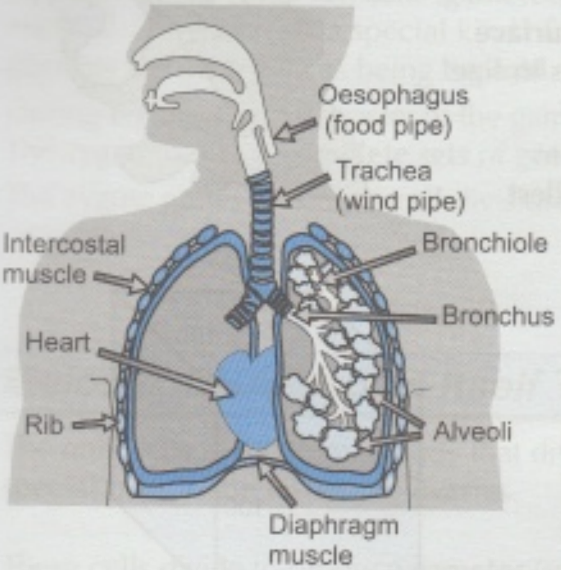
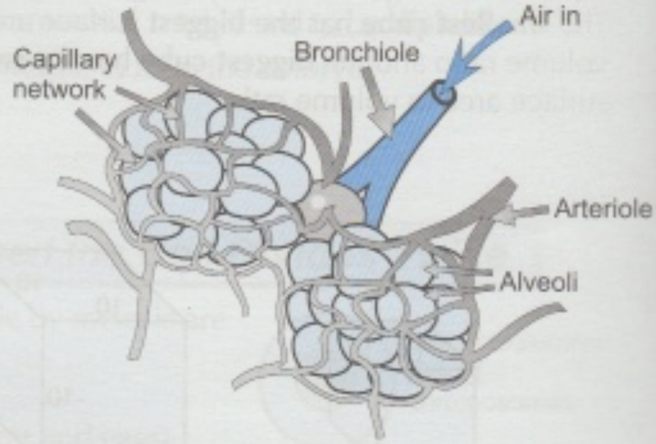
# Structure of the Thorax

## Lungs have a Very Large Gas Exchange Surface

Large, active animals, like mammals, have evolved complex **blood systems** and **lungs** to provide a **large surface area** for the efficient diffusion of oxygen and carbon dioxide.

**Gas exchange** takes place in millions of tiny air sacs, called **alveoli.**




## Alveoli have Adaptations that Increase the Diffusion Rate

1) The walls of the alveoli consist of a **single layer** of thin, flattened, epithelial cells. Diffusion happens **faster** when molecules only have to travel **short** distances.
2) Diffusion is faster when there's a **bigger difference** in concentrations between two regions. The blood flowing through the rich network of capillaries around the alveoli **carries away** the oxygen that has diffused through the alveolar walls. This ensures that there's always a **higher concentration of oxygen** inside the alveoli than in the blood. The reverse is true for **carbon dioxide**.
3) The alveolar walls are **fully permeable** to dissolved gases. Oxygen and carbon dioxide can pass easily through the cell membranes of the epithelial cells.

## I like my ralveoli filled with spinach and ricotta...

1) Why have large mammals evolved complex blood systems and lungs?
2) In which part of the lungs does gas exchange take place?
3) Describe the shape of the cells that make up the walls of the alveoli and explain how their shape suits their function.
4) What type of cell are the alveoli walls made of?
5) a) Why does oxygen diffuse from inside the alveoli into the blood?
   b) Name another gas that can pass easily through the walls of the alveoli.

# Breathing In and Breathing Out

## *Why* do We Need to *Breathe?*

**Ventilation** (breathing) ensures that air with a **high concentration of oxygen** is taken into the lungs, and air with a **high concentration of carbon dioxide** is removed from the lungs. This maintains high **concentration gradients** between air (inside your alveoli) and blood, **increasing** the rate of diffusion of oxygen and carbon dioxide.

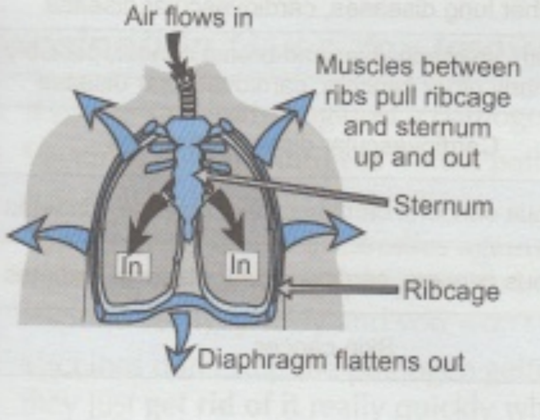
## *If Volume* **Increases***, Air Pressure* **Decreases**

If the **volume** of an enclosed space is **increased**, the **pressure** inside it will **decrease.**

1) The lungs are suspended in the **airtight thorax**.
2) Increasing the volume of the thorax decreases the air pressure in the lungs to below atmospheric pressure. Air flows **into** the lungs, inflating them until the pressure in the alveoli equals that of the atmosphere.
3) Decreasing the volume of the thorax increases the pressure in the lungs and air **flows out** until the pressure in the alveoli drops to atmospheric pressure.

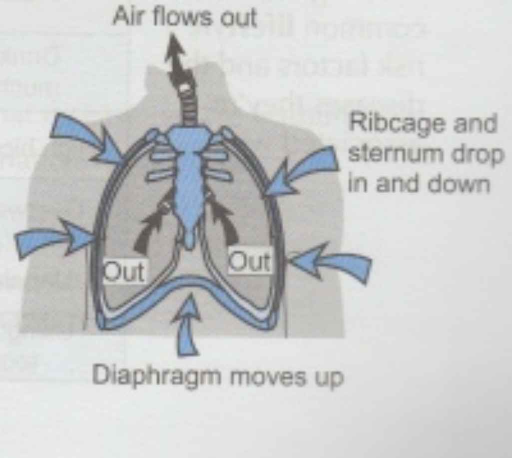
**Breathing In...**

1) **Intercostal muscles** and **diaphragm** (a muscular sheet) **contract.**
2) Thorax volume **increases.**
3) This decreases the pressure, so air **flows in.**




...and **Breathing Out**

1) **Intercostal muscles** and **diaphragm relax.**
2) Thorax volume **decreases.**
3) This increases the pressure, so air flows **out.**




## *We're heading inter-costal waters — look out for rocks at the sternum...*

1) Describe the relationship between volume and pressure in an enclosed space.
2) Does the volume of the thorax increase or decrease when you breathe out?
3) Which two sets of muscles contract when we breathe in?

# Disease

## *Disease can be Caused by Many Things*

1) **Pathogens** — these are organisms that can cause disease, e.g. bacteria and viruses. **Infectious diseases** are caused by pathogens and can be passed from person to person, e.g. TB, malaria and HIV.
2) **Genetic defects** — some diseases are caused by **mutations** in a person's genes, e.g. cystic fibrosis is caused by a mutation in a gene for a protein.
3) **Lifestyle** — certain lifestyles **increase the risk** of getting some diseases, e.g. smokers are more likely to get lung cancer.

## *Risk Factors for Disease*

1) A risk factor is something that **increases the chances** of something bad happening. For example, smoking is a risk factor for heart disease — if you smoke you're **more likely** to get heart disease.
2) Risk factors **don't always** lead to disease though. For example, using sunbeds is a risk factor for skin cancer — if you use sunbeds you increase your risk of skin cancer, but you won't necessarily get the disease.
3) Some risk factors are **unavoidable** because they're **inherited**, e.g. certain versions of genes increase your risk of getting breast cancer.
4) Some risk factors are **avoidable** because they're associated with your **lifestyle**. For example, a diet high in salt is a risk factor for high blood pressure — if you change your lifestyle to reduce your salt intake you reduce the risk.

Here's a table showing some common **lifestyle** risk factors and the diseases they're associated with:

| Risk factor | Diseases |
|---|---|
| Smoking | Mouth, lung and throat cancer, emphysema and other lung diseases, cardiovascular disease |
| Drinking too much alcohol | Mouth, stomach, liver and breast cancer, possibly many other cancers, cardiovascular disease |
| High blood pressure | Cardiovascular disease, diabetes |
| Overweight/obese | Various cancers, cardiovascular disease, diabetes |
| Unbalanced diet | Various cancers, cardiovascular disease, diabetes |
| Using sun beds too much | Skin cancer |

## *Taking your Nan's fashion advice — a risk factor for embarrassment...*

1) What are pathogens?
2) Give an example of an infectious disease.
3) What is a risk factor?
4) List two diseases that smoking is a risk factor for.

# Immunity

## ***Phagocytes*** *Engulf* ***Pathogens***

1) If a pathogen gets into the body it's detected by a type of white blood cell called a **phagocyte**.
2) It's actually the **molecules** on the **surface** of the pathogen that the phagocytes detect. These molecules are called **antigens**.
3) Human cells have antigens on their surface too, but phagocytes can tell the difference between '**self**' (your own) and '**foreign**' antigens.
4) Phagocytes **engulf** pathogens that are carrying foreign antigens and destroy them.

There are lots of **different types** of white blood cells.

## ***White Blood Cells*** *Produce* ***Antibodies***

1) Some white blood cells produce **antibodies** that **bind to** antigens.
2) The ones that produce antibodies are called **B-cells** (they're sometimes called B-lymphocytes — pronounced: lim-fo-sites).
3) When the antibody binds to the antigen it brings about the **death** of the pathogen carrying it.

## ***Another Type*** *of* ***White Blood Cell*** *is Involved*

1) **T-cells** (or T-lymphocytes) are a type of white blood cell that are involved in **communication** between phagocytes and B-cells.
2) When a phagocyte has engulfed a pathogen it signals to the T-cell that it's found something. The T-cell then **activates** the B-cells to produce antibodies.

## ***Vaccination*** *Gives You* ***Immunity***

1) If you're **vaccinated** against a pathogen you can't get that disease (you're **immune**).
2) Vaccines **contain antigens** from a pathogen in a form that can't harm you, e.g. attached to dead bacteria.
3) Your body produces **antibodies** against the antigens so, if the same pathogen (carrying the same antigens) tries to invade again, the immune system can respond **really quickly** and you won't suffer from any **symptoms**.
4) Vaccines don't stop the pathogen getting **into** the body, they just **get rid of it** really quickly when it does.

## *I seem to be immune to learning all this Biology...*

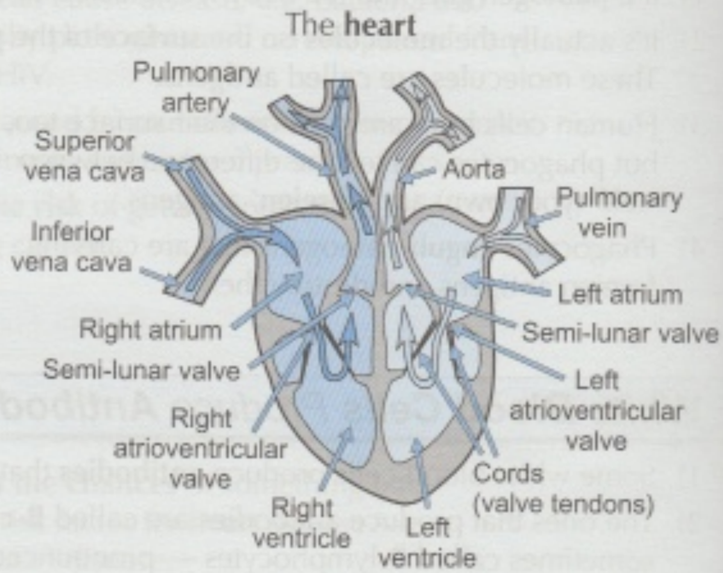
1) What do phagocytes detect?
2) What kind of white blood cells produce antibodies?
3) What is the role of T-cells?
4) What do vaccines contain?

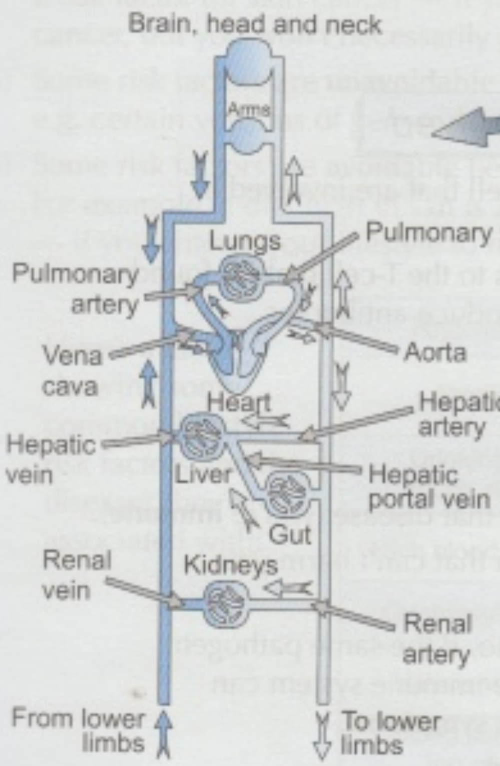
# The Circulatory System

## *Large Animals* Need a *Circulatory System*

1) Diffusion is only efficient over **short distances**, so any animal bigger than a simple worm needs a system that will bring glucose and oxygen into close contact with individual cells.
2) In humans, the **heart** pumps blood around the body through **blood vessels**.

The heart has **four chambers** — two **atria** and two **ventricles**.




3) The blood vessels carry blood around the **entire body** and go to **every organ** before returning the blood to the heart.
4) There are **three** main types of blood vessel:
   - **Arteries** carry blood **away** from the heart.
   - **Veins** carry blood **to** the heart.
   - **Capillaries** are where the exchange between the blood and the cells takes place.
5) As the blood flows through the **tissues**, dissolved substances such as glucose, oxygen and carbon dioxide are **exchanged** between the blood and the cells.

The main artery in the human body is the **aorta**. It carries oxygenated blood **from the heart** to the rest of the body.

## *A circulatory system — going round and round the M25...*

1) Name the organ that pumps blood around the body.
2) Name the four chambers of the heart.
3) Name the three main types of blood vessel.
4) In which type of blood vessel are substances exchanged between the blood and the cells?

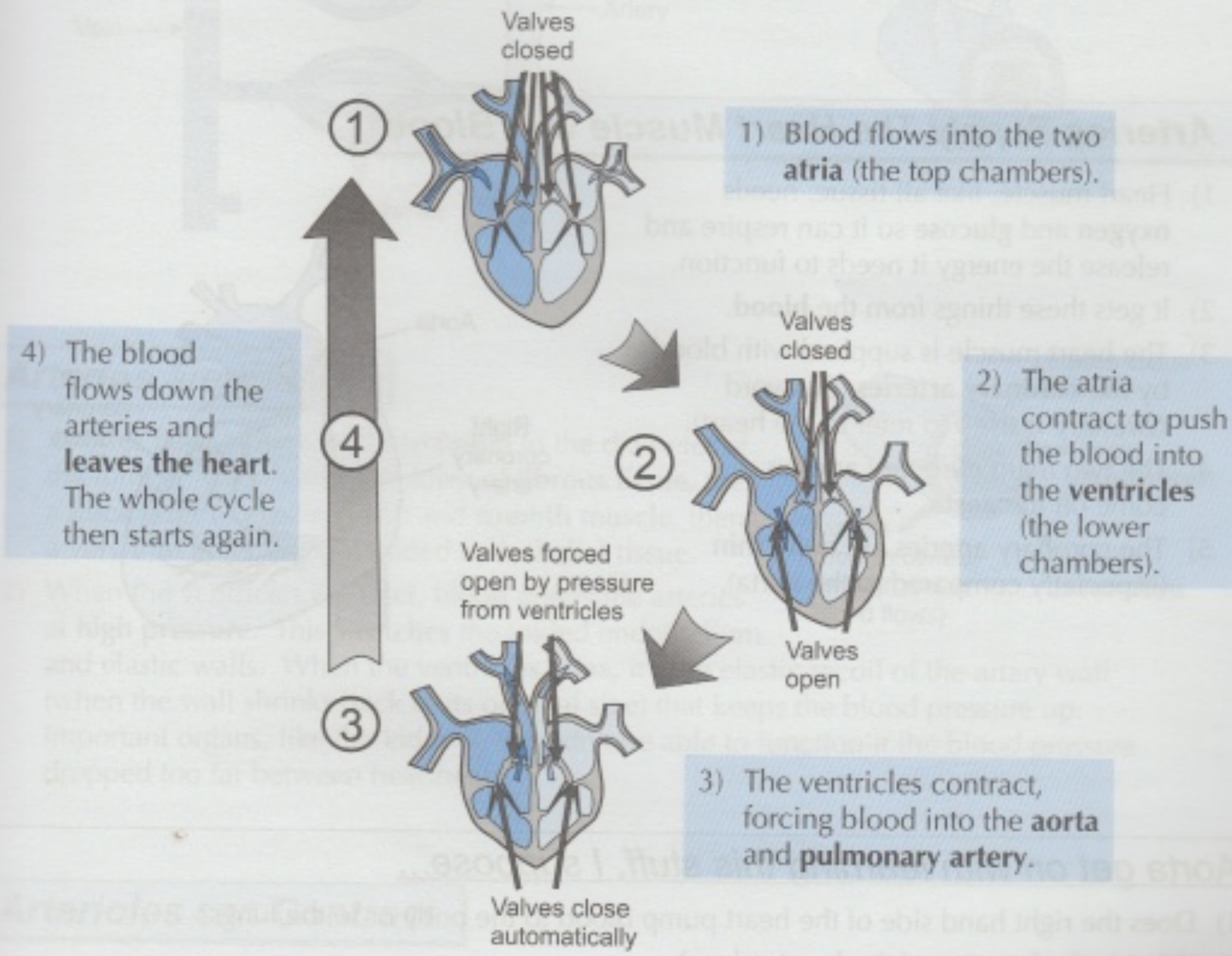
# The Heart

## Important Facts to Remember

1) The heart acts like two separate **pumps**. The **right side** sends blood to the **lungs** and the **left side** pumps blood around the rest of the **body**.
2) Blood always flows from a region of **higher pressure** to a region of **lower pressure**.
3) **Valves** in the heart prevent the blood from flowing backwards.
4) **No energy** is required to make the valves work — it's the **blood pressing** on the valves that makes them **open and close**.

## The Cardiac Cycle

The **cardiac cycle** is the sequence of events that occurs during **one heartbeat**.



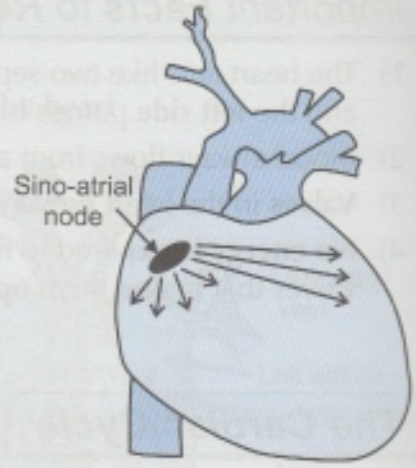

The **ventricles** are much more **powerful** than the atria and, when they contract, the **heart valves** pop shut automatically to prevent **backflow** into the atria. The ventricle walls are **thicker** because they need to push the blood further (e.g. the **left ventricle** has to push **blood all the** way round the body).

As soon as the ventricles relax, the valves at the top of the heart **pop shut** to prevent backflow of blood (back into the ventricles) as the blood in the arteries is now under **a fair bit of pressure**.

# The Heart

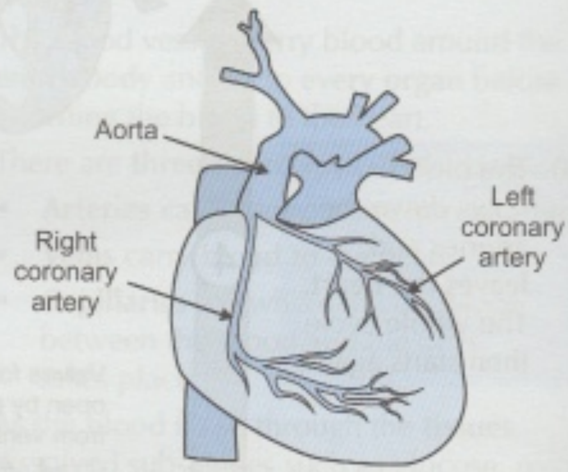
## The Heart has its Own Pacemaker

1) **Most muscles** require **nerve impulses** from the central nervous system to make them **contract**.
2) The heart **produces** its own **electrical impulses**.
3) A group of specialised cells called the **sino-atrial node**, in the wall of the right atrium, sends out **regular impulses**.
4) These spread across the atria, making them **contract**.




## Arteries Supply The Heart Muscle with Blood

1) Heart muscle, like all tissue, needs **oxygen** and **glucose** so it can respire and release the energy it needs to function.
2) It gets these things from the **blood**.
3) The heart muscle is supplied with blood by the **coronary arteries** (the word coronary is used to refer to the heart).
4) The two main coronary arteries come off the **aorta**.
5) The coronary arteries are quite **thin** (especially compared to the aorta).



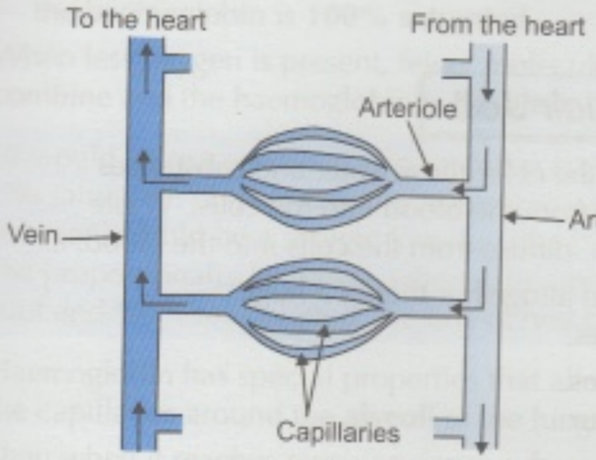

## Aorta get on with learning this stuff, I suppose...

1) Does the right hand side of the heart pump blood to the body or to the lungs?
2) What is the function of the heart valves?
3) Do heart valves require energy to open and close?
4) Where does the blood go after leaving the atria?
5) Why are the walls of the ventricles thicker than the walls of the atria?
6) The sino-atrial node is sometimes called the heart's natural pacemaker. What is its function?
7) Why does heart muscle require a blood supply?
8) Name the blood vessels that supply the heart muscle with blood.

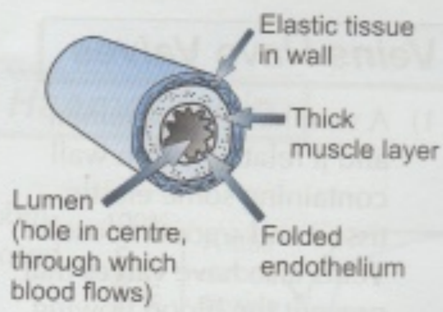
# Blood Vessels

## *Arteries, Arterioles, Capillaries and Veins*

1) **Arteries** carry blood away from the heart.
2) They subdivide into smaller vessels called **arterioles.**
3) Arterioles subdivide into microscopic vessels called **capillaries.**
4) Capillaries join up to form **veins.**
5) Veins **return** blood to the **heart.**



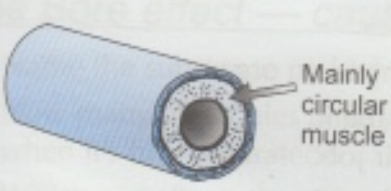

## *Arteries are Elastic*




1) Arteries have a **thick wall** compared to the diameter of the lumen. There's an outer layer of **fibrous tissue**, then a thick layer of **elastic tissue** and **smooth muscle**, then a very thin inner layer of folded **endothelial tissue**.
2) When the ventricles contract, blood enters the arteries at **high pressure**. This **stretches** the folded endothelium and elastic walls. When the ventricles relax, it's the elastic recoil of the artery wall (when the wall shrinks back to its original size) that keeps the blood pressure up. Important organs, like the kidneys, wouldn't be able to function if the blood pressure dropped too far between heartbeats.

## *Arterioles can Contract*

1) Arterioles are **narrower** than arteries and they have a higher proportion of **smooth muscle fibres** and a lower proportion of **elastic tissue**.

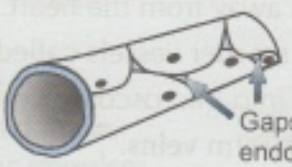



2) When the circular muscle fibres of an arteriole contract, the diameter of the lumen is reduced, so **less blood flows** through that vessel. This means that arterioles can **control** the amount of blood flowing to a particular organ.

# Blood Vessels

## *Capillaries* can *Only* be *Seen* With a *Microscope*

**Capillary walls** consist of a single layer of **endothelial cells** (cells that line the blood vessels). Some capillaries have **tiny gaps** between the endothelial cells.

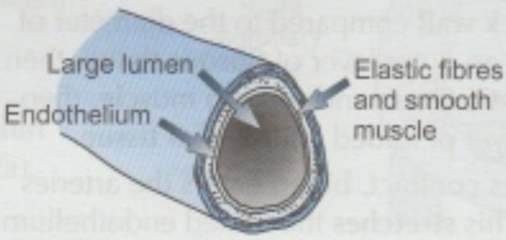


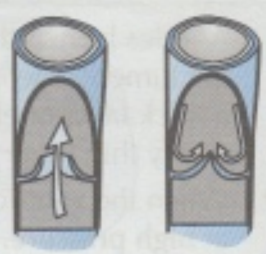

## *Capillaries* are *Well Suited* to Their *Job*

1) The **very thin walls** and the **gaps** between the cells allow water and substances like glucose and oxygen to **diffuse quickly** from the blood into the cells. Waste products, such as carbon dioxide and urea, diffuse from the cells into the blood.
2) Organs contain thousands of capillaries, so altogether there's a **huge surface area** for the exchange of substances.
3) Blood flows quite **slowly** through capillaries. This allows **more time** for diffusion to occur.

## *Veins* Have *Valves*

1) A vein has a **large lumen** and a relatively thin wall containing some elastic tissue and smooth muscle. Veins also have **valves** that prevent the blood flowing backwards.



2) When the **leg muscles** contract they bulge and press on the walls of the veins, pushing the blood up the veins. When the muscles relax, the valves close. This action helps the blood **return** to the heart.

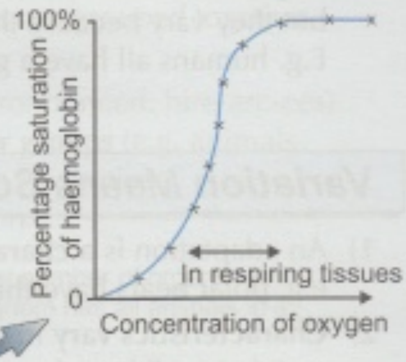
## *HMS Vein — a superior vessel...*

1) What is the role of arteries in the circulatory system?
2) Explain the importance of the elastic tissue in the walls of arteries.
3) Describe how arterioles can control the amount of blood flowing to an organ.
4) Capillaries have very thin walls, which sometimes have gaps in them. Explain how these characteristics make capillaries suited to their job.
5) What structure do veins contain, that other blood vessels don't have?
6) Explain how leg muscles help return blood to the heart.

# Blood

## *Haemoglobin has Special Properties*

1) The blood's main function is to **transport** materials to and from cells.
2) So the blood can do this, red blood cells are packed with **haemoglobin**, a protein that contains iron and can **carry oxygen**.
3) When oxygen combines with haemoglobin it forms **oxyhaemoglobin**.
4) When there's a lot of oxygen present, one molecule of haemoglobin can combine with **four** molecules of oxygen — the haemoglobin is **100% saturated**.
5) When less oxygen is present, fewer molecules of oxygen combine and the haemoglobin is **less than** 100% saturated.

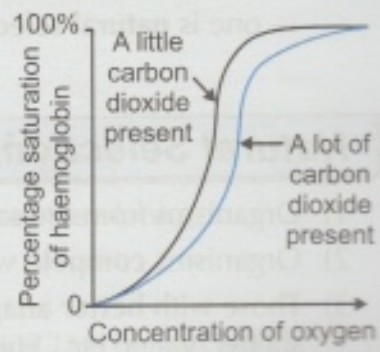



It would be reasonable to expect that a graph of '% saturation of haemoglobin' against 'concentration of oxygen' would be a straight line (i.e. that the two would be proportional). However, when experiments are carried out and the results plotted, the line of best fit is **S-shaped**.

6) Haemoglobin has special properties that allow it to become fully saturated with oxygen in the capillaries around the **alveoli** of the lungs, where there's a **high concentration** of **oxygen**.
7) Then when it reaches respiring tissue, where there's **less oxygen**, it can give up almost all of its oxygen immediately — so the rate of respiration in the tissues isn't slowed down because of an oxygen shortage.

## *Carbon Dioxide Changes the Properties of Haemoglobin*

1) Respiring tissues produce **carbon dioxide**.
2) If there's not a lot of carbon dioxide present, the haemoglobin is **less efficient** at **taking up** oxygen (i.e. it needs to be exposed to more oxygen before it becomes fully saturated).
3) But, when there's a lot of carbon dioxide present, the haemoglobin becomes **more efficient** at **releasing** oxygen (i.e. it can release more oxygen molecules in areas of fairly high oxygen demand).
4) This is good because it means that **rapidly respiring tissues**, e.g. contracting leg muscles and brain cells, get **more oxygen**.
5) This effect of carbon dioxide concentration on the oxygen-binding properties of haemoglobin is known as the **Bohr effect**.




## *The Bore effect — caused by reading this page...*

1) Name the substance picked up by the blood in the lungs.
2) How many molecules of oxygen are bound to a haemoglobin molecule when it's fully saturated?
3) Which gas affects the oxygen-binding properties of haemoglobin?
4) Under what circumstances does a tissue require the most oxygen?

# Variation and Evolution

## We all Vary

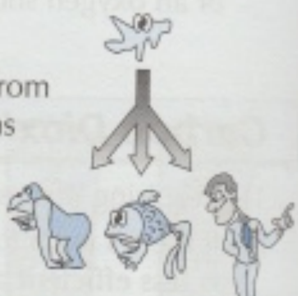
1) All organisms are **different** from each other, e.g. giraffes are loads different from zebras, which are different from lions and tigers and bears...
2) Organisms of the **same species** also show **some variation**, e.g. humans show variation in height, weight, favourite colour of shoe polish...
3) Organisms of the **same species** are similar because they all have the **same genes** but they vary because they have **different versions** of those genes (called **alleles**). E.g. humans all have a gene for blood type, but they can have A, B or O alleles.

## Variation Means Some Organisms are Better Adapted

1) An adaptation is a **characteristic** that helps an organism to **survive** and **have children**, e.g. polar bears have **thick**, **white fur** to stay warm and camouflaged in the snow.
2) **Characteristics vary** in a population so some organisms are **better adapted** for certain conditions than others, e.g. polar bears with thicker fur are better adapted to survive in a cold environment than polar bears with thinner fur. The slightly different adaptations you get **within species** (e.g. slightly thicker fur on one polar bear compared to another) are coded for by **different alleles**.

## Evolution

1) Evolution is the **gradual change** in the **characteristics** of a population from one generation to the next. The theory of evolution is that all organisms evolved from a **common ancestor** (organism) over **millions of years**.
2) There's **more than one** mechanism by which evolution occurs — one is **natural selection**.



## Natural Selection

1) Organisms from the **same population** all **vary** (e.g. different length of fur).
2) Organisms **compete** with each other for food, shelter, water, etc.
3) Those with **better adaptations** (caused by different **alleles**) are more likely to find food, shelter, water, etc., **survive** and have little **kiddies**. So they **pass on** the alleles for their better adaptations. E.g. bears with longer fur will stay warmer and be more likely to survive, and so have kids with longer fur.
4) Over time, the **number** of organisms with the better adaptations (alleles) **increases**.
5) The **whole population** of organisms **evolves** to have the better adaptations (alleles).

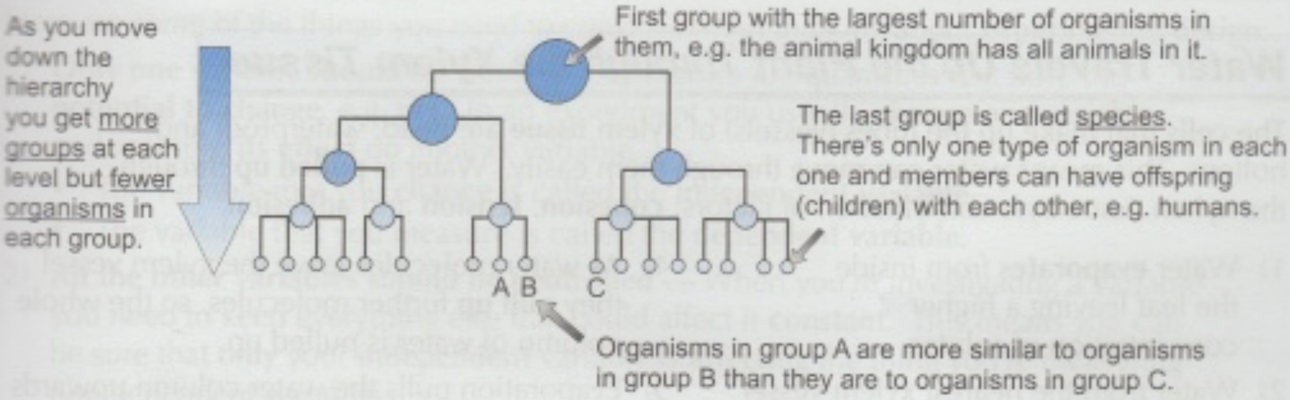
## Bah, evolution takes ages. I want wings NOW...

1) What is an allele?
2) What is an adaptation?
3) Briefly describe natural selection.

# Classification

## Classification Systems

1) Classification is just **sorting** organisms into different **groups** and **naming them.**
2) It makes it **easier** for scientists to **study** organisms without getting **confused**, because every type of organism has a different name, e.g. *Homo sapien* (humans) or *Ursus maritimus* (polar bears).
3) Organisms are arranged into different groups depending on their **similarities** and **differences**, e.g. all animals are grouped together, and all plants are grouped together in a separate group because they're different to animals.
4) Organisms are placed in groups in **classification hierarchies** (pronounced: hire-arc-ees) — the biggest groups (e.g. animals, plants) are **split** into **smaller groups** (e.g. animals with a backbone in one group and animals without a backbone in another). These groups are **split again** into more smaller groups, and so on.




A **species** is a group of organisms that **look similar** and can reproduce to give **fertile offspring** (their children can also reproduce).

## Classification Systems are Based on Lots of Things

1) **Older** classification systems grouped organisms based only on how they look, e.g. four limbs, six eyes, bum chin...
2) **Newer systems** use looks and lots of other things:
   - **DNA** — how similar and different the base sequence is (e.g. ATTTAC vs. ATTTAT).
   - **Other molecules** — e.g. proteins and enzymes.
   - **Early development** — how they grow from an embryo to a baby.

## *My poor brother — at least he's not classified with the apes any more...*

1) What does classification involve?
2) What is a species?
3) List four things newer classification systems use to group organisms.

# Xylem and Phloem

## ***Xylem Tissue*** *Transports* ***Water*** *and* ***Minerals*** *from* ***Roots***

Water from the soil **enters** the roots by **osmosis**. Then it travels through the root to the **xylem** — this is the tissue that **transports water** through the plant and up to the leaves.
Water can travel through the roots in **two** ways:

The **symplast system**:

- Some water moves through the root via the **cytoplasm** of the root cells. The water has to cross the **cell membrane**, which regulates the passage of the water and dissolved minerals.

The **apoplast system**:

- The water moves through the **cell walls** and the **spaces between the cells**.
- There are **no membranes** to regulate the passage.

## ***Water Travels Up*** *the* ***Plant*** *Through the* ***Xylem Tissue***

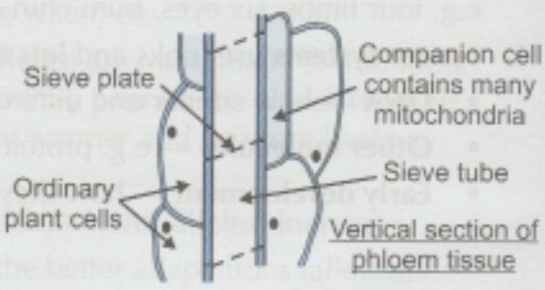
The cells that make up the tubes (vessels) of **xylem tissue** are dead, waterproof and hollow. This means water can **move** through them easily. Water is **pulled up** through the xylem tissue by a combination of factors: **cohesion**, **tension** and **adhesion**:

1) Water **evaporates** from inside the leaf leaving a higher concentration of solutes.
2) Water from the nearest xylem vessel enters by **osmosis**.
3) Water molecules stick together because of weak hydrogen bonds between them — this is called **cohesion**.
4) As water molecules leave the xylem vessel they **pull up** further molecules, so the whole column of water is pulled up.
5) Evaporation pulls the water column upwards and gravity pulls it down, so the water column is under **tension**.
6) The **adhesion** of water molecules to the sides of the xylem vessels stops the column breaking.

## ***Phloem*** *Transports* ***Organic Compounds***

**Sugars** and other organic compounds are **transported** through plants in **phloem tissue**. Phloem tissue is also arranged in **tubes** so the solutions of sugar, etc. can **move** through them easily.

1) The movement of carbohydrates and other organic compounds in plants is known as **translocation**.
2) It occurs in the **sieve tubes** of the **phloem tissue**.
3) **Companion cells** next to the sieve tubes are believed to **actively transport** sugar into the sieve tubes, and then water follows by **osmosis**.




Vertical section of phloem tissue

## *Relax, sit back and just go with the phloem...*

1) In the symplast system, which part of the cell does water move through?
2) Why is the column of water in the xylem under tension?
3) What substances are transported in the phloem tissue?

# Planning an Experiment

## A Good Experiment Gives Precise and Valid Results

1) **Precise** results are **repeatable** (if the same person repeats the experiment using the same methods and equipment, they will get the same results) and **reproducible** (if someone different does the experiment, or a slightly different method or piece of equipment is used, the results will still be the same).
2) **Valid** results are **precise** and **answer the original question**. To get valid results you need to **control all the variables** to make sure you're only testing the thing you want to.

## To Get Good Results You Need to Design Your Experiment Well

Here are some of the things you need to consider when thinking about **experimental design**:

1) **Only one variable should be changed** — Variables are **quantities** that have the **potential to change**, e.g. pH. In an experiment you usually **change one variable** and **measure its effect** on another variable.
   - The variable that you **change** is called the **independent variable**.
   - The variable that you **measure** is called the **dependent variable**.
2) **All the other variables should be controlled** — When you're investigating a variable you need to keep everything else that could affect it **constant**. This means you can be sure that **only** your **independent** variable is **affecting** the thing you're measuring (the dependent variable).
3) **Negative controls should be used** — Negative controls are used to **check** that only the independent variable is affecting the dependent variable. Negative controls **aren't expected** to have **any effect** on the experiment.
4) **Repeat the experiment at least three times** — Doing **repeats** and getting **similar results** each time shows that your data is **repeatable**. This makes it more likely that the same results could be **reproduced** by another scientist in an independent experiment. This makes your data **more precise**. Doing repeats also makes it easier to spot any **anomalous results** — unexpected results that don't fit in with the rest.

**EXAMPLE:** Investigating the effect of **temperature** on **enzyme activity**.

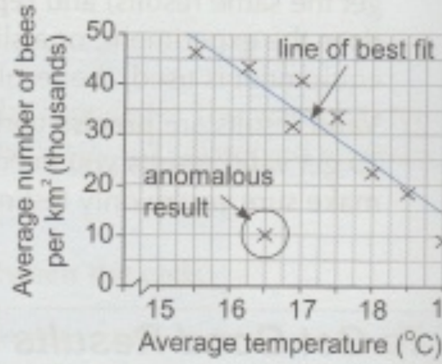
1) Temperature is the **independent** variable.
2) Enzyme activity is the **dependent** variable.
3) pH, volume, substrate concentration and enzyme concentration should all stay the **same**.
4) The experiment should be **repeated** at least three times at each temperature used.
5) A **negative control**, containing everything used except the enzyme, should be measured at each temperature. No enzyme activity should be seen with these controls.

# Graphs

## You Can Use Scatter Graphs to Present Your Data

1) When you want to show how **two variables** are **related** (or **correlated**, see next page) you can use a **scatter graph**.
2) Make sure that:
   - The **dependent variable** goes on the **y-axis** (the vertical axis) and the **independent** on the **x-axis** (the horizontal axis).
   - You always **label** the **axes**, include the quantity and **units**, and choose a **sensible scale**.
3) When you draw a **line** (or curve) **of best fit** on a **scatter graph**, draw the line through or as near to as many points as possible, **ignoring** any **anomalous** results.

**Scatter graph**



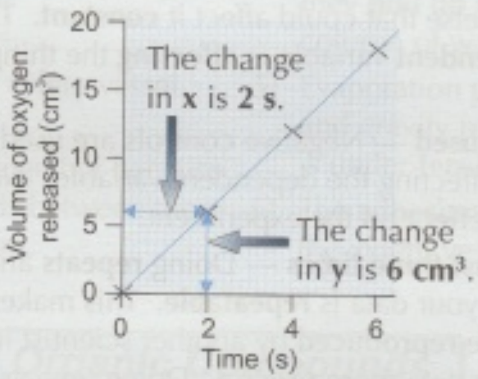

## Find the Rate By Finding the Gradient

**Rate** is a measure of how much something is **changing over time**. Calculating a rate can be useful when **analysing** your data, e.g. you might want to the find the **rate of a reaction**. Rates are easy to work out from a **graph**.

For a **linear** graph you can calculate the **rate** by finding the **gradient of the line**:

**EXAMPLE:**

cm$^3$ s$^{-1}$ means the same as cm$^3$/s (centimetres per second)




$$\text{gradient} = \frac{\text{change in Y}}{\text{change in X}}$$

So in this **example**:

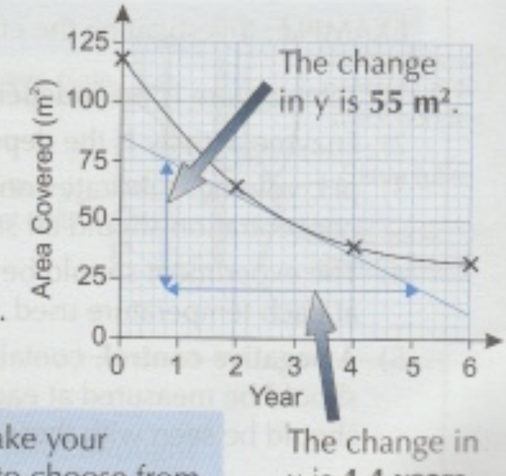
$$\textbf{rate} = \frac{6\ \text{cm}^3}{2\ \text{s}} = \mathbf{3\ cm^3\ s^{-1}}$$

For a **curved** (non-linear) graph you can find the **rate** by drawing a **tangent**:

**EXAMPLE:**

1) Position a ruler on the graph at the **point** where you want to know the **rate**.
2) **Angle** the **ruler** so there is **equal space** between the **ruler** and the **curve** on **either** side of the point.
3) **Draw** a **line** along the ruler to make the tangent.
4) **Calculate** the **gradient** of the **tangent** to find the **rate**.

**gradient** = 55 m$^2$ ÷ 4.4 years = **12.5 m$^2$ year$^{-1}$**



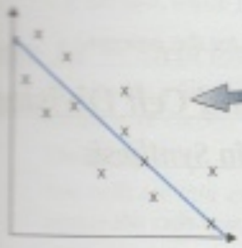

The change in x is **4.4 years**.

**Extend** the line right across the graph — it'll help to make your **gradient calculation easier** as you'll have **more points** to choose from.

# Correlation and Cause

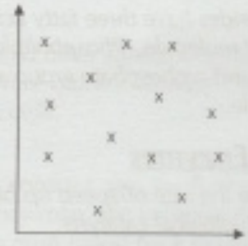
## *Lines of Best Fit* Are Used to *Show Trends*

The line of best fit on this graph shows that as one variable **increases**, the other variable **also increases**. This is called a **positive correlation**. The data points are all quite close to the line of best fit, so you can say the correlation is **strong**. If they were more spread out, the correlation would be **weak**.



Variables can also be **negatively correlated** — this means one variable **increases** as the other one **decreases**. Look at the way the line of best fit **slopes** to work out what sort of correlation your graph shows.

Sometimes the graph won't show any clear trend and you won't be able to draw a line of best fit. In this case, you say there's **no correlation** between the variables.



## *Correlation Doesn't Always* Mean *Cause*

1) Be careful what you **conclude** from an experiment — just because two variables are correlated, it doesn't necessarily mean that one **causes** the other.
2) In lab-based experiments, you can say that the independent variable causes the dependent variable to change — the increase in temperature **causes** an increase in the rate of the reaction. You can say this because everything else has **stayed the same** — nothing else could be causing the change.
3) Outside a lab, it can be much harder:

**EXAMPLE:**

Kate measured the level of air pollution and the incidence of TB, to see whether the two are related. Her results show a positive correlation between the variables — where the level of pollution is highest, the incidence of TB is also highest.

From Kate's results, you can't say that air pollution causes TB.

Neither can you say that TB causes air pollution.

It could be either way round... or one change might not cause the other at all — you just can't tell.