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BIOLOGY

0610/41

Paper 4 Theory (Extended)

May/June 2020

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [].

This document has **20** pages. Blank pages are indicated.

1 The gas exchange system is one of the organ systems of the human body.

Fig. 1.1 shows parts of the gas exchange system during breathing in and breathing out.

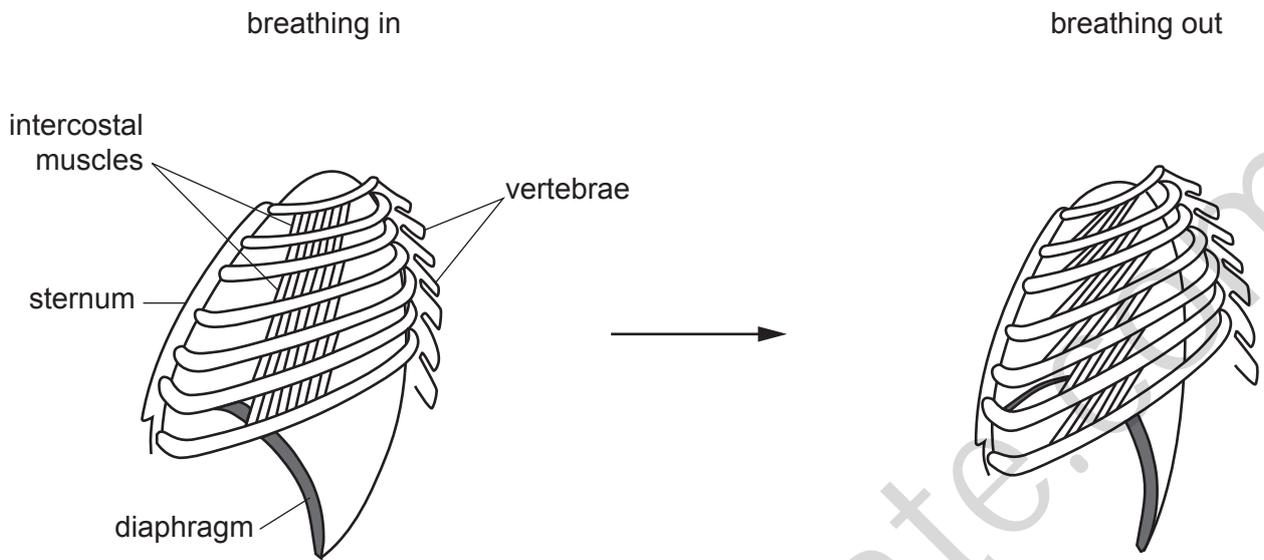


Fig. 1.1

(a) Complete Table 1.1 to show:

- the functions of the diaphragm and the intercostal muscles during breathing in and breathing out
- the pressure changes in the thorax.

Use these words:

contract
relax
increases
decreases.

Table 1.1

	diaphragm	intercostal muscles		pressure change in the thorax
		internal	external	
breathing in				
breathing out				

[4]

Fig. 1.2 shows part of the gas exchange surface of a human.

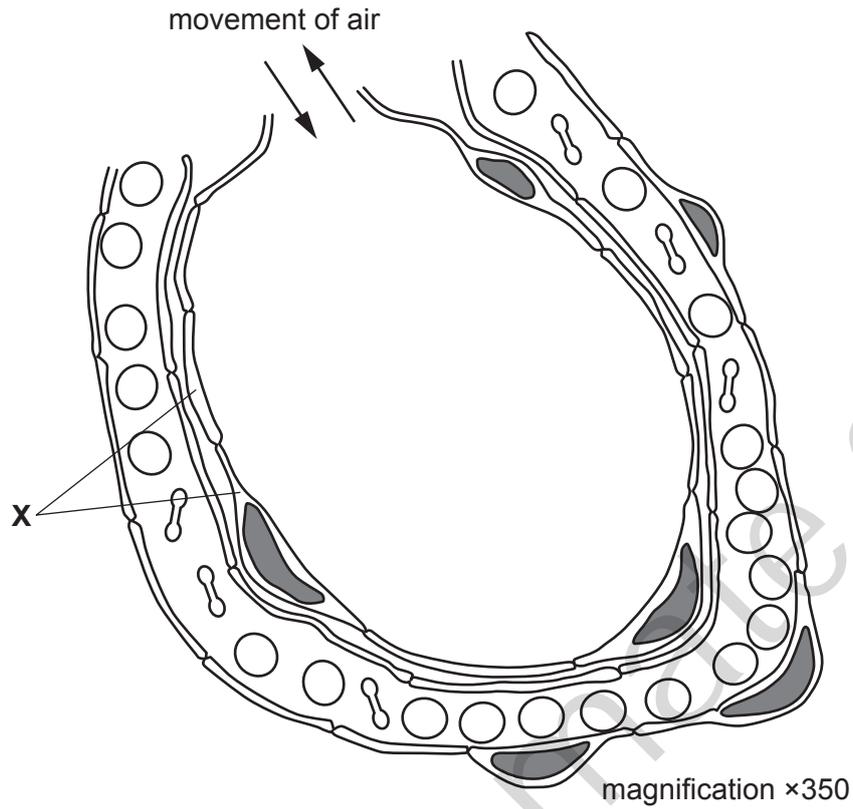


Fig. 1.2

(b) State **two** features of the gas exchange surface that are **visible** in Fig. 1.2.

1

2

[2]

(c) The cells labelled **X** on Fig. 1.2 form a tissue.

(i) Define the term *tissue*.

.....

[2]

(ii) Cartilage is another tissue found in the gas exchange system.

State the functions of cartilage in the gas exchange system.

.....

.....

.....

.....

.....

[2]

[Total: 10]

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Question no. 1

(a) Breathing in and breathing out: muscle actions and pressure changes

During **breathing in (inspiration)**, the **diaphragm contracts**, causing it to flatten and move downwards. At the same time, the **external intercostal muscles contract**, lifting the ribs **upwards and outwards**, while the **internal intercostal muscles relax**. These coordinated movements **increase the volume of the thorax**, which results in a **decrease in pressure inside the thorax** compared with atmospheric pressure. As a result, air moves into the lungs.

During **breathing out (expiration)**, the **diaphragm relaxes** and returns to its dome-shaped position. The **external intercostal muscles relax**, allowing the ribs to move **downwards and inwards**, while the **internal intercostal muscles contract or remain relaxed** (depending on whether expiration is forced or passive). This leads to a **decrease in thoracic volume**, causing the **pressure inside the thorax to increase**, forcing air out of the lungs.

Completed Table 1.1

	diaphragm	internal intercostal muscles	external intercostal muscles	pressure change in the thorax
breathing in	contract	relax	contract	decreases
breathing out	relax	contract / relax	relax	increases

(b) Features of the gas exchange surface visible in Fig. 1.2

One feature visible in Fig. 1.2 is that the gas exchange surface is **very thin**, providing a **short diffusion distance** for oxygen and carbon dioxide.

Another visible feature is that the surface is **surrounded by many capillaries**, showing that it is **well supplied with blood**, which helps maintain a steep diffusion gradient.

(c)(i) Definition of the term *tissue*

A **tissue** is a **group of cells with similar structures, working together to perform a shared function.**

(c)(ii) Functions of cartilage in the gas exchange system

Cartilage in the gas exchange system **forms incomplete rings around the trachea and bronchi**, which **keeps the airways open** and prevents them from collapsing during breathing.

In addition, cartilage **reduces resistance to the movement of air** and **protects the airways**, ensuring efficient airflow to and from the lungs.

2 Biological washing powders contain enzymes that break down food stains.

(a) Complete Table 2.1 by naming the enzymes that break down three substances in food stains and by stating the product or products.

Table 2.1

substance	enzyme	product(s)
starch		
fat		
protein		

[3]

Some students compared how effective biological and non-biological washing powders are at removing stains at temperatures between 10 °C and 60 °C.

- Pieces of stained cloth were washed using two different washing powders.
- The degree of stain removal was measured by using a light meter to record the percentage of light reflected from the cloth.
- A light meter gave a value of 100% when the cloth was completely clean.
- Any stain left on the cloth reduced the percentage of light reflected.

- (c) The students suggested that the enzymes in the biological washing powder were denatured at high temperatures.

Explain why enzyme molecules do not function when they are denatured.

.....

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..... [2]

- (d) Forensic scientists often try to find DNA on items of stained clothing. The DNA can be used to identify individual people.

Suggest why DNA can be used to identify individual people.

.....

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.....

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..... [2]

[Total: 11]

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Question no. 2

(a) Enzymes in biological washing powders and their products

Biological washing powders contain enzymes that are specific to different types of food stains.

Starch stains are broken down by the enzyme **amylase**. Amylase hydrolyses starch into **simple sugars**, such as **maltose** and ultimately **glucose**, which are soluble in water and can be washed away easily.

Fat stains are digested by the enzyme **lipase**. Lipase breaks fats into their constituent molecules, producing **fatty acids and glycerol**, both of which are more easily removed from fabric.

Protein stains are broken down by **proteases** (such as pepsin or trypsin). These enzymes hydrolyse proteins into **amino acids**, which dissolve in water and can be removed during washing.

(b) Comparison of the effectiveness of biological and non-biological washing powders

The effectiveness of each washing powder can be compared by examining the **percentage of light reflected**, since higher reflection indicates **less stain remaining**.

At **lower temperatures**, between **10 °C and about 40 °C**, the **biological washing powder is more effective** than the non-biological powder. For example, at **20 °C**, the biological powder reflects approximately **80% of light**, whereas the non-biological powder reflects only about **45%**, showing that the biological powder removes much more stain at low temperatures.

The biological washing powder becomes **most effective between 30 °C and 40 °C**, where it reaches **100% light reflection**, indicating that **all stains have been removed**. In contrast, the non-biological washing powder does not remove all stains at these temperatures.

However, at **higher temperatures**, the effectiveness of the biological washing powder **decreases sharply** between **40 °C and about 44 °C**, dropping to around **60% light reflection**. This decrease is not seen in the non-biological washing powder.

At **very high temperatures**, around **60 °C**, both washing powders show **similar effectiveness**, with the non-biological powder reaching **100% light reflection** and the biological powder approaching a similar value. This shows that the **non-biological washing powder only removes all stains at high temperatures**, whereas the biological powder is most effective at lower temperatures.

(c) Why denatured enzymes do not function

When enzymes are denatured, their **three-dimensional structure changes**, particularly the shape of the **active site**. As a result, the **substrate no longer fits into the active site**, so an **enzyme–substrate complex cannot form**. Without successful collisions between enzyme and substrate, the reaction cannot take place, and the enzyme no longer functions.

(d) Why DNA can be used to identify individuals

DNA can be used to identify individual people because **each person has a unique DNA sequence** (except identical twins). Although all humans have the same genes, the **order of bases in the DNA**, particularly in non-coding regions, **differs between individuals**. These differences make DNA profiles unique, allowing forensic scientists to match DNA found on clothing to a specific person.

3 (a) Dialysis tubing is an artificial membrane, which is similar to the lining of the intestine.

A student investigated the diffusion of glucose through dialysis tubing by using the apparatus shown in Fig. 3.1.

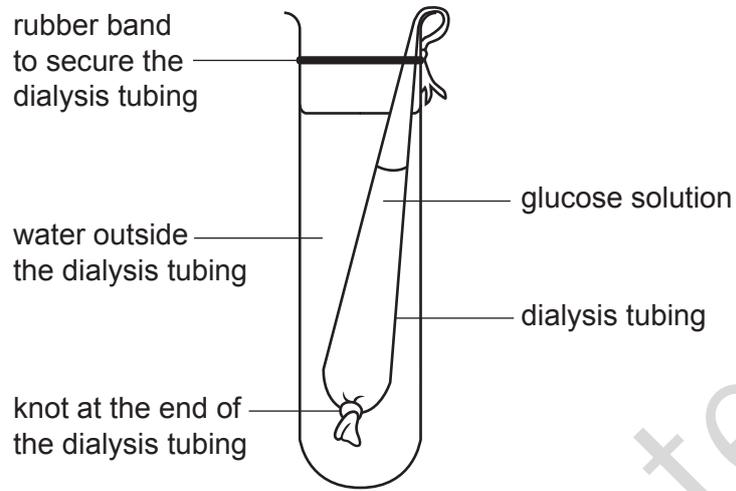


Fig. 3.1

The student took samples of the water outside the dialysis tubing at 5 minute intervals and tested the samples with Benedict's solution.

The results are shown in Table 3.1.

Table 3.1

time / minutes	results of the Benedict's tests on the water outside the dialysis tubing
0	blue
5	green
10	yellow
15	red

- (i) Describe and explain the results shown in Table 3.1.

.....

.....

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.....

.....

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.....

..... [3]

- (ii) The student repeated the investigation with a higher concentration of glucose in the dialysis tubing.

Predict the results that the student would observe.

.....

.....

..... [1]

Question no. 3

(a) Diffusion of glucose through dialysis tubing

At **time 0**, the solution outside the dialysis tubing remains **blue**, showing that **no glucose is present in the surrounding water** at the start of the experiment. This confirms that **there was no glucose contamination outside the tubing due to experimental error**.

After some time, the solution outside the dialysis tubing changes from blue to **green, yellow or red**, indicating the **presence of glucose**. This shows that **glucose has moved out of the dialysis tubing into the surrounding water**.

The movement of glucose occurs **by diffusion**, as glucose moves **down its concentration gradient**, from a **higher concentration inside the dialysis tubing** to a **lower concentration in the surrounding water**. This demonstrates that **dialysis tubing is permeable to glucose**, allowing glucose molecules to pass through the membrane.

(a)(ii) Effect of changing the glucose concentration

If the concentration of glucose inside the dialysis tubing is increased, **Benedict's solution would change colour more quickly** and would produce a **more intense colour**. This is because a **steeper concentration gradient** causes a **faster rate of diffusion**, so more glucose diffuses into the surrounding water in a shorter time.

(b) Structures in the intestinal epithelial cell (Fig. 3.2)

Structure A: Microvilli

Structure A consists of **microvilli**, which are finger-like projections on the surface of the intestinal epithelial cell. Their main role is to **increase the surface area** of the cell, allowing **more efficient absorption of digested nutrients** such as glucose and amino acids. The membranes of microvilli also contain **transport proteins**, enabling absorption by **diffusion and active transport**.

Structure B: Rough endoplasmic reticulum (RER)

Structure B is the **rough endoplasmic reticulum**, identified by the presence of ribosomes on its surface. It functions as the **site of protein synthesis**, where amino acids are **assembled into proteins in a specific sequence**. These proteins may then be **modified and transported** for use in the cell, such as enzymes or membrane transport proteins.

Structure C: Mitochondrion

Structure C is a **mitochondrion**. Its function is to carry out **aerobic respiration**, producing **ATP**. This ATP provides the **energy required for active transport**, particularly important in intestinal cells that absorb substances **against a concentration gradient**.

(c) Effect of cholera toxin

(c)(i) Name of ion X

Ion X is **chloride ions (Cl^-)**.

(c)(ii) Effects on the body of chloride secretion into the intestinal lumen

When chloride ions are secreted into the lumen of the intestine, **water follows by osmosis**, moving **down the water potential gradient** from the intestinal cells and surrounding tissues into the lumen. This leads to a **large loss of water from the body**.

As a result, the individual develops **severe diarrhoea**, as large volumes of watery fluid accumulate in the intestine and are expelled. Continued water loss can cause **dehydration**, which may become life-threatening if untreated. Additionally, there is also a **loss of other ions (salts)** from the body, disrupting normal physiological processes.

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4 Johnson grass, *Sorghum halepense*, is wind-pollinated.

(a) Fig. 4.1 shows some Johnson grass flowers.



Fig. 4.1

(i) State the genus of Johnson grass.

..... [1]

(ii) Describe **two** features **visible in Fig. 4.1** that show that Johnson grass flowers are adapted for wind-pollination.

1

.....

2

.....

[2]

(b) Fig. 4.2 shows a section through a carpel shortly after pollination.

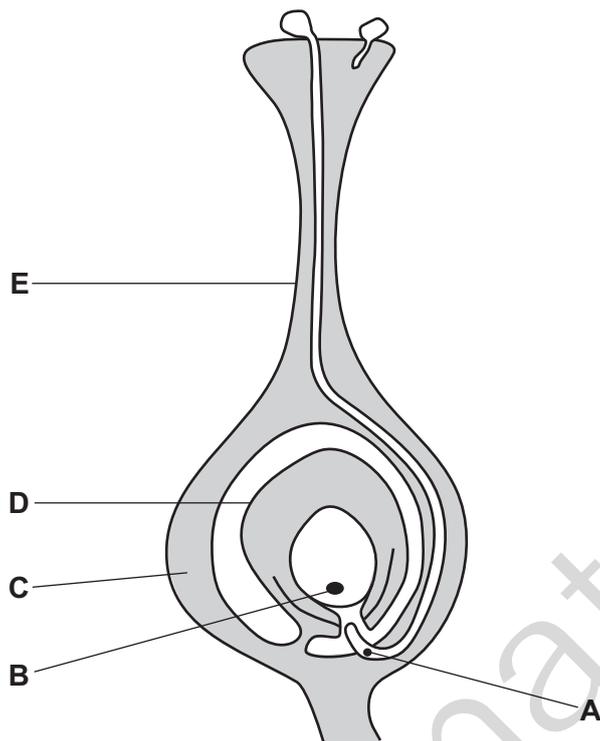


Fig. 4.2

(i) State the names of the parts of the carpel labelled **C**, **D** and **E**.

C

D

E

[3]

(ii) Complete the sentences:

Pollen grains are formed in anthers. During their formation the number of chromosomes in the nuclei is halved by the process of This means the male nucleus **A** in the pollen tube is described as a nucleus.

When nucleus **A** with nucleus **B**, the chromosome number doubles to form a nucleus. The name of this process is Then the divides by the process of to form an embryo.

[7]

Question no. 4

(a)

(i) Genus of Johnson grass

The scientific name of Johnson grass is *Sorghum halepense*. In binomial nomenclature, the **genus is the first name**, therefore the genus of Johnson grass is **Sorghum**.

(ii) Two visible features showing adaptation for wind pollination

From Fig. 4.1, Johnson grass flowers show clear adaptations for **wind pollination**.

Firstly, the **stigmas are feathery and highly branched**, giving them a **large surface area**. This greatly increases the chance of intercepting pollen grains carried by the wind.

Secondly, the **anthers hang outside the flower on long, flexible filaments**. This exposed position allows the anthers to **sway in the wind**, making it easier for large quantities of pollen to be released into the air.

(b)

(i) Names of parts labelled C, D and E

- **C:** ovary (ovary wall)
 - **D:** ovule
 - **E:** style
-

(ii) Completion of the sentences

Pollen grains are formed in anthers. During their formation, the number of chromosomes in the nuclei is halved by the process of **meiosis** (also known as **reduction division**). This means the male nucleus A in the pollen tube is described as a **haploid** nucleus.

When nucleus A **fuses** with nucleus B, the chromosome number doubles to form a **diploid** nucleus. The name of this process is **fertilisation**. Then the **zygote** divides by the process of **mitosis** to form an embryo.

(c) Advantages of sexual reproduction to a wild population of flowering plants

Sexual reproduction produces **genetic variation** within a population because meiosis and fertilisation result in new combinations of alleles. This variation means that individuals differ in their characteristics.

As a result, some individuals are more likely to **survive environmental changes**, such as drought, disease, or competition. These better-adapted individuals are more likely to survive and reproduce, passing on advantageous alleles to the next generation.

Sexual reproduction therefore increases the **long-term survival of the population**, as natural selection can act on the variation present. It also reduces the risk that a single disease or environmental change will eliminate the entire population, making sexual reproduction especially advantageous in **wild and changing environments**.

(d) Three uses of energy in organisms other than reproduction

1. **Active transport**, such as the uptake of mineral ions by root hair cells
2. **Growth and repair**, including protein synthesis and cell division
3. **Movement**, for example cytoplasmic streaming in plant cells or muscle contraction in animals

5 Ciliates are classified in the kingdom Protocist. Bacteria are classified in the kingdom Prokaryote.

(a) State **two structural** features that distinguish the cells of a protocist from a prokaryote.

1

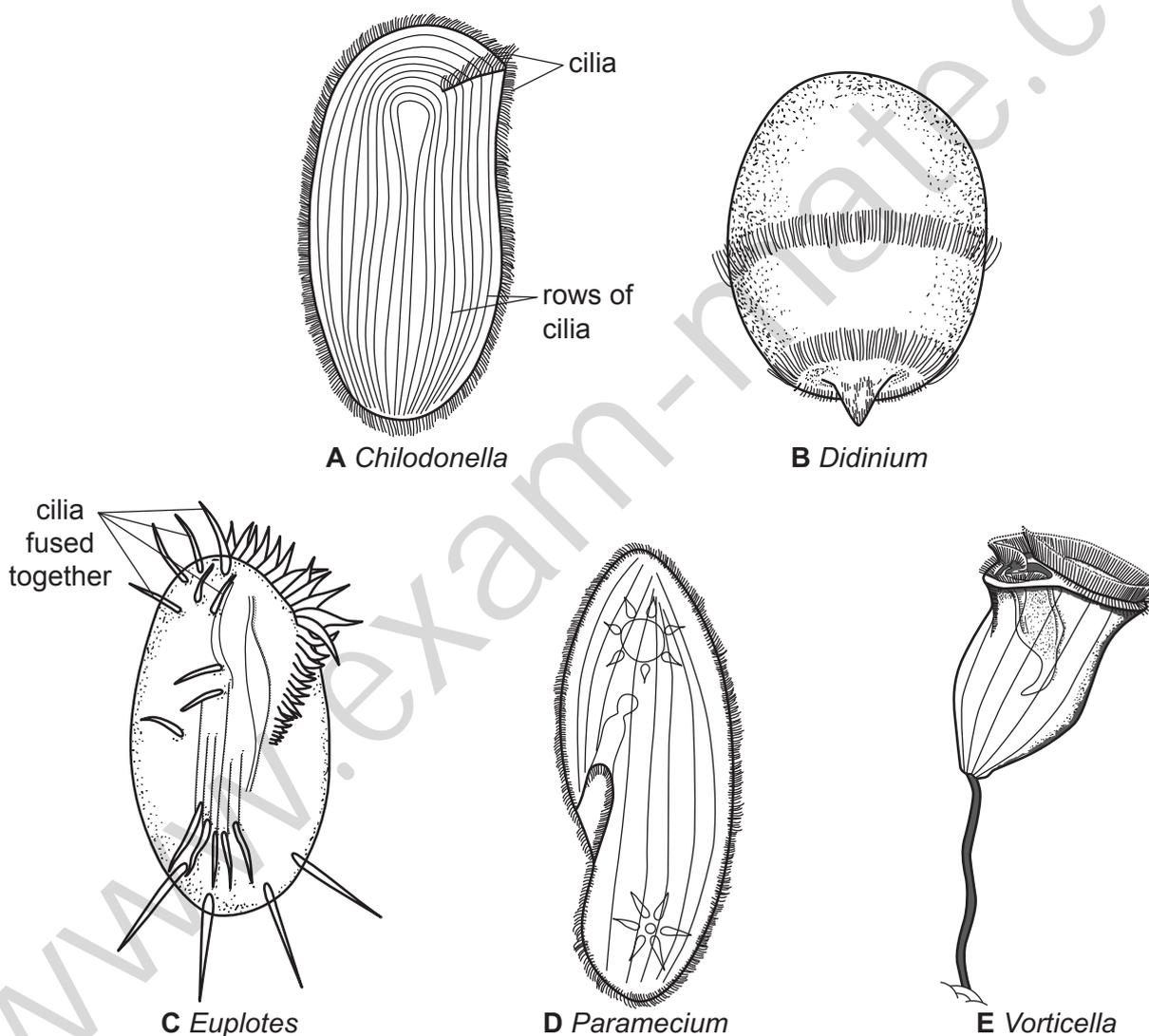
.....

2

.....

[2]

(b) Fig. 5.1 shows five species of ciliate that are found in sewage treatment works.



not to scale

Fig. 5.1

Fig. 5.2 is a dichotomous key to identify the ciliates shown in Fig. 5.1.

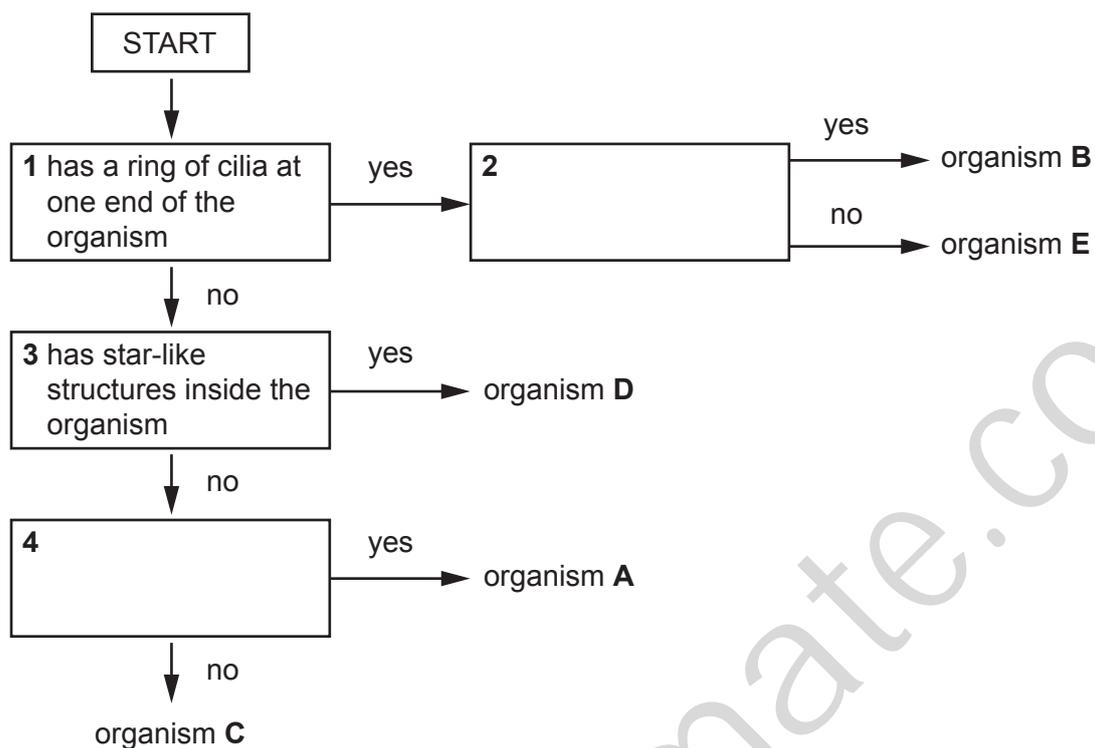


Fig. 5.2

Complete the key in Fig. 5.2 by writing suitable statements:

- for box 2 to distinguish species **B** and **E**
- for box 4 to distinguish species **A** and **C**.

text for box 2

.....

.....

text for box 4

.....

.....

[2]

(c) *Didinium* is a predatory ciliate. A video recording was made of one *Didinium* feeding on a *Paramecium*. Fig. 5.3 shows a sequence of still photographs taken from the video.

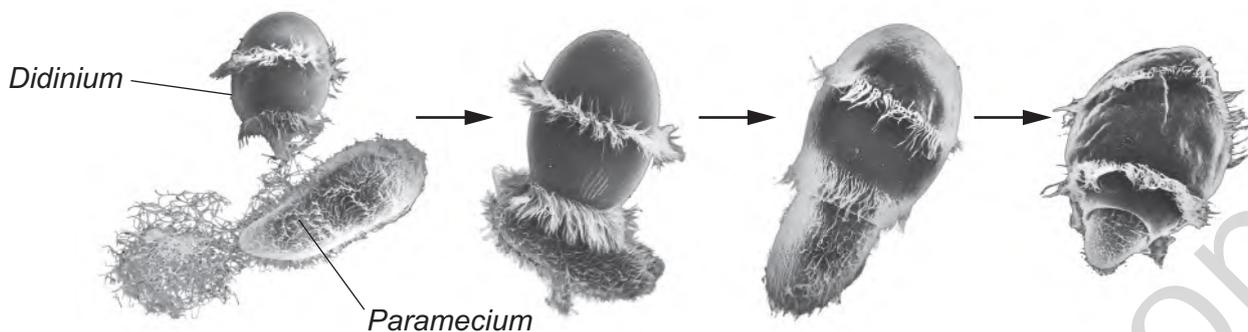


Fig. 5.3

Complete the table by putting a tick (✓) by each characteristic of life that can be seen in the still photographs from the video in Fig. 5.3.

excretion		nutrition	
growth		reproduction	
movement		respiration	

[1]

(d) Fig. 5.4 is a food web for some of the microorganisms in a sewage treatment works.

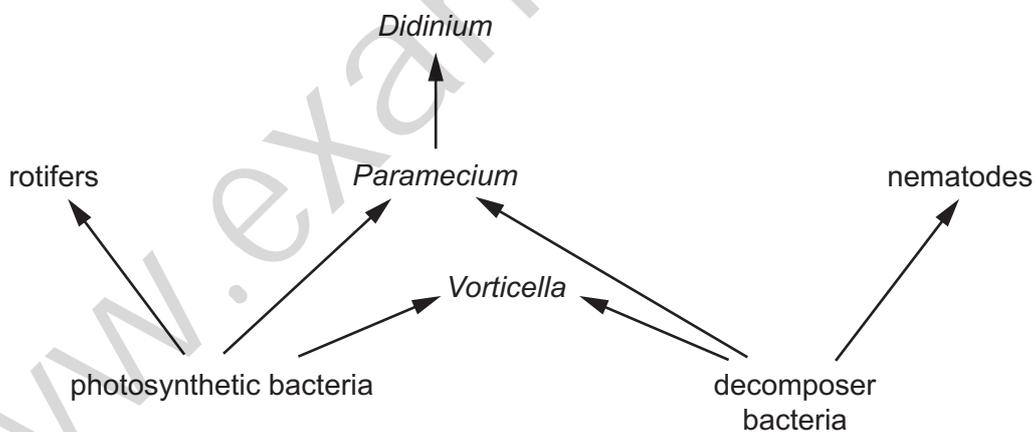


Fig. 5.4

(i) Construct **one** food chain with three trophic levels that use energy derived from the breakdown of sewage. Do **not** draw the organisms.

[1]

- (ii) The water that passed out of the sewage works was often cloudy with suspended matter. Scientists discovered that ciliates reduce the cloudiness of water during sewage treatment.

Suggest how the ciliates reduce the cloudiness of the water using the information in Fig. 5.4.

..... [2]

- (iii) Explain how sewage treatment reduces the spread of disease.

..... [3]

- (iv) Nitrifying bacteria are found in sewage works.

Explain the importance of nitrifying bacteria in the nitrogen cycle.

..... [3]

[Total: 14]

Question no. 5

(a) Structural differences between a protocist cell and a prokaryotic cell

One clear structural difference is that **protocist cells possess a true nucleus**, surrounded by a **nuclear envelope**, whereas **prokaryotic cells do not have a nucleus** and their DNA lies free in the cytoplasm. This reflects the eukaryotic organisation of protocists compared with the simpler cellular structure of prokaryotes.

A second difference is that **protocist cells contain membrane-bound organelles**, such as **mitochondria and endoplasmic reticulum**, while **prokaryotic cells lack membrane-bound organelles**. This allows compartmentalisation of metabolic processes in protocists, which does not occur in prokaryotes.

(b) Completing the dichotomous key

Text for box 2

The organism **has two rings of cilia**.

This statement correctly distinguishes **Didinium (B)**, which has two distinct bands of cilia, from **Vorticella (E)**, which has a stalk and does not have two ciliary rings.

Text for box 4

The organism **has a covering of cilia**.

This separates **Chilodonella (A)**, which is covered in rows of cilia, from **Euplotes (C)**, which has **fused cilia** rather than a uniform covering.

(c) Characteristics of life seen in Fig. 5.3

From the sequence of still photographs, **movement** can clearly be observed, as the **Didinium changes position and shape** while interacting with the Paramecium. In addition, **nutrition** is evident because **Didinium is shown capturing and ingesting Paramecium**, demonstrating feeding.

Therefore, the correct characteristics to tick are **movement** and **nutrition**.

(d)(i) Food chain using energy derived from the breakdown of sewage

One valid food chain with three trophic levels is:

bacteria → **Paramecium** → **Didinium**

This chain begins with bacteria that obtain energy from decomposing sewage, which are then eaten by Paramecium, which in turn is preyed upon by Didinium.

(d)(ii) How ciliates reduce the cloudiness of water

Ciliates reduce the cloudiness of water because **they feed on bacteria**, which are a major component of suspended particles in sewage water. By consuming large numbers of bacteria, ciliates **reduce the amount of particulate matter**, making the water clearer.

In addition, **predatory ciliates such as Didinium feed on other ciliates**, further reducing the number of organisms suspended in the water and therefore lowering turbidity.

(d)(iii) How sewage treatment reduces the spread of disease

Sewage treatment reduces the spread of disease by **removing harmful bacteria and other pathogens** from wastewater before it is released into the environment. This prevents **water-borne diseases**, such as cholera, from being transmitted through contaminated water supplies.

Furthermore, treated sewage water is often subjected to **chemical treatment such as chlorination**, which **kills remaining microorganisms**, ensuring pathogens are not spread to humans via drinking water or recreational water use.

(d)(iv) Importance of nitrifying bacteria in the nitrogen cycle

Nitrifying bacteria are important because they **convert ammonia or ammonium ions into nitrite ions and then into nitrate ions** through nitrification. This process prevents the accumulation of toxic ammonia in the environment.

The **nitrate ions produced are absorbed by plants**, where they are used to **synthesise amino acids and proteins**, allowing nitrogen to enter food chains. As a result, nitrifying bacteria play a crucial role in **recycling nitrogen into a biologically usable form**.

- 6 Colour blindness is a characteristic that is inherited. Colour blindness is more common in males than in females.

Fig. 6.1 is a pedigree diagram showing the inheritance of colour blindness in a family.

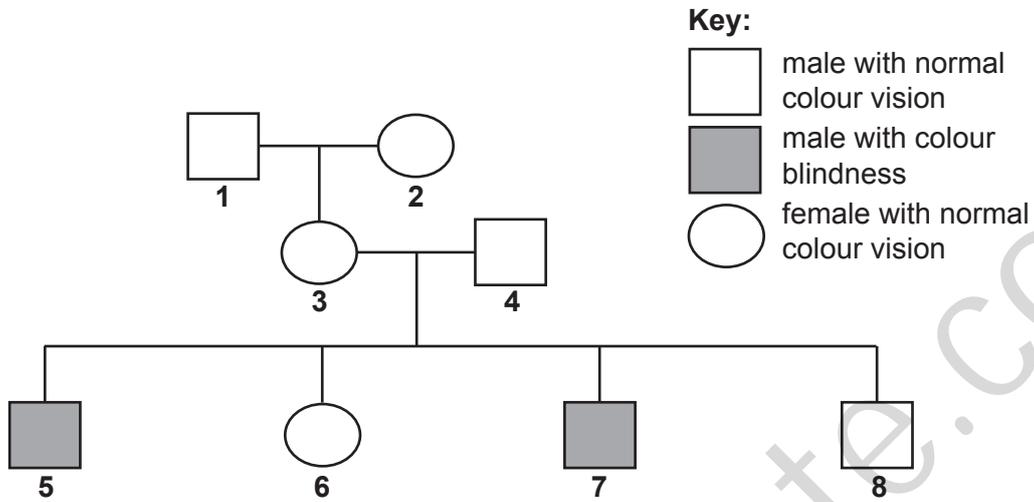


Fig. 6.1

- (a) Define the term *inheritance*.

.....

.....

..... [1]

- (b) (i) Using the symbols **B** and **b**, state the genotypes of individual **5** and individual **8** in the pedigree diagram.

5

8

[3]

- (ii) Individual 3 is a carrier of colour blindness because she has one copy of the allele for colour blindness but has normal colour vision.

Describe the evidence from Fig. 6.1 that shows that individual 3 is a carrier.

.....

.....

.....

.....

.....

.....

.....

..... [3]

- (iii) There was no history of colour blindness in the parents and grandparents of individuals 1 and 2.

Suggest how colour blindness first occurred in the family in Fig. 6.1.

.....

.....

.....

.....

.....

..... [2]

[Total: 9]

Question no. 6

(a) Definition of inheritance

Inheritance is the transmission of genetic information from one generation to the next, from parents to their offspring, through genes carried on chromosomes.

(b)(i) Genotypes of individuals 5 and 8

Colour blindness is a **sex-linked characteristic carried on the X chromosome**, with the allele for colour blindness (b) being **recessive** to the normal allele (B).

Individual **5** is a **male with colour blindness**. Since males have only one X chromosome, the presence of the recessive allele on that X chromosome will cause the condition. Therefore, the genotype of individual 5 is **X^bY**.

Individual **8** is a **male with normal colour vision**. This means his single X chromosome must carry the normal dominant allele. Therefore, the genotype of individual 8 is **X^BY**.

(b)(ii) Evidence that individual 3 is a carrier of colour blindness

The pedigree shows that **colour blindness is sex-linked**, as it occurs in males and is passed through females who themselves have normal colour vision. Individual **3 is female and has normal colour vision**, so she must possess at least one normal allele (B).

However, individual 3 has **two sons (individuals 5 and 7) who are colour blind**. Sons inherit their **X chromosome from their mother** and their **Y chromosome from their father**. Since individual 4 (the father) passes on only a Y chromosome to his sons, the **colour-blind allele must have come from individual 3**.

This means individual 3 must have **one normal allele (B) and one recessive colour-blind allele (b)**. She does not express the condition because the normal allele is dominant, but she is **heterozygous (a carrier)** and is able to pass the recessive allele to her sons.

(b)(iii) How colour blindness first occurred in the family

There was no previous history of colour blindness in the parents or grandparents of individuals 1 and 2. This suggests that the condition **first arose due to a mutation**.

A **mutation in the gene for colour vision on the X chromosome** could have occurred in individual **3 herself**, or in **one of her parents (individual 1 or 2)**, or even earlier in a grandparent. This mutation would have produced the **recessive colour-blind allele (b)**, which was then passed on through inheritance within the family.

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