16. The Titicaca water frog, *Telmatobius culeus*, is an aquatic amphibian found in Lake Titicaca in sub-tropical South America. The water frog has an unusual appearance with large folds of skin as shown in Fig. 21.1.

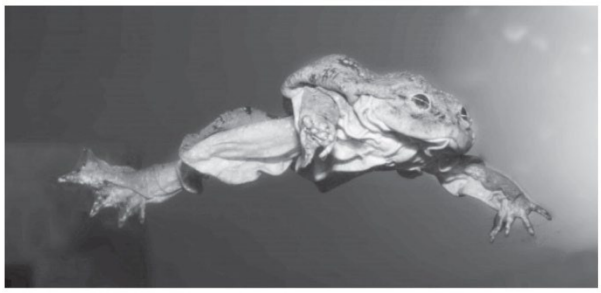


Fig. 21.1

Like all amphibians, frogs are able to absorb oxygen through the skin as well as their lungs.

i. Suggest why the Titicaca water frog has evolved the unusually large folds of skin seen in Fig. 21.1.

---**[2]**

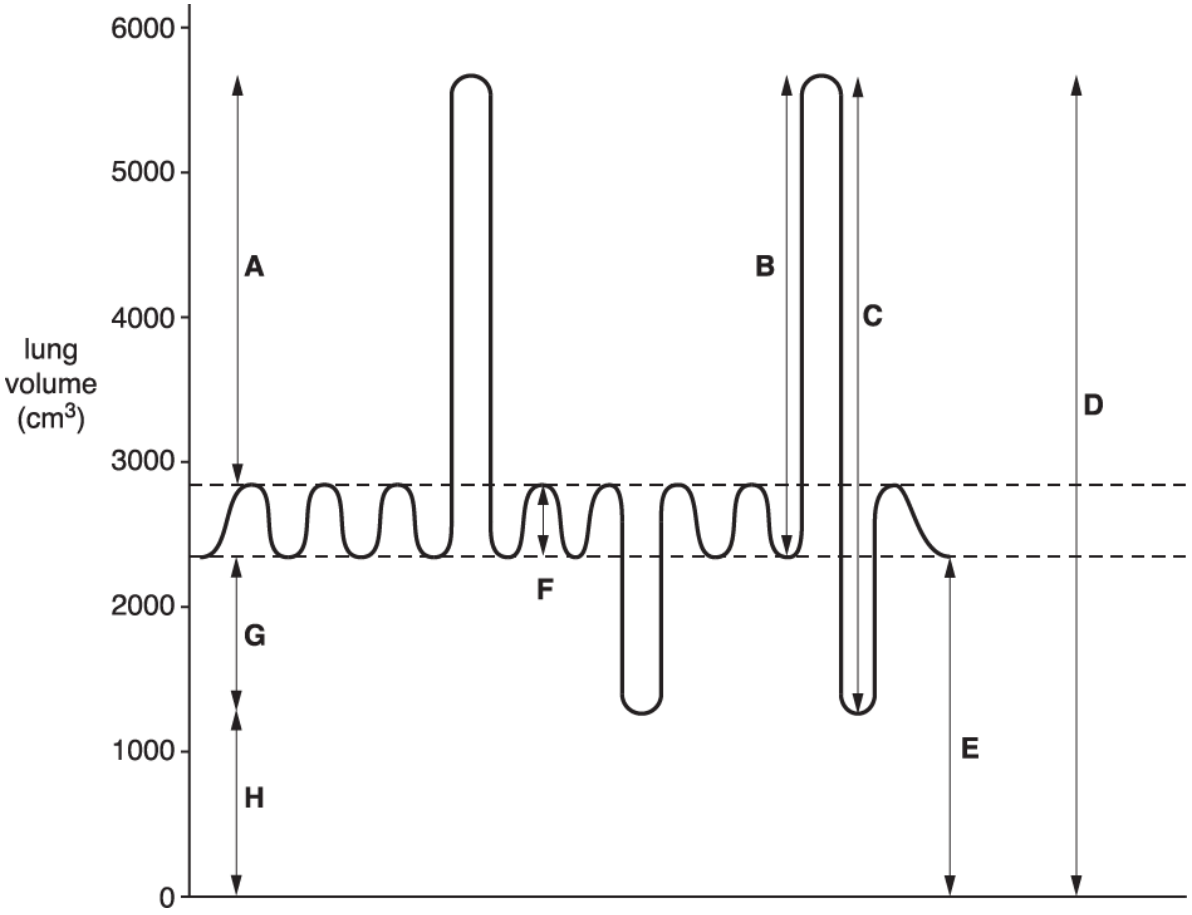
ii. When out of the water, the Titicaca water frog is able to use its lungs to absorb oxygen.

Lungs contain specialised gaseous exchange surfaces.

Describe and explain how **one** feature of the lungs provides an efficient gas exchange surface.

---**[2]**

17. The figure represents the volume changes in the lung of a human.



i. Select the letter, **A** to **H**, that corresponds to each of the following lung volumes.

The first one has been done for you.

Lung volume	Letter
Inspiratory reserve volume	***A***
Residual volume	
Total lung capacity	
Tidal volume	
Vital capacity	

[4]

ii. Volume **C** can be measured using an instrument such as a spirometer.

What **breathing** instructions would be given to a person whose volume **C** was being measured?

---**[2]**

18(a). Termites are highly social insects. They are thought to have evolved from earlier forms of insect at least 150 million years ago, in the Jurassic geological period. They are related to cockroaches.

i. How might scientists a century ago have known that termites evolved in the Jurassic geological period?

---**[1]**

ii. What new source of evidence might help today's scientists to find out how closely related termites are to cockroaches?

---**[1]**

(b). Fig. 5.1 shows a termite mound, the nest of approximately one million individuals. The photograph was taken in Queensland Australia, about 3000 kilometres south of the equator.

i. **Fig. 5.1** shows that the interior of the termite mound is full of interconnecting chambers. At the top of the mound some of these chambers open to the air outside.

Worker termites spend all their time working in brood chambers low in the mound, where eggs and larvae develop.

Explain how carbon dioxide produced in the respiring body cells of worker termites is removed to the air outside the termite mound.

Fig. 5.1

---

[4]

ii. In Africa, closer to the equator, the mounds built by some species of termite are blade-shaped, with the long axis pointing North–South. **Fig. 5.2** shows an example of a termite mound in Africa.

Suggest why the African termites need to build mounds in this shape and orientation.

Fig. 5.2

---

[2]

19. Many organisms have evolved specialised gas exchange surfaces. One feature of these structures is their large surface area to volume ratio.

i. Describe how the structures of the insect tracheal system and fish gills provide a large surface area for gas exchange.

insect tracheal system

---

fish gills

---

[2]

ii. The lugworm, *Arenicola marina*, is a species of segmented worm that lives in burrows in damp sand. They have hair-like external gills that increase the surface area available for gas exchange.

Many other species of segmented worm do not have external gills.

Suggest why lugworms have evolved external gills

---

[1]

20(a). The table compares the features of airways in the lungs
Complete the table by putting a tick (✓) in each box if the feature is present and a cross (***x***) if the feature is absent in each structure.
The first row has been completed for you.

Structure	**Structural feature present**		
	Cartilage	Elastic fibres	Goblet cells
Trachea	✓	✓	✓
Bronchi			
Bronchioles			
Alveoli			

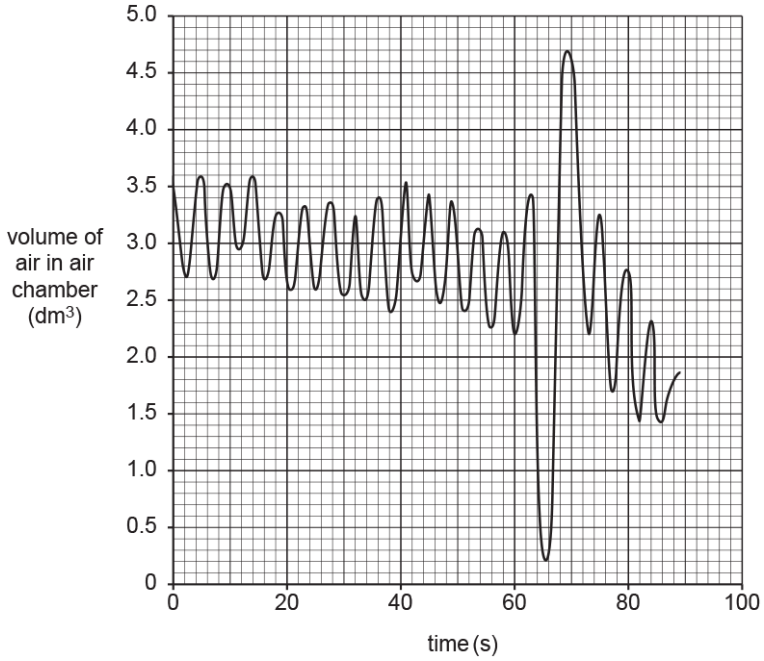
[3]

(b). Ventilation of the lungs creates air movements that can be measured and recorded.

i. Name the apparatus used to measure and record these air movements.

_____ **[1]**

ii. The trace below shows a recording of ventilation movements from an individual subject.



Use the trace to estimate the **maximum** value for tidal volume during the first minute.

maximum tidal volume = ... dm^3 **[1]**

iii. After 60 seconds, the subject was told to breathe in as deeply as possible and then breathe out fully.

Use the trace to calculate the vital capacity of the subject.

vital capacity = ... dm^3 **[2]**

(c). * Compare and contrast the mechanism of expiration during the first 60 seconds of the trace with the mechanism of expiration when the subject was told to breathe out fully.

_____

_____

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_____

_____ **[6]**

(d). Complete the following statements about exchange surfaces.

Use the correct terms selected from the list below.

circulatory system	**concentration gradient**	**diffusion pathway**
flow of air	**Lung capacity**	**Surface area**
Surface area to volume ratio		**ventilation**

Large organisms have a large ..... but they have a small ..... . This means they need a specialised exchange surface and a ..... .

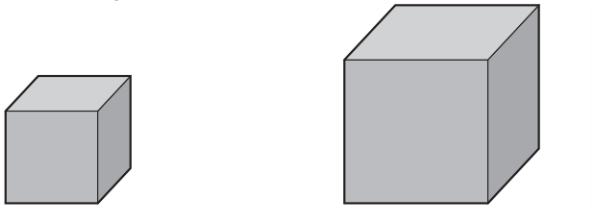
Two features of an efficient exchange surface are:

1. A good blood supply to maintain the _____

2. A short _____

[5]

21(a). The cubes shown in Fig. 6.1 represent two different sized animals.



Small multicellular animal
Volume = 8 cm^3
Surface area = 24 cm^2

Large multicellular animal
Volume = 64 cm^3
Surface area = 96 cm^2

Fig. 6.1

Explain how Fig. 6.1 demonstrates the need for larger multicellular animals to have specialised exchange surfaces.

_____

_____

_____

_____

_____ **[2]**

(b). * Please refer to Insert H020-02, Depth in Biology, November 2020 for this question.

Fig. 6.2 and Fig. 6.3, **on the insert**, show images of exchange surfaces in a bony fish and an insect.

With reference to both Fig. 6.2 and Fig. 6.3 and your own knowledge, outline how the respiratory systems in a bony fish and in an insect are adapted to maximise ventilation and gaseous exchange.

[6]

22. Adult flies have a very different body structure from that of maggots.

- Flies have complex and well-developed exchange surfaces and transport systems.
- Maggots have only a small number of tracheae and a small volume of tracheal fluid.

Suggest why maggots do not need such well-developed exchange surfaces and transport systems.

_____

_____

_____

_____

_____

_____

_____ **[3]**

23. Organisms can use simple diffusion to exchange gases when the diffusion pathway is less than 1 mm.

A beet armyworm larva:

- has a cylindrical shape
- is 15 mm long
- has a volume of 30 mm^3.

Calculate the diffusion pathway of the larva and state whether it **could** or **could not** rely on simple diffusion across its external surface to meet its gas exchange requirements.

Use the formula: Volume of a cylinder = $\pi r^2 l$

diffusion pathway = ... mm

larva ..... rely on simple diffusion
[2]

24. Insects, such as beetles, obtain oxygen by drawing air in through holes in their exoskeleton, called spiracles. Pairs of spiracles on each abdominal segment connect to air tubes that take the air deep into the tissues of the insect for gas exchange.

Diving beetles live in ponds. They carry an air bubble under their wing when they swim underwater. The bubble supplies air to the spiracles. When the bubble has been used up, the beetle comes to the surface to collect a new bubble.

A student carried out an investigation into the effect of temperature on three diving beetles.

- Three beetles (A, B and C) from the same species were used in the investigation.
- They were placed in thermostatically controlled water baths at 10 °C, 20 °C and 30 °C respectively.
- They were observed for one hour.
- The number of times the beetle surfaced to renew its air bubble was recorded.
- Mean values for each temperature were calculated and recorded to the nearest whole number.
- The results are shown in Table 3.

Temperature (°C)	**Number of times beetle resurfaced in one hour**			
	Beetle A	**Beetle B**	**Beetle C**	**Mean**
10	10	12	8	10
20	18	22	18	20
30	44	48	38	43

Table 3

The student made an error in their working.

i. Put a ring around the error in **Table 3** and write the correct answer next to it. Use the space below to show your working.

[2]

ii. Fig. 3 shows a diagram of part of the gas exchange system of an insect.

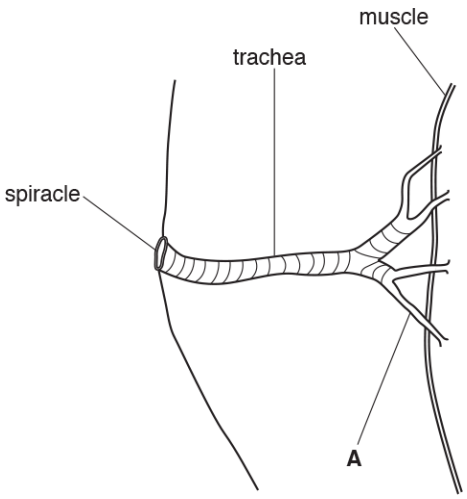


Fig. 3

Name the structure labelled **A**.

_____ **[1]**

iii. Describe how the trachea of a mammal is different from the trachea shown in Fig. 3.

_____

_____

_____

_____ **[2]**

25(a).

i. Mucus is present in goblet cells as condensed granules.

Some studies reveal that when secreted, the mucus expands to 500 times its volume in 20 ms.

40 cm^3 of mucus is held in condensed granules.

Calculate the volume of mucus in these granules **one** second after secretion, assuming a constant rate of expansion.

volume of mucus = ... cm^3 **[2]**

ii. Sjogren's syndrome is a rare condition that can reduce the production of mucus.

Suggest how the upper respiratory tract of a person with Sjogren's syndrome might be affected.

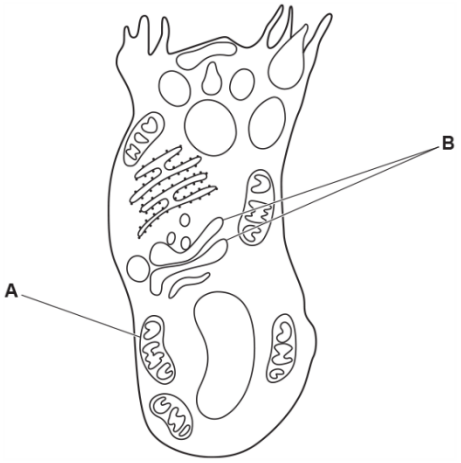
---

[1]

(b). Mucus is composed of water, carbohydrates, proteins and triglycerides.

Mucus is secreted by goblet cells.

Below is a diagram of a goblet cell as seen under an electron microscope.



i. Suggest why goblet cells have large numbers of the cellular component labelled **A**.

---

[1]

ii. Suggest how the role of the cellular component labelled **B** is relevant to the function of the goblet cell.

---

[2]

26. In mammals the lungs act as the gas exchange system. Various components of this system work together to ensure gas exchange is efficient. Two such components are cartilage and elastic fibres.

State the roles of these two components in mammalian gas exchange.

Cartilage

Elastic fibres

---

[2]

27. Mammals use lungs for gas exchange. The following passage describes how gases are moved in and out of the lungs.

Complete the passage using the most appropriate words or phrases.

When air enters the trachea, mucus secreted by ..... cells traps dust and microorganisms. Air diffuses through the bronchi and the bronchioles. Smooth muscle in the bronchioles relaxes during the 'fight or flight' response. This response is produced by the sympathetic nervous system, which contains neurones that secrete the neurotransmitter ..... .

During inspiration, both the ..... and external intercostal muscles contract. The internal intercostal muscles only contract when expiration is ..... .

[4]

28. *Outline the structures involved in the mammalian gaseous exchange system.

For each structure, explain how it increases the efficiency of gaseous exchange.

[6]

29. Fig. 1.1 is a diagram that represents inspiration and expiration in a human.

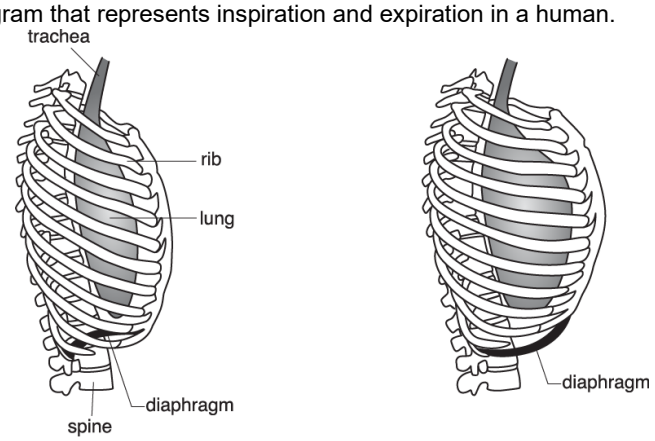


Fig. 1.1

i. Which of the two diagrams, **(a)** or **(b)**, represents the body **immediately after** expiration?

Describe how this diagram justifies your choice.

_____

_____

_____

_____ **[2]**

ii. Why can expiration be a passive process?

_____

_____

_____ **[1]**

iii. Some chemicals can act as allergens. If these allergens are inhaled, they can cause breathing problems. Allergens cause the smooth muscle in the walls of the airways to contract.

Suggest the effects that this muscle contraction has on ventilation.

_____

_____

_____

_____

_____

_____

_____ **[2]**

30. Ventilation involves various parts of the mammalian respiratory system.

Which of the following statements, **A** to **D**, describes **inhalation**?

A. ribcage moves upwards and outwards; external intercostal muscles relax; diaphragm relaxes

B. ribcage moves downwards and inwards; external intercostal muscles relax; diaphragm relaxes

C. ribcage moves upwards and outwards; external intercostal muscles contract; diaphragm contracts

D. ribcage moves downwards and inwards; external intercostal muscles contract; diaphragm contracts

Your answer ☐

[1]

31. During late pregnancy, women find ventilation more difficult, as the developing foetus reduces the volume of the thorax. This can lead to tiredness and difficulty breathing.

A student used a spirometer to measure ventilation in a woman who was 36 weeks pregnant.

Fig. 16.1 shows the trace produced.

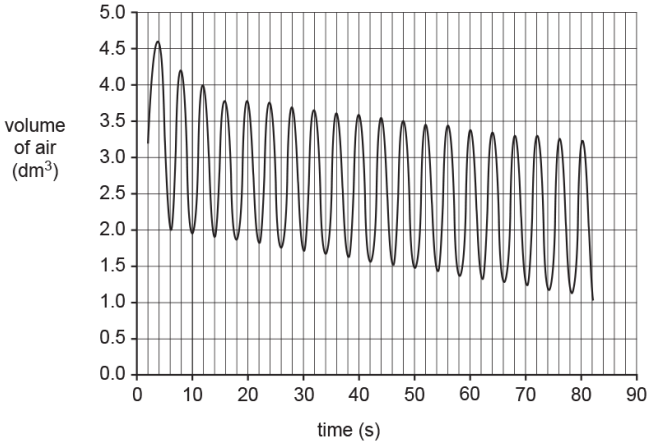


Fig. 16.1

Mean oxygen uptake rate at rest in women is around 0.020 $dm^3\ s^{-1}$.

Using these data, the student made the following conclusion:

My data show that being pregnant reduces rate of oxygen uptake by up to 20%.

Evaluate this claim, using the data in Fig. 16.1.

_____

_____

_____

_____

_____

_____

_____

_____

_____ **[3]**

32. The heart supplies oxygenated blood to the tissues.

VO_2^{max} is a measurement of the maximum volume of oxygen that an individual can use during intense exercise in a given time.

Smart watches can estimate the VO_2^{max} of an individual by measuring heart rate while exercising.

Having a higher VO_2^{max} is associated with improved aerobic fitness.

Two male students exercised for 30 min and used smart watches to record their VO_2^{max}.

Table 16 shows their masses and the VO_2^{max} values they recorded.

Student	Mass (kg)	VO_2^{max} ($cm^3\ kg^{-1}\ min^{-1}$)
1	65	50.4
2	57	48.2

Table 16

Student 1 drew the following conclusion from this result:

> My VO_2^{max} is higher because my mass is greater. I have more cells than Student 2. Each cell needs oxygen to carry out respiration.

Student 2 said that this conclusion is invalid because several variables have not been controlled.

State **three** variables necessary for a valid comparison that have **not** been controlled in the above experiment.

1

_____

_____

2

_____

_____

3

_____

_____

[3]

33(a). The figure below shows a light micrograph of an insect's gas exchange system.

Name the structures labelled **A** and **B** in the figure.

A

B

---

[2]

(b). Fish use gills as specialised gas exchange surfaces.

i. In ventilation, water moves into the buccal cavity, across the gills and out of the opercular cavity.

Complete the table by placing ticks (✓) in the appropriate boxes to show which of the processes occur at each stage of ventilation.

	Mouth closes	**Buccal cavity floor lowers**	**Operculum opens**	**Highest rate of oxygen diffusion into the blood**
Water moves into the buccal cavity				
Water moves across the gills and out of the opercular cavity				

[2]

ii. A student described how they dissected a fish to view the gills:

'I held the fish on a cutting board with one hand. I used scissors and a scalpel to carefully cut from the mouth to the tail, down the ventral side of the fish. I was able to split the fish into two halves and view the gills on the inside of the mouth.'

Suggest **one** improvement to the student's method that would allow them to observe the gills more easily.

_____

_____

_____ **[1]**

34. When walking, the abdomen of caterpillars expands and contracts slowly. Air is taken into the tiny holes along the side of the body.

One of these holes is labelled in Fig. 16.

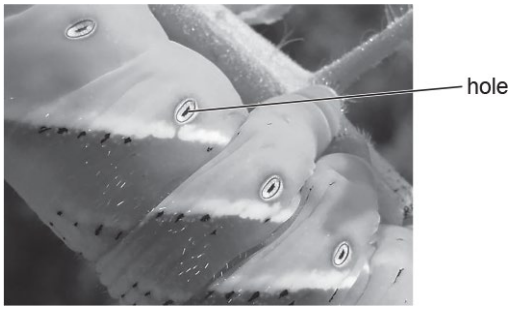


Fig. 16

i. Name these holes.

_____ **[1]**

ii. Fluid is found in the tubes responsible for gaseous exchange in insects.

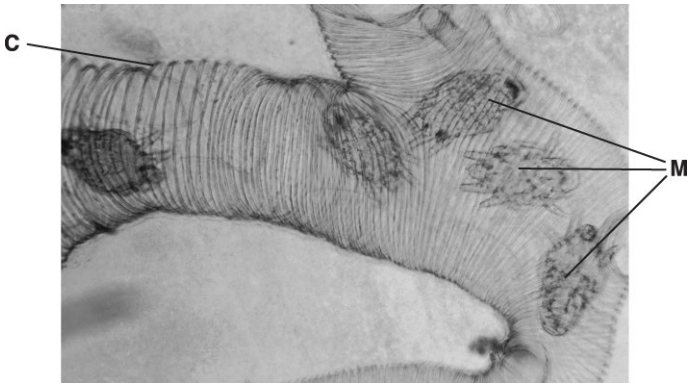
Name this fluid.

_____ **[1]**

35. The figure is a photomicrograph of the trachea of a honeybee, *Apis mellifera.*

The trachea of this honeybee is infected with honeybee tracheal mites, *Acarapis woodi.* Some of these mites are labelled **M** on the figure.

The trachea and tracheoles of insects have circular bands of chitin. One of these bands is labelled **C** on the figure.



i. What is the function of the circular bands of chitin labelled **C**?

---**[1]**

ii. The mites use their mouthparts to bite through the walls of the trachea. They then feed off the haemolymph, the blood-like liquid that bathes the cells and organs of the honeybee.

Suggest **one** other way in which the presence of the mites might affect the honeybee.

---**[1]**

36(a). Fig. 1.1 shows a microscopic image of part of a fish gill.

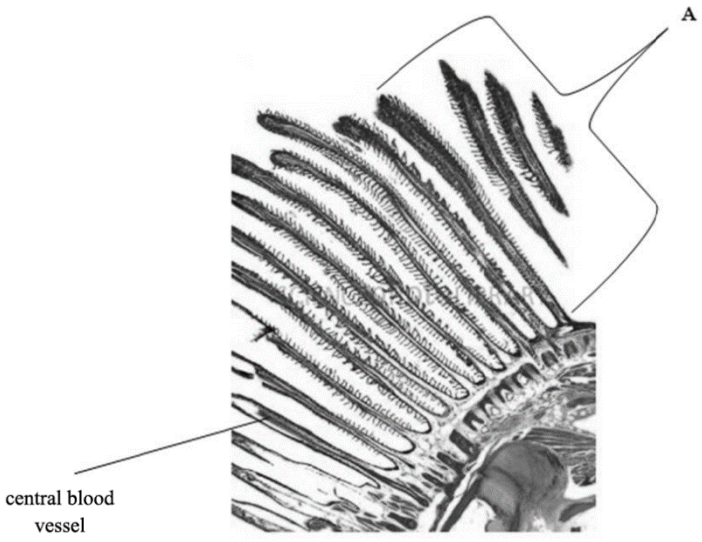


Fig. 1.1

Name structure **A**.

---

[1]

(b). Explain how **Fig. 1.1** shows that gills are adapted for efficient gas exchange.

---

[4]

(c). Each gill is supported by a gill arch made of bone. Bone tissue is made of living cells, collagen and an inorganic component.

Explain why bone is described as a tissue and gills are described as organs.

---

[3]

37. A student planned to carry out a dissection of insect and fish gaseous exchange systems.

The student planned to complete diagrams of the different tissues. They were advised to observe the following guidelines:

- use a sharp pencil
- use ruled label lines
- include a scale bar.

Suggest **two** further guidelines for the student to follow to ensure they present their diagrams clearly and accurately.

1

_____

_____

_____

2

_____

_____

_____ **[2]**

38. Bony fish and insects have different gas exchange systems. Both can be observed by dissection.

Describe how you would carry out the dissection to display maximum detail of either gas exchange system.

_____

_____

_____ **[2]**