Cells, Exchange and Transport

Cells

(a) state the resolution and magnification that can be achieved by a light microscope, a transmission electron microscope and a scanning electron microscope;

	Resolution	**Magnification**
Light microscope	200nm	x1,500
Transmission Electron Microscope	0.1nm	x500,000
Scanning Electron Microscope	0.1nm	X100,000

(b) explain the difference between magnification and resolution;

Magnification is the degree to which the size of an image is larger than the image itself.

Resolution is the degree to which it is possible to distinguish between two objects that are very close together.

(c) explain the need for staining samples for use in light microscopy and electron microscopy;

A lot of biological material inside a cell isn't coloured, so it might be difficult to distinguish between different features. Coloured stains are used to stain specimens for use with the light microscope. Chemicals which bind to other chemicals on, or in, the specimen, which allows the specimen be to seen. Some chemicals bind to specific structures, such as Acetic orcein staining DNA red.

Electron micrographs start off black and white, with the colour being added by a specialised computer program afterwards.

(d) calculate the linear magnification of an image;

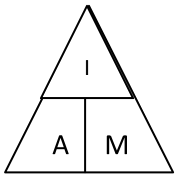


Image size =Actual size x Magnification

(e) describe and interpret drawings and photographs of eukaryotic cells as seen under an electron microscope and be able to recognise the following structures:

Nucleus,

Larges organelle.

Nucleolus,

Dense, spherical structure inside nucleus

Nuclear envelope,

Surrounds the nucleus

Rough and smooth endoplasmic reticulum (ER),

Continuous with the nuclear envelope. RER is studded with ribosomes, SER is not.

Golgi apparatus,

Stack of membrane-bound flattened sacs

Ribosomes,

Tiny. Some are in the cytoplasm and some are bound to the RER

Mitochondria,

Spherical or sausage shaped. Double membrane.

Lysosomes,

Spherical sacs. Single membrane.

Chloroplasts,

Only in plant cells. Two membranes. Contain Thylakoids.

Plasma (cell surface) membrane,

Phospholipid bilayer

Centrioles,

Small tubes of protein fibres. Pair of them next to Nucleus in Animal cells.

Flagella and cilia;

Hair-like extensions projecting from the surface of a cell.

(f) *outline the functions of the structures listed in (e);*

Nucleus,

Houses all of the cell's genetic material in the form of DNA, which contains the instructions for protein synthesis.

Nucleolus,

Makes ribosomes and RNA which pass into the cytoplasm and are used in protein synthesis

Nuclear envelope,

A double membrane with nuclear pores.

Rough endoplasmic reticulum,

Transports proteins made by the attached ribosomes.

Smooth endoplasmic reticulum (ER),

Involved in the making of lipids.

Golgi apparatus,

Modifies proteins received from the Rough ER and then packages them into vesicles so they can be transported.

Ribosomes,

Site of protein synthesis.

Mitochondria,

Where ATP is made.

Lysosomes,

Contain digestive enzymes that are used to break down material

Chloroplasts,

Site of photosynthesis in plant cells.

Plasma (cell surface) membrane,

Controls the entry and exit of substances into and out of the cell.

Centrioles,

Form the spindle which moves chromosomes during cell division.

Flagella and cilia;

Move by ATP. E.g. wave mucus along trachea or make sperm swim.

(f) *outline the interrelationship between the organelles involved in the production and secretion of proteins (no detail of protein synthesis is required);*

1. **The gene containing the instructions for the production of the hormones is copied onto a piece of mRNA**
2. **mRNA leaves the nucleus through the nuclear pore.**
3. **mRNA attaches to a ribosome**
4. **Ribosome reads the instruction to assemble the protein**
5. **Molecules are 'pinched off' in vesicles and travel towards the Golgi Apparatus**
6. **Vesicle fuses with Golgi Apparatus**
7. **Golgi apparatus processes and packages the molecules, ready for release**
8. **The molecules are 'pinched off' in vesicles from the Golgi Apparatus and move towards the cell surface membrane**
9. **Vesicles fuse with the cell surface membrane**
10. **Cell surface membrane opens to release molecules outside**

(g) *explain the importance of the cytoskeleton in providing mechanical strength to cells, aiding transport within cells and enabling cell movement;*

The cytoplasm contains a network of two kinds of proteins fibres which keep the cell's shape stable by providing an internal framework. The types of protein fibres are:

- **Microfilaments (small solid strands made of actin, 7nm diameter)**
- **Microtubules (protein cylinders made of tubulin molecules, 25nm diameter)**

Their functions include:

- **Supporting organelles**
- **Strenghtening the cell and maintaining cell shape**
- **Transporting materials within in the cell (e.g. the spindle during mitosis)**
- **Cell movement (cilia and flagella)**

Microtubules do not move, but they provide an anchor for protein to move along. E.g. kinesin attaches one end to an organelle and the other end to a microtubule. Using ATP it 'swivels', pushing the organelle along. The head then reattaches itself to the microtubule and the process is repeated.

Flagella and cilia are each made from a cylinder containing 9 microtubules. Flagella move with the aid of the protein, Dynein. When a molecule of dyneine 'swivels' it pulls one microtubule past the next, causing the cilium to bend.

Cilia move out of time with each other to create a 'wave'

(h) compare and contrast, with the aid of diagrams and electron micrographs, the structure of prokaryotic cells and eukaryotic cells;

Prokaryotic cells do not have a nucleus. They are bacteria and are much smaller than Eukaryotic cells. They have:

- **One membrane**
- **No membrane-bound organelles**
- **Cell wall made of peptidoglycan not cellulose**
- **Their ribosomes are smaller**
- **Circular DNA**
- **DNA is not surrounded by a membrane.**
- **ATP production takes place in specialised infolded regions of the cell surface membrane**
- **Some have Flagella**

(i) Compare and contrast, with the aid of diagrams and electron micrographs, the structure and ultrastructure of plant cells and animal cells.

Plant cells have a cell wall. This is outside the cell surface membrane and it made of cellulose, which forms a sieve-like network of strands which make the cell wall strong. This is kept rigid by the pressure of the fluid inside the cell, so supports the cell and therefore the entire plant.

Plant cells also contain a Vacuole. This maintains the cell stability by making the cell turgid as it increases the pressure inside the cell. This in turn helps support the plant.

Cells, Exchange and Transport

Cell Membranes

(a) outline the roles of membranes within cells and at the surface of cells;

- **Separate cell contents from the outside environment**
- **Separate cell components from the outside environment**
- **Cell recognition and signalling**
- **Holding the components of some metabolic pathways in place**
- **Regulating the transport of materials into or out of cells**

(b) state that **plasma (cell surface) membranes are partially permeable barriers***;*

(c) describe, with the aid of diagrams, the fluid mosaic model of membrane structure;

A bilayer of phospholipid molecules forms the main structure. Various proteins are studded in the bilayer. Some are partially embedded (extrinsic) whereas some completely span the membrane (intrinsic)

(d) describe the roles of the components of the cell membrane;

Phospholipids,

Have a hydrophobic head and a fatty acid tail. They form a bilayer separating the cell from the outside. They are fluid so components can move around freely. They are permeable to small and/or non-polar molecules, but impermeable to large molecules and ions.

Cholesterol,

Gives the membranes mechanical stability by sitting between fatty acid tails and therefore making the barrier more complete, preventing molecules like water and ions from passing through the membrane.

Glycolipids,

Phosopholipid molecules that have a carbohydrate part attached. They are used for cell signalling, cell surface antigens and cell adhesion.

Proteins

Channel proteins allow the movement of some substances, such as the large molecule sugar, into and out of the cell as they can't travel directly through the cell surface membrane

Carrier proteins actively move substances across the cell surface membrane.

Glycoproteins;

Phospholipid molecules with a protein attached. Same functions as glycolipids.

(e) outline the effect of changing temperature on membrane structure and permeability;

Increasing the temperature means that the molecules have more kinetic energy. This increased movement makes the membrane leaky, so molecules which would not normally do so can move into and out of the cell.

(f) explain the term cell signalling;

Process that leads to communication and coordination between cells, e.g. hormones binding to their receptors on the cell surface membrane

(g) explain the role of membrane-bound receptors as sites where hormones and drugs can bind;

Hormones are used in cell signalling. The Target Cells have a receptor which is complementary to the hormone, meaning that it can bind to the receptor cells, triggering the desired internal response.

Drugs have also been developed which bind to the receptor molecules on cells. Beta-blockers are used to prevent a muscle from increasing the heart rate to a dangerous level, and some drugs used to treat schizophrenia mimic a natural neurotransmitter which some individuals cannot produce.

(h) explain what is meant by

Passive transport (diffusion and facilitated diffusion including the role of membrane proteins),

Passive transport is the transport of a molecule without using energy. Diffusion is the net movement of molecules from a region of high concentration of the molecule to an area of lower concentration of the molecule down a concentration gradient.

Large and charged molecules need to be transported across the phospholipid bilayer, they can't just diffuse across. They travel either through channel proteins, which are shaped to allow only one molecule through and are often gated, or carrier proteins, whose shape can fit a specific molecule, and they then change shape to allow the molecule through to the other side of the membrane.

Active transport

The movement of molecules or ions across membranes, using ATP to drive 'protein pumps' within the membrane

Endocytosis

When large quantities of a material are brought into the cell. Uses ATP.

Exocytosis;

When large quantites of a material are moved out of the cell. Uses ATP.

*(i) explain what is meant by osmosis, in terms of water potential. (***No*** calculations of water potential will be required);*

The movement of water molecules from a region of higher water potential to a region of lower water potential across a partially permeable membrane

(i) recognise and explain the effects that solutions of different water potentials can have upon plant and animal cells

Type of cell	**Pure water (high water potential)**	**Solution with a v –ive water potential**
Animal	Water moves in. Cell bursts-haemolysed	Water moves out. Cell is crenated
Plant	Water moves in. Cell is tugid	Water moves out. Cell is plasmolysed.

Cell Division, Cell Diversity and Cellular Organisation

(a) state that **mitosis occupies only a small percentage of the cell cycle and that the remaining percentage includes the copying and checking of genetic information;**

(b) describe, with the aid of diagrams and photographs, the main stages of mitosis (behaviour of the chromosomes, nuclear envelope, cell membrane and centrioles);

- **In Interphase (Pre-Mitosis):**
  - **The DNA replicates.**
- **In Prophase:**
  - **The chromosomes supercoil & become visible under a light microscope.**
  - **The nuclear envelope breaks down.**
  - **The centriole divides in two and move to opposite ends of the cell to form a spindle.**
- **In Metaphase:**
  - **The chromosomes like up along the middle of the cell.**
  - **They attach to a spindle thread by their centromere.**
- **In Anaphase:**
  - **The replicated sister chromatides are separated when the centromere splits.**
  - **The spindle fibres shorten, pulling the chromatids apart.**
- **In Telophase:**
  - **As the separated sister Chromatids reach the poles of the cells.**
  - **A new nuclear envelope forms around each set.**
  - **The spindle breaks down.**
  - **The Chromosomes uncoil so they are no longer visible under a light microscope.**
- **In Cytokinesis (Post-mitosis):**
  - **The whole cell splits to down two new cells, each one identical to each other and to the parent cell.**

(b) explain the meaning of the term homologous pair of chromosomes;

Chromosomes that have the same genes at the same loci. Members of a homologous pair of chromosomes pair up during meiosis. Diploid organisms produced by sexual reproduction have homologous pairs of choromosomes- one member of each pair from the mother and one from the father.

(c) explain the significance of mitosis for growth, repair and asexual reproduction in plants and animals;

Growth- multicellular organisms produce new extra cells to grow. Each new cell is genetically identical to the parents cell, and so can perform the same function

Repair- damaged cells need to be replaced by new ones that perform the same functions and so need to the genetically identical to the parent cell, as with growth.

Asexual reproduction- single celled organisms divide to produce two daughter cells that are separate organisms. Some multicellular organisms produce offspring from parts of the parent.

(d) outline, with the aid of diagrams and photographs, the process of cell division by budding in yeast;

Yeast cells undergo cytokinesis by producing a small 'bud' that nips of the cell, a process called budding.

(f) state that **cells produced as a result of meiosis are not genetically identical** *(details of meiosis are not required);*

(g) define the term stem cell;

Undifferentiated cells that are capable of becoming differentiated to a number of possible cell types.

(h) define the term differentiation, with reference to the production of erythrocytes (red blood cells) and neutrophils derived from stem cells in bone marrow, and the production of xylem vessels and phloem sieve tubes from cambium;

The changes occurring in the cells of a multicellular organism so that each different type of cell becomes specialised to perform a specific function.

Erythrocytes and neutrophils both originate as undifferentiated stem cells in bone marrow. The cells destined to become erythrocytes lose their nucleus, golgi apparatus and rough endoplasmic reticulum. They are filled with haemoglobin, the shape of the cell changes to become a biconclave disc so that it is capable of transporting oxygen from the lungs to tissues.

The cells destined to become neutrophils keep their nucleus; a huge number of lysosomes are produced, so their cytoplasm appears granular. The lysosomes contain enzymes so that the neutrophil can ingest invading microorganisms.

Xylem and phloem both come from meristem cells.

In xylem, the meristem cells elongate and the walls become elongated and waterproofed by deposits of lignin, which kills the cell contents. The ends of the cell break down so they become long tubes with wide lumen. They are suited to transporting water and minerals up the plant, and also support the plant.

In the phloem, the cells also elongate, but their ends do not break down completely, but form sieve plates between the cells. Next to each sieve plate is a companion cell which is very metabolically active and used in moving the products of photosynthesis up and down the plant.

Cells, Exchange and Transport

(i) describe and explain, with the aid of diagrams and photographs, how cells of multicellular organisms are specialised for particular functions, with reference to

erythrocytes (red blood cells),

Biconclave disc shape to maximise surface area

No nucleus = more room for haemoglobin

neutrophils,

Flexible shape to engulf foreign particles or pathogens

Many lysosomes contain digestive enzymes to break down the engulfed particles

epithelial cells,

Some have cilia to move particles

Some have mnicrovilli to increase surface area

sperm cells,

Organelle content

Many mitochondria to generate energy for movement of undulipodium

Specialised lysosome in sperm head which contains an enzyme specialised to break down the egg wall

Shape

Very small, long and thin to help in easing their movement

Undulipodium to move

Content

Nucleus contains half to number of chromosomes of an adult cell in order to fulfil its role as a gamete.

palisade cells,

Contain chloroplasts to absorb light

Thin walls so that Carbon dioxide can diffuse in

root hair cells

Hair like projections to increase surface area to absorb water and minerals from the soil.

guard cells;

Thin outer wall, thick inner wall.

In light they absorb water to become turgid and allow exchange of gases.

(j) explain the meaning of the terms

tissue,

A group of similar cells that perform a particular function

organ

A collection of tissues that work together to form a specific overall function or set of functions within a multicellular organ

organ system

A number of organs working together to form a life function

(k) explain, with the aid of diagrams and photographs, how cells are organised into tissues, using squamous and ciliated epithelia, xylem and phloem as examples;

There are four main types of animal tissue:

- **Epithelial tissue**
  - **Layers and linings**
- **Connective tissues**
  - **Hold structures together and provide support**
- **Muscle tissue**
  - **Cells specialised to contract and move parts of the body**
- **Nervous tissue**
  - **Cells that convert stimuli to electrical impulses and conduct those impulses.**

Within these main types, there are smaller groups of tissues

Squamous epithelial tissue

- **Flattened cells that form a thin, smooth, flat surface.**
- **Line the insides of tubes such as blood vessels**
- **Also form thin walls**
  - **Alveoli**
- **Held in place by basement membrane**
  - **Made of collagen and glycoproteins**
  - **Secreted by epithelial calls**

Ciliated epithelial tissue

- **Column- shaped**
- **Exposed surface covered with cilia**
- **Move in synchronised waves**
- **Found on surface of tubes (e.g. bronchi, oviduct)**
- **Waft mucus in lungs, egg in oviduct**

Xylem

- **Composed of xylem vessel cells and parenchyma cells**
- **Parenchyma cells fill the gaps between xylem vessels to provide support**

Phloem

- **Comprises of sieve tubes and companion cells**
- **Companion cells are highly metabolically active, moving products of photosynthesis up and down the phloem.**

(l) discuss the importance of cooperation between cells, tissues, organs and organ systems

Movement: the muscular and skeletal system must work together for movement to take place, but this can only happen if the nervous system 'instructs' muscles to coordinate their actions. As muscles and nerves work, they use energy, so they require a supply of nutrients and oxygen from the circulatory system, which in turn receives the chemicals from the digestive and ventilation systems.

Exchange Surfaces and Breathing

(a) explain, in terms of surface area:volume ratio, why multicellular organisms need specialised exchange surfaces and single-celled organisms do not;

Organisms need to absorb certain substances, (e.g. oxygen, glucose, proteins, fats, water and minerals) from the surrounding environment and remove waste products (carbon dioxide, oxygen and other wastes).

Single celled organisms have a large surface-area-to-volume ratio so they can exchange the necessary gases, nutrients and wastes.

Multicellular organisms not only need more supplies as they have more cells, but they also have a smaller surface-area-to-volume ratio, meaning that the outer surface is not large enough to enable gases and nutrients to enter the body fast enough to keep all of the cells alive.

Nutrients and gases also have to travel a larger distance to the centre of the organism.

So, larger organisms need a large area to exchange more substances, so often they combine this with a transport system to move substances around the body.

(b) describe the features of an efficient exchange surface, with reference to diffusion of oxygen and carbon dioxide across an alveolus;

- **Large surface area to provide more space for molecules to pass through**
- **Thin barrier to reduce the diffusion distance**
- **Fresh supply of molecules on one side to maintain the diffusion gradient**
  - **Carbon dioxide is brought in the blood to the lungs. The concentration is higher in the blood than in the alveoli, so it diffuses across.**
  - **Breathing fills the lungs with air, so there is more oxygen in the alveolus than in the blood**
- **Removal of required molecules on the other side to maintain the steep diffusion gradient**
  - **Blood carries oxygen away from the lungs**
  - **Breathing removes Carbon Dioxide from the lungs**

(c) describe the features of the mammalian lung that adapt it to efficient gaseous exchange;

- **Many, many alveoli meaning that the total surface area is about 70m^2.**
- **Alveolus wall is one cell thick**
- **Capillary wall is one cell thick**
- **Both walls consist of squamous cells**
- **Capillaries in close contact with the alveolus wall**
- **Narrow capillaries**
  - **Red blood cells are closer to the capillary wall**
    - **Closer to air in the alveoli**
  - **Reducing the rate at which the red blood cells flow past in the blood**
- **Total barrier is only two flattened cells, or 1µm thick**

(d) describe, with the aid of diagrams and photographs, the distribution of cartilage, ciliated epithelium, goblet cells, smooth muscle and elastic fibres in the trachea, bronchi, bronchioles and alveoli of the mammalian gaseous exchange system;

- **The trachea and bronchi have a similar structure, but the bronchi are narrower than the trachea**
  - **Thick walls made of several layers of tissue**
  - **Much of the wall consists of cartilage**
    - **Regular C-rings in the trachea**
    - **Less regular in the bronchi**
  - **On the inside surface of the cartilage is a layer of glandular tissue, connective tissue, elastic fibres, smooth muscle and blood vessels**
  - **The inner layer is an epithelium layer than has two types of cells. Most of the cells are ciliated epithelium, and there are goblet cells amongst them**
- **Bronchioles**
  - **Much narrower than the bronchi**
  - **Larger bronchioles have some cartilage, but the smaller ones don't.**
  - **The wall is made mostly of smooth muscle and elastic fibres**
- **Alveoli**
  - **Wall is one cell thick**
  - **100-300µm diameter**
  - **Good blood supply**

(e) describe the functions of

cartilage,

Structure.

Holds the trachea and bronchi open

Prevents collapse when the air pressure is low during inhalation

cilia,

Move in a synchronised pattern to waft mucus up the airway to the back of the throat. Once there, the mucus is swallowed and the acidity of the stomach will kill any bacteria

goblet cells,

Secrete mucus.

Traps tiny particles from the air

Reduces risk of infection

smooth muscle

Can contract to restrict airway

Prevents harmful substances from reaching the alveoli

elastic fibres

Reverses the effect of the smooth muscle

When the smooth muscle constricts it deforms the elastic fibres. As the smooth muscle relaxes, the elastic fibres recoil to their original size and shape, helping to dilate the airway

in the mammalian gaseous exchange system;

(f) outline the mechanism of breathing (inspiration and expiration) in mammals, with reference to the function of the rib cage, intercostal muscles and diaphragm;

Inspiration

1. **Diaphragm contracts to becoming flatter, pushing digestive muscles down**
2. **External intercostal muscles contract to raise ribs**
3. **Volume of chest cavity increases**
4. **Pressure in chest cavity drops below atmospheric pressure**
5. **Air moves into lungs**

Expiration

1. **Diaphragm relaxes and is pushed up by displaced organs underneath**
2. **External intercostal muscles relax and ribs fall**
3. **Volume of chest cavity decreases**
4. **Pressure in lungs increases and rises about atmospheric pressure**
5. **Air moves out of lungs**

(g) explain the meanings of the terms

tidal volume

The volume of air moved in and out of the lungs during breathing when at rest

vital capacity

The largest volume of air that can be moved into and out of the lungs in any one breath

(g) describe how a spirometer can be used to measure

A spirometer consists of a chamber filled with oxygen floating on a tank of water. A person breaths from a mouthpiece attached to a tube connected to the oxygen tank. Breathing in takes oxygen from the chamber so it sinks down, and breathing out pushing air back into the chamber which floats up. The movements of the chamber is recorded using a datalogger.

vital capacity,

Asking a person to breathe in and out as much as they can

tidal volume,

Asking a person to breathe normally

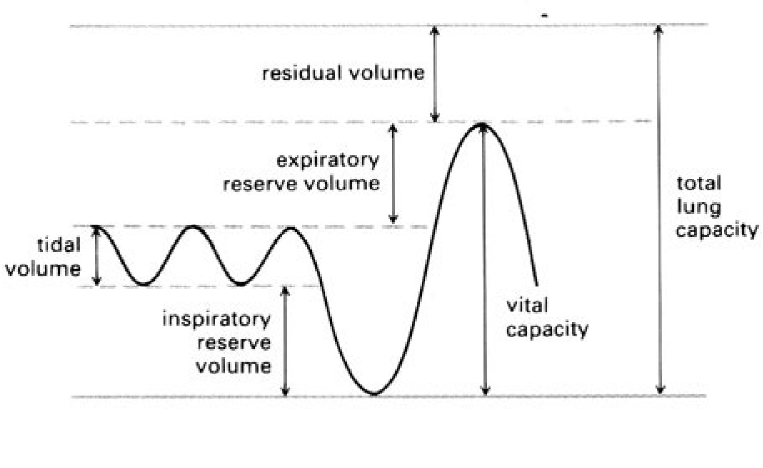
breathing rate

Asking a person to breathe normally, and then dividing the number of breathes by the time in minutes to calculate the number of breaths per minute

oxygen uptake;

Divide (the amount of oxygen (dm^3) times 60) by the time taken in seconds.

(i) analyse and interpret data from a spirometer.



Cells, Exchange and Transport

Transport in Animals

(a) *explain the need for transport systems in multicellular animals in terms of*

size,

Once an animal has several layers of cells any oxygen or nutrients diffusing in form the outside will be used up by the other layers of cells and the cells deeper in the body will not get any oxygen or nutrients.

level of activity

If an animal is very active then it will need a good supply of nutrients and oxygen to supply the energy for movement.

surface area:volume ratio;

To allow animals to grow to a large size, it needs a range of tissues and structural support to give the body strength. Their volume increases as the body gets thicker, but the surface area does not increase as much. So the surface-area-to-volume ratio of a large animal is relatively small. Larger animals do not have a large enough surface area to supply all of the oxygen and nutrients that they need.

(b) *explain the meaning of the terms*

single circulatory system

A circulation in which the blood flows through the heart once during each circulation of the body e.g. fish

double circulatory system

A circulation in which the blood flows through the heart twice during each complete circulation of the body e.g. mammals

with reference to the circulatory systems of fish and mammals;

(c) *explain the meaning of the terms*

Open circulatory system

The blood is not always in vessels

e.g. insects

Closed circulatory system,

The blood is always in vessels

e.g. fish

with reference to the circulatory systems of insects and fish;

(d) *describe, with the aid of diagrams and photographs, the external and internal structure of the mammalian heart;*

External

The largest parts of the heart are the ventricles. Above the ventricles les the atria which are much smaller. The coronary arteries lie over the surface of the heart and carry oxygenated blood to the heart muscle.

At the top of the heart are the veins that carry blood to the heart, and arteries that carry blood away from the heard.

Internal

Divided into four chambers.

The two upper chambers are atria which receive blood from the major veins (deoxygenated blood from the body flows into right atrium from the vena cava, and oxygenated blood flows from the lungs into the left atrium).

The two lower chambers are the ventricles. They are separated from each other by the septum and from the atria by the atrioventricular valves which prevent the blood from flowing the wrong way. These are attached to tendinous cords which prevent the valves from turning inside out.

(e) *explain, with the aid of diagrams, the differences in the thickness of the walls of the different chambers of the heart in terms of their functions;*

The walls of the atria are very thin. They do not need to create much pressure are they are only pushing the blood into the ventricles

The walls of the right ventricle are thicker than the atria as only need to pump blood to the lungs. The blood vessels of the lungs are also very thin, so they would burst of the blood was under too much pressure.

The walls of the left ventricle are two or three times thicker than the right as the blood is pumped around the entire body and so needs to be under high pressure.

(f) describe the cardiac cycle, with reference to the action of the valves in the heart;

1. **When both the atria and the ventricles are relaxed, blood flows into the atria from the major veins.**
2. **The blood flows through the atrioventricular valves into the ventricles**
3. **The atria contract simultaneously, pushing blood into the ventricles**
4. **Blood fills the atrioventricular valve, causing them to snap shut and preventing the blood from flowing back into the ventricles**
5. **When the pressure in the arteries is higher than the pressure in the ventricles, the semilunar valves shut**
6. **The walls of the ventricles contract, starting from the bottom**
7. **When the pressure in the ventricles is higher than the pressure in the arteries, the semilunar valves is pushed open and blood is pushed out of the heart. The contraction only lasts for a short time**
8. **The ventricles relax**
9. **When the pressure in the ventricles drops to below that of the atria, the atrioventricular valves open again**
10. **When the pressure in the ventricles drops to below that of the arteries, the semilunar vavles shut again**

(g) describe how heart action is coordinated with reference to the sinoatrial node (SAN), the atrioventricular node (AVN) and the Purkyne tissue;

The SAN is the pacemaker, situated at the top of the right atrium. The SAN initiates a wave of excitation at regular intervals.
The wave of excitation quickly travels over the walls of both atria. As it passes, it causes the muscle cells to contract.
At the base of the atria is a disc of tissue that cannot conduct the electrical impulse, so the only route through to the ventricles is via the AVN, which is at the top of the septum.
The excitation is delayed here to allow for the atria to finish contracting and for the blood to flow into the ventricles.
The wave is then passes away from the AVN down specialised conduction tissue known as Purkyne tissue.
At the base of the septum, the wave of excitation spreads out over the walls of the ventricles.
As the excitation spreads upwards from the apex, the muscles contract, pushing blood up to the major arteries at the top of the heart

(h) interpret and explain electrocardiogram (ECG) traces, with reference to normal and abnormal heart activity;

(i) describe, with the aid of diagrams and photographs, the structures and functions of

arteries,

Carry blood at high pressure, so artery wall must be able to withstand the pressure
Relatively small lumen to maintain pressure
Relatively thick wall containing collagen to give it strength to withstand high pressure
The wall contains elastic tissue that allows the wall to stretch and then recoil when the heart pumps-this is a pulse. The recoil maintains the high pressure when the heart relaxes
The wall contains smooth muscle that can contract and constrict the artery.
The endothelium is folded and can unfold when the artery stretches.

veins

Carry blood at low pressure so the walls do not need to be thick
Lumen is relatively large to ease the flow of blood
The walls have thinner layers of collagen, smooth muscle and elastic tissue. They do not need to stretch and recoil and are not actively constricted to reduce blood flow.
Contain valves to prevent blood flowing in the wrong direction. As the walls are thin, the vein can be flattened by the action of the surrounding skeletal muscles. Pressure is applied to the blood, forcing it to move along in the direction dictated by the valves.

capillaries;

Walls consist of a single layer of flattened endothelial cells that reduces the diffusion distance for the materials being exchanged
The lumen is the same diameter as a red blood cell (about 7µm). This ensures that the red blood cells are squeezed as they pass along the capillaries. The diffusion distance is shorter, so they are more likely to give up their oxygen

(j) *explain the differences between blood, tissue fluid and lymph;*

Feature	***Blood***	***Tissue Fluid***	***Lymph***
Cells	**Erythrocytes, Leucocytes and platelets**	**Some phagocytic white blood cells**	**Lymphocytes**
Proteins	**Hormones and plasma proteins**	**Some hormones, proteins secreted by body cells**	**Some proteins**
Fats	**Some transported as lipoproteins**	**None**	**More than in blood**
Glucose	**80-120mg per 100cm^3**	**Less**	**Less**
Amino acids	**More**	**Less**	**Less**
Oxygen	**More**	**Less**	**Less**
Carbon dioxide	**Little**	**More**	**More**

(k) *describe how tissue fluid is formed from plasma;*

At the arterial end of a capillary, the blood is under high pressure due to contractions of the heart (hydrostatic pressure). It will tend to push the blood fluid out of the capillaries. It can leave through tiny gaps in the capillary wall. The fluid consists of plasma with dissolved nutrients and oxygen.

(l) *describe the role of haemoglobin in carrying oxygen and carbon dioxide;*

Oxygen

Haemoglobin consists of four subunits. Each subunit consists of a polypeptide and a haem group. The haem group contains one iron ion, Fe^{2+}. Because the iron ion attracts oxygen, it is said to have an affinity for it. A molecule of haemoglobin, and therefore a red blood cell, can hold four molecules of oxygen.

Haemoglobin can take up oxygen in a way that produces an S-shaped curve. This is called the <u>Oxygen Dissociation Curve</u>. At a low oxygen tension the haemoglobin does not readily take up oxygen. This is because it is difficult for the oxygen molecule to reach the haem group, due to it being in the centre of the blood cell.

When the oxygen tension rises, the diffusion gradient into the haemoglobin molecule steeply rises. Once one molecule of oxygen has associated with a haem group, the shape of the haemoglobin molecule slightly changes, making it easier for the second the third molecules of associate. The change in the shape is known as the 'conformational change'.

But, once the haemoglobin molecule contains three oxygen molecules, it is difficult for the forth to associate with the last haem group. This means that it is difficult to achieve 100% saturation, even at high oxygen pressures. A consequence of this is that the curve levels off again, meaning that the graph is S-shaped.

Carbon Dioxide

5% dissolves in the plasma

10% combines with haemoglobin to form carbaminohaemoglobin

85% is transported as hydrogencarbonate ions

As Carbon dioxide diffuses into the blood, some of it enters the red blood cells and combines with water to form carbonic acid, catalysed by carbonic anhydrase.

$CO_2 + H_2O \rightarrow H_2CO_3$

This carbonic acid then dissociates to form Hydrogen ions and Hydrogencarbonate ions

$H_2CO_3 \rightarrow H^+ + HCO_3^-$

The Hydrogencarbonate ions diffuse out of the red blood cell. The charge in the red blood cell is maintained by the <u>Chloride Shift</u>; the movement for Chloride ions into the cell.

Hydrogen ions could cause the contents of the cell to become very acidic, so the haemoglobin acts as a buffer. They oxyhaemoglobin dissociates, and the hydrogen ions are taken up by the haemoglobin to form haemoglobonic acid.

(m) *describe and explain the significance of the dissociation curves of adult oxyhaemoglobin at different carbon dioxide levels (the Bohr effect);* `

When tissues are respiring more, there will be more carbon dioxide, and therefore more Hydrogen ions. This means that more oxygen will be released from oxyhaemoglobin into the tissues. So, when more carbon dioxide is present, the oxyhaemoglobin dissociation curve shifts down and to the right.

(n) *explain the significance of the different affinities of fetal haemoglobin and adult haemoglobin for oxygen*

Fetal haemoglobin has a higher affinity for oxygen than the haemoglobin of its mother. This is because the fetal haemoglobin must be able to 'pick up' oxygen from the haemoglobin from its mother. This reduces the oxygen tension within the blood fluid, so the maternal blood release oxygen.

The oxyhaemoglobin dissociation curve for fetal haemoglobin is to the left of the curve for adult haemoglobin.

Transport in Plants

(a) *explain the need for transport systems in multicellular plants in terms of size and surface area:volume ratio;*

All living things need to take substances from, and return wastes to, the environment. Every cell of a multicellular plant needs a regular supply of water and nutrients. In large plants, the epithelial cells could gain all they need by simple diffusion, as they are close to the supply. But there are many cells inside the plant which are further from the supply, and would not receive enough water or nutrients to survive.
One particular problem is that roots can obtain water but not sugarsds, and leaves can produce sugars but cannot obtain enough water from the air.

(b) *describe, with the aid of diagrams and photographs, the distribution of xylem and phloem tissue in roots, stems and leaves of dicotyledonous plants;*

Roots

In roots, the xylem is arranged in an X shape, with the phloem found between the arms of the xylem.

Stem

In the stem, the vascular bundles are found around the outside of the stem in a ring shape. They xylem is on the inside, with the phloem on the outside and they are separated by a layer of cambium, a layer of meristem cells which can divide to produce new xylem and phloem.

Leaves

They xylem is on top of the phloem in the 'veins' of a leaf

(c) *describe, with the aid of diagrams and photographs, the structure and function of xylem vessels, sieve tube elements and companion cells;*

Xylem vessels

Long, thick walls that have been impregnated by ligin. As the xylem develops, the ligin waterproofs the walls of the cell. Consequently, the cells die and their end walls and contents break down. This leaves a long column of collow, dead cells. The ligin strengthens the walls and prevents the vessel from collapsing- the vessels stay open even when water is in short supply.
The thickening of the ligin forms patters on the cell walls. This prevents the vessel from becoming too rigid and allows the stem or branch to be flexible.
In some places the lignification is not complete. Pits or Bordered Pits, like pores in the walls, are left which allow water to leave the vessel to either join another vessel of pass into the living parts of the cell.

Sieve Tube elements

They are not true cells as they contain very little cytoplasm and no nucleus. They are lined up end to end to form a tube in which sugars (usually in the form of sucrose) are transported. At intervals, there are sieve plates- cross walls which are perforated, which are at intervals down the tube. Sieve tubes have very thin walls and are five or six sided.

Companion cells

These are between the sieve tubes. They have a dense cytoplasm, a large nucleus and many mitochondria to produse ATP for active processes. They use ATP as a source of energy to load sucrose into the phloem. There are many plasmodesmata between the companion cells and they sieve tube, which are gaps in the cell walls allowing communication and flow of minerals between the cells.

(d) *define the term transpiration;*

The loss of water vapour from the aerial parts of a plant due to evaporation

(e) *explain why transpiration is a consequence of gaseous exchange;*

For the exchange of gases to occur, the stomata of plants must be open. This is an easy route by which water can be lost.
To reduce this, plants have many structural and behavioural adaptations

A waxy cuticle waterproofs the leaf preventing water loss through the epidermis
The stomata are often on the underside of leaves, to reduce evaporation due to direct heating
Most stomata close at night- there is no light, so no photosynthesis can occur, so no need for gaseous exchange
Deciduous plants lose their leaves in winter when temperatures are too low for photosynthesis, and the ground may be frozen, so less water is available, meaning that plants have to conserve what they've got.

(f) describe the factors that affect transpiration rate;

Number of leaves

More leaves = large surface area which water can be lost from

Number, size and position of stomata

If leaves have many, large stomata water vapour is lost more quickly

If the stomata are on the lower surface, water loss is slower

Presence of cuticle

A waxy cuticle prevents water loss from the leaf surface

Light

In light, the stomata open to allow gaseous exchange for photosynthesis

Temperature

Higher temperature will increase the rate of water loss

Increase the rate of evaporation

Increase the rate of diffusion as the water molecules have more kinetic energy

Decrease the relative water vapour potential in the air, causing the rapid diffusion of molecules out of the leaf

Relative humidity

Higher relative humidity in the air will decrease the rate of water loss. This is because there will be a smaller water potential gradient between the air spaces in the leaf and the air outside.

Air movement or wind

Air moving outside the leaf will carry water vapour away from the leaf. This will maintain a high water potential gradient

Water availability

If there is little water in the soil, plants cannot replace water lost, so water loss has to be reduce by closing the stomata, or shedding leaves in winter

(g) describe, with the aid of diagrams, how a potometer is used to estimate transpiration rates;

1. **Cut healthy shoot underwater to stop air entering xylem**
2. **Cut shoot at a slant to increase surface area**
3. **Ensure apparatus is full of water and that there is only the desired air bubble**
4. **Insert shoot into apparatus underwater**
5. **Remove potometer form water and ensure it is airtight around the shoot**
6. **Dry leaves**
7. **Keep conditions constant to allow shoot to acclimatise**
8. **Shut screw clip**
9. **Keep scale fixed and record position of air bubble**
10. **Start timing and measure distance moved per unit of time.**

*(h) explain, in terms of water potential, the movement of water between plant cells, and between plant cells and their environment. (**No** calculations involving water potential will be set);*

Between plant cells

Water passes from the cell with the higher (less negative) water potential to the cell with the lower (more negative) water potential.

Between plant cells and their environment

Water moves down the water potential gradient. If the water potential inside the cell is greater than the water potential outside the cell, water will move out of the cell by osmosis and vice versa.

(i) describe, with the aid of diagrams, the pathway by which water is transported from the root cortex to the air surrounding the leaves, with reference to the; casparian strip, apoplast pathway, symplast pathway, xylem, stomata;

Water enters the root hair cells by osmosis. At the same time, minerals are actively pumped from the root cortex into the xylem. The consequence of this is that water moves from the root hair cell along the symplast pathway to follow the xylem. The symplast pathway is where water enters the cytoplasm and travels through the plasodesma (gaps in the cell wall that contain fine strands of cytoplasm). Water can move through the continuous strand of cytoplasm from cell to cell. Water can also travel via the apoplast pathway, where water travels between the cell walls without passing through any plasma membranes. The Casparian strip blocks the apoplast pathway between the cortex and the xylem meaning that, to reach to xylem, the water must join the symplast pathway.

When water reaches the top of the xylem, it enters the leaves, and leaves the leaves through the stomata

(j) explain the mechanism by which water is transported from the root cortex to the air surrounding the leaves, with reference to

adhesion,

Water molecules in the xylem form hydrogen bonds with the walls of the xylem vessel. Because the xylem vessels are narrow, the hydrogen bonds can pull the water up the sides of the vessel

Cohesion and the transpiration stream

Water molecules are attracted to each other by the forces of cohesion. These forces are strong enough to hold the molecules together in a long chain. As molecules are lost from the top, the whole column is pulled up as one chain. This is the transpiration stream

(k) describe, with the aid of diagrams and photographs, how the leaves of some xerophytes are adapted to reduce water loss by transpiration;

Smaller leaves- reduced surface area, so less water is lost by transpiration

Densely packed spongy mesophyll- Reduced cell surface area is exposed to the air spaces.

Thicker waxy cuticle

Closing the stomata when water availability is low

Hairs on the surface of the leaf- trap a layer of air close to the surface which can become saturated with moisture and so will reduce the diffusion of water out of the stomata as the water vapour potential is low.

Stomata in pits- as above

Rolling the leaves so that the lower epidermis is not exposed to the atmosphere- as above

Low water potential inside cells- water potential gradient between the cells and the air space is reduced.

(l) explain translocation as an energy-requiring process transporting assimilates, especially sucrose, between sources (eg leaves) and sinks (eg roots, meristem);

The source is where the sugars come from, and the sink is where they go to.

Sugar is made in the leaves, so they are the source, and transported to the roots, so they are the sink

In early spring, the leaves need energy to grow, so they sugars are transported from the roots (now the source) to the leaves (now the sink)

(m) describe, with the aid of diagrams, the mechanism of transport in phloem involving:

Active loading at the source and removal at the sink,

1. **ATP is used by companion cells to actively transport protons out of the their cytoplasm and into the surrounding tissue**
2. **This sets up a diffusion gradient and the hydrogen ions diffuse back into the cells**
3. **This is done through co transporter proteins which enable hydrogen ions to bring sucrose back into the cell with them**
4. **As the concentration of sucrose molecules builds up, they diffuse into the sieve tube elements through the plasmodesmata**
5. **The entrance of sucrose into the sieve tube elements reduces the water potential.**
6. **Water follows by osmosis and increases the hydrostatic pressure in the sieve tube element**
7. **Water moves down the sieve tube element from higher hydrostatic pressure at the source, to lower hydrostatic pressure at the sink.**
8. **Sucrose moves, via either diffusion or active transport, from the sieve tubes to the surrounding cells.**
9. **This increases the water potential in the sieve tube element, so water molecules move into the surrounding cells by osmosis**
10. **This reduces the hydrostatic pressure at the sink**

The evidence for and against this mechanism

For

We know that the phloem is used

Supply the plant with radioactively labelled Carbon Dioxide (for photosynthesis), and the labelled CO_2 soon appears in the phloem

Ringing a tree to remove the phloem results in sugars collecting above the ring

An aphid feeding on a plant stem can be used to show that the mouthparts are taking food from the phloem

We know that it needs ATP

Many mitochondria in the companion cells

Translocation can be stopped by using a metabolic poison that inhibits the formation of ATP

The rate of flow of sugars is too fast for it to be done by diffusion alone, so energy must be needed to drive the flow

We know that it uses this mechanism

The pH of the companion cells is higher than that of the surrounding cells (H^+ ions actively pumped out)

The concentration of sucrose is higher in the source than in the sink

Against

Not all solutes in the phloem sap move at the same rate

Sucrose is moves to all parts of the plant at the same rate, rather than more quickly to areas with a low concentration

The role of sieve plates is unclear