Active Biology - student worksheets for VCE Biology Units 3 & 4 contains the following worksheets (including answer sheets)

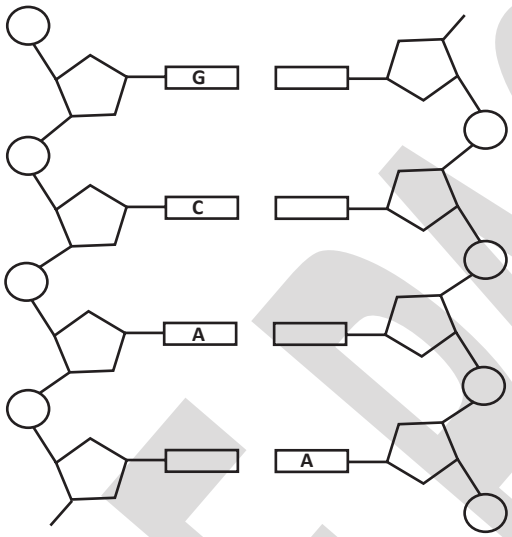
NUCLEIC ACIDS

1. DNA, or deoxyribonucleic acid, is a 'polymer'. What does this mean?

_____

_____

2. The following diagram shows part of a DNA molecule. It is unlabelled and not quite complete.



(a) Using two different colours, shade *and* label (i) the 'phosphate' part of each nucleotide (ii) the 'sugar' part of each nucleotide.

(b) Colour-code the four different types of nitrogen-containing bases and fill in any missing letters.

(c) Add hydrogen bonds (correct number) between each pair of complementary bases.

(d) Circle one complete nucleotide.

(e) For each chain, indicate the *5 prime* (5') and *3 prime* (3') end.

3. The two chains in a DNA molecule are said to run 'anti-parallel'. What does this mean?

_____

4. The two chains in a DNA molecule are actually arranged to form a double-helical structure, rather like a twisted rope ladder. In the space provided below, draw a simple diagram of a DNA double helix.

DNA double helix

(a) Which part of the double-stranded DNA molecule forms the 'rungs' of the ladder?

_____

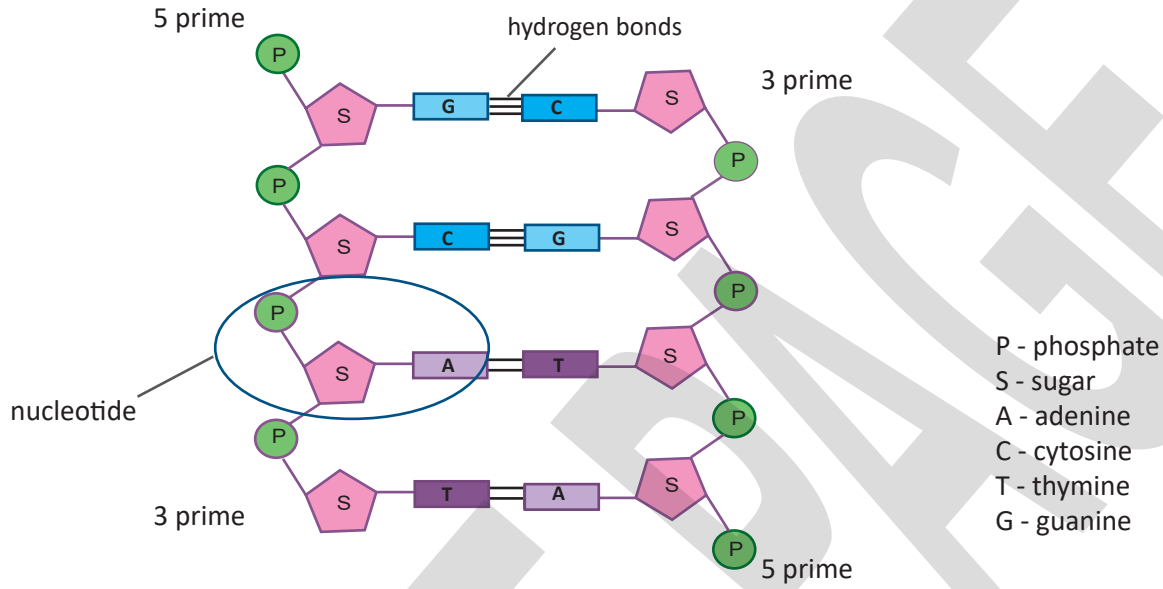
(b) Which part of the double-stranded DNA molecule forms the 'side rails' of the ladder?

_____

NUCLEIC ACIDS
(answers)

1. Being a *polymer* means that DNA is made up of similar sub-units called 'monomers'.

2.



(a) See above diagram.

(b) See above diagram.

(c) See above diagram.

(d) See above diagram.

(e) See above diagram.

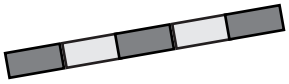
3. The two chains running 'anti-parallel' means that they run in opposite directions; one chain runs from the *5 prime* to *3 prime* end, while the other runs from *3 prime* to *5 prime*.

4.

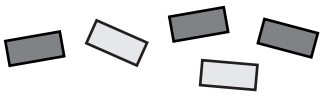
DNA double helix

(a) The nitrogen-containing bases form the 'rungs' of the ladder.

(b) The sugar-phosphate backbones form the 'side rails' of the ladder.



ALTERNATIVE SPLICING



1. What is meant by 'alternative splicing'?

_____

_____

2. What are the two ways in which alternative splicing can occur?

_____

MODELLING ALTERNATIVE SPLICING (activity)

MATERIALS: plasticine in four different colours, sharp pencil.

Part A

1. Cut 12 small rectangular pieces of plasticine in two different colours, with six pieces representing EXONS and six representing INTRONS

2. Number your introns and exons **1** - **6** by using the pencil to punch small holes into each piece.

3. Arrange all 12 pieces of plasticine to model a piece of pre-mRNA with 6 exons and 6 introns. This is your **base pre-mRNA** strand.

4. Use plasticine in two other colours to create a *cap* and a *poly-A tail.*

Part B

1. From your **base pre-mRNA** strand, remove all introns and then create four different, *complete* **mRNA** strands by:

    (a) removing exon 5
    (b) removing exons 2 and 6
    (c) removing exons 1, 2 and 4
    (d) removing exons 2, 3 and 5

2. Draw diagrams of your complete mRNA strands.

3. Use your **base pre-mRNA** strand to model INTRON RETENTION, where certain introns are retained rather than being cut out of the pre-mRNA. Create three different, *complete* mRNA strands of your own, removing some of the exons and retaining some of the introns. Draw diagrams of each of your mRNA strands.

The discovery of alternative splicing had profound implications in the science of genetics. How did it change what we believe about the way genes work?

_____

_____

_____

ALTERNATIVE SPLICING (answers)

1. Alternative splicing is a process in which genes are regulated so that they are able to produce more than one protein.

2. *Exon juggling* and *intron retention*.

MODELLING ALTERNATIVE SPLICING (activity)

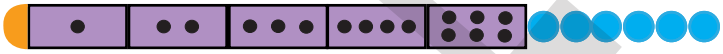
Part A

Base pre-mRNA strand (colours may vary):

 exon  intron

Cap:  Poly-A tail:  (shapes/colours may vary)

Part B

1. (a) 

(b) 

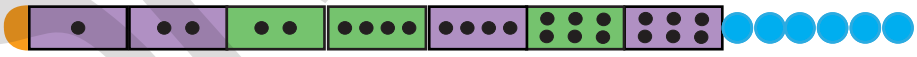
(c) 

(d) 

2. See diagrams 1 (a) - (d) above.

3. Student answers may vary. Examples of mRNA created as a result of intron retention could include:

(i) 
(remove exons 2, 4, 5 & introns 1, 4 - 6)

(ii) 
(remove exons 3, 5 & introns 1, 3 and 5)

(iii) 
(remove exons 1, 5 and 6 & introns 1, 3 and 5)

Previously, it was believed that genes produced only one protein each, that is, the 'one gene, one polypeptide concept'. The discovery of alternative splicing changed this thinking, as it became apparent that some genes are able to produce a variety of protein products. Alternative splicing also helps to explain why a relatively small number of genes (approximately 21,000) can account for the total number of different proteins that the human body can make, which scientists estimate could be as many as 2 million.

PHOTOSYNTHESIS IN C_3 AND C_4 PLANTS

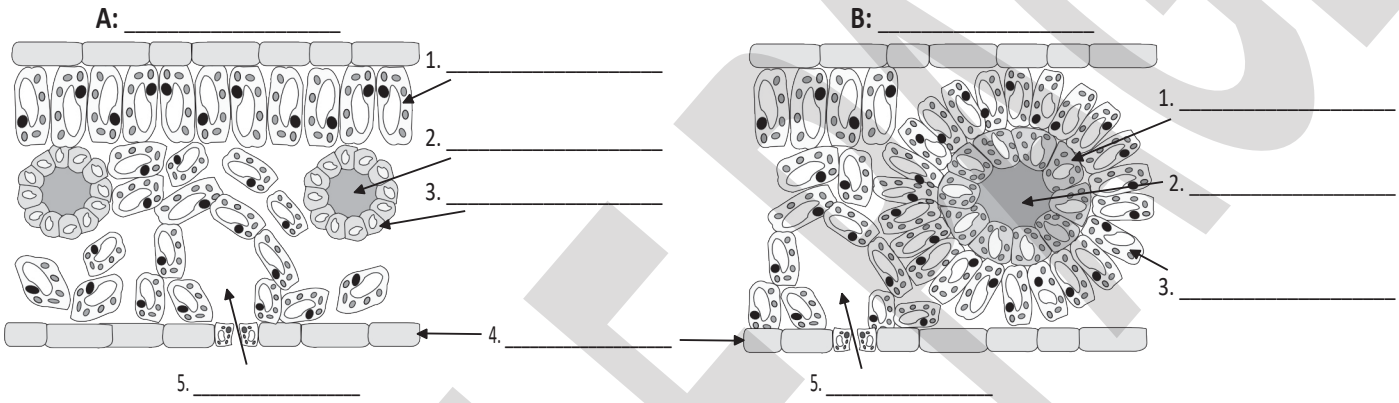
1. In terms of glucose production during photosynthesis, what are two differences between C_3 and C_4 plants?

_____

_____

_____

2. The following diagrams show the structure of a leaf in two different plants. One is a C_3 plant and one is a C_4 plant:



(a) Which plant is which? Indicate this on the diagram.

(b) Label structures **1** - **5** on each diagram.

3. (a) An important enzyme involved in the Calvin cycle of C_3 plants is *Rubisco*. What is its role?

_____

_____

(b) In C_3 plants, Rubisco sometimes binds with the wrong substrate, resulting in the plant carrying out *photorespiration*. What are the consequences of this for the plant?

_____

_____

_____

(c) Explain *why* Rubisco sometimes binds with the wrong substrate.

_____

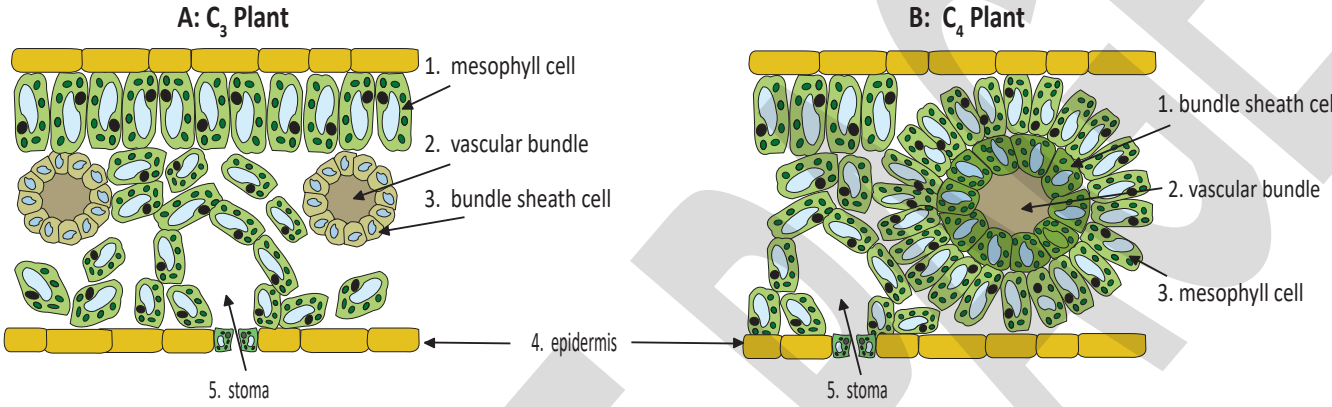
_____

_____

PHOTOSYNTHESIS IN C_3 AND C_4 PLANTS
(answers)

1. In **C_3** plants, the production of glucose in the light-independent stage is a *one-stage* process (the *Calvin cycle*), and it occurs in *mesophyll* cells, while in '**C_4**' plants, production of glucose involves *two* stages, the second of which is the Calvin cycle. In C_4 plants, the Calvin cycle occurs in *bundle sheath* cells.

2.



(a) See above diagram.

(b) See above diagram.

3. (a) Rubisco catalyses the reaction between the acceptor molecule *RuBP* (ribulose biphosphate) and carbon dioxide, allowing it to pick up the CO_2 from the air and bring it into the plant. Rubisco does this by binding to the CO_2, its substrate.

(b) Rubisco sometimes binds to *oxygen* instead of carbon dioxide. When Rubisco binds with oxygen, a process known as *photorespiration* occurs. Photorespiration is a wasteful process and results in less glucose being produced for the plant; instead, energy from the ATP produced during the light-dependent stage of photosynthesis goes into producing carbon dioxide.

(c) Rubisco has an active site that can accommodate both oxygen and carbon dioxide.
Answer should also include one of the following:

(i) When the temperature rises, the solubility of carbon dioxide decreases at a faster rate than that of oxygen, meaning that more oxygen becomes available in the fluid cytosol of plant cells carrying out photosynthesis.

(ii) When conditions become too dry, C_3 plants tend to close their stomata (pores) to prevent water loss, meaning that carbon dioxide can no longer enter the leaf from the air. Any oxygen produced during the light-dependent stage of photosynthesis cannot leave the plant, and so builds up inside the cells. This makes it more likely that Rubisco will bind with oxygen instead of carbon dioxide.

THE LYMPHATIC SYSTEM

1. Fill in the missing words (use words from the list below):

The lymphatic system is a network of special _____ that run throughout the body. One of its main functions is to drain fluid, or _____, that has leaked from _____ _____ into body _____ and return it to the _____.

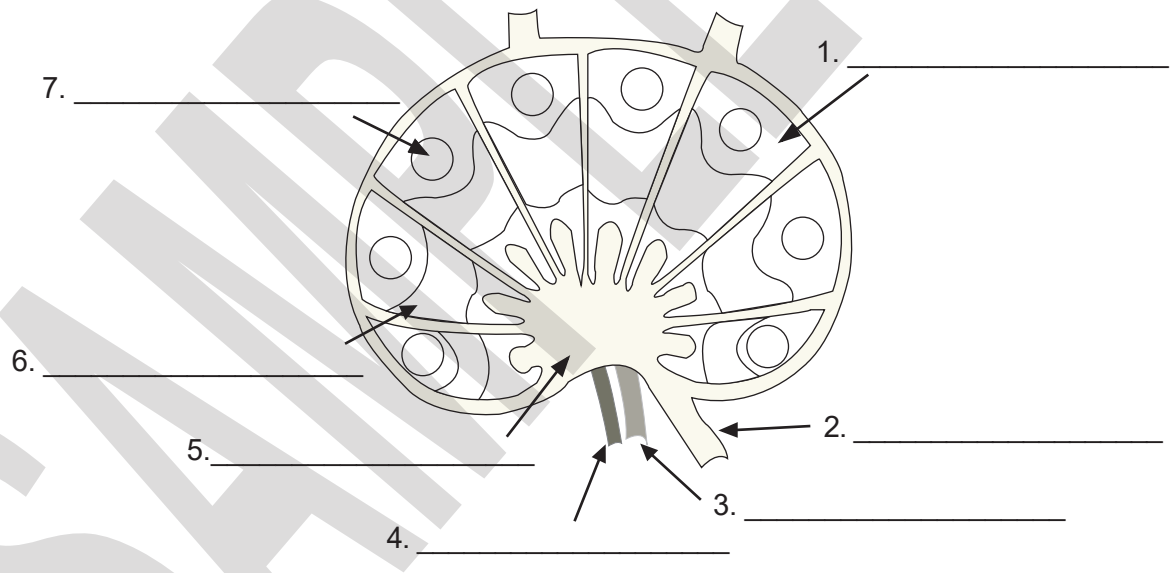
Along the lymphatic system are small, bean-shaped structures known as _____ _____. These contain special white blood cells, known as _____, which can _____ rapidly and release _____ to fight pathogens such as _____ and _____, as well as _____ cells.

Another function of the lymphatic system is to _____ and transport some of the _____ from our diet.

Word list:

viruses - nodes - vessels - antibodies - bloodstream - fats - tubes - bacteria - blood - lymph - absorb - lymphocytes - multiply - lymph - tissues - cancer

2. The following diagram shows the structure of a lymph node:



Key: ♦ B cell ▬ T cell ● dendritic cell ▲ macrophage ✱ plasma cell

(a) Label the structures 1 - 7.

(b) Add colour to the diagram, making sure you use the same colour for all similar parts/structures.

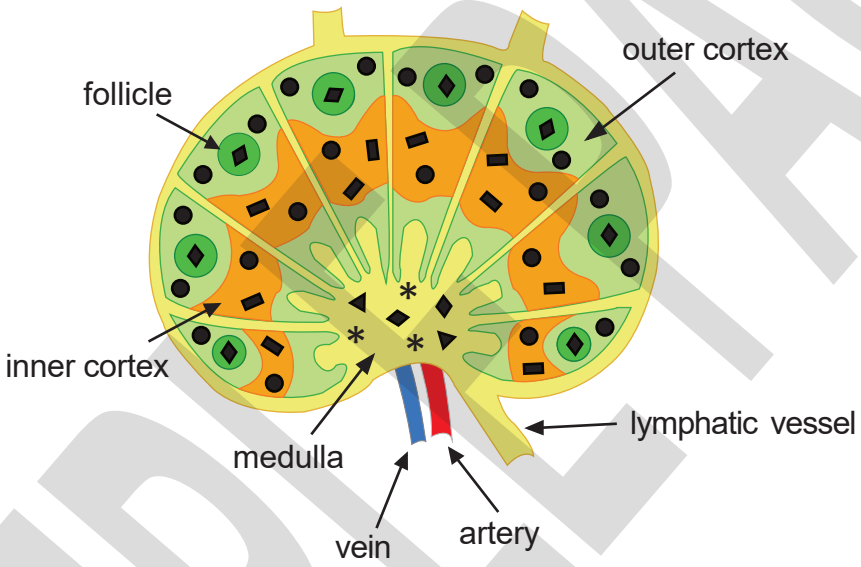
(c) Using the symbols indicated in the key, show where in the lymph node you would find:

(i) B cells (ii) T cells (iii) dendritic cells (iv) macrophages (v) plasma cells.

THE LYMPHATIC SYSTEM
(answers)

1. The lymphatic system is a network of special **tubes** that run throughout the body. One of its main functions is to drain fluid, or **lymph**, that has leaked from **blood vessels** into body **tissues** and return it to the **bloodstream**.
Along the lymphatic system are small, bean-shaped structures known as **lymph nodes**. These contain special white blood cells, known as **lymphocytes**, which can **multiply** rapidly and release **antibodies** to fight pathogens such as **bacteria** and **viruses**, as well as **cancer** cells.
Another function of the lymphatic system is to **absorb** and transport some of the **fats** from our diet.

2.



Key: ♦ B cell ▬ T cell ● dendritic cell ▲ macrophage ✱ plasma cell

3. (a) Bone marrow and thymus.

(b) Lymph nodes and spleen.

(c) The bone marrow and thymus are known as *primary lymphoid organs* because this is where the important B and T cells develop, that is, B cells in the bone marrow and T cells in the thymus. Lymph nodes and the spleen are known as *secondary lymphoid organs* because this is where both B and T cells are activated.

IMMUNOTHERAPY

1. (a) What is meant by 'immunotherapy'? Give two examples of this type of therapy.

_____

_____

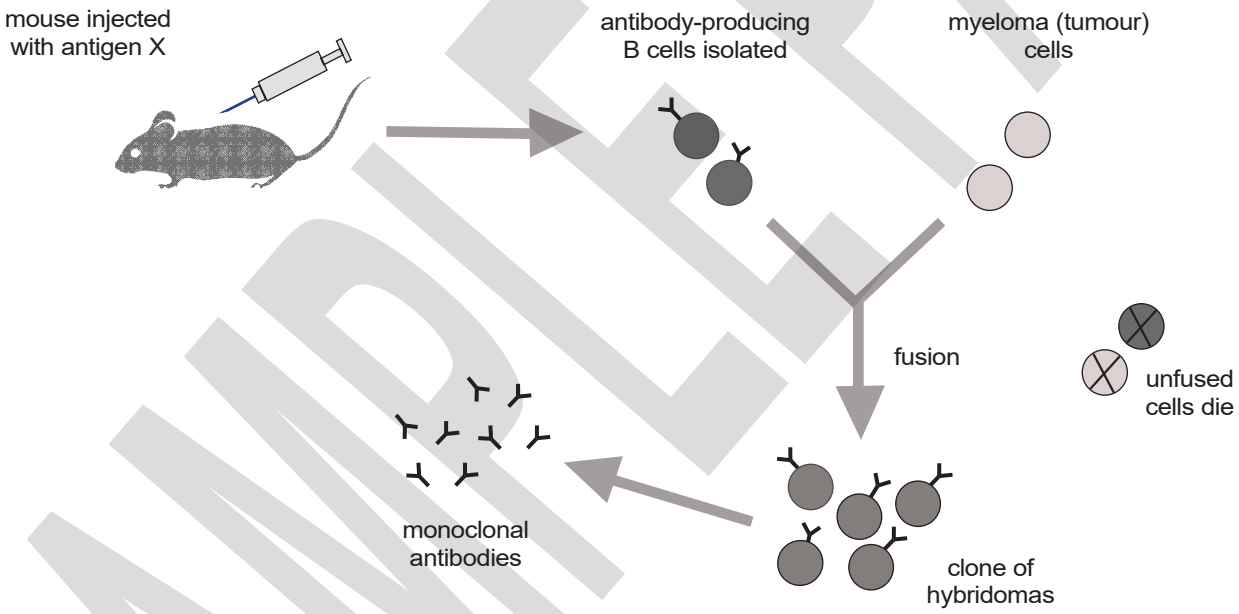
(b) What is involved in *CAR T cell therapy*?

_____

_____

_____

2. The following diagram shows the process involved in making monoclonal antibodies by generating 'hybridomas'. Conduct some Internet research to find out more about this process and answer the questions below.



(a) What are 'monoclonal antibodies' and why are they so named?

_____

_____

_____

_____

(b) What immune response occurs in the mouse after being injected with antigen X?

_____

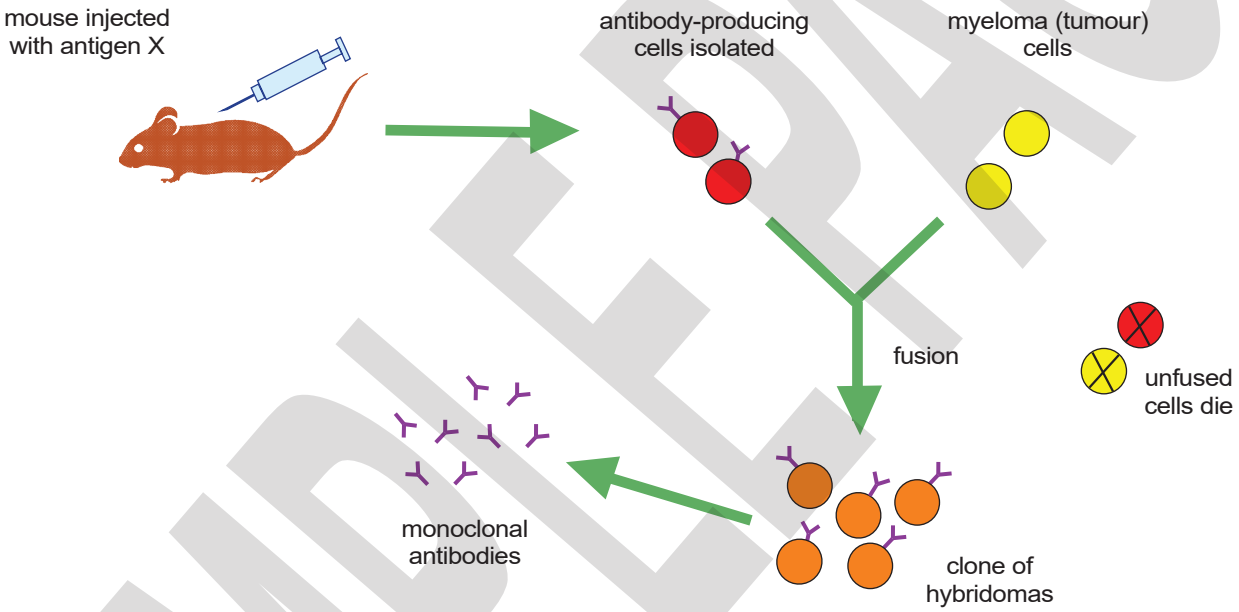
_____

IMMUNOTHERAPY

1. (a) *Immunotherapy* is the treatment or prevention of disease - including cancer, autoimmune disease or allergy - that involves altering the immune system in some way. This may involve stimulating, enhancing or suppressing the immune response. Examples of this type of therapy include (any two of) *checkpoint inhibitors*, *cytokine therapy*, *vaccination*, *CAR T cell therapy* and *monoclonal antibodies*.

   (b) *CAR T cell therapy* involves extracting special T cells from a person's body and making changes to them so that they are able to recognise and attack cancer cells. A gene that codes for a specific antigen receptor is added to the T cell, which then enables it to recognise and target a certain protein on cancer cells.

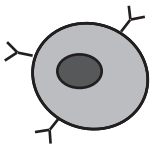
2.



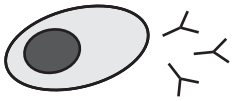
   (a) Monoclonal antibodies are laboratory-made antibodies that are designed and created for use in the treatment of diseases such as cancer and autoimmune disorders. They are described as 'monoclonal' because they are identical copies of *one* type of antibody, and always bind to the same 'epitope' on an antigen (note that an *epitope* is a part of an antigen that is recognised by the antibody; an antigen can have numerous different epitopes).

   (b) After the mouse is injected with antigen X, it starts to produce antibodies to that antigen.

   (c) Antibody-producing cells are fused with myeloma cells because the resulting 'hybridomas' will have both the antibody-producing ability of the B cell and the longevity and reproductivity of the myeloma. This effectively creates 'immortalised' B cells that can be grown continuously in culture, providing a never-ending supply of important monoclonal antibodies.



TYPES OF WHITE BLOOD CELLS



Using a system of colour-coding, match the name of the cells to their correct function:

B lymphocytes

Release histamines during inflammation

Plasma cells

Memory B cells

Destroy intracellular pathogens in 3rd line of defence

Main antigen-presenting cells

T helper cells

Can 'remember' an antigen; involved in cellular immunity

Monocytes

NK cells

Basophils

Release histamines during the allergic response

Suppressor T cells

Differentiate into plasma cells

Neutrophils

Produce cytokines that stimulate B and T cells

Dendritic cells

Mast cells

Differentiate into macrophages

Can 'remember' an antigen; involved in humoral immunity

Memory T cells

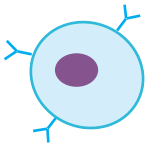
Eliminate pathogens by degranulation

Produce antibodies

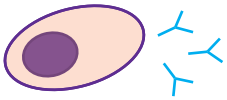
Cytotoxic T cells

Type of phagocytes involved in 2nd line of defence

Limit or stop an immune response



TYPES OF WHITE BLOOD CELLS
(answers)



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Type of phagocytes involved in 2nd line of defence

Limit or stop an immune response

THE COVID 19 VACCINE: HOW IT WORKS

1. The Oxford-AstraZeneca COVID 19 vaccine uses a modified chimpanzee *adenovirus* to carry a gene that codes for the coronavirus 'spike protein' into a cell (this gene has been inserted into the adenovirus).

   (a) What is an 'adenovirus'?

   _____

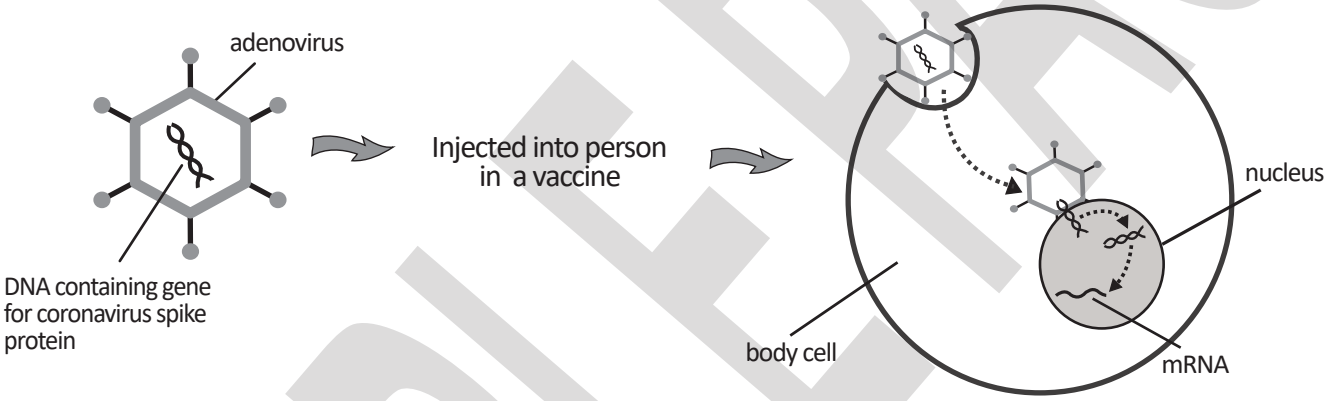
   (b) Why does the adenovirus need to be modified?

   _____

   (c) Where on a coronavirus particle would you find the spike proteins?

   _____

2. The following diagrams show early stages in the workings of the Oxford-AstraZeneca vaccine:



(i) **(ii)**

Once a person receives the vaccine, the adenoviruses make contact with body cells. Look carefully at diagram **(ii)** and describe what happens.

_____

_____

_____

3. The diagram on the right shows the next stage. Explain what is happening.

_____

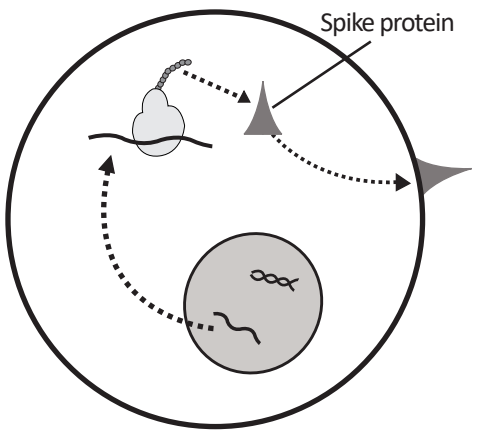
_____

_____

_____

_____

_____



(iii)

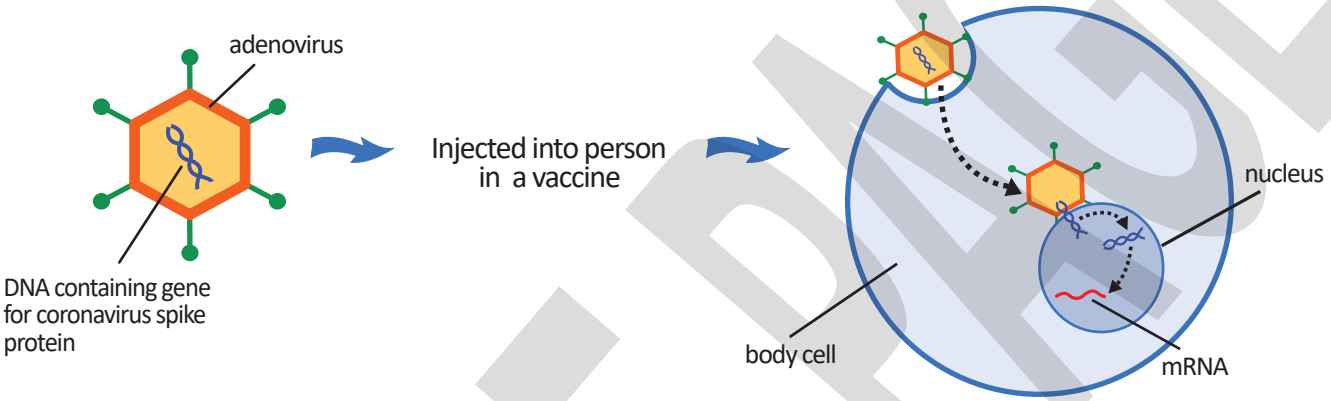
THE COVID 19 VACCINE: HOW IT WORKS
(answers)

1. (a) An 'adenovirus' is a type of DNA virus that tends to cause respiratory disease.

   (b) The adenovirus needs to be modified so that it cannot itself replicate inside the body of the person being vaccinated and cause disease.

   (c) The spike proteins are found on the surface of the coronavirus.

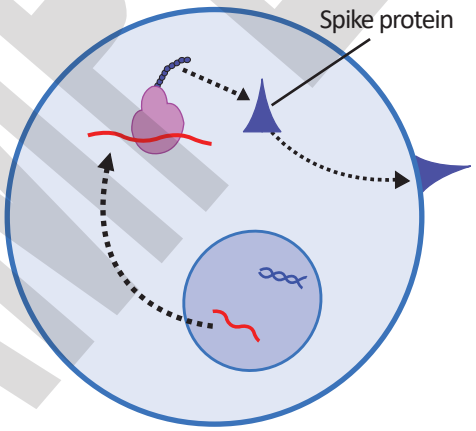
2.



(i) **(ii)**

The diagram shows that the adenovirus carrying the gene for coronavirus spike protein is engulfed by the body cell. It then makes its way towards the nucleus and injects the DNA into it. The gene is then transcribed into mRNA.

3.



(iii)

The mRNA leaves the nucleus and moves into the cytosol. Here, at a ribosome, it is translated into a polypeptide which is then folded into a spike protein. The spike protein migrates to the surface of the cell.

SELECTIVE BREEDING IN DOGS

1. Throughout time, dog breeders have carried out a practice known as 'artificial selection' or 'selective breeding'. What does this mean?

_____

_____

2. The following table shows four popular dog breeds that have been 'created' by humans through selective breeding. Carry out Internet research and complete the last two columns of the table.

NAME	IMAGE	ORIGIN OF BREED	REASON FOR BREEDING
Beagle			
English Bulldog			
Daschund			
Basset Hound			

3. There is evidence to suggest that pure-bred dogs tend to experience more health issues than mixed-breed dogs.

   (a) Choose one of the dog breeds above and describe any associated health issues.

_____

_____

   (b) Explain *why* pure-bred dogs might be more prone to health issues than mixed-breed dogs.

_____

_____

_____

SELECTIVE BREEDING IN DOGS

1. *Artificial selection*, or *selective breeding* is a process whereby breeders are the ones who choose those individuals they wish to become the parents of the next generation; the animals chosen are those that possess certain desirable characteristics.

2.

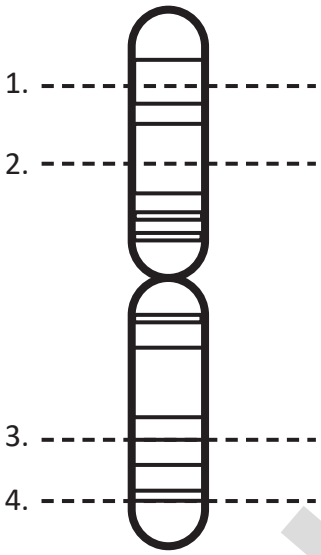
NAME	IMAGE	ORIGIN OF BREED	REASON FOR BREEDING
Beagle		Developed in Great Britain during the 1930s from several breeds, including the Talbot Hound, North Country Beagle and Southern Hound.	Originally bred as hound dogs for hunting small game such as hares and rabbits.
English Bulldog		Originated in the British Isles and believed to be descended from the Asiatic Mastiff and the Pug.	Originally bred for bull baiting. When this practice became illegal, they were bred as a domestic pet.
Daschund		Originally created in Germany by selectively breeding the dwarf gene into taller hunting dogs, including Bloodhounds, Pinschers, Terriers, Hanover Hound and German Bibarhund.	Originally bred to hunt badgers and other burrow-dwelling animals like rabbits.
Basset Hound		Originated in sixth-century France, and thought to be a descendant of the St Hubert Hound, following a genetic mutation.	Originally bred to assist hunters on foot in search of small game such as the hare and rabbit.

3. (a) One of the following:
Beagle: prone to back problems; eye conditions such as glaucoma and cataracts; diabetes; haemophilia, as well as certain neurological problems.
English Bulldog: breathing problems (due to short muzzle); skin problems such as eczema; bone and joint diseases; eye problems such as Cherry Eye; allergies.
Daschund: prone to ruptured vertebral discs (due to their short legs and long back); hip dysplasia; congenital eye problems such as dry eye and cataracts; obesity.
Basset Hound: prone to bleeding disorders; elbow and hip dysplasia; eye problems such as glaucoma; obesity; patella luxation (shifting of kneecap).

(b) Pure-bred dogs tend to be more prone to health issues than mixed-breed dogs because the 'desirable' characteristics chosen by breeders may not necessarily be the ones that would be selected for in the wild, and may in fact be disadvantageous for the species. Also, selective breeding often involves *inbreeding*, that is, mating between direct relatives, potentially increasing the incidence of inherited diseases being passed on to offspring (if, for example, the two chosen parents *both* possess one recessive allele for a disease, their offspring could inherit both copies and be affected).

BLOCK MUTATIONS

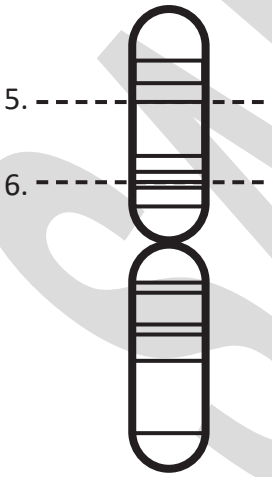
1. Colour in the different segments of chromosomes **A** and **B** as shown on the screen (see next page).
2. Redraw chromosome **A** showing a *duplication* of the segment between lines 1 and 2.
3. Redraw chromosome **A** showing a *deletion* of the segment between lines 3 and 4.
4. Redraw chromosome **B** showing an *inversion* between lines 5 and 6.
5. Draw the chromosomes that would result from a *reciprocal exchange* between the segments 1 - 2 of chromosome **A** and 5 - 6 of chromosome **B**.



Normal Chromosome **A**

Chromosome **A** with duplicated segment

Chromosome **A** with deleted segment



Normal Chromosome **B**

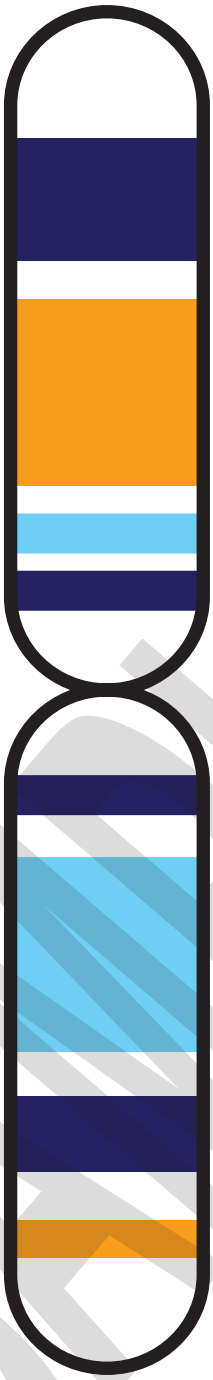
Chromosome **B** with inversion

Chromosome **A** following reciprocal exchange

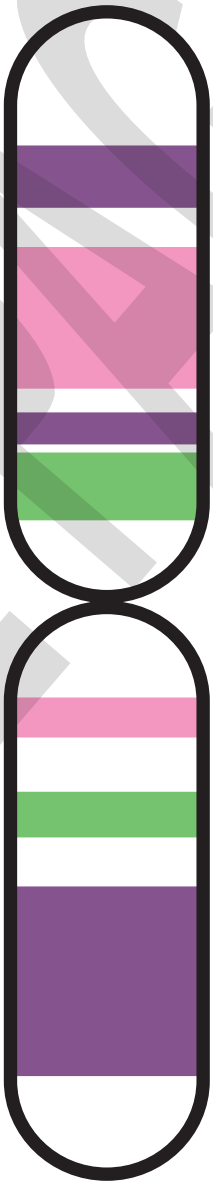
Chromosome **B** following reciprocal exchange

BLOCK MUTATIONS

Give chromosomes **A** and **B** the following colours:



Chromosome A



Chromosome B

BLOCK MUTATIONS
(answers)

Normal Chromosome **A**

Chromosome **A** with duplicated segment

Chromosome **A** with deleted segment

Normal Chromosome **B**

Chromosome **B** with inversion

Chromosome **A** following reciprocal exchange

Chromosome **B** following reciprocal exchange

DATING ROCKS

1. A person's age can be described in either *relative* or *absolute* terms. Explain, using an example.

_____

_____

_____

2. The relative age of rock strata (layers) can be determined using the *stratigraphic method*. What does this mean?

_____

_____

3. The following diagrams show rock strata containing various types of fossils in South America and Africa.

(a) Which layer in South America is (i) the oldest? (ii) the youngest?

_____

(b) Which of the fossils is most likely to be classed as an 'index' fossil? Indicate this on the diagram.

(c) Explain your answer to (b).

_____

_____

(d) What important piece of information does the index fossil provide about the rock strata in South America and Africa?

_____

_____

4. The absolute age of rock can be determined using *radiometric dating*. Describe what this involves.

_____

_____

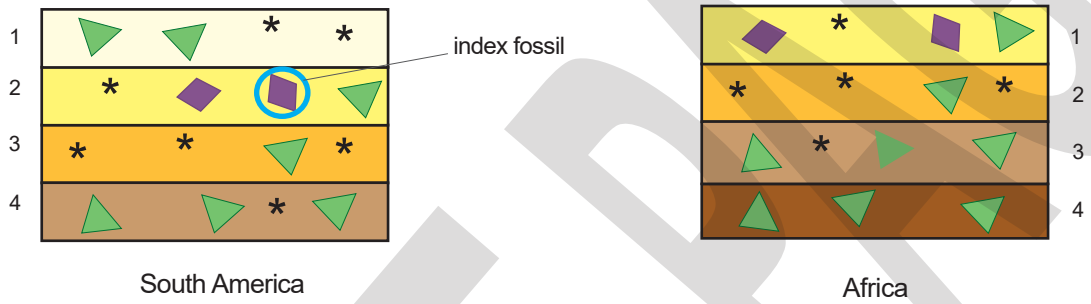
_____

DATING ROCKS
(Answers)

1. When describing the *relative* age of a person, you are comparing them to another person, for example, *Sarah is older than Tom*. When describing a person's *absolute* age, however, you are giving the actual figure in years, for example, *Sarah is eighteen*.

2. The stratigraphic method of determining the relative ages of rock strata is one based on the *principle of superposition*, which simply states that the oldest layer occurs at the bottom, with layers above becoming progressively younger.

3.



(a) (i) Layer **4**. (ii) Layer **1**.

(b) See above diagram.

(c) Index fossils are those formed from species that existed on Earth for only a short time, and are therefore usually restricted to just one or two layers of rock. The fossil indicated is found in only one rock layer in both South America and Africa.

(d) Being an index fossil, it tells us that layer **2** in South America is the same age as layer **1** in Africa, which also contains the fossil.

4. Radiometric dating of rock is based on the rate of decay of certain radioactive isotopes found in igneous rock. These 'parent' isotopes are unstable and decay over time to form stable 'daughter' isotopes. By measuring the relative amounts of parent and daughter isotope present in a rock, its absolute age can be determined.

5. (a)
(shading method):

MIGRATION OF MODERN HUMANS

1. Why is Africa described as the 'cradle of humanity'?

_____

_____

2. Explain the difference between the 'Out of Africa' and the 'Multiregional' hypotheses of human migration. Which is more accepted by scientists?

_____

_____

_____

3. Mitochondrial DNA (mtDNA) has been used to track ancient human migration.

   (a) Identify four major differences between mtDNA and nuclear DNA.

_____

_____

_____

_____

   (b) The 'D-loop' region of a mtDNA molecule is particularly useful for studying human ancestry. Why?

_____

_____

_____

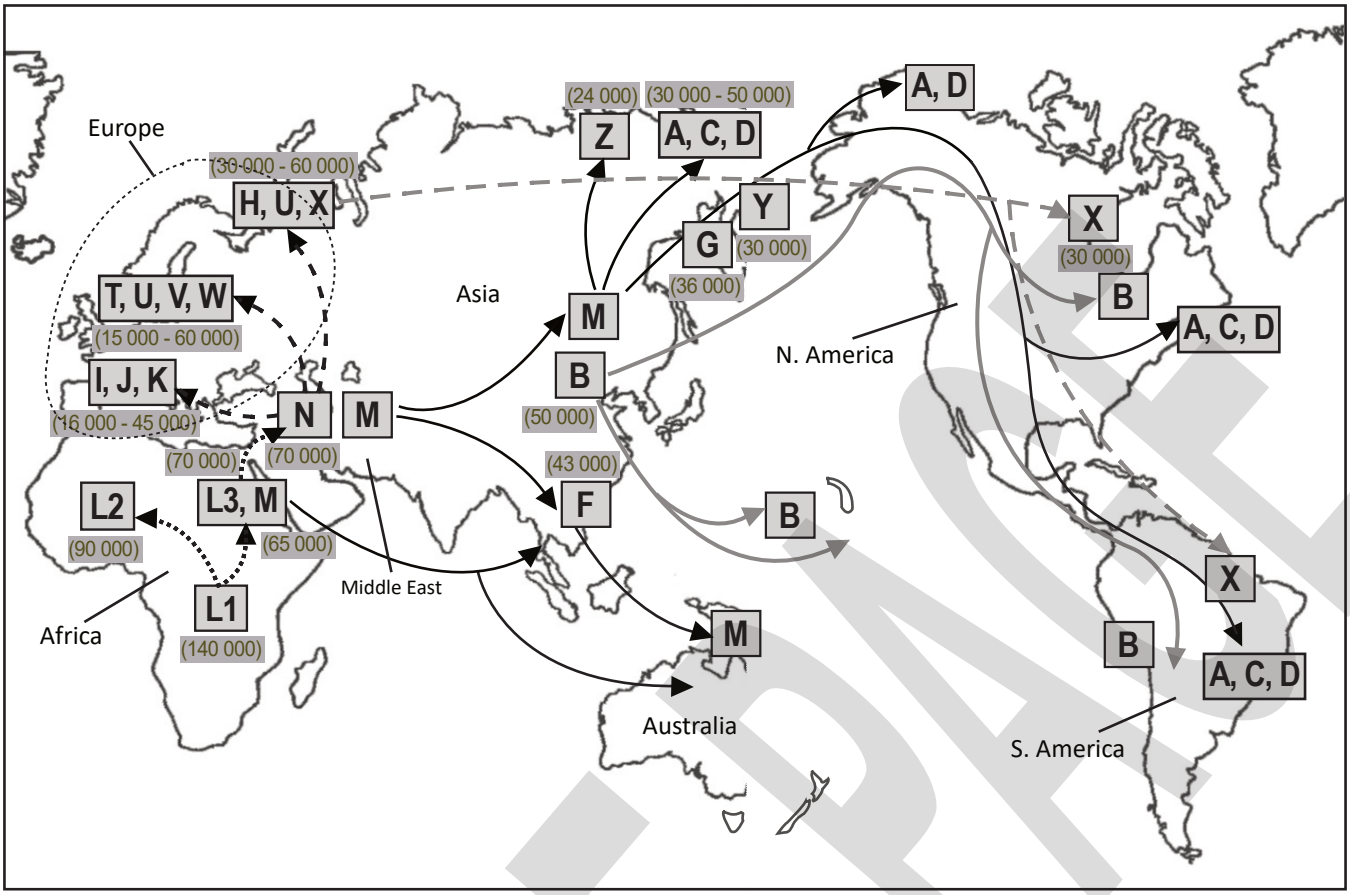
4. What is meant by (a) 'haplotype'? (b) 'haplogroup'?

_____

_____

_____

5. The map on the next page shows how haplogroups (denoted by a capital letter) can be used to track early human migration. Note that the numbers in brackets are estimates of the ages of a particular haplogroup or groups of haplogroups. Study the map carefully and answer the questions that follow.



(a) Which haplogroups are the oldest and where are they found?

_____

(b) What haplogroups are common in Europe and what is their range in age?

_____

_____

(c) Which haplogroups are common in North and South America, and are they generally older or younger than those found in Europe?

_____

_____

(d) On which continent did haplogroup **B** probably first appear? How old is this haplogroup?

_____

(e) Beginning with Africa, track the movement of modern humans from start to finish.

_____

_____

MIGRATION OF MODERN HUMANS
(answers)

1. Africa is described as the 'cradle of humanity' because this is where the first human species evolved.

2. The 'Out of Africa' hypothesis states that Homo *sapiens* first evolved in Africa, then spread out to all parts of the world, while the 'Multiregional' hypothesis suggests that Homo *sapiens* evolved in separate locations around the world after Homo *erectus* left Africa. The Out of Africa hypothesis is more accepted by scientists.

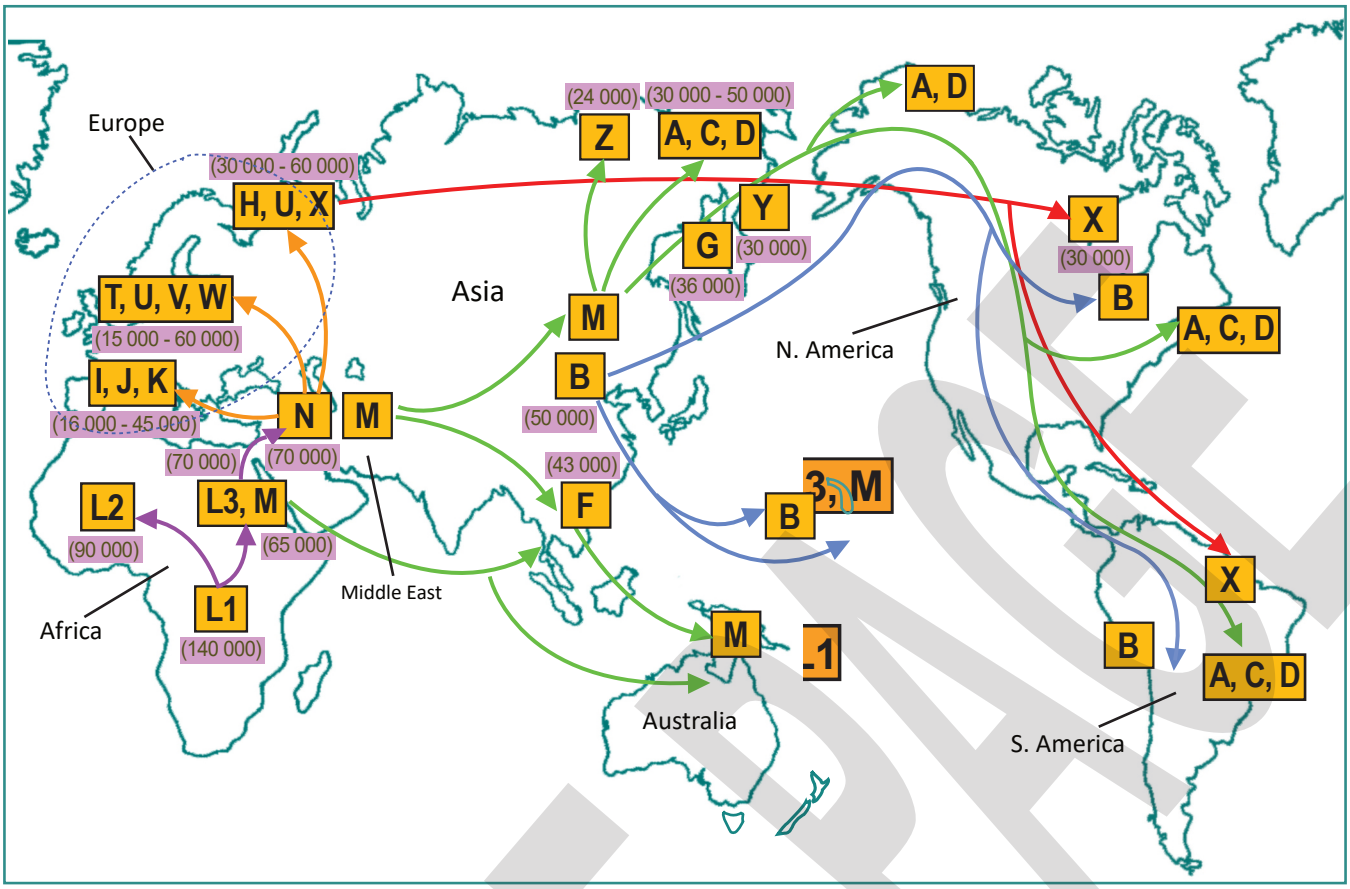
3. (a) Any four of: (i) mitochondrial DNA is inherited only from the mother, while nuclear DNA is inherited from both parents (ii) unlike nuclear DNA, no recombination occurs in the transmission of mtDNA from parent to child (iii) mtDNA is circular, while nuclear DNA is linear (iv) mtDNA contains only one chromosome, while nuclear DNA contains 46 chromosomes (v) mtDNA contains only 37 genes, while nuclear DNA contains around 25 000 genes (vi) mtDNA has a higher rate of mutation than nuclear DNA.

   (b) The 'D-loop' region of a mtDNA molecule is particularly useful for studying human ancestry because it contains two hypervariable regions, *HVR1* and *HVR2*, that accumulate mutations at a rapid rate. These mutations are then passed onto offspring through the maternal line, leading to the creation of entire populations with the same D-loop mtDNA sequence. This in turn means that different populations in the world can potentially be distinguished by their mtDNA sequences.

4. (a) A 'haplotype' is a region of DNA, located in the D-loop of mtDNA, that varies between individuals.

   (b) A 'haplogroup' is a group of similar haplotypes that share a common ancestor.

5. See next page.



(a) Haplogroups **L1**, **L2** and **L3** are the oldest and they are found in Africa.

(b) Haplogroups **I**, **J**, **K**, **T**, **U**, **V**, **W**, **H** and **X** are common in Europe and their ages range from 15 000 to 60 000 years old.

(c) Haplogroups **A**, **B**, **C**, **D** and **X** are common in North and South America, and they are generally younger than those found in Europe.

(d) Haplogroup **B** probably first appeared in Asia and is around 50 000 years old.

(e) Humans started migrating through the north of Africa, followed by the Middle East and Europe, Asia, (including the Indian subcontinent), Oceania and Australia, then North and South America.