Animal, plant, fungal and protoctist cells are eukaryotic. This means they have:

- → nucleus
- → nucleolus
- → cytoplasm
- → cytoskeleton
- → plasma membrane
- → vesicles
- → ribosomes
- → centrioles
- → mitochondria (MB)
- → Golgi apparatus (MB)
- → rough endoplasmic reticulum (MB)
- → smooth endoplasmic reticulum (MB)
- → lysosomes (MB)
- → cilia (MB)
- → undulipodia (MB)
- → vacuole (plants)
- → chloroplasts (plants)
- → cellulose cell wall (plants)

Organelles each have specific functions. This provides a division of labour so every cell can carry out its functions efficiently. Most organelles are membrane bound which means they have a membrane that separates them from the rest of the cell.

Name	Description	Function
Nucleus	Surrounded by a double membrane – nuclear envelope.	Control centre of the cell. Stores organism's genome. Transmits genetic info. Provides instructions for protein synthesis.
Nuclear envelope	Contains pores.	Separates nucleus from rest of cell. Some regions where outer & inner nuclear membranes fuse – dissolved substances + ribosomes can get through. Pores allow mRNA to leave the nucleus.
Nucleolus	No membrane. Contains RNA.	Where ribosomes are made. Chromosomes contain the organism's genes.
Cytoplasm	Jelly-like substance.	Where the organelles are suspended.
Cytoskeleton	Network of protein structures within cytoplasm. Consists of: microfilaments made of actin, intermediate filaments, microtubules made of tubulin, and cytoskeletal motor proteins. These are enzymes that have a site that binds to and allows hydrolysis of ATP as their energy source.	Microfilaments: give support and mechanical strength, keep cell's shape stable and allow cell movement. Intermediate filaments anchor the nucleus within cytoplasm, and stabilise tissues. Microtubules provide shape and support to cells and help substances and organelles move through the cytoplasm. They form a track along which motor proteins walk and drag organelles. Also form a spindle before a cell divides. Microtubules also make up the cilia, undulipodia and centrioles.
Plasma membrane	Membrane at the cell surface.	Controls what enters and exits the cell.
Vesicles	Packages containing proteins.	Bring materials to and from the Golgi apparatus.
Ribosomes	Made of ribosomal RNA in the nucleolus as 2	When bound to the RER, are for synthesising proteins that will be exported outside the cell.

Similarities to eukaryotic cells:

- → plasma membrane
- → cytoplasm
- → DNA and RNA
- → ribosomes for assembling proteins

Differences to eukaryotic cells:

- → much smaller
- → less well-developed cytoskeleton with no centrioles
- → no nucleus
- → no membrane-bound organelles
- → peptidoglycan wall instead of cellulose
- → smaller ribosomes
- → naked DNA that floats freely in cytoplasm as a loop (not linear chromosomes)

Prokaryotic cells divide by binary fission and not by mitosis because they do not have linear chromosomes. Before they divide, they copy their DNA so each new cell receives a large loop of DNA and any smaller plasmids.

Molecular and biochemical evidence indicates that eukaryotic cells evolved from prokaryotic cells around 2 billion years ago when some prokaryotic cells with infolded membranes invaded or were engulfed by other prokaryotes but not digested. This produced the double membrane of what are now chloroplasts and mitochondria. Both chloroplasts and mitochondria share characteristics with prokaryotic cells:

- → small ribosomes
- → loops of DNA
- → contain RNA
- → can divide by binary fission

This theory is called the endosymbiont theory.

As a liquid, water molecules constantly move around, making and breaking H bonds. The H bonds make it hard for water molecules to escape and become a gas. Because it is a liquid at room temperature, water can:

→ provide habitat for living things in rivers, lakes, seas
→ form a major component of tissue in living organisms
→ provide a reaction medium
→ provide an effective transport medium e.g. blood

If water was less dense, aquatic organisms would find it hard to float. When most liquids get colder they become denser. If water did this, water at the top of a pond would freeze and sink. The water replacing it would do the same until the pond was full of ice. However, water only gets denser as it gets colder until about 4°C. As it lowers to freezing, the water molecules align themselves in a structure less dense than liquid water. Because ice is less dense than water:

→ aquatic organisms have a stable environment to live in through winter
→ bodies of water insulated against extreme cold by the layer of ice reducing the rate of heat loss

Water is a good solvent for many substances in living things. This includes ionic solutes such as sodium chloride and covalent substances like glucose. As water is polar, the positive and negative parts are attracted to the negative and positive parts of the solute. The water molecules cluster around the charged parts of the solute molecules or ions and will help separate them and keep them apart. They dissolve and a solution is formed. Because water is a good solvent:

→ molecules/ions can move around and react together in water
→ molecules/ions can be transported around living things while dissolved

Hydrogen bonding between water molecules in a drop pull them together. The water molecules demonstrate cohesion. Water molecules at the surface are all H-bonded to the water molecules beneath them and hence are more attracted to these than to the air above. This means the surface of the water contracts and gives the surface of water an ability to resist force applied to it. This is known as surface tension. Because of cohesion and surface tension:

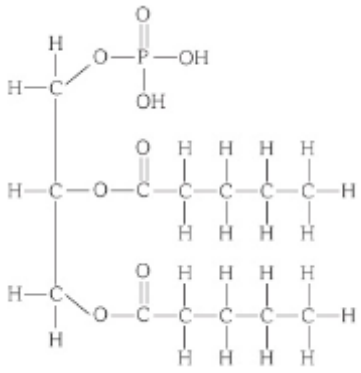
→ columns of water in plant vascular tissue are pulled up the xylem
→ insects like pond-skaters can walk on water

Water temperature is a measure of the kinetic energy of the molecules. Water molecules are held together tightly by hydrogen bonds. Therefore, a lot of heat energy has to be put in to increase the kinetic energy and temperature. The amount of heat energy required is called the specific heat capacity. This means water does not heat up or cool down quickly. This is important because:

→ living things need a stable temperature for enzyme-controlled reactions
→ aquatic organisms need a stable environment in which to live

When water evaporates, heat energy known as the latent heat of vaporisation, helps molecules to break away from each other to become a gas. Because the molecules are held together by H bonds, a large amount of energy is needed for water to evaporate. Therefore, water can help cool living things and keep their temperature stable. E.g. mammals are cooled when sweat evaporates.

Phospholipids have the same structure as triglycerides except one of the fatty acids is replaced by a phosphate group. A condensation reaction occurs between an OH group on a phosphoric acid molecule and one of the three OH groups on the glycerol, and an ester bond is formed. Commonly one of the chains on a phospholipid is saturated and one unsaturated.



When surrounded by water, the phosphate group has a negative charge, making it polar. However, the fatty acid chains are non-polar and repelled by water. The head is hydrophilic and the tail is hydrophobic. This makes the phospholipid amphipathic. Membrane lipids tend to be amphipathic whereas storage lipids are not.

Amphipathic phospholipids form a layer on the surface of water with heads in the water and tails sticking out of the water. They may also form micelles, balls with the tails tucked inside and the heads pointing outwards.

Amphipathic phospholipids form membranes around cells and organelles. Inside and outside a cell membrane is an aqueous solution. The phospholipids form a bilayer with two rows of phospholipids, tails pointing in.

- → The individual phospholipids are free to move around in their layer but will not move into any position where their tails are exposed to water. This gives the membrane some stability.
- → The membrane is selectively permeable. It is only possible for small and non-polar molecules to move through the tails such as oxygen and carbon dioxide. This allows the membrane to control what goes in and out of the cell and keep it functioning properly.

Cholesterol is a sterol (steroid alcohol), a type of lipid not made of glycerol and fatty acids. It consists of four carbon based rings or isoprene units. It is a small, hydrophobic molecule, meaning it can sit in the middle of the hydrophobic part of the bilayer. It regulates the fluidity of the membrane, preventing it becoming too fluid or stiff.

It is mainly made in the liver in animals. Plants have stigmasterol, which is only different in that it has a double bond between carbon 22 and 23.
The steroid hormones testosterone, oestrogen and vitamin D are made of cholesterol. They are small and hydrophobic so can pass through the hydrophobic part of the cell membrane and any other membranes inside the cell.

- → Amino acids - monomers of all proteins; all have the same basic structure.
- → Peptide bond - bond formed when two amino acids are joined by a condensation reaction.

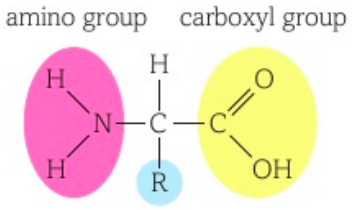
Proteins are large polymers consisting of long chains of amino acids. The properties of proteins give them these functions:

- → form structural components of animals e.g. muscle
- → tendency to adopt specific shapes makes them important as enzymes, antibodies and hormones

→ membranes have protein components that act as carriers and pores for active transport across the membrane and facilitated diffusion

Plants and animals need amino acids to make proteins. Animals can make some amino acids but must ingest others (essential amino acids). Plants can make all the amino acids they need if they can access nitrates.

Each amino acid contains C, H, O and N. Some contain sulphur. There are over 500 different amino acids but only 20 are proteinogenic (formed in proteins). Each protein chain has an amino group and a carboxyl group. The R group stands for a different element in each amino acid. It is the variable group.



Amino acids can act as buffers. When dissolved in water, the amino group and carboxyl group can ionise. The amino group can accept a H^+ ion to change from NH_2 to NH_3^+. It acts as a base. The carboxyl group can give up a H^+ ion to change from COOH to COO^-. It acids as an acid, in producing H^+ ions.

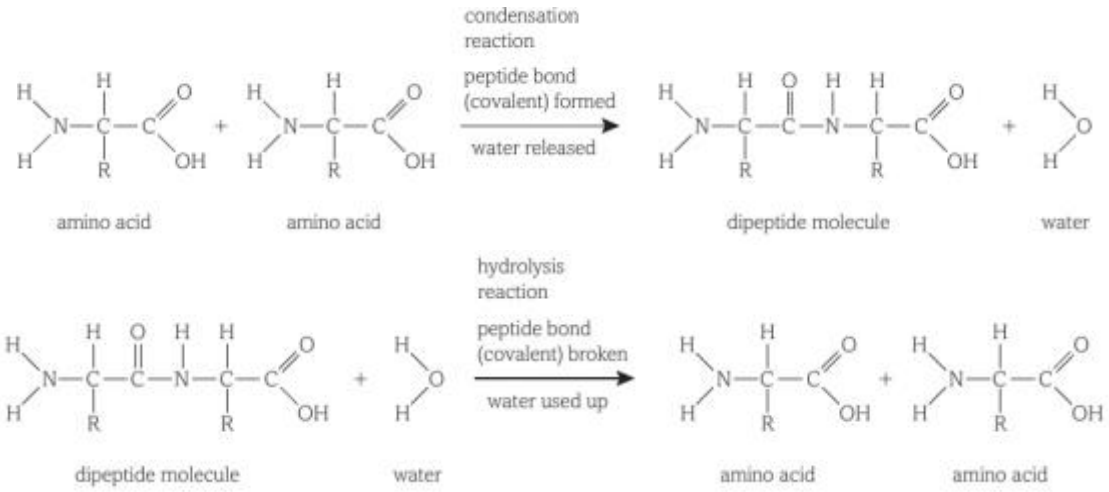
→ At low pH, (lots of H^+) the amino acid will accept H^+ ions.

→ At high pH, (fewer H^+) the amino acid will release H^+ ions.

This means an amino acid has acidic and basic properties and is known as amphoteric. Protein chains can be affected by this amphoteric nature. Amino acids can help regulate the changes in pH. This is known as buffering. A buffer is a substance which helps resist changes to pH.

Amino acids are joined together by covalent bonds called peptide bonds. Making a peptide bond involves a condensation reaction and breaking one involves hydrolysis. Enzymes catalyse these reactions. Protease enzymes in the intestines break peptide bonds during digestion. They also break down protein hormones.

All amino acids join in the same way, whatever R group they have. Two amino acids joined are called a dipeptide. Joining a longer chain of amino acids together forms a polypeptide. A protein may consist of a single polypeptide chain or more than one chain bonded together.



→ Primary structure - the sequence of amino acids found in a molecule.

Ionic bonds can form between carboxyl and amino groups that are part of R groups. These ionise into NH_3^+ and COO groups. Positive and negative groups like this are strongly attracted to each other to form an ionic bond.

The R group of cysteine contains sulphur. Disulphide bridges are formed between the R groups of two cysteines. These are strong covalent bonds.

Hydrophobic parts of the R groups tend to associate together in the centre of the polypeptide to avoid water. Hydrophilic parts are found at the edge, close to the water. Hydrophobic and hydrophilic interactions cause twisting of the amino acid chain, which changes the shape of the protein.

- → Fibrous protein - has a long, thin structure, insoluble in water and metabolically inactive, often having a structural role within an organism.
- → Globular protein - has molecules of a relatively spherical shape which are soluble in water and often have metabolic roles within the organism.
- → Prosthetic group - a non-protein component that forms a permanent part of a functioning protein molecule.

The 3D tertiary and quaternary structures fall into two categories:

- → Fibrous proteins have regular, repetitive sequences of amino acids and are insoluble in water. These features enable them to form fibres, which tend to have a structural function, e.g. collagen and elastin in connective tissue.
- → Globular proteins tend to roll up into a spherical shape. Any hydrophobic R groups are turned inwards towards the centre of the molecule, while hydrophilic groups are on the outside. This makes the protein water soluble, because water molecules can easily cluster round and bind to them. They often have very specific shapes, helping them to take up roles as enzymes, hormones, haemoglobin etc.

The function of collagen is to provide mechanical strength:

- → In artery walls, a layer of collagen prevents the artery bursting when withstanding high pressure from blood being pumped by the heart.
- → Tendons are made of collagen and connect muscles to bones, allowing them to pull on bones.
- → Bones are made of collagen and reinforced with calcium phosphate, which makes them hard.
- → Cartilage and connective tissue are made from collagen.

Keratin is rich in cysteine so lots of disulphide bridges form between its polypeptide chains. Alongside H bonding, this makes the molecule very strong. Keratin is found in hard, strong body parts such as nails, hair, claws, hoofs, horns, scales etc. It provides mechanical protection and an impermeable barrier to infection and, being waterproof, prevents entry of water-borne pollutants.

Elastin is strong and extensible from cross-linking and coiling. It's found in living things where they need to stretch or adapt their shape. Skin can stretch around our bones and muscles because of elastin. Elastin is also in lungs to allow them to inflate and deflate, and in the bladder to help it expand to hold urine. Elastin helps our blood vessels stretch and recoil as blood is pumped through them, helping maintain the pressure wave of blood as it passes through.

→ When dry, lower it into the solvent. Ensure the level of solvent is below the pencil line.
→ Cover the beaker with a watch glass.
→ Let the apparatus run until the solvent has reached a point just under the top of the paper. Remove it from the solvent and lay it out to dry.

As the solvent travels up the paper, the components of the solution mixture travel with it. You can use relative distances travelled to help identify the pigments. The R_f value is calculated by x/y (on diagram).

Sometimes with colourless molecules, you must use:
→ UV light - TLC plates have a chemical that fluoresces under UV light. It will all glow except the spots where the solvent has travelled.
→ Ninhydrin - This binds to amino acids which are then visible as brown or purple spots.
→ Iodine - This forms a gas which binds to the molecules in each of the spots.

The speed at which molecules move along the paper depends on their solubility in the solvent and their polarity. In the case of paper chromatography, it may also depend on their size. Exposed OH groups make the surface of the paper polar, allowing it to form H bonds with the molecules along with other dipole interactions. A highly polar solute will be adsorbed to the surface and move more slowly. A non-polar solute will move much quicker. If two molecules travel at the same speed, you can try to use a different solvent or change the pH.

Thin layer chromatography is commonly used to monitor the progress of reactions because it works quickly. It is also used for urine testing of athletes for illegal drugs, analysing drugs for purity and analysis of food to determine presence of contaminants.

Catalase is an enzyme that protects cells from damage by reactive oxygen by quickly breaking down hydrogen peroxide, a potentially harmful by-product of many metabolic reactions, to water and oxygen.

- → consists of four polypeptide chains and contains a haem group with iron
- → fastest-acting enzyme, with highest turnover number (6 million/second)
- → in eukaryotic cells, found inside vesicles called peroxisomes
- → when white blood cells ingest pathogens they use catalase to help kill the invading microbe
- → optimum pH in humans is around 7 but varies by species
- → optimum temp. in humans is 45 degrees C but also varies

Extracellular enzymes:
Some enzymes are secreted from the cells where they're made and act on their substrates extracellularly. In the digestive system, many enzymes are secreted from cells lining the alimentary canal into the gut lumen. There they extracellularly digest the large molecules such as proteins, lipids, carbohydrates etc. in food. The products of digestion are then absorbed into the bloodstream.

- → Amylase is produced in the salivary glands and acts in the mouth to digest the polysaccharide starch to the disaccharide maltose. It is also made in the pancreas and catalyses the same reaction in the small intestine.
- → Trypsin is made in the pancreas and acts in the small intestine to digest proteins to smaller peptides by hydrolysing peptide bonds.

- → Cofactor - substance that has to be present for an enzyme catalysed reaction to take place at the appropriate rate. Some (prosthetic groups) are part of the enzyme structure and others (mineral ion cofactors and organic coenzymes) form temporary associations with the enzyme.
- → Enzyme-substrate complex - complex formed by temporary binding of enzyme and substrate molecules during reaction, joined by non-covalent forces.

Some enzymes only work if another small non-protein molecule is attached to them. These are called cofactors. A cofactor that is permanently bound by covalent bonds to an enzyme molecule is called a prosthetic group.
Carbonic anhydrase contains a zinc ion as a prosthetic group to its active site. This enzyme is found in erythrocytes and catalyses the interconversion of carbon dioxide and water to carbonic acid which then breaks down to protons and hydrogencarbonate ions. This reaction can happen in either direction depending on the concentration of substrate or product molecules.

- → $CO_2 + H_2O$ <---> H_2CO_3 <---> $H^+ + HCO_3^-$

This reaction is important as it enables carbon dioxide to be carried in the blood from tissues to the lungs.

Some enzymes work better in the presence of ions that are not permanently bound to them. These ions are also cofactors. During an enzyme catalysed reaction, the enzyme and substrate temporarily form an enzyme-substrate complex. The presence of certain ions that may temporarily bind to either the substrate or the enzyme may ease the formation of such ES complexes and therefore increase the rate of reaction.

- → Some cofactors act as co-substrates - they and the substrate together form the correct shape to bind to the active site.

Enzymes work within a narrow range of pH:

- → Small pH changes either side of the optimum slow the rate of reaction because the shape of the active site is disrupted.
- → If the normal optimum is restored, the H bonds can re-form and the active site shape is restored.
- → At extreme pH, the enzyme's active site is denatured (cannot return).

- → Enzymes that work intracellularly have an optimum pH around 7.
- → Enzymes that work extracellularly may have different optimums e.g. during digestion, enzymes in the mouth work best at pH 6.8 whereas when food passes to the stomach HCl is secreted, giving a low pH (1-2). The acid kills bacteria and other pathogens in the food. As the food moves to the small intestine, salts in bile neutralise it and raise it to pH 7.8. This is optimum for the protein-digesting enzymes that catalyse further digestion.

- → Concentration - number of molecules per unit volume.

If there is no substrate present, an enzyme catalysed reaction cannot occur as no ES complexes can be formed. As substrate is added and its concentration increased, the rate of reaction increases:

- → more ES complexes can form
- → more product can form
- → substrate concentration is the limiting factor because as it increases, the rate of reaction increases
- → as the concentration increases further, the reaction reaches its max. rate
- → adding more substrate will not increase the rate of reaction
- → this is because all the active sites are occupied with substrate molecules

To investigate the effect of increasing the substrate concentration, you can use urease (breaks down urea) which releases ammonia. As ammonia is released, the pH is increased. The indicator phenol changes from yellow to pink when alkaline. Colorimetry can be used to measure the depth of colour and therefore the amount of ammonia produced in a set time. This gives an indication of the rate of reaction.
Control variables:

- → concentration of enzymes
- → volume of enzyme and substrate solutions
- → temperature
- → time for reaction
- → stirring/shaking
- → filter in colorimeter

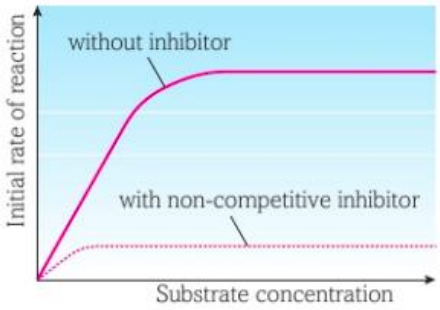
Depending on a cell's needs, genes for synthesising particular enzymes can be switched on or off. Cells are continuously degrading old enzymes to their component amino acids and synthesising new enzymes. Advantages:

- → the elimination of abnormally shaped proteins that might accumulate and harm the cell
- → regulation of metabolism in the cell by eliminating any enzymes surplus to requirements

→ They compete directly with substrate molecules for a position in the active site, forming an enzyme-inhibitor complex.
→ Once on the active site, the inhibitor is not affected/changed.
→ The presence prevents the substrate from joining the active site.
→ It reduces the number of free active sites available to bind with substrates.
→ Most inhibition by competitive inhibitors is reversible.
→ If the inhibitor binds irreversibly with the enzyme it is called an inactivator.

If the inhibitor binds to the enzyme somewhere other than the active site, it is non-competitive inhibition. These inhibitors do not compete with the substrates; they attach to the enzyme at the allosteric site, away from the active site, and disrupt the tertiary structure and to change its shape.

→ This distortion makes the active site no longer complementary to the shape of the substrate so ES complexes cannot form.
→ The max. rate of reaction is reduced. Adding more substrate might allow the reaction to attain this new lower maximum but even very high substrate concentrations will not allow the rate of reaction to return to its uninhibited maximum.



→ The more inhibitor molecules present, the greater the degree of inhibition as more enzymes are distorted.
→ Some bind reversibly and some irreversibly.

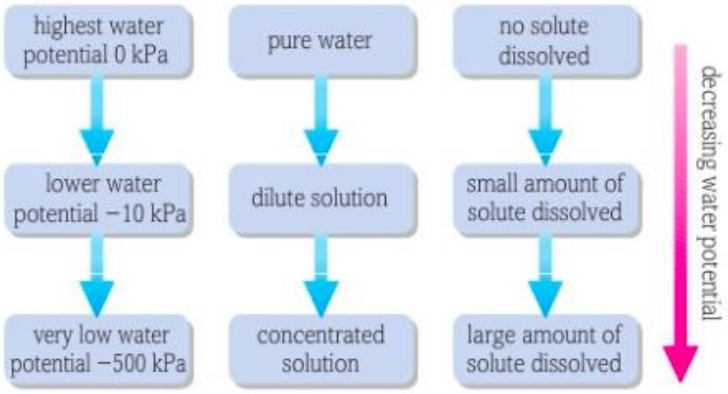
One way in which enzyme-catalysed reactions may be regulated is by end-product inhibition. After the catalysed reaction is complete product molecules may stay tightly bound to the enzyme. Therefore, the enzyme cannot form more of the product than the cell needs. This is an example of negative feedback.

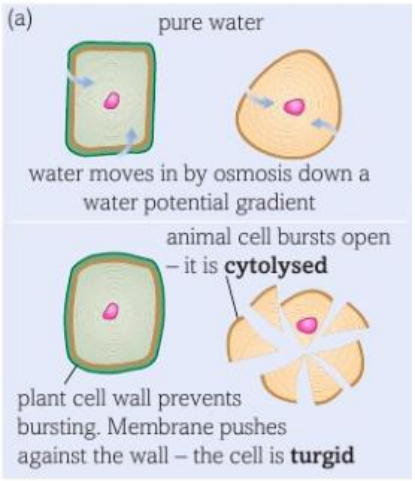
Some enzymes are synthesised and produced in an inactive precursor form. Before they can carry out their function, some amino acids must be removed so their active sites assume the correct shape or are exposed. Many digestive enzymes are produced in this way so they don't digest any of the cell's molecules.

Many metabolic reactions such as photosynthesis and respiration, involve a series of enzyme-catalysed reactions (metabolic pathway):

→ The product of one reaction becomes the substrate for the next reaction.
→ Cells do not need to accumulate too much of the end product so the product of the last reaction in the pathway may attach to a part of the first enzyme in the pathway, but not its active site.
→ This binding prevents the pathway from running, a type of reversible non-competitive inhibition.
→ When the concentration of this product within the cell falls, those molecules will detach from the first enzyme so the metabolic pathway can run again.

Multi-enzyme complexes increase the efficiency of metabolic reactions without increasing substrate concentration as they keep the enzyme and substrate in the same vicinity and reduce





→ the water potential inside cells is lower than that of pure water as there are solutes in solution in the cytoplasm and inside vacuoles
→ when cells are placed in a solution of higher water potential, water molecules move by osmosis down the water potential gradient, across the plasma membrane and into the cell
→ in animal cells, if a lot of water molecules enter, the cell will swell and burst as the plasma membrane breaks (cytolysis)
→ in plant cells, the rigid cellulose wall will prevent bursting; the cell swells up and becomes turgid (turgidity supports plants)
→ when cells are placed in a solution of lower water potential, water leaves the cells by osmosis
→ animal cells shrivel and are described as crenated
→ the cytoplasm of plant cells shrinks and the membrane pulls away from the cellulose cell wall; the cells are plasmolysed
→ plant tissue with plasmolysed cells are described as flaccid
→ plasmolysed cells become dehydrated and their metabolism cannot proceed as their enzyme-catalysed reactions need to be in solution

→ Active transport - the movement of substances against their concentration gradient, using ATP and protein carriers.
→ Endocytosis - bulk transport of molecules too large to pass through a cell membrane, into a cell.
→ Exocytosis - bulk transport of molecules too large to pass through a cell membrane, out of a cell.

Sometimes cells need to move substances against their concentration gradient. This requires energy, provided by hydrolysis of ATP. Cells or organelles may also need to accumulate more of a particular ion than they could do by simple/facilitated diffusion alone.

Integumentary system	Skin, hair, nails	Waterproofing, protection, temperature regulation
Musculo-skeletal system	Skeleton, skeletal muscles	Support, protection, movement
Immune system	Bone marrow, thymus gland, skin, stomach acid, blood	Protection against pathogens
Nervous system	Brain, spinal cord, nerves	Communication, control, coordination
Endocrine system	Glands that make hormones	Communication, control, coordination
Reproductive system	Testes, penis, ovaries, uterus, vagina	Reproduction
Lymph system	Lymph nodes and vessels	Transports fluid back to the circulatory system and important in resisting infections

→ Stem cell - unspecialised cell able to express all its genes and divide by mitosis.

Stem cells:

→ undifferentiated cells capable of becoming any type of cell in the organism
→ pluripotent
→ able to express all their genes
→ can divide by mitosis and provide more cells that can then differentiate into specialised cells for growth and repair

Sources of stem cells:

→ embryonic stem cells – present in an early embryo formed when the zygote begins to divide
→ umbilical cord blood
→ adult stem cells – found in developed tissue such as blood, brain, bone etc. amongst differentiated cells; they act like a repair system because they are a renewing source of undifferentiated stem cells
→ induced pluripotent stem cells – developed in labs by reprogramming differentiated cells to switch on certain genes to become undifferentiated

Potential uses:

→ Bone marrow transplants:
  - to treat blood diseases and immune diseases
  - to restore patient's blood system after cancer treatments where the patient's bone marrow cells can be obtained before treatment, stored and then put back into the patient after treatment

→ Drug research:
  - if stem cells can be made into different types of human tissue then drugs can be tested on these tissues before animal tissues

→ Developmental biology:
  - scientists can study how these cells develop to make particular cell types (e.g. blood) and can learn how each cell type functions and see what goes wrong when they are diseased

- they are trying to find out if they can extend the capacity that embryos have for growth and tissue repair, into later life

→ Repair of damaged tissues or replacement of lost tissues:

- stem cells have been used to treat mice with type 1 diabetes, and research is underway for use in humans
- bone marrow stem cells can be made to develop into liver cells
- stem cells directed to become nerve tissue could be used to treat Alzheimer and Parkinson diseases or repair spinal cord injuries
- stem cells may be used to populate a bioscaffold of an organ and then directed to develop and grow into specific organs for transplanting (regenerative medicine); this could mean there is no need for immunosuppressant drugs
- stem cells may eventually be used to treat conditions such as arthritis, strokes, burns, vision and hearing loss, and heart disease

Exchange Surfaces and Breathing 3.1

→ Surface area to volume ratio - surface area of an organism divided by its volume expressed as a ratio.

In small organisms, the gas exchange can take place over the surface of the body, and they do not need a specialised exchange system. However, in large organisms need a specialised surface for exchange of substances with the environment.
Three main factors that affect need for an exchange system:

→ size
→ surface area to volume ratio
→ level of activity

In small organisms, all the cytoplasm is close to the environment, and diffusion can supply enough oxygen and nutrients to keep the cells alive and active. However, in multicellular organisms the oxygen and nutrients have a longer diffusion pathway. Diffusion is too slow to enable sufficient supple to the innermost cells.

Small organisms have a small surface area but also a small volume. The surface area is relatively larger compared to the volume (large SA:V ratio). This means their surface area is large enough to supple all cells with sufficient oxygen.
Large organisms have a larger surface area but also a larger volume. Volume increases more rapidly than surface area as organisms get bigger, so they have a small SA:V ratio.

Some organisms increase their SA:V ratio e.g. flatworms have a thin flat body. However, such a body form limits the overall size the animal can reach. Most large organisms need a range of tissues to give the body support and strength.

Metabolic activity uses energy from food and required oxygen to release the energy in respiration. The cells of an active organism need a good supply of oxygen to supply energy for movement. Mammals that need to keep themselves warm also require more energy.

Features of a good exchange system:

→ large surface area to provide more space for molecules to pass through, often achieved by folding walls/membranes involved (e.g. root hairs)
→ thin permeable barrier to reduce diffusion distance (e.g. alveoli in lungs)
→ good blood supply that can bring fresh supplies of molecules to the supply side, keeping the concentration high or remove molecules from the demand side to keep the concentration low (important to maintain steep concentration gradient)

→ Alveoli - tiny folds of the lung epithelium to increase the surface area.
→ Bronchi/bronchioles - smaller airways leading into the lungs.
→ Diaphragm - a layer of muscle beneath the lungs.
→ Intercostal muscles - muscles between the ribs. Contraction of the external intercostal muscles raises the ribcage.
→ Trachea - the main airway leading from the back of the mouth to the lungs.
→ Ventilation - the refreshing of the air from the lungs so there is a higher oxygen concentration than in the blood, and a lower carbon dioxide concentration.

Pathogens have a life cycle:

→ travel from one host to another (transmission)
→ enter host's tissues
→ reproduce
→ leave host's tissues

Pathogens can be transmitted between animals in many ways. The most common is direct transmission.

Means of transmission	Factors that affect transmission
Direct physical contact e.g. touching an infected person or contaminated surfaces. Examples: HIV, meningitis, ringworm, athlete's foot.	Hygiene: washing hands regularly, keeping surfaces clean, disinfecting cuts, sterilising surgical instruments, using condoms.
Faecal-oral transmission, usually by eating/drinking water contaminated by the pathogen. Examples: cholera, food poisoning.	Treatment of waste water and drinking water, thorough washing of fresh food, careful preparation of food.
Droplet infection, where the pathogen is carried in water droplets in the air. Examples: tuberculosis, influenza.	Cover mouth when coughing/sneezing, using a tissue and ensuring it is disposed of correctly.
Transmission by spores carried in the air or on surfaces. Examples: anthrax, tetanus.	Use of a mask, washing skin after contact with soil.

Other factors that affect transmission include social factors:

→ overcrowding – many people living and sleeping together in one house
→ poor ventilation
→ poor health
→ poor diet
→ homelessness
→ living/working with people migrated from areas where disease is more common

Some pathogens are transmitted indirectly via a vector. For example, transmission of malaria:

→ person with malaria
→ gametes of Plasmodium in blood
→ female Anopheles mosquito sucks blood
→ Plasmodium develops and migrates to a mosquito's salivary glands
→ uninfected person is bitten
→ Plasmodium migrates to liver
→ Plasmodium migrates to blood

Plant pathogens can also be spread by direct and indirect means. Many pathogens are present in soil and infect plants by entering the roots. Many fungi produce spores to reproduce. These spores may be carried in the wind (airborne transmission). Once a pathogen is inside the plant it can infect the vascular tissue. Pathogens in leaves are distributed when leaves are shed and carry the pathogen to infect another plant. Pathogens that enter fruit and seeds are also distributed (with the seeds). Indirect transmission of plant pathogens often occurs as a result of insect attack. Spores or bacteria become attached to a burrowing insect which attacks an infected plant. When the insect attacks another plant, the pathogen is transmitted. The insect acts as a vector.

Activation of the specific B and T cells is called clonal selection. This leads to the production of antibodies that can combat the specific pathogen and memory cells that will provide long-term immunity. The series of events is stimulated by chemicals called cytokines.

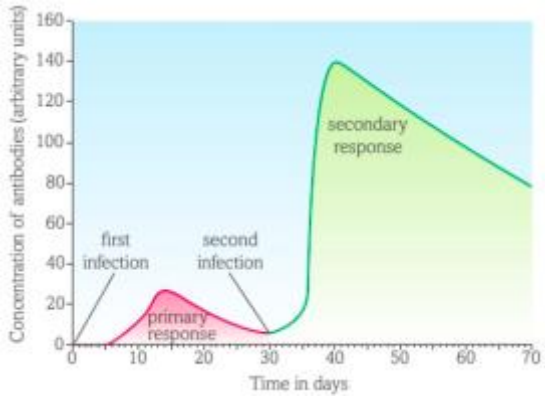
- → Antibodies – specific proteins released by plasma cells that can attach to pathogenic antigens.
- → B memory cells – cells that remain in the blood for a long time, providing long term immunity.
- → Clonal expansion – an increase in the number of cells by mitotic cell division.
- → Interleukins – signalling molecules used to communicate between different white blood cells.
- → Plasma cells – derived from the B lymphocytes, cells that manufacture antibodies.
- → T helper cells – cells that release signalling molecules to stimulate the immune response.
- → T killer cells – cells that attack our own body cells that are infected by a pathogen.
- → T memory cells – cells that remain in the blood for a long time, providing long term immunity.
- → T regulator cells – cells involved with inhibiting or ending the immune response.

The specific immune response involves B and T lymphocytes. These are white blood cells with a large nucleus and specialised receptors on their plasma membranes. The immune response produces antibodies. These neutralise the foreign antigens. The immune response also provides long-term protection from the disease. It produces memory cells that stay in the blood for decades.

cell. In this case, the opsonin bound to the antigen renders the antigen useless (neutralisation).

→ Agglutinins – as each antibody has two identical binding sites it can crosslink pathogens. By using each binding site to bind a different pathogen the antibodies crosslink pathogens into a clump which is non-infective and easily phagocytosed.

→ Anti-toxins – some antibodies bind to molecules released by pathogenic cells. These molecules may be toxic and the action of anti-toxins makes them harmless.



Antibodies are produced in response to infection. When an infection is first detected, the immune system starts to produce antibodies but it takes days before there are enough to combat the infection. This is the primary immune response. Once the pathogens have been dealt with, the number of antibodies in the blood drops rapidly. Antibodies do not stay in the blood. If the body is infected a second time by the same pathogen, the antibodies must be made again, however there will be B and T memory cells in the blood that recognise the antigens, and the immune system can produce antibodies more rapidly so the concentration rises sooner and reaches a higher total. This is the secondary immune response. It is quick enough to prevent symptoms.

→ Active immunity – where the immune system is activated and manufactures its own antibodies.

→ Passive immunity – immunity achieved when antibodies are passed to the individual through breast feeding or injection.

→ Artificial immunity – immunity achieved as a result of medical intervention.

→ Natural immunity – immunity achieved through normal life processes.

→ Epidemic – rapid spread of disease through a high proportion of the population

→ Vaccination – way of stimulating an immune response so immunity is achieved.

Vaccination provides immunity to diseases by deliberate exposure to harmless antigenic material. It is usually injected. The immune system treats the antigenic material as a real disease, and the immune system is activated and manufactures antibodies and memory cells. The antigenic material can take a variety of forms:

→ whole, live microorganism (smallpox)

→ harmless or attenuated (weakened) pathogen (measles)

→ dead pathogen (cholera)

→ preparation of the antigens from a pathogen (hepatitis B)

→ a toxoid (harmless version of a toxin) (tetanus)

Herd vaccination is using a vaccine to provide immunity to almost all the population at risk. Once enough people are immune, the disease can no longer be spread and ‘herd immunity’ is achieved. It is essential to vaccinate almost all the population.

→ Research into disease-causing mechanisms – pharmaceutical companies are researching the way microorganisms cause disease. Many use receptors on plasma membranes, e.g. HIV binds to receptors on the surface of T helper cells. If the binding between the pathogen and receptor site can be blocked, the disease-causing pathogen cannot gain access to the cell. The glycoprotein receptor molecules can be isolated and sequenced. Once the amino acid sequence is known, molecular modelling can be used to determine the shape of the receptor. A drug must be found to mimic the shape of the receptor and could be used to bind to the virus, blocking it from entering the T helper cell.

→ Personalised medicine – it is possible to screen the genomes of plants or microorganisms to identify potential medicinal compounds from the DNA sequences. Once the technology has developed, it may be possible to sequence the genes from individuals with a particular condition and develop specific drugs.

→ Synthetic biology – the development of new molecules that mimic biological systems is one form. Another is to design and construct new devices and systems that may be useful in research or healthcare. For example, developing tomatoes with anthocyanin pigment, an antioxidant that helps protect against coronary heart disease.

→ Antibiotic use and abuse – overuse and misuse of antibiotics have enabled microorganisms to develop resistance. Many current antibiotics have limited effectiveness as a result. Some bacteria such as MRSA are known for their resistance to a range of antibiotics.

→ A Tullgren funnel is a device for collecting small animals from leaf litter. You place leaf litter in a funnel and a light above the litter drives the animals downwards as it dries out and warms up. They fall through the mesh screen to be collected in a jar.
→ A light trap can be used to attract insects in the dark; they fly towards the light and eventually fall into the collecting vessel under the light that contains alcohol.

Small animals can be trapped and population estimates calculated. Small mammals can be trapped using a Longworth trap. This is a humane trap and enables population size to be calculated using the mark-and-recapture technique.

→ capture a sample of animals
→ mark each individual in some way; the number captured is C1
→ release marked animals and leave traps for another period of time
→ the number captured on the second occasion is C2
→ the number of already marked animals captured on the second occasion is C3
→ total population = (C1 x C2) / C3

However the estimate can be affected by animals that learn the trap is harmless and contains food, or animals who do not like the experience and avoid traps after the first capture.

→ Allele/gene variant – version of a gene.
→ Locus – position of a gene on a chromosome.
→ Polymorphic gene locus – a locus that has more than two alleles.
→ Simpson's index of biodiversity – a measure of the diversity of a habitat.
→ Species evenness – measure of how evenly represented the species are.
→ Species richness – measure of how many different species are present.

Species evenness is a measure of the relative numbers or abundance of individuals in each species. A habitat in which there are even numbers of individuals in each species is likely to be more diverse than one in which individuals of one species outnumber all others.

Species richness can be measured by counting all the species present in the habitat. To measure species evenness, you need to carry out a quantitative survey. Once a full quantitative survey has been carried out the data can be used to calculate biodiversity.

To survey the frequency of plants, record % cover of each plant species. To measure density of animals in a habitat, calculate how many animals of each species there are per unit area of the habitat. To measure population of small animals such as insects in living in the soil, the only way is to use handfuls of soil and sift through it. To sample in water you can use a net, and sift through the mud at the bottom.

Simpson's index of diversity is a measure of the diversity of a habitat. It takes into account species richness and species evenness. It is calculated by:
$D = 1 - [\sum(n/N)^2]$
where n is the number of individuals of a species (or % cover for plants) and N is the total number of all individuals of all species (or total % cover).
A high value indicates a diverse habitat. Here, a small change to the environment may affect one species. If this species is only a small part of the habitat, the total number of individuals affected is small therefore the effect on the habitat is small. The habitat tends to be more stable and able to withstand change.