Gas and Solute Exchange

- The cells in animals and plants need oxygen to release energy for the jobs they do.
- They all produce carbon dioxide as a waste product.

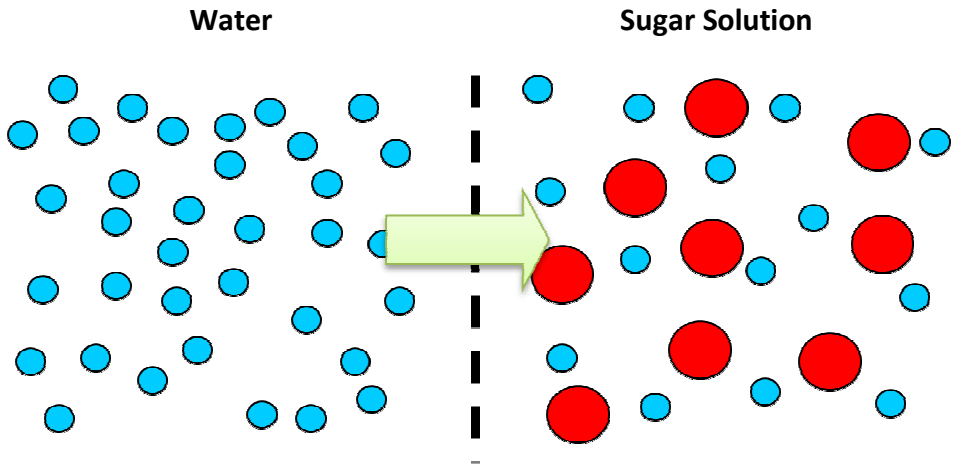
- **Dissolved substances move by diffusion.**
- DIFFUSION is from an area of high concentration to low concentration.
- No energy is required.

REMINDER OF RESPIRATION EQUATION:

glucose + oxygen → carbon dioxide + water + energy

- Substances are sometimes absorbed <u>against a concentration gradient</u>.
- This requires the use of energy from respiration.
- The process is called ACTIVE TRANSPORT.
- It enables cells to absorb ions from very dilute solutions.
- Other substances, such as sugar and ions, can also pass through cell membranes.

- OSMOSIS is a "special kind of diffusion".
- Water diffuses from a concentrated area to a less concentrated area through a semi-permeable membrane...



- **Many organ systems are specialised for exchanging materials.**
- In humans, surface area of the:
  - Lungs is increased by the alveoli
  - Small intestine is increased by villi

- The lungs are in the upper part of the body (thorax) protected by the ribcage.
- They are separated from the lower part of the body (abdomen) by the diaphragm.
- The breathing system takes air into and out of the body.
- This means that oxygen from the air can diffuse into the bloodstream.
- Carbon dioxide can diffuse out of the bloodstream into the air.

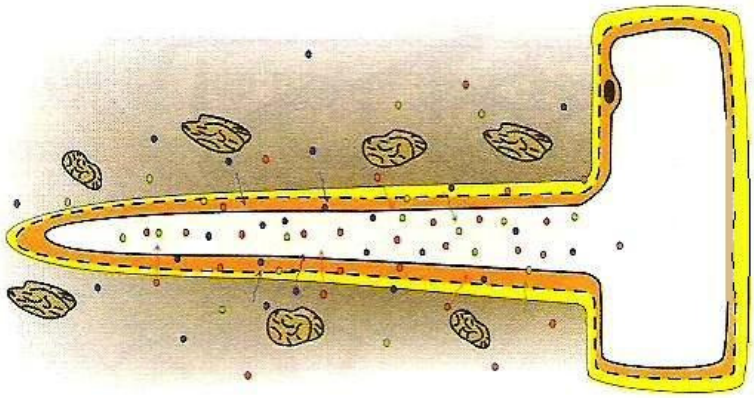
- Alveoli and villi have the following properties which makes them ideal for gas exchange:
  - Large surface area
  - Good blood supply
  - Moist
  - Thin (so small diffusion distance)

- In plants:
  - Carbon dioxide enters leaf cells by diffusion
  - Most water and mineral ions are absorbed by root hair cells

REMINDER OF PHOTOSYNTHESIS EQUATION (practically reverse of respiration):

$$\text{carbon dioxide + water} \xrightarrow[\text{sunlight}]{\text{chlorophyll}} \text{glucose + oxygen}$$

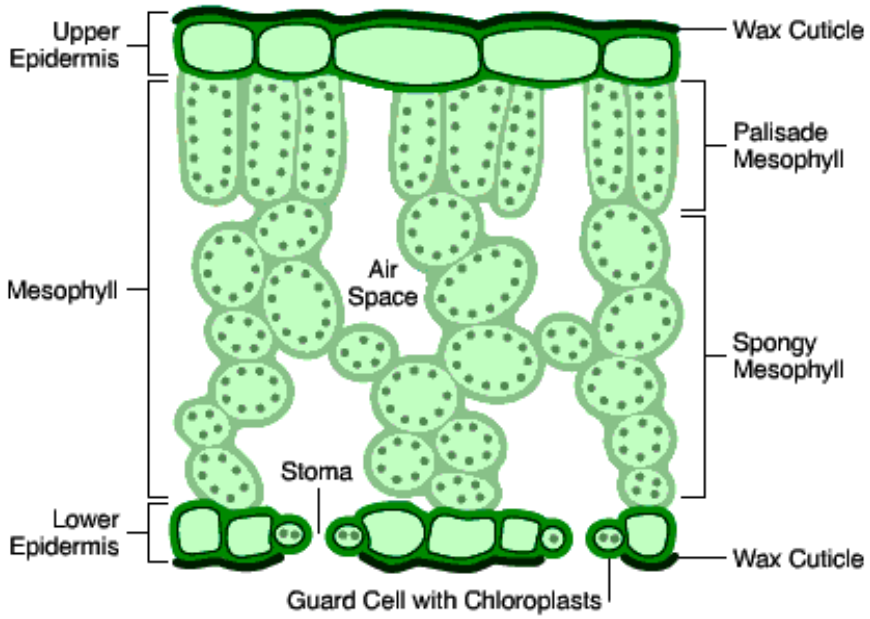
- The surface area of the roots is increased by root hairs...



- Surface area of leaves by the flattened shape and internal air spaces.
- Plants have stomata to obtain carbon dioxide from the atmosphere.

- Plants lose water vapour from the surface of their leaves.
- **This loss of water vapour is called TRANSPIRATION.**

- Transpiration is more rapid in hot, dry and windy conditions.
- *Plants that live in these conditions often have a thicker waxy layer...*



- Most of the transpiration is through stomata.
- The size of stomata is controlled by guard cells which surround them.
- If plants lose water faster than the roots replace it, the stomata can close to prevent wilting.

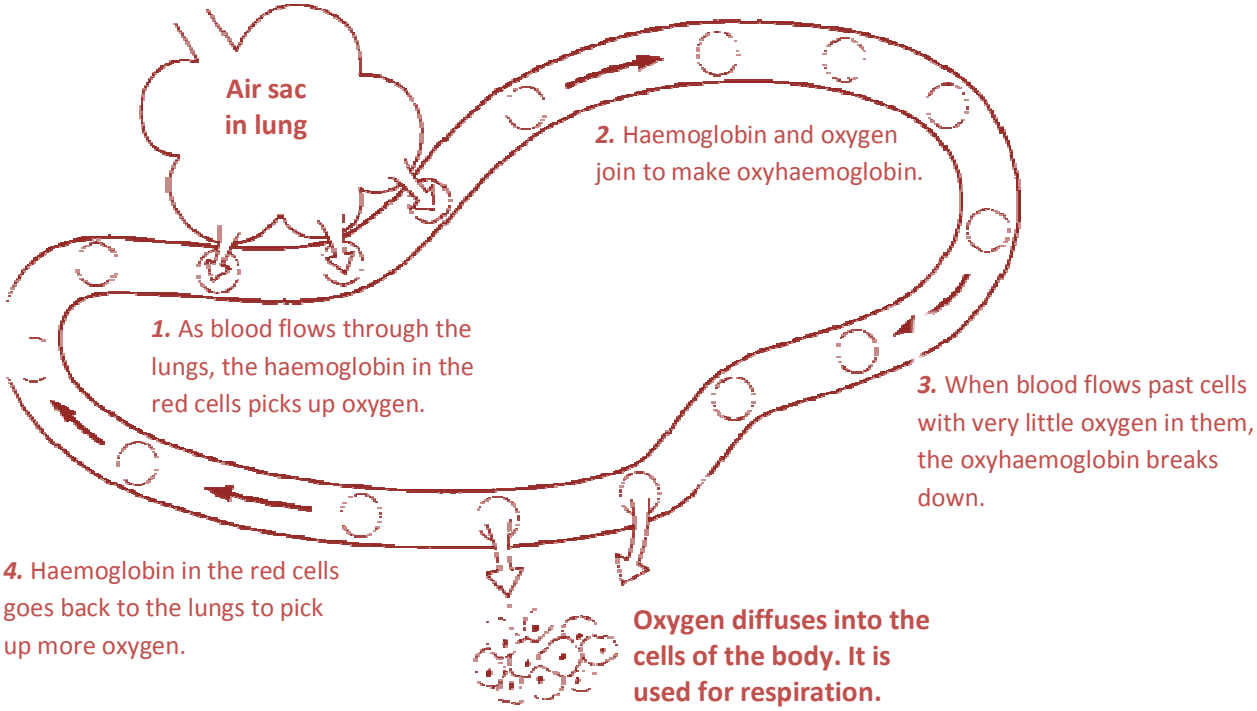
Transportation

- **Substances are transported around the body by the circulation system** (the heart, the blood vessels and the blood). Main organs: heart, lungs and kidneys.
- They are transported from where they are taken into the body to the cells, or from the cells to where they are removed from the body.
- The heart pumps blood around the body.
- **Blood flows from the heart to the organs through arteries and returns through veins.** *In the organs, blood flows through capillaries.*

- Substances needed by cells in the body tissues pass out of the blood, and substances produced by the cells pass into the blood through the walls of the capillaries.

- Blood plasma transports:
    - Carbon dioxide from the organs to the lungs

  - Soluble products of digestion from the small intestine to other organs
  - Urea from the liver to the kidneys.
- Red blood cells transport oxygen from the lungs to the organs.
- Red blood cells have no nucleus...



- Red blood cells are packed with a red pigment called haemoglobin.
- **In the lungs, *haemoglobin* combines with oxygen to form OXY*HAEMOGLOBIN*.**
- In other organs, oxyhaemoglobin splits up into haemoglobin and oxygen.

Exercise

- **The human body needs to react to the increased demand for energy during exercise.**
- The energy that is released during respiration is used to enable muscles to contract.
- During exercise a number of changes take place:
  - Heart rate increases
  - Rate and depth of breathing increases
  - Arteries supplying the muscles dilate
- These changes increase the blood flow to the muscles.
- This increases the supply of sugar and oxygen.

- It also increases the rate of removal of carbon dioxide.

- GLYCOGEN stores in the muscle are used during exercise.
- If muscles are subjected to long periods of vigorous activity they become fatigued.
- If insufficient oxygen is reaching the muscles, they use ANAEROBIC RESPIRATION.

- Anaerobic respiration is the incomplete breakdown of glucose.
- It produces lactic acid.
- Lactic acid is poisonous if it does not leave the body – it causes cramps.
- As the breakdown of glucose is incomplete, much less energy is released.
- Anaerobic respiration results in an OXYGEN DEBT.
- This has to be repaid in order to oxidise lactic acid to carbon dioxide and water.

The Kidney

- People whose kidneys do not function properly die because toxic substances accumulate in their blood.
- **Their lives can be saved by using dialysis machines or having a kidney transplant.**
- A healthy kidney produces urine by:
    - First filtering the blood
    - Reabsorbing all the sugar
    - Reabsorbing the dissolved ions needed by the body
    - Reabsorbing as much water as the body needs
    - Releasing urea, excess ions and water as urine

- Sugar and dissolved ions may be actively absorbed <u>against</u> a concentration gradient.

	Dialysis	**Kidney Transplant**
Advantages	If the patient owns a haemodialysis machine, it can be carried out at home. No scheduled hospital visits are required. Arguably, there is a longer living life.	Fewer, if any, diet and fluid restrictions. You feel better physically (more energy). One experiences a better quality of life than when using a dialysis machine.
Disadvantages	Dialysis takes a huge amount of time. Your life revolves around it. You also risk infection. Nausea, vomiting, headaches, muscle cramps and depression.	Apart from the obvious risks associated with any surgery, the risk of rejection by your body. You also have to take anti-rejection drugs your whole life.

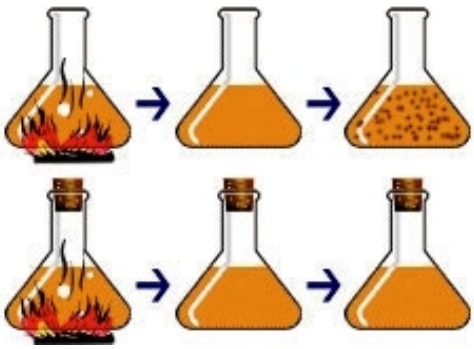
- **In a dialysis machine, a person's blood flows between semi-permeable membranes.**
- Dialysis fluid contains the same concentration of useful substances as the blood.
- This ensures that glucose and useful mineral ions are not lost.
- Urea passes out from the blood into dialysis fluid.
- Treatment by dialysis restores the concentrations of dissolved substances in the blood to normal levels and has to be carried out at regular intervals.

- **A kidney transplant enables a diseased kidney to be replaced with a healthy one from a donor.**
- However, the donor kidney may be rejected by the immune system unless precautions are taken.
- To prevent rejection of the transplanted kidney:
    - A donor kidney with a 'tissue-type' similar to that of the recipient is used.
    - The recipient is treated with drugs that suppress the immune system.

Microorganisms

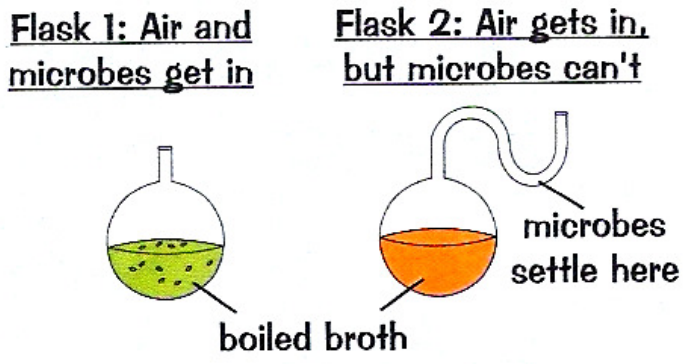
- **The Theory of Biogenesis has been developed over the years.**
- People used to think that life could spontaneously generate from non-living material.
- Evidence showed that this could not be the case.
- The evidence supported the theory that living things are created from other living organisms – this is the THEORY OF BIOGENESIS.

- Before 1765, it was believed that substances in food were changed into microbes.
- *This apparently caused the food to go off.*
- Scientist Lazzaro Spallanzani boiled two sets of broth to kill the microbes.
- He sealed one flask and left the other open – only the open one went off.
- This showed that microbes got into the food from the air.
- However, opponents just thought that it meant air from outside the flash was necessary to start the change...



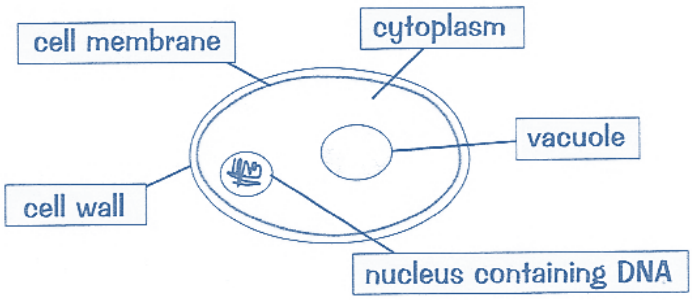
- **The theory that fresh air caused substances in food to change into microbes was <u>disproved</u> by Theodor Schwann in 1837.**
- He showed that meat would not go off in air.
- This was if the air was first heated to kill microorganisms.

- In 1859, Louis Pasteur carried out a far more conclusive experiment.
- He heated broth in two flasks, both of which were left open to the air.
- However, one of the flasks has a curved neck so that bacteria from the air would settle in the loop, and not get through to the broth.
- The broth in the flask with the curved neck stayed fresh.
- **This proved that it was the microbes and <u>not the air</u> causing it to go off.**



- People from many different cultures have known for thousands of years how to use microorganisms to make various types of food and drink:
    - Bacteria are used in yoghurt and cheese manufacture
    - Yeast is used in making bread and alcoholic drinks

- **Yeast is a single-celled organism (fungus).**
- *The cells have a nucleus, cytoplasm and a membrane surrounded by a cell wall...*



- Yeast can respire with or without oxygen (anaerobic respiration), producing carbon dioxide and ethanol (alcohol).

- This is called FERMENTATION.
- In the presence of oxygen, yeast carries out aerobic respiration.
- This produces carbon dioxide and water.
- Aerobic respiration provides more energy.
- It is also necessary for the yeast to grow and reproduce.

- **In brewing beer and winemaking, carbohydrates are used.**
- This is because they are needed as an energy source for yeast to respire.
- For making beer:
    - Starch in barley grains is broken down into a sugary solution by enzymes in the germinating grains, in a process called MALTING.
    - Sugary solution is extracted then fermented.
    - Hops are then added to give the beer flavour.
- In winemaking, the yeast uses the natural sugars in the grapes as its energy source.

- In the production of yoghurt:
    - A starter of bacteria is added to warm milk.
    - Bacteria ferment the milk sugar (lactose) producing lactic acid.
    - Lactic acid causes the milk to clot and solidify into yoghurt.

Industrial Microbe Production

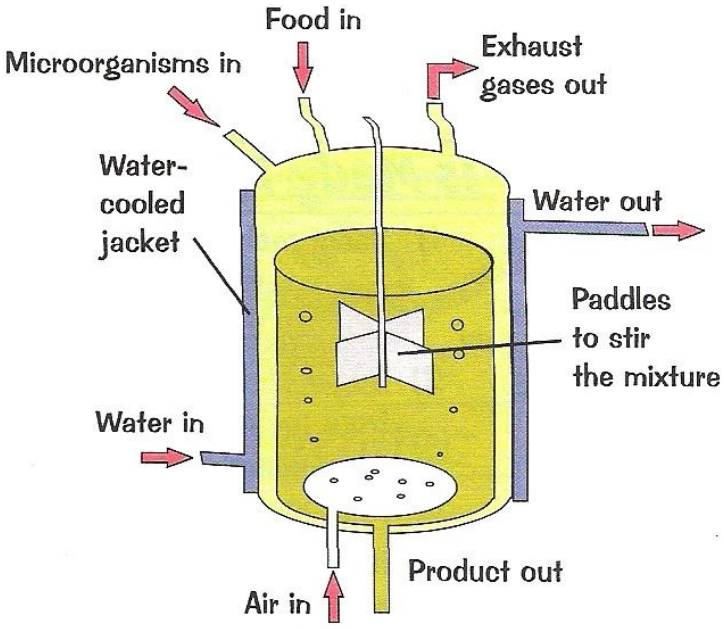
- **Microorganisms are used on a large scale to make many useful substances:**
    - Antibiotics*, such as penicillin*
    - Foods*, such as mycoprotein*
    - Fuels*, such as biogas and ethanol*

- The microorganisms are grown in large vessels called FERMENTERS.
- Industrial fermenters usually have:
    - AIR SUPPLY: to provide oxygen for respiration of the microorganisms.
    - STIRRER: to keep microorganisms in suspension and maintain an even temperature.
    - WATER-COOLED JACKET: to remove heat produced by respiring microorganisms.
    - INSTRUMENTS: to monitor factors such as pH and temperature.

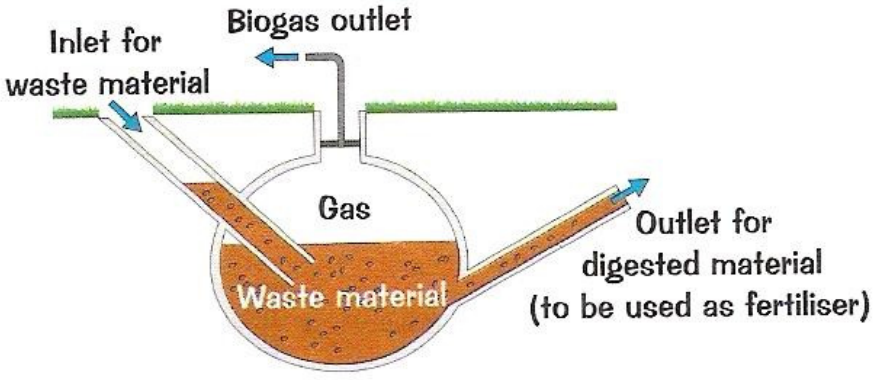
- The antibiotic, penicillin, is made by growing the mould Penicillium, in a fermenter.
- The medium contains sugar and other nutrients, *e.g. a source of nitrogen*.

- Penicillium only starts to make penicillin after using most of the nutrients for growth.
- The fungus Fusarium is used to make mycoprotein.
- Mycoprotein is a protein-rich food suitable for vegetarians.
- The fungus is grown on starch in aerobic conditions.
- Its biomass is harvested and purified.

- *An example of a fermenter...*



- **Fuels can be made from natural products by fermentation.**
- Biogas (mainly methane) can be produced by anaerobic fermentation of a wide range of plant products or waste material containing carbohydrates.
- On a large scale, waste from sugar factories or sewage works can be used, for example.
- *On a small scale, **biogas generators** can be used to supply the energy needs of individual families or farms...*

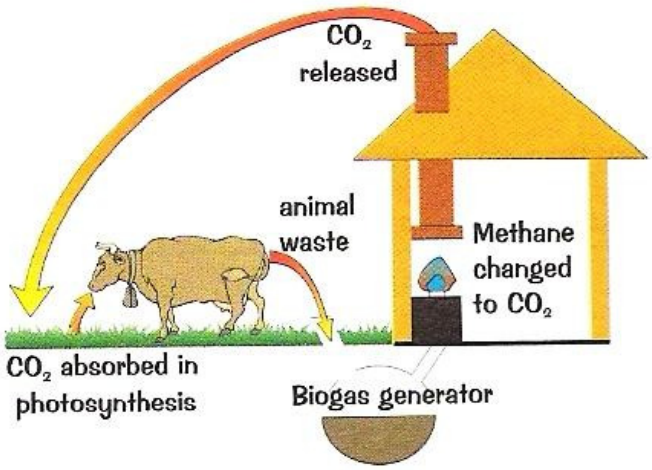


- Four factors to consider when designing a generator:

COST	**CONVENIENCE**
Continuous generators are more expensive than batch ones. This is because waste has to be mechanically pumped in and digested material mechanically removed constantly.	Batch generators are less convenient because they have to be continually loaded, emptied and cleaned.
EFFICIENCY	**POSITION**
Gas is produced most quickly at about 35°C. If the temperature falls below this, gas production will be slower. Generators in some areas will need to be insulated or kept warm. There should not be any leaks.	The waste will smell during delivery, so generators should be sited away from homes. The generator is also best located fairly close to the waste source.

- **Many <u>different microorganisms</u> are involved in the breakdown of materials in biogas production.**
- Ethanol-based fuels can be produced by the anaerobic fermentation of sugar cane juices and from glucose derived from maize starch by the action of carbohydrase.

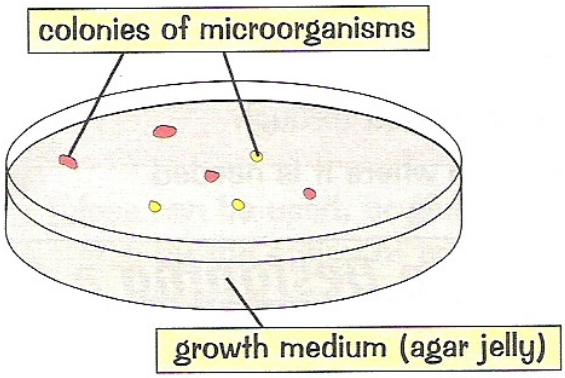
- Using biofuels has economic and environmental effects.
- **Biofuels are a greener alternative to fossil fuels.**
- Carbon dioxide released into the atmosphere is taken in by plants which lived recently, so they are CARBON NEUTRAL.
- The use of biofuels does not produce significant amounts of sulphur dioxide or nitrous oxides – the causes of acid rain.
- Methane is a greenhouse gas – linked to global warming.
- Raw material is cheap and readily available.



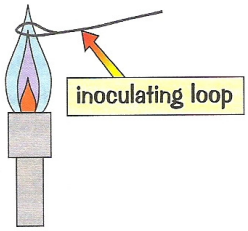
Using Microbiology Safely

- If the microorganisms that we want to use are contaminated, the other microorganisms that are present may produce harmful substances.
- **Therefore, it is only safe to use microorganisms if we have a pure culture containing only one particular species of microorganism.**

- Microorganisms can be grown in a culture medium containing carbohydrates as an energy source, mineral ions, and in some cases supplementary protein and vitamins.
- These nutrients are often contained in an agar medium which can be poured into a Petri dish.



- In order to prepare useful products, uncontaminated cultures of microorganism are required. For this:
  - Petri dishes and culture media must be sterilised before use.
  - INOCULATING LOOPS used to transfer microorganisms to the media must be sterilised by passing them through a flame (→).
  - The lid of the Petri dish should be taped down to prevent microorganisms from the air contaminating the culture.



- In school laboratories, cultures should be incubated at a maximum temperature of 25°C.
- This greatly reduces the likelihood of pathogens growing that might be harmful to humans.
- In industrial conditions, higher temperatures can produce more rapid growth.