

B.2.3 Cell specialization [65 marks]

1.

[Maximum mark: 1]

In multicellular animals, embryonic stem cells have the ability to differentiate into a range of cells with different functions. What is the term used to describe cells with this property?
- A. Pluripotent

B. Multipotent

C. Totipotent

D. Specialized
- [1]

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2.

[Maximum mark: 1]

What best describes stem cells?
- A. Cells found only in the early embryo.

B. Multipotent embryonic cells that can differentiate into all cell types.

C. Totipotent stem cells that are found in specific niches in adults.

D. Pluripotent stem cells that may differentiate into blood cells.
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3. [Maximum mark: 6]

Stem cells can differentiate into other cell types.

(a) Outline how stem cells develop into specialized cells during development of the embryo.

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(b) Cardiac muscle cells and striated muscle fibres are highly specialized to produce movement. Compare and contrast the structure of both types of muscle cells.

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(c) State a development in electron microscopy that has improved the study of cell ultrastructure.

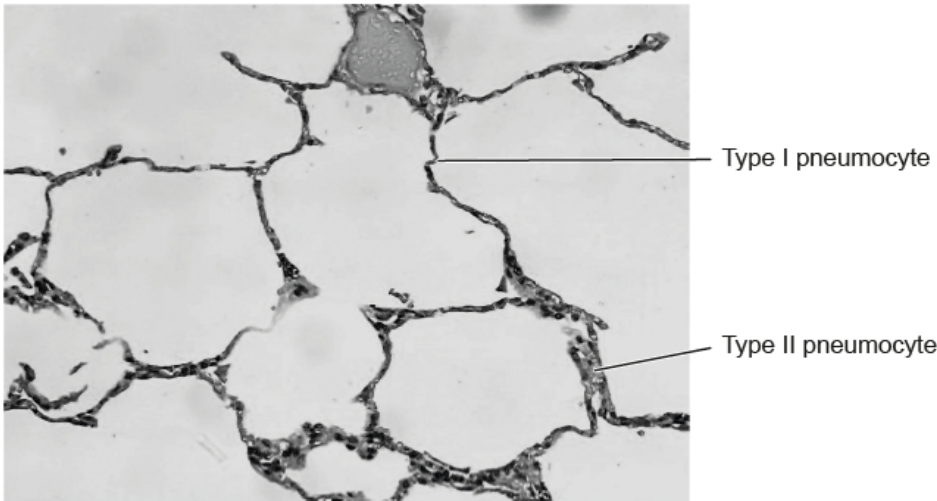
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4. [Maximum mark: 1]
The micrograph shows alveoli in a human lung.



[Source: Yale Rosen, 2008. Normal lung Alveoli. [image online] Available at: [https://commons.wikimedia.org/wiki/File:Normal_lung_Alveoli_\(3678762542\).jpg](https://commons.wikimedia.org/wiki/File:Normal_lung_Alveoli_(3678762542).jpg). Licensed under the Creative Commons Attribution-Share Alike 2.0 Generic license: <https://creativecommons.org/licenses/by-sa/2.0/deed.en>. [Accessed 7 June 2024]. Source adapted.]

How are the pneumocytes adapted to their function?

	Type I pneumocytes	Type II pneumocytes
A.	many secretory vesicles (lamellar bodies)	many secretory vesicles (lamellar bodies)
B.	many secretory vesicles (lamellar bodies)	large number of mitochondria
C.	large number of mitochondria	extreme thinness
D.	extreme thinness	many secretory vesicles (lamellar bodies)

[1]

5. [Maximum mark: 1]
Which term describes very early-stage embryonic stem cells in a mouse?

A. Totipotent

B. Pluripotent

C. Multipotent

D. Unipotent

[1]

6. [Maximum mark: 1]

Which features are found in both cardiac and striated muscle?

A. Nuclei and branched myofibrils

B. Sarcomeres and unbranched myofibrils

C. Mitochondria and branched myofibrils

D. Sarcomeres and mitochondria

[1]

7. [Maximum mark: 8]

Duchenne muscular dystrophy (DMD) is a sex-linked genetic disorder caused by a recessive allele resulting from mutations in the X-linked dystrophin gene. This causes the degeneration of cardiac and skeletal muscle. These mutations can include deletions, insertions and base substitution mutations.

(a) Using a Punnett grid, deduce the probability of inheriting DMD if an unaffected male has offspring with a female carrier.

Probability:

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(b) Distinguish between deletion and insertion mutations.

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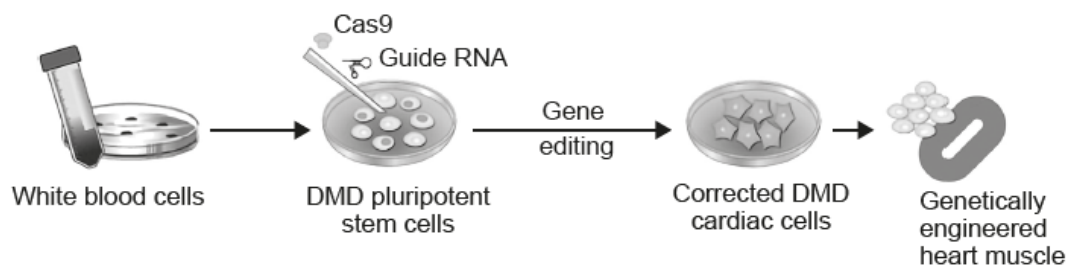
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Gene editing technologies using CRISPR (clustered regularly interspaced short palindromic repeats) can potentially treat various diseases such as DMD. CRISPR-Cas9 can be used to repair the mutated DMD gene, leading to the expression of the encoded protein, dystrophin.

The diagram shows the correction of dystrophin expression by gene editing.



[Source: Reprinted with permission of AAAS from Fig 2a from Long et al *Science Advances*, 31 Jan 2018, Vol 4, Issue 1 DOI: 10.1126/sciadv.aap9004. © The Authors, some rights reserved; exclusive licensee AAAS. Distributed under a CC BY-NC 4.0 License (<http://creativecommons.org/licenses/by-nc/4.0/>).]

(c) Explain ways in which CRISPR-Cas9 gene editing could be used to change the mutated dystrophin protein produced.

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(d) Suggest **one** reason for the use of pluripotent instead of multipotent stem cells in this process.

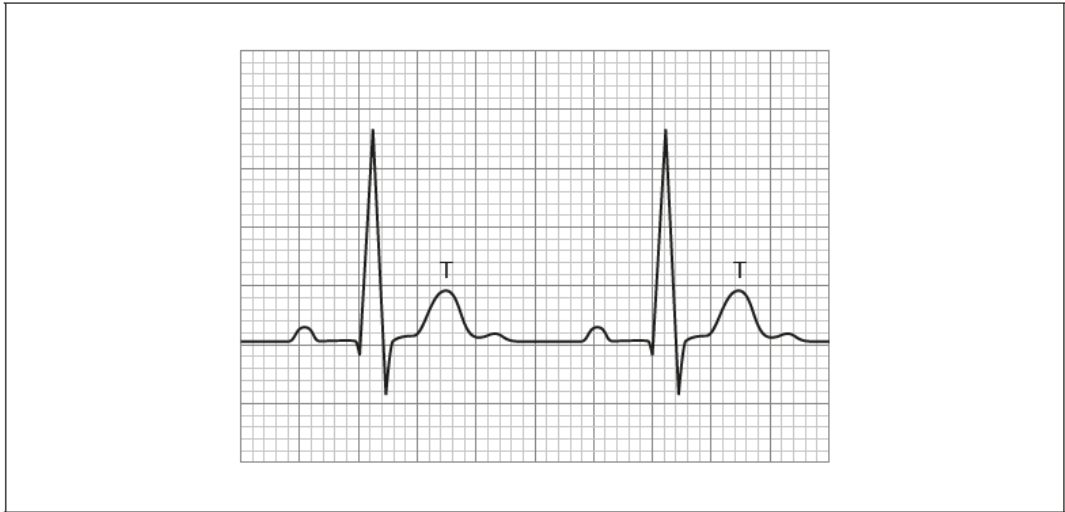
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8. [Maximum mark: 6]
The diagram of a normal electrocardiogram (ECG) trace shows two cardiac cycles.



[Source: Chromatos, n.d. *Medical electrocardiogram* - ECG on grid. [graph online] Available at: <https://www.gettyimages.co.uk/detail/illustration/medical-electrocardiogram-ecg-on-grid-royalty-free-illustration/488117198?adppopup=true> [Accessed 31 January 2024]. Source adapted.]

- (a) Annotate the diagram to show the wave produced by
- (a.i) the contraction of the atria; [1]
- (a.ii) the contraction of the ventricles. [1]
- (b) State the stage of the cardiac cycle shown at T. [1]

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- (c) Explain how the structure of cardiac muscle cells is adapted to their function. [3]

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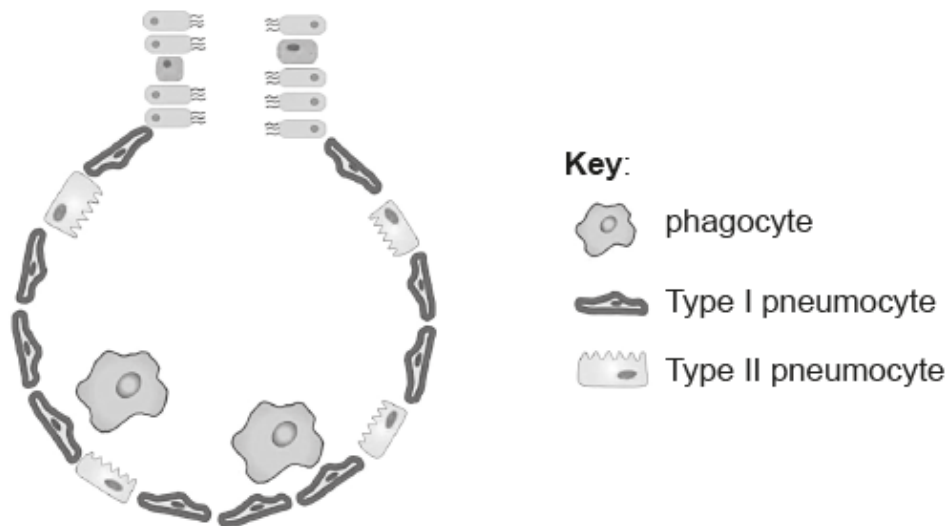
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9. [Maximum mark: 1]

The diagram shows an alveolus from a healthy human lung with type I and II pneumocytes and phagocytes.



[Source: Huang, B., 2021. *Cellular & Molecular Immunology* 18, pp. 1823–25. [e-journal] Available at: <https://www.nature.com/articles/s41423-021-00714-8#Fig1> [Accessed 12 April 2023]. Source adapted.]

[1]

What are the main functions of these cells?

	Type I pneumocyte	Type II pneumocyte	Phagocyte
A.	Production of surfactant	Gas exchange	Production of antibodies
B.	Gas exchange	Production of surfactant	Production of antibodies
C.	Production of surfactant	Gas exchange	Ingestion of pathogens
D.	Gas exchange	Production of surfactant	Ingestion of pathogens

10. [Maximum mark: 1]

Scientists are investigating the potential use of embryonic stem cells to repair spinal cord injuries in humans. What would be an advantage of using embryonic rather than adult stem cells?

- A. More cell types can be obtained.
- B. Possibilities of rejection are lower.

C. The risk of stem cells forming malignant tumours is lower.

D. Unlimited numbers of cells can be extracted from the umbilical cord.

[1]

11. [Maximum mark: 1]

Stargardt's is an inherited disease caused by the mutation of a gene associated with vitamin A processing in the eye. It results in degeneration of receptor cells and loss of vision. For what reason are stem cells suitable to treat this disease?

A. They can be taken from the eye of an embryo and transplanted into a patient.

B. They can produce vitamin A in newborn babies.

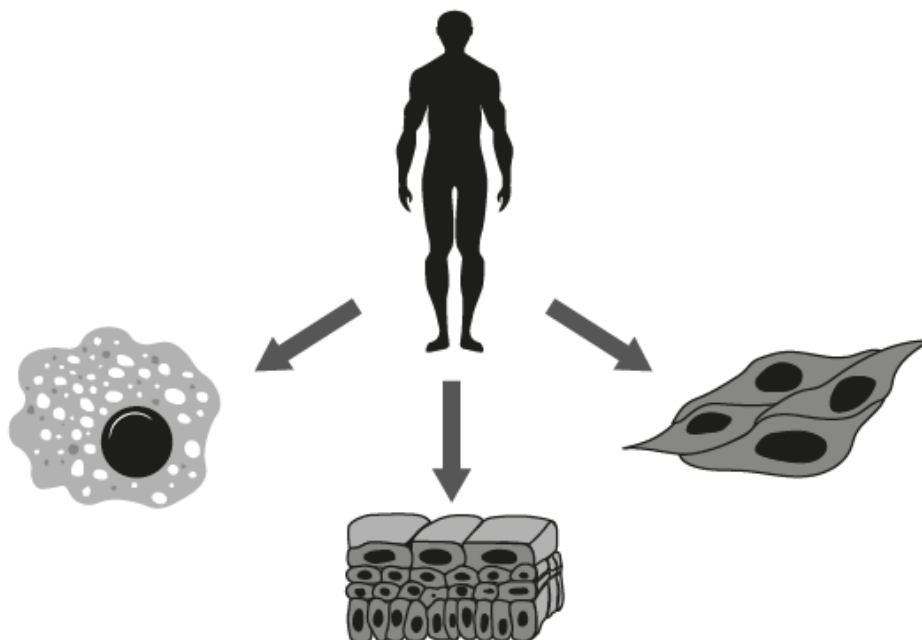
C. They can develop into receptor cells and prevent blindness.

D. They can be removed from an embryo to detect early onset of the disease.

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12. [Maximum mark: 1]

Undifferentiated cells can become specialized to perform specific functions in a multicellular organism.



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What accounts for the differences in these cells?

- A. Their chromosome number differs.
- B. Their proteomes are different.
- C. They have slightly different genomes.
- D. They express different chromosomes.

13. [Maximum mark: 1]

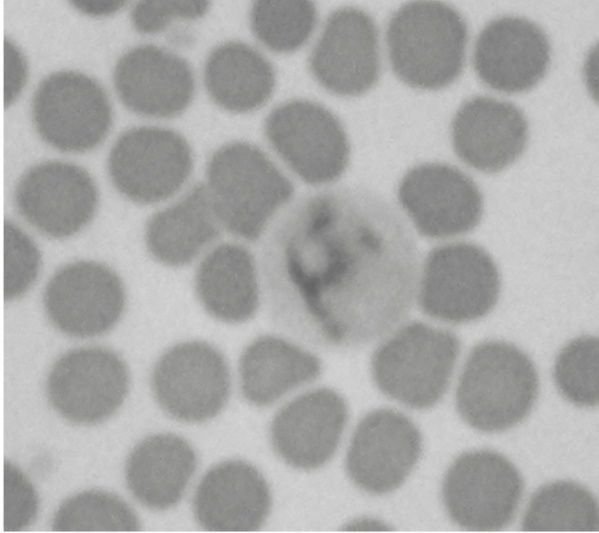
What are functions of type I and type II alveolar pneumocytes?

	Type I	Type II
A.	Produce surfactant	Exchange CO ₂
B.	Exchange CO ₂	Exchange CO ₂
C.	Phagocytic cells	Protective epithelial cells
D.	Carry out gas exchange	Produce surfactant

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14. [Maximum mark: 1]

The micrograph shows two types of blood cell.



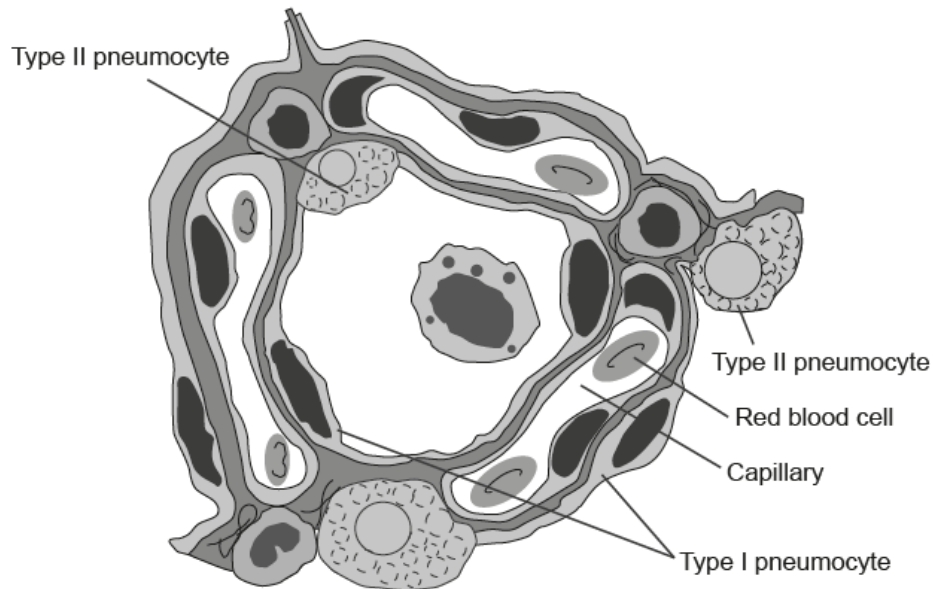
What determines the differences between the two types of cell?

- A. Different number of mitotic cycles
- B. Different expression of some genes
- C. Reaction to oxygen of red blood cells
- D. Reaction to antigens of white blood cells

[1]

15. [Maximum mark: 1]

The diagram shows a section through an alveolus.



[Source: Bergman, Ronald A., Ph.D., and D'Alessandro, Michael P., M.D. Pulmonary alveoli, "Anatomy Atlases". Available online: <http://www.anatomyatlases.org/> [Accessed 02/01/2023].]

What are the functions of the following labelled structures?

	Type I pneumocyte	Type II pneumocyte	Capillary
A.	Gas exchange	Produces surfactant	Transports carbon dioxide from alveolus
B.	Produces surfactant	Gas exchange	Transports oxygen to alveolus
C.	Gas exchange	Produces surfactant	Transports carbon dioxide to alveolus
D.	Produces surfactant	Gas exchange	Transports oxygen from alveolus

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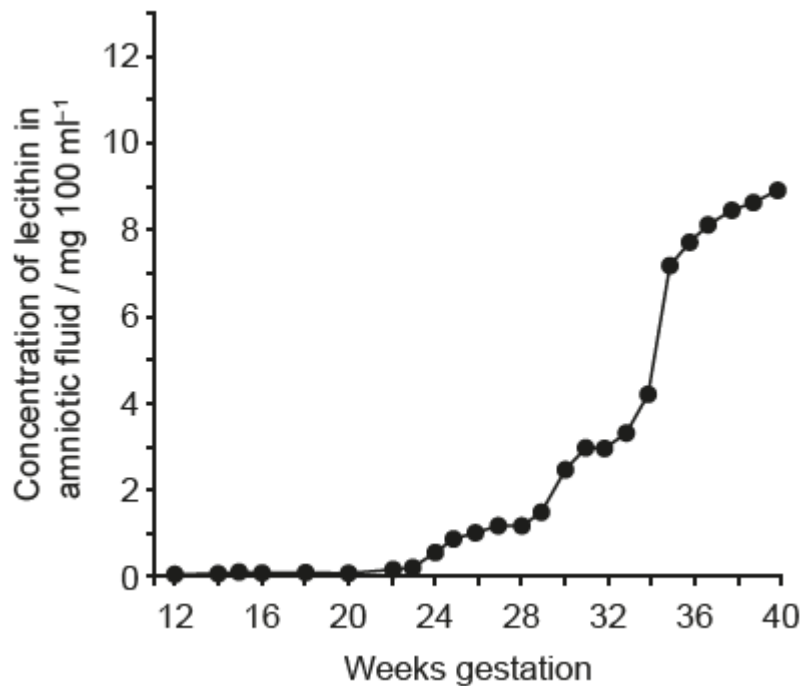
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16. [Maximum mark: 1]

The graph shows the concentration of the lipid lecithin in the amniotic fluid surrounding the fetus during normal gestation. This lipid is produced in the lungs of the fetus and acts as a surfactant.



[Source: Gluck, L. and Kulovich, M., n.d. [*Concentrations of phospholipids*].

[graph online] Available at:

<http://www.columbia.edu/itc/hs/medical/humandev/2004/Chpt12-LungDev.pdf> [Accessed 28 October 2021].]

What problem may occur in a baby born before 34 weeks gestation?

- A. Type I pneumocytes do not produce sufficient surfactant for lungs to inflate.
- B. There are no type II pneumocytes.
- C. The alveolar walls stick together.
- D. The alveoli are too large.

[1]

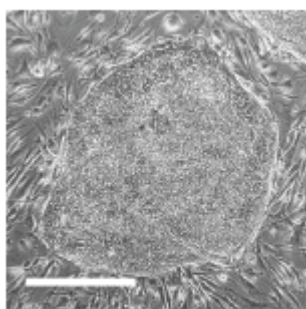
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17. [Maximum mark: 5]

An oval-shaped stem cell cluster is shown in the micrograph.



500 μm

[Source: Sontag, S., Förster, M., Seré, K. and Zenke, M., 2017. [online] Available at: <https://bio-protocol.org/e2419> [Accessed 6 December 2019]. Source adapted.]

(a) State the main characteristic of stem cells.

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(b) Calculate the maximum diameter of the stem cell cluster on the micrograph, showing your working and giving the units.

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(c) State **one** therapeutic role of stem cells.

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(d) Discuss how the use of stem cells to treat hereditary diseases could affect the person who received the treatment **and** their progeny.

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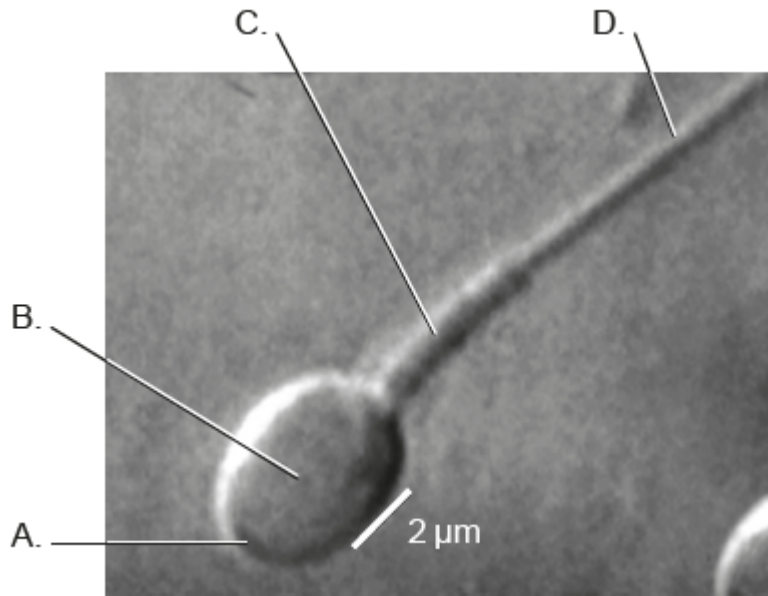
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18. [Maximum mark: 1]

The micrograph shows part of a human sperm cell. Which region of the cell is responsible for the greatest production of ATP?



[Source: Oliveira, J.B.A., Petersen, C.G., Massaro, F.C. et al. Motile sperm organelle morphology examination (MSOME):

intervariation study of normal sperm and sperm with large nuclear vacuoles. *Reprod Biol Endocrinol* 8, 56 (2010).

<https://doi.org/10.1186/1477-7827-8-56>.

https://embryology.med.unsw.edu.au/embryology/index.php/File:Single_human_spermatozoa.jpg Creative Commons Attribution License (CC BY

2.0) (<http://creativecommons.org/licenses/by/2.0>).]

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19. [Maximum mark: 15]

Substances can move into and out of cells through the cell membrane.

- (a) Outline the significance of surface area to volume ratio in the limitation of cell size.

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(b) Describe transport across cell membranes by osmosis.

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(c) Explain the adaptations of the small intestine to its function.

[7]

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[Maximum mark: 1]

Which process results in the exchange of gases across the membrane of pneumocytes?

A. Active transport

B. Simple diffusion

C. Facilitated diffusion

D. Mass flow
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21.

[Maximum mark: 1]

In mammals, mature red blood cells are specialized in that they lack nuclei, mitochondria or ribosomes. Which statement applies to red blood cells?

A. No chemical reactions take place within their cytoplasm.

B. They cannot produce new enzymes.

C. Materials cannot enter red blood cells.

D. Materials cannot exit red blood cells.
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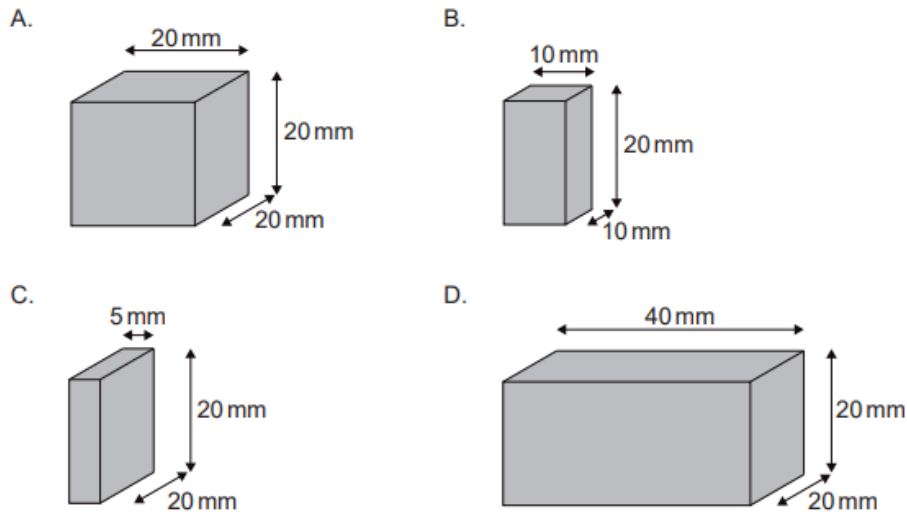
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22.

[Maximum mark: 1]

The diagrams represent cells with the same concentration of dissolved substances in their cytoplasm. If all the cells were placed in the same hypertonic sucrose solution, which cell would show the greatest rate of change in the concentration of its cytoplasm?



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23. [Maximum mark: 1]

In premature babies born earlier than the 30th week of pregnancy, type II pneumocytes are usually not fully developed, so they do not carry out their function normally. What is a possible consequence of this?

- A. The number of alveoli reduces.
- B. The size of the alveoli increases.
- C. Capillary networks do not develop fully and oxygen is not absorbed.
- D. Surface tension between alveoli does not decrease and the alveoli stick together.

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24. [Maximum mark: 1]
What is produced by type II pneumocytes?

- A. Epinephrine
- B. Elastase
- C. Pulmonary surfactant
- D. Alpha 1-antitrypsin

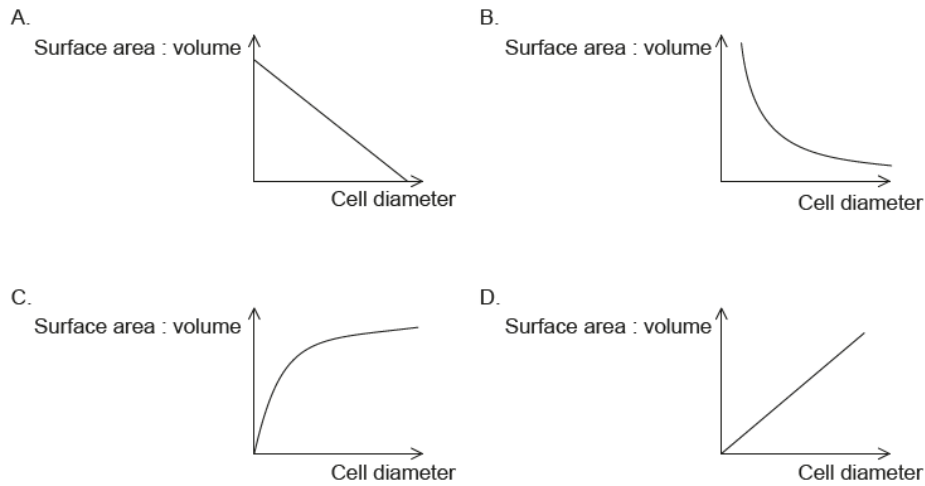
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25. [Maximum mark: 1]
Which graph represents the change in cell surface area to volume ratio
with increasing cell diameter?



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[Source: © International Baccalaureate Organization 2019]

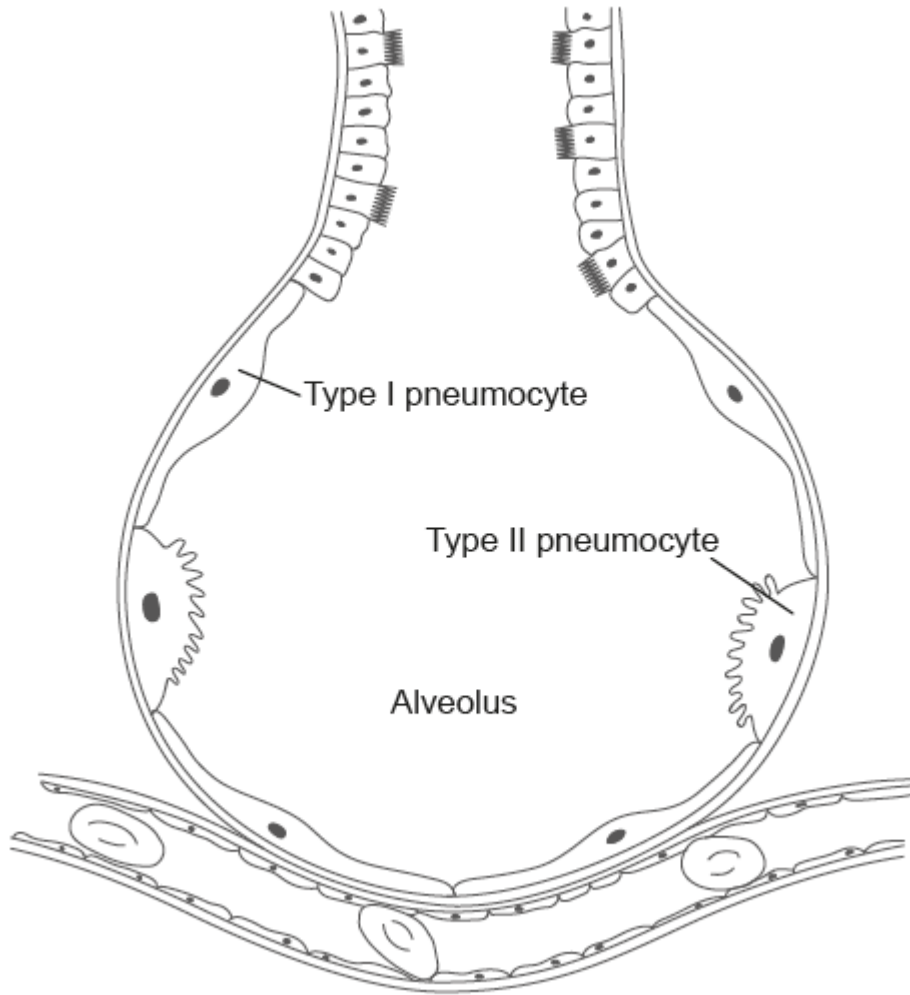
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26. [Maximum mark: 5]

The diagram shows the structure of an alveolus and an adjacent capillary.



[Source: © International Baccalaureate Organization 2019]

(a) Outline the functions of type I and type II pneumocytes.

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(b) Explain how gases are exchanged between the air in the alveolus and the blood in the capillaries.

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