be very unpleasant – involving cramp, sleeplessness, violent vomiting, sweating and hallucinations.

- The body develops a tolerance to the drug, so an addict needs to take increasing amount to achieve the same feeling. This leads the risk of **overdosing** on the drug.

- When injected using unsterilized and shared needles, there is a risk of infections such as **hepatitis** and **HIV**.

- Addiction creates **financial problems** leading to family breakdown, **criminal activity** and sexual promiscuity.
3. Effects of excessive consumption of alcohol

- Small amounts – alcohol can relax the body and create a sense of wellbeing.

- Alcohol is a depressant: larger amounts slow down the transmission of electrical impulses in the brain, so reactions are depressed, coordination is impaired and reasoned judgments become difficult. Mood swings involving violence can result.

- Increase reaction time makes driving and handling machinery dangerous.

- Poor judgments may lead to criminal activity and sexual promiscuity.

- Long-term excessive drinking can lead to addiction (alcoholism).

- This can lead to financial difficulties and family problems.

- As the liver removes alcohol from the blood, heavy drinking can lead to liver damage such as cirrhosis.

- Drinking can cause brain damage, peptic ulcers in the stomach and obesity.

- Drinking during pregnancy can damage the fetus, increase the risk of miscarriage or premature birth, and reduce the average birth weight.

_Alcoholism Health Issues._
Summary of homeostasis, excretion, drugs

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Reproduction is the process that makes more of the same kind of an organism.

There are 2 types of reproduction: asexual and sexual.

1. Asexual reproduction:

- the process resulting in the production of **genetically identical offspring** from one parent.
- formation of a new organism, **without involvement of gametes or fertilisation**.

Examples

**Bacteria**

Bacteria reproduce asexually by binary fission. Inside an individual bacterium, the DNA replicates. Then the cell divides into two, with each daughter cell containing a copy of the parental DNA. Once the daughter cells have grown, they can also reproduce.
Fungi

Fungi can reproduce asexually by producing spores, which may be formed inside a structure called a sporangium. When ripe, the sporangium bursts open allowing the spores to be dispersed. In suitable conditions the spores germinate and grow to form new individuals.

Potatoes

Potatoes are stem tubers. The parent plant photosynthesises and stores the food produced in underground stems, which swell to form tubers. Each tuber contains stored starch, and there are buds in depressions in the surface known as eyes. In suitable conditions the buds use the stored food to form shoots, form which roots also develop. Each tuber can form a new plant.

Advantages and disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- quick</td>
<td>- little variation ---+ adaptation to environment is unlikely</td>
</tr>
<tr>
<td>- only one parent needed</td>
<td>- offsprings inherit bad characteristics (e.g.: resistance from a disease)</td>
</tr>
<tr>
<td>- no gametes needed</td>
<td>- lack of dispersal ---+ competition (nutrients, water, light)</td>
</tr>
<tr>
<td>- all good characteristics passed on</td>
<td></td>
</tr>
<tr>
<td>- no dispersal (potato tubers) ---+ grow in same favourable environment as parent</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>- store large amounts of food ---+ rapid growth</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
2. **Sexual reproduction:**

- the process involving the *fusion of haploid nuclei* to form a *diploid zygote* and the production of *genetically dissimilar offspring*.

**OR**

- formation of a new organism by the fusion of gametes (fertilisation)

---

**Table: Advantages vs. Disadvantages**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>variation in offspring ---&gt;</td>
<td>2 parents needed</td>
</tr>
<tr>
<td>adaptation to environment</td>
<td>Growth (of plant) is slow</td>
</tr>
<tr>
<td>new varieties created ---&gt;</td>
<td></td>
</tr>
<tr>
<td>disease resistance</td>
<td></td>
</tr>
</tbody>
</table>

**Video: Asexual Reproduction**
https://www.youtube.com/watch?v=jk2RJm5RBEk

**Video: Sexual Reproduction**
https://www.youtube.com/watch?v=tFZeyFbBLXE
Reproduction in flowering plants may occur both sexually or asexually. **Pollination** can take place with the help of **agents**: wind or insects.

**Pollination**: transfer of **pollen grains** from the male part of the plant (anther) to the female part (stigma).

Pollen grains.
Structural adaptations

### Features of wind- and insect-pollinated flowers

<table>
<thead>
<tr>
<th>Feature</th>
<th>Insect-pollinated</th>
<th>Wind-pollinated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petals</td>
<td>- large, coloured, scented</td>
<td>- absent/small</td>
</tr>
<tr>
<td></td>
<td>- guidelines for insects into flower</td>
<td></td>
</tr>
<tr>
<td>Nectar</td>
<td>- produce by nectarines</td>
<td>- absent/small and green</td>
</tr>
<tr>
<td></td>
<td>- attract insects</td>
<td></td>
</tr>
<tr>
<td>Stamen</td>
<td>- inside flower</td>
<td>- long filaments: anther hang freely</td>
</tr>
<tr>
<td></td>
<td></td>
<td>outside flower → pollen exposed to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wind</td>
</tr>
<tr>
<td>Stigme</td>
<td>- small, sticky</td>
<td>- large, feathery</td>
</tr>
<tr>
<td></td>
<td>- inside flower → insects rub against</td>
<td>- hang outside flower → catch pollen</td>
</tr>
<tr>
<td>Pollen</td>
<td>- smaller amount</td>
<td>- larger amount</td>
</tr>
<tr>
<td></td>
<td>- grain round and sticky or covered in spikes</td>
<td>- grain smooth, light, easily carried</td>
</tr>
<tr>
<td></td>
<td>in spikes to attract to insects</td>
<td>by wind</td>
</tr>
<tr>
<td>Bracts (modified</td>
<td>- Absent</td>
<td>- Sometime present</td>
</tr>
<tr>
<td>leaves)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Common misconceptions

Students often get confused between pollination and seed dispersal. When animals such as insects carry pollen, they aid pollination. When animal carry seeds, they aid seed dispersal.
Growth of pollen tube and the process of fertilization

Figure below shows a section through a single carpel.

If pollen grains are of the same species as the flower they land on, they may germinate. Germination is triggered by a sugary solution on the stigma, an involves the growth of a pollen tube from the pollen grain.

The pollen tube contains the male nucleus, which is needed to fertilise the ovule inside the ovary. The pollen tube grows down the style, through the ovary wall, and through the micropyle of the ovule.

Fertilisation is the fusion of the male nucleus with the female nucleus. If the ovary contains a lot of ovules, each will need to be fertilised by a different pollen nucleus.

**Video: Flower Reproduction**

https://www.youtube.com/watch?v=YqM6rgB_I_o

**Video: Sexual Reproduction in Flowering Plants**

https://www.youtube.com/watch?v=CkBNEM2mD30
You need to be able to describe the **structure** and **functions** of a named **dicotyledonous** (two seed leaves) flower.

**Functions of parts of a flower**

<table>
<thead>
<tr>
<th>Part</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Petal</td>
<td>Often large and coloured, to attract insects</td>
</tr>
<tr>
<td>2 Sepal</td>
<td>Protects the flower while in bud</td>
</tr>
<tr>
<td>3 Petiole (stalk)</td>
<td>Supports the flower to make it easily seen by insects, and to be able to withstand wind</td>
</tr>
<tr>
<td>4 Nectary</td>
<td>Produces nectar, to attract insects</td>
</tr>
<tr>
<td>5 Stamen</td>
<td>The male reproductive part of the flower, made up of anther and filament</td>
</tr>
<tr>
<td>6 Anther</td>
<td>Contains pollen sacs, in which pollen grains are formed. Pollen contains male sex cells.</td>
</tr>
<tr>
<td>7 Filament</td>
<td>Support the anther</td>
</tr>
<tr>
<td>8 Carpel</td>
<td>The female reproductive part of the flower, made up of stigma, style and ovary</td>
</tr>
<tr>
<td>9 Stigma</td>
<td>A sticky surface to the ovary, through which pollen tubes grow</td>
</tr>
<tr>
<td>10 Style</td>
<td>Links the stigma to the ovary, through which pollen tubes grow</td>
</tr>
<tr>
<td>11 Ovary</td>
<td>Contains ovules, which develop into seeds when fertilised.</td>
</tr>
</tbody>
</table>
The fertilised ovule divides by mitosis to form a seed containing the embryo plant and food stores called cotyledons.

- The wall of the ovule forms the seed testa (coat).
- The ovary wall develops into a fruit, which may be fleshy (e.g. plum) or a dry pod (e.g. lupin or pea).

**Structure of a non-endospermic seed**
Try this

Figure below shows a section through a bean flower.

![Diagram of a bean flower](image)

(a) Name the parts labeled A and B [2 marks]

(b) This flower is insect-pollinated. Suggest how parts C, D and E help in pollination of this flower. [3 marks]

(c) After pollination, the ovules develop into seeds. Describe the events which occur after pollination and which result in the formation of seeds [4 marks]

**Answer**

(a) **A**: ovule, **B**: sepal

(b) **C** (petal) are large and colourful to attract insects
   **D** (stigma) is sticky and lies in the way of the insects to collect pollen
   **E** (anther) produces pollen and lies in the way of the insects to transfer pollen on to their bodies.

(c) **Four** points form:
   - pollen grains germinate
   - pollen tube grows down the style
   - through the micropyle
   - into the ovule
   - the male nucleus fuses with the female nucleus
   - reference to fertilisation
Environmental conditions affecting germination

1. Water:
   - absorbed through microphyle until radicle is forced out of testa
   - activate enzymes for converting soluble food stores in the cotyledons down to soluble food ---> for growth + energy production of baby plant.

2. Oxygen: respiration ---> release energy ---> growth

3. Warmth/temperature: enzymes present in the seed get activated and work best at optimum temperature (20-40°C) which trigger growth in the baby plant.

4. Light intensity: high or very low light intensity does not allow enzymes to function normally.
The flowers produce seeds which can be dispersed by the wind or other animals, providing a means of colonising new areas.

Nutmeg is dispersed by birds.
Photo credit: russolab.unl.edu

1. Wind-dispersed seeds

- Fruits contain seeds, and usually have a parachute or a wing to help them be carried away from the parent plant by the wind.

- Examples: dandelion, sycamore

The dandelion fruit has a group of fine hairs called a pappus, which catches the wind and acts like a parachute. The fruit counterbalances the pappus.

The sycamore has a wing with a large surface area. When the fruit drops off the tree it spins, slowing down in descent. If caught by the wind the seed will be carried away from the parent plant, reducing competition for nutrients, water and light.
2. Animal-dispersed seeds

There are 2 main modification of fruits for animal dispersal: **succulent** fruits and **hooked** fruits.

**Succulent** fruits attract animals because they are brightly coloured, juicy and nutritious. When eaten, the seed pass through animal’s **faeces**, which may be a long way from the parent plant. The faeces provides nutrients when the seeds germinate.

**Hooked** fruits catch on to an **animal’s fur** as it brushes past the parent plant. Eventually the seeds drops off, or the animal grooms itself to remove them. This disperses the seeds away from the parent plant.
Try this

Figure below shows a section through a bean seed.

1. i) Name the parts labeled A, B and C. [3 marks]
   ii) Copy the diagram and label with an X the part that contains the seed’s food reserves. [1 mark]

2. Seeds and fruits are dispersed away from the parents plant.
   i) Sketch a seed or fruit that is adapted for dispersal by wind. Label with a Y the special feature of the seed or fruit that helps in wind dispersal. [1 mark]
   ii) Suggest how this feature helps in wind dispersal. [2 marks]
   iii) Suggest another way in which wind assist in the reproduction of plants. [1 mark]

Answer

1. i) A plumule; B cotyledon, C testa (seed coat)
   ii) X on any part of the cotyledon.

2. i) Sketch of dandelion, sycamore...
   Y on the part that catches the wind (parachute, wing...).
   ii) Two points from:
   - description of how the feature catches the wind
   - and slows down the descent of the seed or fruit
   - so the seed or fruit is carried away from the parent plant.
   iii) Wind pollination

Video: Seeds - An amazing video taken from BBC's The Private Life of Plants documentary series (MUST SEE).
https://www.youtube.com/watch?v=buZV0h4vfMq
#111 Self-pollination and cross-pollination

**Self-pollination** - transfer of pollen from the anther to the stigma of the same flower, or to another flower of the same plant.

**Cross-pollination** - transfer of pollen from the anther of a flower to the stigma of a flower on a different plant of the same species.

**Self-pollination**
- ↑ chance of successful pollination à smaller numbers of pollen
- ↑ chance of fertilisation and seed formation
- ↓ variation in the offspring.
- ↓ ability to adapt to environmental change.

**Cross-pollination**
- ↓ chance of successful pollination à large amounts of pollen
- ↓ chance of fertilisation
- ↑ variation
- ↑ ability to adapt to environmental change.
#112 Growth and development

**Growth** - permanent *increase* in *size* and *dry mass*, by an increase in cell number or cell size or both.

**Development** - increase in *complexity*

1. **Development**

   - increase in complexity of an organism as it grows. As the number of cells increases, they become differentiated (specialized for different tasks).

   - change in shape to adapt for a specific function.

Examples:

- nerve cells are very elongated and can transmit electrical impulses

- xylem cells are elongated and lose their cell contents, with the cell walls becoming lignified so the cells conduct water efficiently.
2. Growth

- due to an increase in cells, produced by mitosis.
- controlled by hormones (in animals) and growth substance like auxins (in plants).

Dry mass

- Often used as a measure of growth, because wet mass varies from day to day (e.g. plant will take up more water on a wet day than on a dry day, but the water does not all become part of the biomass – living material of the plant).
- Obtained by drying out the organism in an oven (killing it).
- Many individual have to be germinated at the same time and grown in the same conditions.
- Samples are dried at various times during the growth period.

Example: Changes of dry mass during the growth of a plant from a seed.

- ↓ slightly when the seed germinates, at day 2 (some of the stores in the cotyledon are being used in respiration).

- ↑ when the plumule stars to photosynthesise, and foliage leaves form to continue the process.

- ↓ at the end of the growth period (loss of seeds and fruits; leaves die).
Try this

1. Figure below shoes a section through a seed of a dicotyledon.

   ![Diagram of a seed section](image)

   i) What is the role of part A? [1 mark]

   ii) What do parts B and C of the seed develop into after germination? [2 marks]

2. Figure below shows changes in mass of sets of pea seeds as they germinate and grow into seedlings, after germination set B was grown in the dark and set Q in the light.

   ![Graph showing mass changes](image)
i) Why is mass measured as dry mass? [1 mark]

ii) Explain the changes in dry mass between days X and Y in both sets of seedling. [4 marks]

iii) Explain why there is a difference in the dry mass of set P and Q between day Y and Z. [4 marks]

Answer

1. i) Stored food.
   ii) B develops into the shoot (or leaves)
       C develops into the root.

2. i) Wet mass varies according to the amount of water absorbed or lost from the plant, or dry mass represents the amount of cytoplasm.

   ii) Four points from:
       - the dry mass drops between days X and Y for both sets of seedlings
       - food stored in the cotyledons
       - is used to supply energy
       - through respiration
       - some food is converted into other materials
       - for growth of the radical and plumule.

   iii) Four points from:
       - set Q increases in dry mass and st P decreases in mass
       - set Q is in the light and can photosynthesise
       - to make new cytoplasm
       - set P is in the dark and can not photosynthesise
       - set P uses up remaining food stores through respiration.
Reproduction in humans is when the male gamete (sperm) fuses together with the female gamete (ovum/egg).

At first, it is just one single cell, which duplicates over and over until after 9 months...... TA-Dahh! - A baby is born!

Male reproductive system

- **Testes**: produce sperm and testosterone
- **Scrotum**: a sac that keeps testes cool (outside body)
- **Sperm ducts**: link testis to urethra: allow passage of semen containing sperm
- **Prostate gland**: produce alkaline fluid ---> semen
- **Urethra**: urinate; pass semen (+sperm) through penis
- **Penis**: become firm, inserted into vagina during sexual intercourse ---> transfer sperm
Female reproductive system

- **Ovaries**: contains follicles, produce and stores **eggs**, produce **oestrogen**
- **Oviducts**: carries ovum to uterus; Fallopian tubes = site of fertilisation
- **Uterus** – where fetus develops
- **Cervix**: a ring of muscles that separate the vagina from the uterus
- **Vagina**: receives sperm from erect penis during intercourse

Comparing male and female gametes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Sperm cell</th>
<th>Egg cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>small</td>
<td>Larger than sperm</td>
</tr>
<tr>
<td>movement</td>
<td>Tail lashes from side to side</td>
<td>Doesn’t move by itself – cilia and peristalsis in oviduct</td>
</tr>
<tr>
<td>Number produced</td>
<td>Millions constantly produced</td>
<td>Once a month (puberty --&gt; menopause)</td>
</tr>
</tbody>
</table>

Slide Show: Reproduction from TGES Biology

Video: Human Body Systems - Reproductive System
https://www.youtube.com/watch?v=GArALyhGtfQ
The **menstrual cycle** in women is a recurring process in which the **lining** of the uterus is prepared for pregnancy, and if pregnancy does not happen, the lining is shed at **menstruation**. The cycle lasts about 28 days.

Several **hormones** control this cycle:

<table>
<thead>
<tr>
<th></th>
<th><strong>FSH</strong></th>
<th><strong>LH</strong></th>
<th><strong>Oestrogen, Progesterone</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Secreted by</strong></td>
<td>Pituitary gland (at the base of the brain)</td>
<td>Ovaries</td>
<td></td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Control the release of egg from ovary</td>
<td>Change the thickness of uterus lining</td>
<td></td>
</tr>
</tbody>
</table>

The **Hormonal Cycle**
1. Menstruation

- Usually, one egg is released from an ovary every month. Before the egg is released, the **lining** of the uterus becomes thick and spongy to prepare for a fertilised egg. It is full of tiny blood vessels, ready to supply the embryo with food and oxygen if it should arrive.
- If the egg is not fertilised, it is dead by the time it reaches the uterus.
- It does not sink into the spongy wall, but continues onwards, down through the vagina.
- As the spongy lining is not needed now it gradually disintegrates and is slowly lost through the vagina.
- This is called menstruation, or period and it last for about 5 days.

2. Ovulation
<table>
<thead>
<tr>
<th><strong>Ovary</strong></th>
<th><strong>Pituitary gland</strong></th>
</tr>
</thead>
</table>
| • a **follicle** develops  
• secretes **oestrogen**  
• ↑↑ oestrogen in the blood.  
• lining of the uterus grows thick, spongy | • secretes **LH, FSH**  
• stimulates follicle to secrete oestrogen. |

When the **follicle** is fully developed ---> **LH ↑↑↑↑** and **FSH ↑↑**

• follicles rupture and release fully developed **ovarian cells** *(ovulation)*

• empty follicle stops secreting oestrogen  
• becomes a **corpus luteum**  
• secretes **progesterone**  
• uterus lining thick, spongy, well supplied with blood in case a egg is fertilised.  

• ↓↓ **LH, FSH**

**If the egg is not fertilized**

• corpus luteum gradually disappears  
• no more progesterone secreted  
• uterus lining breaks down

**Menstruation**

• a new **follicle** develops

**If the egg is fertilized**

• corpus luteum does not degenerate so quickly  
• secretes progesterone until the embryo sinks into uterus wall and a placenta develops

**Placenta secretes progesterone through pregnancy**

• it maintains the uterus lining so that the menstruation does not happen during pregnancy
Ovulation

Egg fertilised

Implantation in uterus

No Bleeding

If no fertilisation then again menstruation

Lasts for 4–5 days as non-pregnancy condition

Ovulation

Egg not fertilised

No uterine implantation

Menstrual bleeding
After sexual intercourse, sperms swim through the cervix and the uterus into the oviducts, where they meet an egg. One sperm may fertilise the egg to produce a zygote.

After ovulation, the egg is caught in the funnel of the oviduct. Very slowly, the egg travels towards the uterus. If the egg is not fertilised by a sperm within 8-24 hours after ovulation, it will die. By this time, it has only traveled a short way along the oviduct. So a sperm must reach an egg while it is quite near the top of the oviduct if fertilization is to be successful.
1. **Sexual intercourse** involves inserting the erect penis into the vagina.

- When stimulated, spongy tissue in the penis filled with blood and becomes erect.
- At the climax, semen is ejaculated from the penis into the neck of the vagina.
- Muscles in the wall of the sperm duct help to propel the semen forward.
- The sperms with their tails swim from the vagina, through the cervix and uterus, into an oviduct.

2. **Fertilisation happens in the oviduct**

- **ovum/egg** pass down in **oviduct**
- A single **sperm penetrates the membrane of ovum** by secreting a protease enzyme; only the head of the sperm goes in, the tail is left outside.

- The sperm nucleus and the egg nucleus **fuse** to form a **diploid zygote** = **fertilization**

- Sperm can remain active in the oviduct for at least 2 days and the ovum may take a day to pass from the ovary to the uterus, so there is a fertile period of 3 to 4 days around ovulation when fertilization can happen.

3. **The zygote implants in the uterus wall**

- The zygote moves slowly down the oviduct. As it goes, it **divides** by mitosis.
• It takes several hours for the embryo to reach the uterus, and by this time it is a ball of 16 or 32 cells (a blastocyst).

![Image of an egg implanting in the uterus. Credit: Web MD](image)

• The uterus has a thin, spongy lining, and the embryo sinks into it = implantation.

![Diagram of the reproductive system showing stages of fertilization and implantation. Credit: soc.hawaii.edu](image)
The blastula develops into an embryo and some of the cells form a placenta, linking the embryo with the uterus lining. Organs such as the heart develop and, after 8 weeks, the embryo is called a fetus.

Growth of the fetus requires a good supply of nutrients and O₂. This is achieved through the link between the placenta and the mother’s blood supply in the uterus lining. The placenta is soft and dark red, and has finger-like projections called villi. The villi fit closely into the uterus wall.
1. **Umbilical cord**
   - joins fetus to placenta; contains:
   - 2 arteries: blood from fetus ---> placenta
   - 1 vein: returns blood ---> fetus

2. **Placenta**

   *Brings blood supply of fetus close to mother’s*

   - Blood from the fetus passes through the **umbilical cord** in the **umbilical artery** to the placenta.
   - Here it comes close to the mother's blood.
   - transport O₂ + nutrients (amino acids, glucose...) from mother ---> fetus
   - transport CO₂ + wastes (urea...) from fetus ---> mother (through umbilical vein).
Prevents mixing

This is really important because the fetus and mother may have different blood groups - any mixing could result in blood clotting, which could be fatal to both mother and fetus.

3. An amnion protects the fetus

The fetus is surrounded by a strong membrane, called amnion. Inside the amnion is a liquid called amniotic fluid.

The fetus in the amniotic sac. Credit: preventdisease.com

Amniotic sac: membrane from embryo cells: encloses fetus, prevents entry of bacteria

Amniotic fluid: supports, protects fetus from mechanical damage; absorbs urine released by fetus.

Try this
Answer

a) i) A, umbilical cord ; B, vagina

ii) Tree functions from:
- transfers O₂ from mother to fetus
- transfers nutrients (of named nutrients) from mother to fetus
- transfers CO₂ from fetus to mother
- transfers wastes (or named wastes) from fetus to mother
- allows the transfer of antibodies from mother to fetus
- prevents mixing of the blood of mother and fetus.

iii) Helps prevent bacteria passing from mother to fetus, the blood group of mother and fetus may be different.
Antenatal care

Ante-natal (before birth) care is a routine care for the healthy pregnant woman.

Dietary needs

Before the baby is born, it obtains all its dietary requirements from its mother through the placenta. The mother’s diet needs to be balanced so that’s the fetus receives all the materials needed for healthy growth and development.

If the mother’s diet is deficient in any nutrients, the bay may not develop properly. So her diet should contain plenty of:

- amino acids --- healthy grow and development
- calcium ---> development of the skeleton
- iron ---> red blood cell formation
- energy (carbohydrates/ fats) – help to move mother’s heavier body.

Exercise

- gentle exercise (swimming, walking...)
- special exercises

Things to avoid

- drugs: aspirin, heroin
- smoking: nicotine and CO
- alcohol drinking
- viruses: HIV, rubella (can pass across the placenta, risking the fetus health).
Birth begins when the strong muscles in the wall of the uterus start to contract. This first stage of birth (called labour) is triggered by the hormone oxytocin.

**Stages of birth**

**Stage 1**

The muscular walls of the uterus start to contract, slowly stretch the opening of the cervix.

The pressure breaks the amniotic sac, releasing the amniotic fluid.

Contraction gradually become more frequent, pushing the baby down towards the cervix, which become dilated to allow baby to pass through.

**Stage 2**

The vagina stretches to allow the baby to be born.

**Stage 3**

The baby is still attached to the placenta by the umbilical cord, so this is cut and tied. The placenta breaks away form the wall of the uterus and passed out (afterbirth).
Try this

Describe, in sequence the main events which occur during birth. [3 marks]

Answer

Three points from:

- the wall of the uterus contracts
- the amniotic sac bursts
- amniotic fluid passes out though the vagina
- the cervix dilates
- the baby passes out through the cervix and vagina.
#119 Sex hormones

**Sex hormones** (testosterone in boys and oestrogen in girls) are responsible for the development of secondary sexual characteristics at puberty.

**Sex hormones**

<table>
<thead>
<tr>
<th></th>
<th>Testosterone</th>
<th>Oestrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secreted by</td>
<td>testes</td>
<td>ovaries</td>
</tr>
<tr>
<td>Make changes</td>
<td>in boys</td>
<td>in girls</td>
</tr>
</tbody>
</table>

**Puberty**

- the **sex organs** (ovaries in girls, testes in boys) become **mature** and start to secret hormones, making gametes (ova and sperms)
- happens at about **10-14 years**.

**Secondary sexual characteristics at puberty**

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice becomes much lower (breaks)</td>
<td>Breasts grow, nipples enlarge</td>
<td></td>
</tr>
<tr>
<td>Hair start to grow on chest, face, under arms and in pubic area</td>
<td>Hair develops under arms and in pubic area</td>
<td></td>
</tr>
<tr>
<td>Body becomes more muscular</td>
<td>Hip become wider</td>
<td></td>
</tr>
<tr>
<td>Penis becomes larger</td>
<td>Uterus and vagina become larger</td>
<td></td>
</tr>
<tr>
<td>Testers start to produce sperm</td>
<td>Ovaries start to release eggs and period begin (menstruation)</td>
<td></td>
</tr>
</tbody>
</table>

Sites of production of **oestrogen** and **progesterone** in the menstrual cycle and in pregnancy

<table>
<thead>
<tr>
<th>Hormones</th>
<th>Site of production</th>
<th>Site of production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oestrogen</strong></td>
<td><strong>In the menstrual cycle</strong></td>
<td><strong>In pregnancy</strong></td>
</tr>
<tr>
<td><strong>Progesterone</strong></td>
<td>Corpus luteum (remains of follicle in ovary after ovulation)</td>
<td>Placenta</td>
</tr>
</tbody>
</table>
Try this

a) i) Sperm duct labeled correctly between the testes and urethra.

   ii) Urethra labeled correctly between bladder and tip of penis.

b) In males the urethra carries urine and semen at different times; in females the urethra only carries urine.

c) i) **Two** male secondary sexual characteristics from:
   - voice becomes much lower (breaks)
   - hair starts to grow on chest, face, under arms and pubic area
   - body becomes more muscular
   - penis becomes larger
   - testes start to produce sperm.

   ii) Testis (or testes) labeled correctly.

   iii) Testosterone makes muscles grow, so the athletes can run faster or perform better.
#120 Method of birth control

There are 4 main groups of **birth control** methods: **natural, chemical, mechanical** and **surgical**.

1. **Natural methods**

   - Withdrawal
   - Withdrawal of penis before ejaculation
   - Not very reliable
   - Abstinence
   - No sexual intercourse
   - Most reliable
   - Rhythm method
   - Intercourse is avoided at the ovulation period
   - Cannot be exactly predicted

2. **Chemical methods**

   - Contraception pill
   - Contains progesterone and oestrogen which prevent ovulation
   - Progesterone only prevents implantation of blastula
   - Spermicidal
   - Kills sperm in the vagina
   - Should only be used with condom/diaphragm

3. **Mechanical methods**

   - Use of condom
   - A rubber sheath placed to stop sperm entering the vagina
   - Also prevents venereal diseases spreading
   - Femidom
   - A plastic sheath placed inside the vagina
   - Prevents entry of sperm
   - Prevents sexually transmitted diseases
   - Diaphragm
   - Dome shaped rubber barrier fitted in the cervix by a doctor
   - Prevents the entry of sperm into the cervix
   - IUD/Intrauterine device
   - Plastic-coated copper coil is surgically inserted into the wall of the uterus
   - Prevents implantation of blastula
4. Surgical methods

- Vasectomy
- Sperm ducts are tied or cut
- So no sperm leaves the testes
- Not normally reversible but extremely reliable

- Laparotomy/tubectomy
- Oviducts are tied or cut
- No eggs/ova can pass down

Photos from WebMD:

Chemical methods

Birth Control Pill

The most common type of birth control pill uses the hormones estrogen and progestin to prevent ovulation. When taken on schedule, the pill is highly effective.

About 8% of typical users get pregnant, including those who miss doses. Like all hormonal contraceptives, the pill requires a prescription.

Spermicide

Spermicide contains a chemical that kills sperm.

It comes in the form of foam, jelly, cream, or film that is placed inside the vagina before sex.
**Mechanical methods**

**Male Condom**

The latex condom is the classic barrier method. It prevents sperm from entering the woman’s body, protecting against pregnancy and STDs.

Of couples who rely only on male condoms, 15% get pregnant in a year.

**Female Condom**

The female condom is a thin plastic pouch that lines the vagina and can be put in place up to 8 hours before sex.

Users grasp a flexible, plastic ring at the closed end to guide it into position.

It's somewhat less effective than the male condom.

**Diaphragm**

The diaphragm is a rubber dome that is placed over the cervix before sex.
**IUD**

IUD stands for intrauterine device, a T-shaped piece of plastic that is placed inside the uterus by a doctor.

The copper IUD, ParaGard, works for as long as 12 years. The hormonal IUD, Mirena, must be replaced after 5 years. Both types make it more difficult for sperm to fertilize the egg.

Fewer than eight in 1,000 women get pregnant.

**Surgical methods**

**Tubal Ligation**

A surgeon closes off the fallopian tubes, preventing eggs from making their journey out of the ovaries.

**Vasectomy**

Besides condoms, a vasectomy is the only birth control option available to men. It involves surgically closing the vas deferens—the tubes that carry sperm from the testes, through the reproductive system. This prevents the release of sperm but doesn’t interfere with ejaculation.
Least Effective Methods

Without using any form of birth control, 85% of sexually active couples will get pregnant within a year. Even the least effective birth control options reduce that number considerably.

Source: Letts Revise IGCSE - Biology:Complete Study and Revision Guide

Slide Show: Birth control Options from WebMD

http://www.webmd.com/sex/birth-control/ss/slideshow-birth-control-options
An artificial insemination procedure uses a thin, flexible tube (catheter) to put sperm into the woman's reproductive tract (vagina, cervix, uterus) around the time of ovulation. For some couples with infertility problems, insemination can improve the chances of pregnancy.

Prior to insemination, the sperm usually are washed and concentrated (placing unwashed sperm directly into the uterus can cause severe cramps). Concentration is accomplished by selectively choosing highly active, healthy sperm that are more capable of fertilizing an egg.

The artificial insemination may be a real help to a couple, as it allows them to have a child that they could not otherwise have.

Problems:

- The man has to be able to accept that the child is not biologically his.

- When the child grows up, he may wants to know who his biological father is. Some people think that the identity of the sperm donor should be given to the child. However, this may cause more problems than it solves. Many sperm donors wish to remain anonymous.
Use of hormones in fertility drugs

Fertility drugs are used when the woman is not producing enough eggs. She is given hormones, including FSH and LH, that cause multiple release of eggs.

- The eggs can be allowed to be released into the oviduct in the normal way.

- If the woman has a problem with blocked oviducts, the eggs are removed from her ovaries just before they are due to be released, and placed in a warm liquid in a Petri dish. Some of her partner sperms are added, and fertilization takes place in the dish. 2 or 3 of the resulting zygotes are placed into her uterus, where they develop in the usual way. This is called In vitro fertilization (IVF).

Problems:

- The treatment is quite expensive, and not always successful. Some argue that the it should not be freely available to anyone who wants it. Other think that the inability to have children can be so devastating to a couple that they should receive the treatment free of charge.

- Sometimes 2 or 3 embryos develop, so the couple might have twins or triplets when they really only wanted one child.
#122 Breast feeding vs formula milk?

This has been a tough question for many years: Which is better - *breast milk* or *formula milk*? While breast milk is nutritious, it has its inconveniences. Formula milk is convenient but expensive. What to choose?

<table>
<thead>
<tr>
<th>Breast feeding</th>
<th>Formula milk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td></td>
</tr>
<tr>
<td>- has antibodies; no bacteria</td>
<td>- less painful</td>
</tr>
<tr>
<td>- foodstuffs in correct proportions</td>
<td>- other people can feed baby</td>
</tr>
<tr>
<td>- no risk of allergic reaction</td>
<td>- may contain supplement vitamins, minerals</td>
</tr>
<tr>
<td>- correct °</td>
<td></td>
</tr>
<tr>
<td>- no additives/p preservatives</td>
<td></td>
</tr>
<tr>
<td>- builds mother - child bond</td>
<td></td>
</tr>
<tr>
<td>- no cost; no preparation</td>
<td></td>
</tr>
<tr>
<td>- breast-feeding triggers</td>
<td></td>
</tr>
<tr>
<td>- reduction of uterus size</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
</tr>
<tr>
<td>- may be painful</td>
<td>- more likely to develop illness (diarrhoea, urine infection...)</td>
</tr>
<tr>
<td>- mother needs to be present</td>
<td>- risks of wrong mixture</td>
</tr>
<tr>
<td>- damage beauty</td>
<td>- expensive</td>
</tr>
</tbody>
</table>

**Fun fact!** Breast milk can naturally and easily remove eye make-up! Plus, it can cure certain eye diseases!

There are several other things you could do with breast-milk :) Find out more, just for fun, at:


I swear, some of these facts can blow your mind!

**Video: Breastfeeding vs bottle feeding - DrTummmmy.com**

https://www.youtube.com/watch?v=XPl0odcvegM
#123 HIV/ AIDS - transmission and prevention methods

AIDS (Acquired Immune Deficiency Syndrome) is a disease caused by the HIV. HIV can not live outside the human body. It is an especially fragile virus - much less tough than the cold virus. It is transported in body fluids. You can only become infected with HIV through direct contact of your body fluid with those of someone with the virus.

How HIV affects the immune system

- The HIV virus attacks some types of lymphocyte (white blood cells) in the blood stream.
- Lymphocytes produce antibodies ---> attack the antigens on invading microbes.
- Some lymphocytes are stored in lympho nodes ---> protection against future infection.
- HIV prevents this immunity being retained, so the AIDS sufferer has no protection against diseases such as tuberculosis (TB) and pneumonia.

Methods of transmission:

- unprotected sexual intercourse with infected person
- drug use involving sharing needle used by infected person
- transfusion of infected blood
- infected mother to fetus
- feeding a baby with milk from an infected mother
- unsterilised surgical instruments

HIV CAN BE TRANSMITTED THROUGH...
**Prevention methods**

- condom for sexual intercourse
- refuse sexual intercourse
- screen blood (for transfusion)
- use sterilized needles
- feed baby with bottled powdered milk (if mom has HIV)
- use sterilised surgical instruments.

**Video: How is HIV Transmitted?**

https://www.youtube.com/watch?v=z8BwYFIrTAGY

**Video: How to prevent HIV transmission?**

https://www.youtube.com/watch?v=NXnvP_sKS9k
Gonorrhoea is caused by bacteria that can be passed from one person to another during sexual intercourse. *Neisseria bacterium* is a small, round cell. It can only survive in moist places, such as tissues lining the tubes in the **productive systems** of a man and a woman.

**Symptoms**

- If gonorrhoea bacteria are living in a woman’s vagina or a man’s urethra, the infection can be passed during sexual intercourse.

- The first symptoms occur 2-7 days after infection.

- Man: the bacteria reproduce inside the urethra ---> unpleasant discharge and pain when urinating.

- Woman: the bacteria reproduce mostly in the cervix, although they can also do so in the vagina ---> many women do not notice discharge or suffer a pain as men do.

- Most men with gonorrhoea know that they have it, many women are unaware that they have the infection.
<table>
<thead>
<tr>
<th>Signs and symptoms</th>
<th>Effects</th>
<th>Treatment</th>
</tr>
</thead>
</table>
| Male               | - Sores on penis  
- Discharge of pus from penis  
- Pain when urinating  
- Damage to urinary and reproductive organs  
- Sterility  
- Blindness in a baby born to a mother with the disease.  
- Antibiotic, e.g. penicillin |
| Female             | - Discharge of pus from vagina, but not always obvious  
- Often **no symptoms** |

*Severe eye pathology in a baby born to a mother with gonorrhoea: eyelids swollen, profuse purulent discharge. If untreated blindness may result.*
*Cred: cehjournal.org*
Reproduction is the biological process by which new "offspring" individual organisms are produced from their "parents". It is a fundamental feature of all known life.

Two types of reproduction: sexual and asexual.

Asexual reproduction

It involves cell division by mitosis, producing a group of genetically identical individuals called a clone. Bacteria, fungi and potatoes can reproduce asexually.
Sexual reproduction

Sexual reproduction involves the production of genetically different gametes by **meiosis**. A male gamete fertilises a female gamete, producing a zygote which is genetically different from its parents.

![Diagram of sexual reproduction](image)

**In human**

- The male gametes are **sperms**, they are made in the **testes**. During sexual intercourse, semen containing sperms passes out to the penis and into a woman’s vagina.

- The female gametes are **eggs** and are made in the **ovaries**. After sexual intercourse, sperm swim through the cervix and uterus into the **oviducts**, where they may meet an egg. One sperm may fertilise the egg to produce a **zygote**.

- The **zygote** travels to the uterus and **implants** into the lining, growing into an **embryo** attached to the uterus wall via an umbilical cord and **placenta**. The placenta brings the growing embryo’s blood very close to the mother’s blood, so that’s nutrients and waste products can diffuse between them.

- The growing embryo is protected by **amniotic fluid** produced by the amnion.

- After birth, a young mammal is fed on **milk** from its mother. This provides it with exactly the correct balance of nutrients, as well as antibodies which protect it from infectious diseases.
• An egg is released from an ovary about one a moth. If it is not fertilised, the thick lining of the uterus breaks down, in menstruation.

• The menstrual cycle is controlled by the hormones oestrogen, progesterone, FSH and LH.

• Birth control helps a couple to avoid having unwanted children. There are natural, surgical, mechanical and chemical methods.

• Hormones can be used to increase fertility.

• Gonorrhoea and HIV/AIDS are infectious diseases that can be transmitted by sexual contact.

**In plants**

• The flowers are the reproductive organs. Male gametes are made inside pollen grains, produced by anthers. Female gametes are made inside ovules produced by ovaries.

• The movement of pollen from an anther to a stigma is called pollination, and may be brought about by insects of the wind.

• After landing on a suitable stigma, a pollen grain germinates and the gametes travel down the style to the ovules. Here, fertilisation takes place and a zygote is produced. The zygote develops into an embryo, and the ovule develops into a seed. The ovary develops into the fruit, containing the seeds which contain the embryos.

• Fruits are adapted to disperse seeds, using animals or the wind.

• Seeds require certain condition before they will germinate.
Inheritance is the transmission of genetic information from one generation to the next, leading to continuity of the species and variation within it.

**Key definitions**

| **Chromosome** | A thread of DNA, made up of genes. |
| **Allele** | An alternative form of a gene. Pairs of alleles occupy the same relative positions on chromosome pairs. |
| **Gene** | A section of DNA, which codes for the formation of a protein controlling a specific characteristic of the organism. |
| **Haploid nucleus** | A nucleus containing a single set of unpaired chromosomes, e.g. in sperm and ova (eggs). In humans, the haploid number is 23. |
| **Diploid nucleus** | A nucleus containing pairs of chromosomes, e.g. in somatic (body) cells, In humans the diploid number is 46. |
| **Genotype** | The genetic make-up of an organism, e.g. Tt, where T and t are alleles of a gene. |
| **Phenotype** | The characteristics visible in an organism, controlled by the genotype, e.g. a tall plant or a dwarf plant. |
| **Homozygous** | Having a pair of identical alleles controlling the same characteristics, e.g. TT, where T=tall. The organism will be pure-breeding for that characteristic. |
| **Heterozygous** | Having a pair of dissimilar alleles for a characteristic, e.g. Tt. |
| **Dominant** | A gene, e.g. T, that always shows in the phenotype of an organism whether the organism is heterozygous (Tt) or homozygous (TT). |
| **Recessive** | A gene, e.g. t, that only has an effect on the phenotype when the organism is homozygous (tt). |

**Video: The Human Genome Project, 3D Animation**
https://www.youtube.com/watch?v=VJycRYBNtwY
In the nucleus of every cell there are a number of long threads called **chromosomes**.

**Chromosomes**

Most of the time, the chromosomes are too thin to be seen except with an electron microscope. But when a cell is dividing, they get shorter and fatter so they can be seen with a light microscope.

Human chromosomes and nucleus. Chromosomes are a packaged form of DNA. The DNA normally exists in a non-condensed form in the cell nucleus (upper right). It condenses into chromosomes (centre and lower left) during cell replication.

Human cells contain 46 chromosomes, which are in pairs. Sex cells (sperm and ova) contain only 23 chromosomes. The 23 chromosomes comprise one from each pair.
Inheritance of sex in humans

Of the 23 pairs of chromosomes present in each human cell, one pair is the sex chromosomes. These determine the sex of the individual. Male have XY, female have XX. So the presence of a Y chromosome results in male features developing.

**DNA**

Each chromosome contains one very long molecule of DNA. The DNA molecule carries a code that instructs the cell about which kind of **proteins** it should make. Each chromosome carries instructions for making many different proteins.

**Gene**

Each chromosome is made up of a large number of **genes** coding for the formation of different proteins which give us our characteristics. The gene responsible for a particular characteristic is always on the same relative position on the chromosome.

*A part of a DNA molecule coding for one protein is called a gene.*
Alleles

When the chromosomes are in pairs, there may be a different form (allele) of the gene on each chromosome.

Video: What is a Chromosome?
https://www.youtube.com/watch?v=xUrlreMaUrs

Video: What is DNA?
https://www.youtube.com/watch?v=zwibgNGe4aY
**Mitosis** is a nuclear division giving rise to genetically **identical** cells in which the chromosome number is maintained by the exact duplication of chromosome.

**Meiosis** is a reduction division in which the chromosome number is **halved** from diploid to haploid.

---

**Mitosis**

Mitosis is the way in which **any cell** (plant or animal) divides when an organism is:

- **growing**
- **repairing** a damaged part of its body
- **replacing** worn out cells

**Growth** means getting bigger. An individual cell can grow a certain amount, but not indefinitely. Once a cell gets to a certain size, it becomes difficult for all parts of the cell to obtain oxygen and nutrients by division. In order to grow any more, the cell divides to form two smaller cells, each of which can then grow and divide again.

Mitosis is also used in **asexual reproduction**. For example, sweet potato plant can reproduce by growing adventitious roots or runners which eventually produce new plants.
Process of mitosis

- During the process, all the **chromosomes** in the parent cell are **copied**.
- Each copy remains attached to the original one --> each chromosome is made up of 2 identical threads joined together.
- The parent cell (with 4 chromosomes) **split** to form 2 nuclei each with 2 chromosomes as the parent nucleus cell.
- At the end of a mitotic cell division, the number of cells is doubled and the **daughter cells** produced are genetically **identical** to the **parent**.

Meiosis

Meiosis is the way in which **gametes** (sex cells) are produced. Gametes have only **half** the number of chromosome of a normal body cell. They have 1 set of chromosome instead of 2. When they fuse together, the zygote formed has 2 sets.
Human gametes are formed by the division of cells in the ovaries and testes. The gametes produced are haploid, but they are formed from diploid cells, so meiosis involves **halving** the normal chromosome number - the pairs of chromosomes are separated.

During meiosis, the new cells get a mixture of homologous chromosomes from father and mother -- A sperm cell could contain a chromosome 1 from father and a chromosome 2 from mother.

There are all sorts of combinations --> gametes are **genetically different** form the parent cells. Meiosis produces genetic variation.

When ova are formed in a woman, all the ova will carry an X chromosome. When sperm are formed in a man, half the sperm will carry an X chromosome, half will carry a Y chromosome.

---

**Sample question**

Complete the following passage, using only words form the list below.

**diploid** **gametes** **haploid** **meiosis** **mitosis** **red blood cells**

*The transfer of inherited characteristics to new cells and new individuals depends on two types of cell division. During ___________, the chromosomes are duplicated exactly and _________ cells are produced.*

*However, during _____________, the chromosome sets are first duplicated and then halved, producing cells. These cells will become _________ . [4 marks]*

**Student’s answer**

During **meiosis** â, the chromosomes are duplicated exactly and **identical** â cells are produced.
However, during **meiosis**, the chromosome sets are first duplicated and then halved, producing cells. These cells will become **gametes**.

**Examiner’s comments**

_The first answer is not clear – it mixes up the terms ‘mitosis’ and ‘meiosis’. Sometimes candidates do this deliberately when they are not sure of the answer, hoping that the examiner will give them the benefit of the doubt. (We don’t!). This candidate has not followed the rubric (instructions) in the question for the second answer: the term ‘identical’ does not appear in the word list. The correct answers are ‘mitosis’ and ‘diploid’._

**Try this**

1) The nuclei of human liver cells contain 46 chromosomes. Complete the table below to show how many chromosomes would be present in the cells listed. [3 marks]

<table>
<thead>
<tr>
<th>Type of cell</th>
<th>Number of chromosomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciliated cell in windpipe</td>
<td></td>
</tr>
<tr>
<td>Red blood cell</td>
<td></td>
</tr>
<tr>
<td>Ovum</td>
<td></td>
</tr>
</tbody>
</table>

2) Describe 2 differences, other than the number of chromosomes, between nuclei produced by mitosis and those produced by meiosis. [2 marks].

**Answer:**

1) Ciliated cell: 46  
Red blood cell: 0 (this cell has no nucleus)  
Ovum: 23

2) Two differences from:

- chromosomes in daughter mitotic cells will be identical to parental chromosomes (or there is no variation).  
- genes in daughter mitotic cells will be identical to parental genes.  
- chromosomes in daughter mitotic cells will be in homologous pairs, but they will be single in meiotic nuclei.

**Video: Mitosis**  
https://www.youtube.com/watch?v=VIN7K1-9QB0

**Video: Meiosis**  
https://www.youtube.com/watch?v=D1_-mQS_FZ0

**Video: Difference between mitosis and meiosis**  
https://www.youtube.com/watch?v=Ba9LXKH2ztU
A monohybrid cross involves the crossing of individuals and the examination of one (mono) character (flower colour, pod shape...) and different (hybrid) traits (red colour, white colour) in their offspring.

The Punnett square is a useful tool for predicting the genotypes and phenotypes of offspring in a genetic cross involving Mendelian traits.

Mendel crossed true-breeding plants that differed for a given character. Pollen from true-breeding pea plants with purple flowers (one trait) was placed on stigmas of true-breeding plants with white flowers (another trait).

The F1 seeds were all purple; the white flower trait failed to appear at all. Because the purple flower trait completely masks the white flower trait when true-breeding plants are crossed, the purple flower trait is called dominant, and the white flower trait is called recessive.

The F1 plants were allowed to self-pollinate. This step was the monohybrid cross. (or the F1 cross). The progeny, called F2, were examined: roughly 1/4 were white, and 3/4 were purple.

All the genetic crosses shown below will involve examples using pea plants, which can be tall (T) of dwarf (t) – tall is dominant to dwarf.
Examiner’s tips

- When you write out a genetic cross, make sure you state what the symbols represent, e.g. T=tall, t=dwarf.
- Make sure you label each line in the cross (phenotype, genotype...).
- It’s a good idea to circle gametes to show that meiosis has happened.
- Read the question really carefully – are you asked to state the outcome in terms of the genotype or the phenotype?

Punnett square

1. A cross between a pure-breeding **tall** pea plant and a pure-breeding **dwarf** pea plant.

As tall is dominant to dwarf, and both plants are pure-breeding, their genotypes must be **TT** and **tt**.

2. A cross between two **heterozygous tall** pea plant.

The genotype of both plants must be **Tt**.
3. A cross between two heterozygous tall pea plant.

The heterozygous tall pea plants must be **Tt**.
The dwarf pea plants must be **tt**.

![Punnett Square Diagram]

**Common misconceptions**

Some students ignore the letters for alleles given in genetic questions and make up their own, without stating a key. This usually results in a number of marks being lost through errors that could easily have been avoided.

**Try this**

1. In exam questions involving genetic crosses, you often need to predict the genotypes of the parents from descriptions of them. Work out the following genotypes, based on peas that can be round or wrinkled, with round being dominant to wrinkled. Remember that the dominant allele normally takes the capital letter or the characteristic it represents.

   a) A heterozygous round pea  
   b) A wrinkled pea  
   c) A pure-breeding round pea

**Answer**

   a) Rr  
   b) rr  
   c) RR

2. Complete the passage by writing the most appropriate word from the list in each space.
Petal colour in pea plants is controlled by a single gene which has two forms, red and white. The pollen grains are produced by meiosis. After pollination, fertilization occurs and the gametes join to form a diploid zygote.

When two red-flowered pea plants were crossed with each other, some of the offspring were white-flowered. The phenotype of the rest of the offspring was red-flowered. The white-flowered form is recessive to the red-flowered form and each of the parent plants was therefore heterozygous.

Answer
gene meiosis diploid phenotype recessive heterozygous

Video: Punnett squares

https://www.youtube.com/watch?v=_ksIajiPUAU
Sometimes, neither of a pair of alleles is completely dominant or completely recessive. Instead of one of them completely hiding the effect of the other in a heterozygote, they both have an effect on the phenotype. This is called codominance.

The result is that there can be three different phenotypes. When writing the genotypes of codominant alleles, the common convention is to use a capital letter to represent the gene involved, and a small raised letter for each phenotype.

Imagine a kind of flower which has two alleles for flower colour. The allele $C^w$ produces white flowers, while the allele $C^R$ produces red ones. If these alleles show codominance, then the genotypes and phenotypes are:

<table>
<thead>
<tr>
<th>genotype</th>
<th>phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C^w C^w$</td>
<td>white flowers</td>
</tr>
<tr>
<td>$C^w C^R$</td>
<td>pink flowers</td>
</tr>
<tr>
<td>$C^R C^R$</td>
<td>red flowers</td>
</tr>
</tbody>
</table>

**Common misconceptions**

When factors are codominant, students often think this will result in different proportions of offspring having the parents’ features. However, codominance results in the appearance of a new characteristic, which is intermediate to the parents features. For example, if the parents are pure-breeding for long fur and short fur, the offspring will all have medium-length fur.
Inheritance of A, B, AB and O blood group - an example of codominance

- In humans, there are 4 blood types (phenotypes): A, B, AB, and O
- Blood type is controlled by 3 alleles: $I^A$, $I^B$, $I^O$ (the base letter = I stands for immunoglobulin)
- $I^O$ is recessive, two $I^O$ alleles must be present for the person to have type O blood
- $I^A$ and $I^B$ are codominant but both are dominant to $I^O$. If a person receives an $I^A$ allele and a $I^B$ allele, their blood type is type AB, in which characteristics of both A and B antigens are expressed.

Because $I^O$ is dominated by both $I^A$ and $I^B$ alleles, a person with blood group A could have the genotype $I^A I^O$ or $I^A I^A$. This has implication when having children because, if both parents carry the $I^O$ allele, a child could be born with the genotype $I^O I^O$ (blood group O), even though neither of the parents have this phenotype.

<table>
<thead>
<tr>
<th>Blood type</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$I^A$, $I^O$, $I^A$, $I^A$</td>
</tr>
<tr>
<td></td>
<td>AO, AA</td>
</tr>
<tr>
<td>B</td>
<td>$I^B$, $I^O$, $I^B$, $I^B$</td>
</tr>
<tr>
<td></td>
<td>BO, BB</td>
</tr>
<tr>
<td>AB</td>
<td>$I^A$, $I^B$</td>
</tr>
<tr>
<td></td>
<td>AB</td>
</tr>
<tr>
<td>O</td>
<td>$I^O$, $I^O$</td>
</tr>
<tr>
<td></td>
<td>OO</td>
</tr>
</tbody>
</table>

Video: Codominance and the inheritance of blood type

https://www.youtube.com/watch?v=nykVH9Z7Gw8
Variation is all the **differences** which exist between members of the same species. It is caused by a combination of **genetic** and **environmental** factors.

There are two kinds of variation: **continuous** and **discontinuous**.

**Continuous variation**

- shows a complete range of the characteristic within a population.
- caused both by both **gens** (often a number of different genes) and **environment**:
  - Plants: availability of/competition for: nutrients, light, water; exposure to disease...
  - Animals: availability of food/balanced diet; exposure to disease (or the availability of health serviced for humans).

**Discontinuous variation**

- seen where there are obvious, distinct categories for a feature.
- no intermediates between categories, the feature cannot usually change during life.
- caused by a single gen/a small number of **genes**, with **no environmental** influence.
Seventy seeds were collected from a cross between two plants of the same species. The seeds were sown at the same time and, after 3 weeks, the heights of the plants which grew were measured and found to fall into two groups, A and B, as shown in figure below.

<table>
<thead>
<tr>
<th>Continuous variation</th>
<th>Discontinuous variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td></td>
</tr>
<tr>
<td>- No distinct categories</td>
<td>- Distinct categories.</td>
</tr>
<tr>
<td>- No limit on the value</td>
<td>- No in-between categories</td>
</tr>
<tr>
<td>- Tends to be quantitative</td>
<td>- Tends to be qualitative</td>
</tr>
<tr>
<td>Examples</td>
<td></td>
</tr>
<tr>
<td>- height</td>
<td>- tongue rolling</td>
</tr>
<tr>
<td>- weight</td>
<td>- finger prints</td>
</tr>
<tr>
<td>- heart rate</td>
<td>- eye colour</td>
</tr>
<tr>
<td>- finger length</td>
<td>- blood groups</td>
</tr>
<tr>
<td>- leaf length</td>
<td></td>
</tr>
<tr>
<td>Representation</td>
<td></td>
</tr>
<tr>
<td>Line graph</td>
<td>Bar graph</td>
</tr>
</tbody>
</table>

**Try this**

Seventy seeds were collected from a cross between two plants of the same species. The seeds were sown at the same time and, after 3 weeks, the heights of the plants which grew were measured and found to fall in to two groups, A and B, as shown in figure below.

a) Calculate the percentage of seeds which germinated. Show your working. [2 marks]

b) i) Name the type of variation shown within each group [1 mark]

   ii) State three factors which might have caused this variation. [3 marks]
Answer

a) \( \frac{56}{70} \times 100 = 80\% \)

b) i) continuous variation.

   ii) Any 3 factors from: genes, temperature, disease, seed size, light, \( O_2 \), \( CO_2 \), \( H_2O \), minerals, mutation, trampling by animals.

**Video: What is meant by genetic difference?**

https://www.youtube.com/watch?v=a5yzRRvROpE
Mutation is an unpredictable change in the genes or chromosome number, as a result of fault copying when DNA is replicated, faulty separation of chromosomes during cell division, or exposure to radiation or some chemicals.

Down’s syndrome is caused by a mutation. When ova are formed in the ovaries, the chromosome number is halve. During this division process (meiosis), one of the chromosome (number 23) sticks to its partner. This results in one ovum with 24 chromosomes and one with only 22, and the ovum with 24 chromosomes is still viable. If it is fertilized, the fetus formed will have 47 chromosomes instead of 46.

The presence of the extra chromosome causes unusual characteristics in the baby. These usually include lowered life expectancy, mental retardation (although some Down’s children are very intelligent), early puberty, and a distinctive round face and short neck.
A child with Down syndrome.
Effects of ionising radiation and chemicals on the rate of mutation

- Mutation are normally very rare. However, exposure to radiation and some chemicals, such as tar in tobacco smoke, increases the rate of mutation.
- Exposure can cause uncontrolled cell division, leading to the formation of tumours (cancer).

The development of cancer from mutated cells.

- Exposure of gonads (testes and ovaries) to radiation can lead to sterility or to damage to genes in sex cells that can be passed on to children.
- Some scientists argue that there is a higher incidence of leukaemia (a form a white blood cells cancer) in the children of workers at nuclear power stations.

Video: DNA mutation, effect of radiation and chemicals on mutation

https://www.youtube.com/watch?v=efstlgoynlk
#133 Sickle cell anaemia and its incidence to that of malaria

**Sickle cell anaemia** is caused by a **mutation** in the blood pigment **haemoglobin**. When the faulty haemoglobin is present in a red blood cell, it causes the cell to deform and become **sickle-shaped**, especially when oxygen levels in the blood become low.

In this state the sickled red blood cells are less efficient at transporting oxygen and more likely to become stuck in a capillary, preventing blood flow.

The faulty allele is dominated by the allele for normal haemoglobin, but still has some effect in a heterozygous genotype.

The possible genotypes are:

- **H^N^N** normal haemoglobin, no anaemia
- **H^N^H^n** some abnormal haemoglobin, sickle cells trait (not life-threatening)
- **H^n^H^n** abnormal haemoglobin, sickle cells anaemia (life-threatening)

**Malaria** is a life-threatening disease caused by a parasite that invades red blood cells. The parasite is carried by some species of mosquito.

- A person who is heterozygous (**H^N^H^n**) for sickle cell anaemia has **protection** from malaria, because the malaria parasite is unable to invade and reproduce in the sickle cells.
- A person who is homozygous for sickle cell anaemia (**H^n^H^n**) also has **protection**, but is at high risk of dying from sickle cell anaemia.
- A person with normal haemoglobin (**H^N^H^N**) in a malarial country is at **high risk** of contracting malaria.

When the distributions of malaria and sickle cell anaemia are shown on a map of the world, it is found that the two coincide in tropical areas because of the selective advantage of the **H^n** allele in providing protection against malaria.

**Video: Sickle cell disease**
[https://www.youtube.com/watch?v=9AHFHleYwdU](https://www.youtube.com/watch?v=9AHFHleYwdU)

**Video: What is Sickle cell anaemia**
[https://www.youtube.com/watch?v=Qd0HrY2NILwY](https://www.youtube.com/watch?v=Qd0HrY2NILwY)

**Video: Evolution of sickle cell malaria**
[https://www.youtube.com/watch?v=1fN7rOwDyMQ](https://www.youtube.com/watch?v=1fN7rOwDyMQ)
Artificial selection is a method used by humans to produce varieties of animals and plants which have an increased economic importance. People use selective breeding to produce new varieties of a species, so that certain desirable traits are represented in successive generations.

A variety is a type of a particular species that is different in some clear way from other varieties of that species. The different breeds of domestic dogs and large ears of maize corn are products of artificial selection.

These common vegetables were cultivated from forms of wild mustard. This is evolution through artificial selection.
Selective breeding of cows

Suppose you wanted a variety of cow that produced a lot of milk. This is what you could do:

- choose or select the cows in your herd that produce the most milk
- let only these cows reproduce
- select the offspring that produce the most milk
- let only these offspring reproduce
- keep repeating the process of selection and breeding until you achieve your goal.

Natural selection is the process by which plants and animals that can adapt to changes in their environment are able to survive and reproduce while those that cannot adapt do not survive. It gives the greater chance of passing on of genes by the best adapted organisms.

Try this

Farmers have carried out artificial selection to improve the breeds of some animals. Some of the original breeds have become very rare and are in danger of becoming extinct.

a) Explain what is meant by artificial selection [2 marks]

b) i) Name one species which is in danger of extinction. [1 mark]
ii) Biologists are concerned that species of animals and plants should not become extinct. Why is it important to prevent the extinction of plant and animal species? [2 marks]
**Answer**

a) A method used by humans to produce varieties of animals and plants which have an increased economic importance.

b) i) Any endangered species, such as panda, tiger, elephant, named whales species, named tuna species.

   ii) Two point from:

   - to maintain the gene pool
   - to provide chemicals that may be useful in development of medicines
   - the species may be an important part of a food chain
   - rare species may provide tourism to supply poor communities with money.

Additional source: [BBC Bitesize](https://www.bbc.co.uk/bitesize/topics/zmr6f4f/articles/b84wcyx)

**Video: What is Natural Selection?**

https://www.youtube.com/watch?v=0SCjhI86grU&list=PLfHpBjIQ933u6AuVra6y78X5rd-AFr0aq8

**SlideShow**

http://learn.genetics.utah.edu/content/selection/artificial/
**Variation** is the slight individual differences within populations. All living things change and evolve from one generation to the next. As they do so, more variation is produced.

Some variations is *inherited* (passed on from parents) and some is *acquired* (developed during life).

Animals and plants produced by sexual reproduction will show variation from their parents, for example in the size of the muscles in the legs of lions.

When new organisms are produced, not all of them are likely to survive because of competition for resources such as food, water and shelter. The same is true for plants (they compete for resources such as nutrients, light, water and space).

The individuals with the most favourable characteristics are most likely to survive.

The process of natural selection follows a sequence, as listed below.

- Some of the variations within a population may give some individuals an advantage over others in the population. Bigger muscles in the legs of a lion would enable it to run more quickly and get food more successfully.
- In an environment where there is food shortage, the lion with the biggest leg muscles is most likely to survive to adulthood.
The weaker individuals die before having the chance to breed, but the surviving adults breed and pass on the advantageous genes to their offspring.

More of the next generation carry the advantageous genes, resulting in a stronger population, better adapted to a changing environment.

Slow changes in the environment results in adaptation in a population to cope with the change. Failure to adapt could result in the species becoming extinct. This gradual change in the species through natural selection over time, in response to changes in the environment, is a possible mechanism for evolution.

Examples: antibiotic-resistance strains of bacteria
Bacteria reproduced rapidly - a new generation can be produced every 20 minutes by binary fission. Antibiotics are used to treat bacterial infections: an antibiotic is a chemical that kills bacteria by preventing bacterial cell wall formation.

Mutations occur during reproduction, which produce some variation in the population of bacteria.

Individual bacteria with the most favourable features are most likely to survive and reproduce.

A mutation may occur that enables a bacterium to resist being killed by antibiotic treatment, while the rest of the populating is killed when treated. This bacterium would survive the treatment and breed, passing on the antibiotic-resistant gene to its offspring. Future treatment of this population of bacteria using the antibiotic would be ineffective.

Video GCSE BBC Science Bitesize - Variation, Inheritance and Evolution: https://www.youtube.com/watch?v=1m_m18UaxUs

Video The Animation of Antimicrobial Resistance
https://www.youtube.com/watch?v=AYvX8tnCM9s
Genetic engineering is a process of taking a gene from one species and putting it into another species.

The control of all the normal activities of a bacterium depends upon its single chromosome and small rings of genes called plasmids. In genetic engineering pieces of chromosome from a different organism can be inserted into a plasmid. This allows the bacteria to make a new substance.

The ethics of genetic engineering:

Benefits:
- cures for diseases, such as cystic fibrosis and cancer
- food which is healthier, stays fresh for longer periods and tastes better.

Risks:
- unknown effects of moving genes from one organism to the other
- new dangerous diseases being created
- against God and nature.
Using genetic engineering to put human insulin genes into bacteria

1. Human cells with genes for healthy insulin are selected.
2. A chromosome (a length of DNA) is removed from the cell.
3. The insulin gene is cut from the chromosome using restriction endonuclease enzyme.
4. A suitable bacterial cell is selected. Some of its DNA is in the form of circular plasmids.
5. All the plasmids are removed from the bacterial cell.
6. The plasmids are cut open using the same restriction endonuclease enzyme.
7. The human insulin gene is inserted into the plasmids using ligase enzyme.
8. The plasmid are returned to the bacterial cell (only one is shown in the diagram).
9. The bacterial cell is allowed to reproduce in a fermenter. All the cells produced contain plasmids with the human insulin gene.

The importance of this process

- Diabetics need a source of insulin to control their blood sugar level. In the past cow insulin has been used, but some people are allergic to it. Human insulin produced from genetically engineered bacteria will not trigger an allergic reaction.
- The insulin is acceptable to people with a range of religious belief who may not be allowed to use insulin from animals such as cows or pigs.
- The product is very pure.
- Human insulin can be made on a commercial scale, reducing costs.

Video Genetic Engineering

https://www.youtube.com/watch?v=zlqD4UWCuws

Video Genetically Engineered Insulin

https://www.youtube.com/watch?v=MJ_6oXaLRj4
Using genetic engineering to produce bacteria that make human insulin.
# Summary of inheritance

- **Chromosomes** are long threads of DNA made up of strings of **genes**. In a diploid cell, each of a pair of homologous chromosomes carries the same genes in the same position. A diploid cell therefore has 2 copies of each gene.

- **Gametes** have only one set of chromosomes, and so they have only one copy of each gene.

- Different forms of a particular gene are called **alleles**. They may be **dominant** or **recessive**. The genotype of an organism tells us the alleles of genes that it carries. If the 2 alleles of a gene are the same in the organism, then it is **homozygous**. If they are different, it is **heterozygous**.

- If 2 **heterozygous** organisms breed together, we expect a 3:1 **ratio** of offspring showing the dominant characteristic to offspring showing the recessive characteristic. If one parent is **heterozygous** and the other is **homozygous** recessive, we expect to see a 1:1 **ratio** in the offspring.

- **Variations** is caused by genes and environment. **Continuous** variation, such as human height, has no distinct categories and is usually caused by both genes and environment. **Discontinuous** variation, such as human blood groups, involves a small number of discrete categories and is caused by genes alone.

- New alleles of genes, or changes in categories chromosomes, can be caused by **mutation**. Most mutations are harmful. Ionising radiation and certain chemicals increase the risk of mutation happening.
• In a population of organisms, those with the characteristics best adapted to the environment are most likely to survive and reproduce. This is called **natural selection**.

• If the environment changes, or if a new advantageous allele appears, natural selection can lead to change over many generations. This is called **evolution**.

• **Sickle cells anaemia** is caused by recessive allele of the gene for haemoglobin. People who are homozygous recessive often die before they can reproduce. People who are homozygous dominant have a greater chance of getting **malaria** if they live in places where this disease is present. People who are heterozygous have a selective advantage, because they are less likely to get malaria. Natural selection therefore maintains this allele in the population in parts of the world where people may be killed by malaria.

• Human select plants and animals with desirable characteristics and breed from them. Over many generations, this produces new strain of plants or animals with features that we require. This is called **artificial selection**.

• **Genetic engineering** involves taking a **gene** from one species and inserting it into another. This has been done with the human insulin gene, to give bacteria that produce **insulin** for harvest and sale, for use by people with diabetes.
The Sun is the principal source of energy input to biological systems. The Earth receives 2 main types of energy from the Sun: light (solar) and heat. Photosynthetic plants and some bacteria can trap light energy and convert it into chemical energy.

Non-cyclical nature of energy flow

Heterotrophic organisms obtain their energy by eating plants or animals that have eaten plants. So all organisms, directly or indirectly, get their energy from the Sun. The energy is passed from one organism to another in a food chain but, unlike water and elements such as carbon and nitrogen, energy does not return in a cycle. Energy give out by organisms is lost to the environment.
Energy is lost at each level in the food chain, as in the examples below.

- Energy lost through the process of respiration (as heat)
- Energy used up for movement (to search for food, find a mate, escape from predators...).
- Warm-blood animals (birds and mammals) maintain a standard blood temperature – they lose heat to the environment.
- Warm-blood animals lose heat energy in faeces and urine.
- Some of the material in the organism being eaten is not used by the consumer, for example a locust does not eat the roots of maize, and some of the parts eaten are not digestible.

Even plants do not make use of all the light energy available to them. This is because some light:

- is reflected off shiny leaves
- is the wrong wavelength for chlorophyll to trap
- passes through the leaves without passing through any chloroplasts
- does not fall on the leaves.

On average, about 90% of the energy is lost at each level in a food chain. This means that in long food chains, very little of the energy entering the chain through the producer is available to the top carnivore. So there tend to be small numbers of top carnivores. The food chain below shows how energy reduces through the chain. It is based on maize obtaining 100 units of energy.

```
maize → locust → lizard → snake
100 units   10 units   1 unit   0.1 unit
```

On shorter food chains, less energy is lost.

**Try this**
Figure below shows the flow of energy through a complete food chain:
1. a) Which form of the Sun’s energy is trapped by the producer? [1 mark]
   b) Into which energy form is the Sun’s energy converted when it is trapped by the producer? [1 mark]

2. a) The first consumer has received 6000 units of energy. How many units of energy (X on the figure) have been passed to the second consumer? [1 mark]
   b) How many units of energy (Y on the figure) are lost from the third consumer to the decomposers. [1 marks]

3. a) Suggest why the proportion of the energy intake which a producer loses to the environment (20%) is smaller than that lost to the environment by a first consumer (30%). [2 marks]
   b) Many countries have difficulty in producing enough food for their population. How might it help to overcome this problem if humans were always fed as first consumers, rather than second or third consumers? [3 marks]

**Answer**

1. a) Light (or solar) energy
   b) Chemical energy

2. a) 1200 units
   b) 48 units

3. a) The consumer may be warm-blooded, so some energy is lost as heat. Consumers usually move around to find food, a mate, or escape from predators, which uses up energy, but producers do not move.
   b) Feeding as a first consumer involves eating plants. Less energy is lost to the environment when feeding at this level, so food production is more efficient in terms of energy conservation.
Food chain is a chart showing the flow of energy (food) from one organism to the next beginning with a producer.

Examples:

- mahogany tree → caterpillar → songbird → hawk
- maize → locust → lizard → snake

A food chain usually starts with a photosynthetic plant, which gains its energy from the Sun.
- The arrows used to link each organism to the next represent the direction of energy flow. They always points towards the ‘eater’, and away from the plant.
- The feeding level is known as the trophic level.
- Plant are producers (they make/produce food for other organisms).
- Animals that eat plants are primary consumers (a consumer is an ‘eater’). They are also called carnivores.
Examiner’s tips

- Make sure you can write a food chain involving 3 consumers, with the arrows in the correct direction.
- Don’t include the Sun (it is not an organism).
- Always start with the producer on the left of diagram.
- Practice labeling each trophic level in your food chain under the organisms (producer, primary consumer, etc.).
- Don’t waste time drawing plants and animals: this will not get you any extra marks.

Common misconceptions

Marks are often lost when students write out food chains and webs because they draw the arrows the wrong way round or put the chain back-to-front (or both). The following example was seen in a recent paper:

\[ \text{jackal} \rightarrow \text{sheep} \rightarrow \text{grass} \]

This student is suggesting that grass eats sheep and sheep eat jackals!
**# 140 Food web**

**Food web** is a network of interconnected food chains showing the energy flow through part of an ecosystem.

These are a more accurate way of showing feeding relationships than food chains, because most animals have more than one food source. For example, in the food webs in figure below, the leopard feeds on baboons and impala.

The leopard can be placed at 2 different trophic levels:

- secondary consumer (feeding on impala)
- quaternary or fourth level consumer (feeding on baboons).
Food webs are easily **unbalanced**, especially if one population of organisms in the web dies or disappears. This may happen for a number of reasons, including:

- over-predation or hunting
- disease
- pollution
- use of pesticides
- lack of food (or other resources)
- emigration.

For example, in the food web here, if all the baboons were killed by hunters the leopard would have only impala to eat. So the impala population would decrease. The scorpion population may increase because of less predation by baboons, but if there are more scorpions they will eat more locusts, reducing the locust population, and so on.
Try this
Figure below shows a food web:

![Food Web Diagram]

1. Select appropriate organisms form the food web to complete each column in the table below. [4 marks]

<table>
<thead>
<tr>
<th></th>
<th>Consumer</th>
<th>Producer</th>
<th>Carnivore</th>
<th>Herbivore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organism 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organism 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Ladybirds eat aphids. A very large number of ladybirds arrive in the habitat where these organisms live. Predict some of the possible effects this could have on the organisms in the above food web. [6 marks]

**Answer**

a) 2 organisms from

<table>
<thead>
<tr>
<th></th>
<th>Consumer</th>
<th>Producer</th>
<th>Carnivore</th>
<th>Herbivore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank voles</td>
<td><strong>Goldfinches</strong></td>
<td><strong>Grass</strong></td>
<td><strong>Wrens</strong></td>
<td><strong>Bank voles</strong></td>
</tr>
<tr>
<td>Goldfinches</td>
<td><strong>Aphids</strong></td>
<td><strong>Hogweed</strong></td>
<td><strong>Kestrels</strong></td>
<td><strong>Goldfinches</strong></td>
</tr>
<tr>
<td>Aphids</td>
<td><strong>Caterpillar</strong></td>
<td><strong>Ivy</strong></td>
<td><strong>Aphids</strong></td>
<td></td>
</tr>
<tr>
<td>Caterpillar</td>
<td><strong>Wrens</strong></td>
<td><strong>Oak tree</strong></td>
<td><strong>Caterpillars</strong></td>
<td></td>
</tr>
<tr>
<td>Wrens</td>
<td><strong>Kestrels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kestrels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) 6 suggestion such as:

- decrease in aphids because ladybirds eat aphids
- increase in ivy because there will be fewer aphids feeding
- decrease in wrens because there are fewer aphids to eat
- decrease in caterpillars because the wrens now have only caterpillars for food
- increase in oak trees because there will be fewer aphids feeding
- increase in hogweed because there will be fewer aphids feeding
- increase in goldfinches because there is more hogweed to eat.

There are other possible suggestions.
A food pyramid shows the relative sizes of different components at the various trophic levels of a food chain. There are three types of ecological pyramid we use: numbers, biomass and energy.

In a food pyramid, each trophic level in a food chain is represented by a horizontal bar, with the width of the bar representing the number of organisms, the amount of biomass or the amount of energy available at that level. The base of the pyramid represents the producer; the second level is the primary consumer; and so on.

1. Pyramids of numbers

A pyramid of numbers shows the relative number of organisms at each stage of a food chain.

Example 1: clover → snail → thrush → hawk

Clover is a plant and it is the producer in this food chain. Its bar goes at the bottom of the pyramid.

Energy is lost to the surroundings as we go from one level to the next, so there are fewer organisms at each level in this food chain. A lot of clover is needed to support the snail population. A thrush eats lots of snails, and a hawk eats lots of thrushes, so the population of hawks is very small.
Other pyramid shapes

Sometimes the pyramid of numbers doesn't look like a pyramid at all. This could happen if the producer is a large plant such as a tree, or if one of the animals is very small. Remember, though, that whatever the situation, the producer still goes at the bottom of the pyramid.

Here are two examples like this:

**Example 2: Oak tree → Insects → Woodpecker**

An oak tree is very large so many insects can feed on it.

**Example 3: Grass → Rabbit → Flea**

Fleas are very small and lots of them can feed on a rabbit.
2. Pyramids of biomass

Sometimes a pyramid of numbers is not the best way to represent a food chain. In this case a pyramid of biomass (the dry mass of an organism) is a better diagram to use. It shows the total mass of organisms at each stage of a food chain.

In general, all producers have a higher biomass than the primary consumer, so a pyramid will always be produced.

The total energy (and biomass) present at a lower tier of the pyramid, must be greater than the higher tiers in order to support the energy requirements of the subsequent organisms.
3. Pyramids of energy

Pyramid of energy shows *amount of energy* trapped per unit *time* and *area* at each *stage* of a *food chain*.

A normal-shaped pyramid is always produced because there is a reduced amount of energy at each successive level.

*Most of information in this post is taken from BBCBitesize*
#142 Food chain and energy efficiency

In term of conversations of energy, there is an increased efficiency in supplying green plants as human food and a relative inefficiency in feeding crop plants to animals.

Short food chains are more efficient than long ones in providing energy to the top consumer. Below are two food chains and energy values for each level in them. Both food chains have a human being as the top consumer.

- maize → cow → human
  unit of energy 100 10 1

- maize → human
  unit of energy 100 10

Ten times more energy is available to the human in the second food chain than in the first. In the second food chain, the human is a herbivore (vegetarian). But eating parts of a cow provide humans with other nutrients, as well as those we gain energy from – it would be very difficult to persuade everyone to become vegetarian for the sake of energy efficiency.
Some farmers try to maximize meat production by reducing movement of their animals (keeping them in pens or cages with a food supply) and keeping them warm in winter. This means less stored energy is wasted by the animals.

**Why food chains usually have fewer than 5 trophic levels?**

As the energy is passed along the chain, each organism uses some of it. So the further along the chain you go, the less energy there is. The loose of energy along the food chain limits the length of it. There rarely more than 5 links in a chain, because there is not enough energy left to supply the next link. Many food chains only have 3 links.
Most of the chemicals that make up living tissue contain carbon. When organisms die the carbon is recycled so that it can be used by future generations.

Four main processes are involved: photosynthesis, respiration, decomposition, combustion.

A. Carbon cycle
1. Carbon enters the atmosphere as $\text{CO}_2$ from **respiration** and **combustion**.

2. $\text{CO}_2$ is absorbed by producers to make **carbohydrates** in **photosynthesis**.
3. **Animals** feed on the plant passing the carbon compounds along the food chain. Most of the carbon they consume is exhaled as CO$_2$ formed during respiration. The animals and plants eventually **die**.

4. The dead organisms are eaten by **decomposers** and the carbon in their bodies is returned to the atmosphere as CO$_2$. In some conditions **decomposition** is blocked. The plant and animal material may then be available as **fossil fuel** in the future for combustion.

**Common misconception**

*Plants do not start respiring when they stop photosynthesizing (at night) – they respire all the time, but during the day there is usually a net intake of CO$_2$ and output of O$_2$.***
B. Water cycle

- Energy from the Sun heats the surface of the Earth.
- Plants release water vapour into the air through transpiration.
- Water evaporates from oceans, rivers, lakes and soil.
- The warm, moist air rises because it is less dense.
- Water vapour condenses into water droplets as it cools down, forming clouds.
- Water droplets get bigger and heavier they begin to fall as rain, snow and sleet (precipitation), draining into streams, rivers, lakes and sea.
- Plant root take up water by osmosis.
- In addition, animals lose water to the environment through exhaling and sweating, and in urine and faeces.
Try this

Figure below shows a diagram of the carbon cycle.

a) Copy and complete the cycle by filling in boxes A and B. [2 marks]

b) On your diagram, label with the letter indicated an arrow that represents the process of:

   i) combustion – C [1 mark]
   ii) decomposition – D [1 mark]
   iii) photosynthesis – P [1 mark]
   iv) respiration – R [1 mark]

Answer

a) A, carbon compounds in plants.
   B, carbon compounds in dead plants and animals.

b) i) C on arrow between fossil fuels and CO₂ in the air.
    ii) D on arrow between box B and CO₂ in the air.
    iii) P on arrow between CO₂ in the air and box A.
    iv) R on arrow between carbon compounds in animals (or box A) and CO₂ in the air.
Nitrogen is essential for the formation of amino acids to make proteins. The nitrogen cycle describes the ways in which nitrogen is recycled.

The element nitrogen is a very unreactive gas. Plants are not able to change it into nitrogen compounds, but it is needed to form proteins. Nitrogen compounds become available for plants in the soil in a number of ways, including:

- **nitrogen-fixing bacteria** (some plants – legumes such as peas, beans and clover – have roots with nodules that contain these bacteria, so the plant receives a direct source of nitrates)
- breakdown of dead plants and animals by decomposers (bacteria, fungi and invertebrates)
- the addition of artificial fertilizers, compost (decaying plant material) and manure (decaying animal waste – urine and faeces)
- lightning – its energy causes nitrogen to react with oxygen.
Plants absorb nitrates into their roots by active uptake. The nitrates are combined with glucose (from photosynthesis) to form protein. Proteins are passed through the food chain as animals eat the plants. When animals digest proteins the amino acids released can be reorganized to form different proteins.

Some soil bacteria - denitrifying bacteria- break down nitrogen compounds and release nitrogen back into the atmosphere. This is a destructive process, commonly occurring in waterlogged soil. Farmers try to keep soil well drained to prevent this happening – a shortage of nitrates in the soil stunts the growth of crop plants.

Nitrates and other ammonium compounds are very soluble, so they are easy leaches out of the soil and can cause pollution.

Farmer can increase the fertility (nitrogen compound concentration) of their soil by:

- adding artificial fertilisers
- adding manure or compost
- growing leguminous plants, then digging the roots (with their nodules) into the soil.

Try this

The figure below shows the nitrogen cycle.
1. i) Name the main nitrogen-containing compound found both in plants and in animals. [1 mark]

   ii) Name one nitrogen-containing compound that is present in urine. [1 mark]

   iii) Name the type of organism that causes the changes at A. [1 mark]

   iv) What atmospheric conditions bring about the change at B? [1 mark]

2. Using the figure, explain why it is an advantage to have good drainage in most agricultural land. [4 marks]

**Answer**

1. i) Proteins (or amino acids)

   ii) Urea or ammonia or uric acid.

   iii) Bacteria

   iv) Lightning or electrical storms.

2. Four points from:

   - aerated soils allow the activity of useful bacteria
   - to convert ammonium compounds into nitrites
   - and to convert nitrites into nitrates
   - nitrates can be absorbed by plants
   - to allow growth or formation of protein
   - waterlogged soils encourage denitrifying bacteria
   - which break down nitrates into nitrogen
   - so there would be a shortage of nitrates for plants to absorb
   - leading to poor growth.
#145 Effects of combustion of fossil fuels on CO2 level

**Photosynthesis** takes CO\(_2\) out of the atmosphere and replaces it with O\(_2\). **Respiration** and **combustion** both do the opposite: they use up O\(_2\) and replace it with CO\(_2\).

The equations are essentially the same, but reversed:

\[
\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{glucose} + \text{O}_2 \\
\text{photosynthesis} \quad \text{respiration, combustion}
\]

In order for the amount of CO\(_2\) in the atmosphere to remain stable, the rates of these processes need to be balanced.

Processes that change the equilibrium (balance) include:

- cutting down forests (deforestation) – less photosynthesis
- combustion of fossil fuel (coal, oil and gas)
- increasing numbers of animals (including humans) – they all respire.
An increase in CO₂ levels in the atmosphere is thought to contribute to global warming.

CO₂ forms a layer in the atmosphere, which traps heat radiation from the Sun. This causes a gradual increase in the atmospheric temperature which can:

- melt polar ice caps, causing flooding of low-lying land
- change weather conditions in some countries, increasing flooding or reducing rainfall and changing arable (farm) land to desert
- cause the extinction of some species that cannot survive at higher temperatures.
A population is a group of organisms of one species, living in the same area at the same time. Factors affecting the rate of population growth include food supply, predation and disease.

1. The rate of growth of a population depends on:

- **Food supply** – abundant food will enable organisms to breed more successfully to produce more offspring; shortage of food can result in death or force emigration, reducing the population.

- **Predation** - if there is heavy predation of a population, the breeding rate may not be sufficient to produce enough organisms to replace those eaten, so the population will drop in numbers. There tends to be a time lag in population size change for predators and their pray: as predator numbers increase, prey number drops; and as predator numbers drop, prey numbers rise again (unless there are other limiting factors).

- **Disease** – this is a particular problem in large populations, because disease can spread easily from one individual to another. Epidemics can reduce population sizes very rapidly.

- Use of **contraceptives** (for humans).
2. Population growth in an environment with limited resources

When a limiting factor influences population growth, a sigmoid (S-shaped) curve is created. You need to be able to place the terms lag, log, stationary and death phase on a graph of population growth.

**Lag phase** – the new population takes time to settle and mature before breeding begins. When this happens, a doubling of small numbers does not have a big impact on the total populations size, so the line of the graph rises only slowly with time.

**Log (exponential) phase** – there are no limiting factors. Rapid breeding in an increasing population causes a significant increase in numbers. A steady doubling in numbers per unit of time produces a straight line.

**Stationary phase** – limiting factors, such as shortage of food, cause the rate of reproduction to slow down and there are more deaths in the population. When the birth rate and death rate are equal, the line of the graph becomes horizontal.

**Death phase** – as food runs out, more organisms die than are born, so the number in the population drops.
3. Population growth in the absence of limiting factors

If there is no limiting factors, there will be **no stationary or death phase** – the log phase will continue upwards, instead of the line leveling off. This has happened with human population growth. Human population size has increased exponentially because of improvements on food supply and the development of medicine to control diseases. Infant mortality has decreased, while lifer expectancy has increased.

Such a **rapid increase in population size** has **social implications**:

- increase demand for basic resources (food, water, space, medical care, fossil fuels).
- increase pressures on the environment (more land needed for housing, growing crops, road buildings, more wood for fuel and housing) and more pollution.
- larger population of young people --> greater demands on education.
- more old people --> greater demands on healthcare.

Abundant food supplies can leads to more people becoming obese --> greater demands on healthcare (heart disease, diabetes, blindness...). In the long term --> reduce average life expectant, as poor health becomes a limiting factor.
# 147 Summary of Ecosystem

- **Energy** enters ecosystems in sunlight. **Producers** (photosynthetic plants) capture some of this energy and transfer it to organic substances such as carbohydrates. **Consumers** (animals and fungi) gets their energy by eating producers or other consumers.

- **Food chains** and **food webs** show how energy flows through an ecosystem. The level at which an organism feeds in a food chain is its trophic level.

- Energy is lost as it passed along food chains.

- The **energy losses** in food chains limit the length of the chain, so few food chains have more than five trophic levels.

- It would be more energy-efficient for humans to harvest and eat plant crops, rather than feeding the crops to animals and then eating those.

- **Pyramids of numbers** and pyramids of **biomass** are ways of showing the relative numbers or biomass at different trophic level in a food chain.

- The **carbon cycle** shows how CO₂ from the air is used in **photosynthesis** to make organic compounds in plants, which are then eaten by animals. **Decomposers** obtain their carbon by feeding on dead plants or animals, or on their waist materials. **Respiration** by all organisms returns CO₂ to the air.

- **Nitrogen** gas is very inert, and must be fixed (to produce ammonium ions or nitrate ions) before it can be used by living organisms. Some plants have **nitrogen-fixing bacteria** in their roots, and other nitrogen-fixing bacteria live freely in the soil. Plants absorb ammonium or nitrate ions and use them to make proteins, which can then be eaten by animals. Decomposers and **nitrifying bacteria** convert proteins to ammonia and nitrates, which can be re-used by plants. Denitrifying bacteria convert nitrates to nitrogen gas which is returned to the air.

- The **size of a population** of organisms is affected by environmental factors such as food **supply**, **predation** and **disease**.

- When a resource is in **limited** supply, the growth of a population often shows a **lag** phase, **exponential** phase, **stationary** phase and **death** phase.

- Age pyramids show the structure of a population at one moment in time, and can be used to predict how the population is likely to change in the future. The global **human population** is increasing, but there is hope that by the end of this century the growth will have slowed significantly.
15 Human and Ecosystem

#148 The human influences on the ecosystem

- Increasing use of **pesticides**, **fertilizers** and **herbicides** à ‡ levels of nutrients in the soil, kill insect pests, kill weeds à ‡ crop yields.

- Use of modern **machinery** (tractors, combined harvesters) à manage land and crop more efficiently.

- **Artificial selection** to produce varieties of plants suited to particular climates and soil types, and breeds of animal for specific purposes (optimum meat, milk, wool production).

- Use of **yeast** and **bacteria** in the large-scale production of breads, beer and wine, yoghurt and cheese. Single-cell protein and fungi are used to produce meat substitutes.

- Use of **medicines** such as antibiotics, hormones and artificial insemination techniques in intensive **animal rearing**.

- Use of **plant hormones** in plant growing and fruit production.

- Use of **genetic engineering** and **cloning** techniques to produce organisms to produce hormones...

- Development of systems to water plants in **greenhouses** automatically and to grow plants in nutrient solutions (hydroponics).

- Use of **satellites** to monitor crop development, observe crop diseases and assess the need for additional fertilizer.

- Development of intensive farming and automated feeding mechanisms.
Deforestation is the removal of large areas of forest to provide land for farming and roads, and to provide timber (wood) for building, furniture and fuel. Deforestation has a number of undesirable effects on the environment.

**Deforestation:**

- Reduction of habitats or food sources for animals, which can result in their extinction. Animal and plant diversity is reduced, and food chains are disrupted.

- **Loss of plant species** and their genes which may be important for medical use or genetic engineering in the future.

- Removal of trees means there are no roots to hold soil, which can result in soil erosion and leaching of minerals. Desertification can eventually occur.

- Lack of roots and soil à flooding and mudslides. Lakes can become silted up.

- Leaching of nutrients into lakes and rivers à eutrophication.

- Less CO₂ is absorbed from the atmosphere, more CO₂ build up à increase the greenhouse effect.

- Less O₂ is produced à atmospheric O₂ level can drop.

- Less transpiration à reduced rainfall.
Try this

Figure below show the area of tropical rainforest deforested annually in five different countries, labeled A to E.

1. i) Which of the countries shown has the largest area deforested annually? [1 mark]

   ii) Which of the countries shown has 600 000 hectares of rainforest removed each year? [1 mark]

   iii) In another country, F, 550 000 hectares are deforested annually. Plot this on a copy of the figure. [1 mark]

2. i) Country E has a total of 9 000 000 hectares of tropical rainforest remaining. How long will it be before it is all destroyed, if the present rate of deforestation continues? [1 mark]

   ii) Stat 2 reasons why tropical rainforests are being destroyed by humans. [2 marks]

   iii) After deforestation has taken place, soil erosion often occurs rapidly. Suggest 2 ways in which this may occur. [2 marks]
3. Tropical rainforests reduce the amount of CO$_2$ and increase the amount of O$_2$ in the atmosphere. Explain why both these occurrences are important to living organisms. [2 marks]

**Answer**

1. i) B
   
   ii) A
   
   iii) Column for F drawn to 550. Column shaded in the same way as the others, and labeled. Column drawn an equal width and distance from the others.

2. i) 30 years
   
   ii) 2 reasons from:
   
   - to clear land for agriculture, housing, industry or roads.
   - to collect timber for housing
   - to collect timber for fuel.

   iii) 2 suggestions from:
   
   - plants have gone so there are no roots to bind the soil.
   - wind blows soil away
   - rain washes soil away.

3. Increased CO$_2$ can lead to global warming, or flooding, or desertification.
O$_2$: organisms need O$_2$ for respiration to release energy.
It is very tempting for farmers to increase the amount of fertilisers applied to crops to try and increase crop yields. However, this can lead to the eutrophication of rivers and lakes and the sequence occurs.

1. Overuse of fertilisers

- fertilisers (very soluble) are easily leached out of the soil
- fertilisers are washed into a water system (river or lake)
- algae absorb fertiliser and grow rapidly (algal bloom)
- algae form a blanket on the surface of the water, blocking light from algae below
- algae die without light
- bacteria decompose dead algae, using up $O_2$ in the water for respiration
- animals in water die through lack of $O_2$. 

*Fishermen row a boat in a algae-filled lake in China. Credit: Totallycoolpix.com*
A second effect of overuse of fertilisers can be the death of the plants. High concentrations of the fertilizer around plant roots can cause the roots to lose water by osmosis. The plant then wilts and dies.

**2. Sewage**

Sewage can result in eutrophication in a similar way to overuse of fertilisers. This is because sewage contains high levels of nutrients such as phosphates, organic matter and bacteria. The phosphates act as fertilisers for algae, while the bacteria feed on the organic matter and reproduce rapidly, using up O$_2$ in respiration.

If sewage is untreated before disposal it can lead to disease organisms such as cholera and typhoid being transmitted in the water.

**3. Chemical waste**

Chemical waste such as heavy metal (mercury, nickel...) and oil can cause serious pollution. Some chemicals may be dumped (or enter water systems through leaching) in low concentrations, at which levels they are not toxics. However, bioaccumulation occurs if they enter a food chain. Plankton absorb the chemical and has no mechanism for excreting it. Animals such as small fish, feeding on large number of plankton, build up the chemical because, again, they have no means of excreting it.

Animals, including humans, at the top of the food chain, eat many fish and accumulate high concentration of the chemical, which is now toxic. Poisons such as mercury damage the central nervous system and can lead to death.

Seabirds are severely affected by oil spills.
When oil is dumped into water it can form a surface layer, coating animals such as birds that feed in the water. When the birds try to clean their feathers they swallow the oil, which poisons them. Oil also disrupts food chains.

**Try this**

Figure below shows part of a river into which sewage is pumped. The river water flows form W to Z, with the sewage being added at X.

![Diagram of river with sewage pump](image)

Some of the effects of adding sewage to the river are shown in picture below.

![Graph showing changes in water quality](image)

**Try this**

1. Describe the changes in the levels from W to Z of:
i) nitrates
ii) suspended solid

2. Suggest why the level of O2:

i) drops at X
ii) increase again toward Z

3. Suggest 2 reasons why levels of algae drop:

i) when sewage is added to the river
ii) towards Z

4. A farm at Z used herbicides on the field next to the river. Suggest why this could cause further problems in the river.

Answer

1. i) Constant level between W and X, or starts off quite low, or at point X it start to drop then increases toward Y before dropping again toward Z.

   ii) Level starts off quite low, then at point X it increases sharply; level returns nearly to original level between Y and Z.

2. i) One suggestion from:
   - aerobic respiration by sewage fungus
   - lack of algae to produce O₂

   ii) One suggestion from:
   - lack of sewage fungus
   - photosynthesis by algae.

3. i) Two suggestions from:
   - presence of suspended solids blocks light for algae
   - lack of nitrate in the water
   - possible presence of toxins in sewage
   - possible increase in temperature or unsuitable temperature.

   ii) Two suggestions from:
   - shortage of nitrates
   - grazing by aquatic herbivores
   - possible drop in temperature, or unsuitable temperature.

4. One suggestion from:
   - herbicides could leach into river and kill algae
   - herbicides will kill algae and disrupt food chain
   - herbicides may be toxic to other organisms in the river.
SO\textsubscript{2} released into the air when coal and oil are burned. Power stations burn large amounts of these fossil fuels. SO\textsubscript{2} dissolves in the water vapour in clouds, forming sulphuric acid (H\textsubscript{2}SO\textsubscript{4}). When it rains, the rain is acidic.

The combustion of petrol in car engines also contributes to acid rain, but this is mainly due to the production of oxides of nitrogen in the exhaust fumes, rather than SO\textsubscript{2}. 

Acid rain
The main causes of acid rain are processes that release \( \text{SO}_2 \) and oxides of nitrogen into the atmosphere. These include:

- burning of **fossil fuels**, such as coal and gas, by power stations
- combustion of petrol in **car engines**.

Problems caused by acid rain include:

- **Damage** to **plant leaves**, eventually killing the plants. Whole forests of pine trees have been destroyed by acid rain.

  ![Plant leaves damaged by acid rain.](image)

- **Acidification of lakes**: as the water becomes more acidic, some animals such as fish cannot survive and fish stocks are destroyed.
- Increased risk of **asthma attacks** and bronchitis in humans.
- **Corrosion** of stonework on buildings.
- Release into soil of soluble **aluminium ions** that are toxic to fish when washed into lakes.

Ways of **reducing the incidence** of acid rain:

- changing the types of power stations that generate electricity from coal and oil to **gas** or **nuclear power**, or using more renewable energy sources such as wind
- using ‘**scrubbers’** in power station chimneys – these remove most of the \( \text{SO}_2 \) present in the waste gases
- using catalytic **converters** in car exhausts – these convert oxides of nitrogen to harmless nitrogen.
Common misconceptions

Remember that car engines do not make large amount of SO₂ – but they are responsible for producing large amount of oxides of nitrogen, CO₂ and CO.

Examiner’s tip

When describing the effects of car exhaust fumes on the environment, don’t make a list of the chemicals and then link them all to acid rain or global warming. Be specific:

- oxides of nitrogen leas to acid rain;
- CO can reduce the ability of haemoglobin to carry O₂;
- CO₂ increases can lead to global warming.

Try this

1. SO₂ is a major pollutant of the air. Which process is mainly responsible for the release of SO₂ into the air? [1 mark]

2. SO₂ is one of the gases which contributes to acid rain. Acid rain can affect trees and their surrounding soil in a variety of ways. Figure below shows where these effects can occur.

Suggest how each of the following affects the tree and explain how it can lead to its death.
i) Damage of the leaves [2 marks]
ii) Damage of the fine roots [2 marks]
iii) Death of the soil microorganisms [2 marks]

Answer


2. i) The leaves are unable to photosynthesise, so it cannot make food.

   ii) One suggestion and explanation from:

   - the roots are unable to absorb water, so cells will become flaccid, or the tree will wilt, or transport of materials will not happen

   - the roots are unable to absorb mineral salts which are needed, e.g. for formation of chlorophyll, or for growth.

   iii) One suggestion and explanation from:

   - less decomposition will occur, so there will be less minerals available to the plant, e.g. magnesium ions for formation of chlorophyll.

   - there will be no nitrogen-fixing bacteria, so there will be less nitrates for the roots to take up, which are needed for protein formation.
Some gases in the Earth’s atmosphere stop heat radiating into space from the Earth. This is called the **greenhouse effect** and the gases involved are called greenhouse gases. They include: **methane**, **CO₂** and **water vapour**. An increased greenhouse effect can lead to global warming and climate change.

The diagram shows how the greenhouse effect works.

1. Electromagnetic radiation at most wavelengths from the Sun passes through the Earth’s atmosphere.

2. The Earth absorbs electromagnetic radiation with short wavelengths and so warms up. Heat is radiated from the Earth as longer wavelength infrared radiation.

3. Some of this infrared radiation is absorbed by greenhouse gases in the atmosphere.

4. The atmosphere warms up.

Source: **BBC Bytesize**
Some pesticides are non-biodegradable and stay in the environment for a long time. For example, DDT has been a very effective insecticide, used to kill mosquitoes to reduce the spread of malaria. However, because it does not break down, it enters water systems such as lakes, where it is absorbed into plankton.

DDT spraying.

They are unable to excrete DDT. In a similar way to heavy metal, it is passed up the food chain and bioaccumulation occurs: the top carnivores suffer from its toxicity. For example, when fish eagles are exposed to DDT passed through the food chain, they produce eggs with very thin shells. When the adult birds sit on the nest, the eggs break, so they are unable to produce offspring.

Some insecticides are non-specific: when applied to kill an insect pest, they also kill all the other insects that are exposed to it. This may include useful insects, such as bees that are needed to pollinate crops. Food webs can be affected, threatening the extinction of top carnivores such as birds of prey.

Herbicides are used to kill weeds in a crop, to reduce competition to increase crop yield. However, herbicides may also kill rare plants species near the field being sprayed.

Nuclear fallout can be the result of a leak from a nuclear power station, or from a nuclear explosion. Radioactive particles are carried by the wind or water and gradually settle in the environment. If the radiation has a long half-life, it remains in the environment and is absorbed by living organisms. The radio active material bioaccumulates in food chains and can cause cancer in top carnivores.
Effects of non-biodegradable plastics in the environment

Plastics that are non-biodegradable are not broken down by decomposers when dumped in landfill sites or left as litter. This means they remain in the environment, taking up valuable space or causing visual pollution. Discarded plastic bottles can trap small animals; nylon fishing line and nets can trap birds and mammals such as seals and dolphins. When plastic is burned it can release toxic gases.
Koala is an endangered animal

Conservation is the process of looking after the natural environment. Conservation attempts to maintain or increase the range of different species living in an area, known as biodiversity.

The need for conservation of species

- Many species of animals and plants are in danger of extinction, due to factors such as habitat destruction, the introduction of other species, international trade and pollution.

- Loss of a species also means that its genes are lost: these may be important in the future for genetic engineering (e.g. to improve crops) and the production of useful chemicals such as medicines.

- The presence of rare species can be an important source of money for poor communities, through tourism.

- The species may play an important role in a food chain: its loss could endanger other species.

The need for conservation of habitats

- If habitat is lost, so are the species that live in them, so habitat destruction poses the greatest threat to the survival of species.
- A habitat maybe conserved by:
  - using laws to protect the habitat
  - using wardens to protect the habitat
  - reducing or controlling public access to the habitat
  - controlling factors, such as water drainage and grazing, that may otherwise contribute to destruction of the habitat

**The need for conservation of natural resources**

Some natural resources (the material we take from Earth) are not replaceable (renewable). For example, *fossil fuels* such as coal took millions of years to form. Increasing demands for energy are depleting these resources.

Ways of conserving natural resources:

- Increase the use of renewable energy (wind farms, solar power, hydroelectric power...).
- Improve the efficiency of energy use (better insulation, smaller car engines, more public transports...).
- Grow tree specifically for fuel, then replant as they are cut down --> the greenhouse effect is not increased, and habitats can be maintained when trees felling is carefully managed.

**The principle of recycling sewage (water) and paper**

*Sewage* is mainly water, contaminated with organic material, solids, bacteria and minerals such as phosphates. In places where water is in short supply, the sewage is treated to provide water that is clean enough to drink. Any treated effluent that is returned to water system such as a river will not cause problems such as eutrophication.

Treatment of sewage:

1. Large object such as sticks *screened* out of raw sewage.
2. Suspended grit allowed to settle out by gravity in *grit settling tank*.
3. Organic matter allowed to settle out by gravity in *sludge-settling tank* – after digestion in a *sludge digester*, sludge can be used as fertiliser on farmland – methane gas can also be generated for use as a fuel.
4. Remaining liquid sprinkled on to the top of an aeration tank containing stone – microorganisms (protoctists and aerobic bacteria) on surface of stones digest any remaining organic mater.

5. Water passing out may be chlorinated to kill any bacteria, so it is safe to drink.


**Paper** is made from wood (trees). If the paper is recycled after use, fewer trees need to be cut down. The used paper is turned into a pulp and any dyes such as printing ink are removed. The pulp is then rolled into sheets and dried to produce recycled paper that can be used for newspapers, toilet paper, hand towels...
• **CO₂** and **methane** are **greenhouse gases**, trapping outgoing long wavelength radiation in the atmosphere and warming the Earth. Increased concentrations of these gases are causing **global warming**.

• **SO₂** is produced when **coal** and other **fossil fuels** burn.

• **SO₂** and **nitrogen oxides** dissolves and react in water droplets in the atmosphere, and fall to the ground as **acid rain**. This leaches aluminum ions from soils, and kills plants and aquatic organisms.

• Fall-out from accidents at **nuclear reactions** emits ionising radiation, which damages DNA and can cause mutations, cancer and radiation burns.

• **Deforestation** reduces the amount of **CO₂** that is taken out of the atmosphere for photosynthesis, and so may increase global warming. **Combustion** of the felled trees releases **CO₂** into the atmosphere. Deforestation also destroys habitats for animals, possibly leading to their extinction. It increases soil erosion and flooding.

• **Water pollution** by fertilisers or raw sewage can cause eutrophication, in which large populations of aerobic bacteria form, reducing the amount of dissolved **O₂** in the water and making it impossible for most animals to live there. Other chemical wastes, such as heavy metals, can also cause water pollution.