

© International Baccalaureate Organization 2021

All rights reserved. No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without the prior written permission from the IB. Additionally, the license tied with this product prohibits use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, whether fee-covered or not, is prohibited and is a criminal offense.

More information on how to request written permission in the form of a license can be obtained from <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organisation du Baccalauréat International 2021

Tous droits réservés. Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite préalable de l'IB. De plus, la licence associée à ce produit interdit toute utilisation de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, moyennant paiement ou non, est interdite et constitue une infraction pénale.

Pour plus d'informations sur la procédure à suivre pour obtenir une autorisation écrite sous la forme d'une licence, rendez-vous à l'adresse <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organización del Bachillerato Internacional, 2021

Todos los derechos reservados. No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin la previa autorización por escrito del IB. Además, la licencia vinculada a este producto prohíbe el uso de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales—, ya sea incluido en tasas o no, está prohibido y constituye un delito.

En este enlace encontrará más información sobre cómo solicitar una autorización por escrito en forma de licencia: <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

**Biology**  
**Higher level**  
**Paper 1**

Wednesday 27 October 2021 (morning)

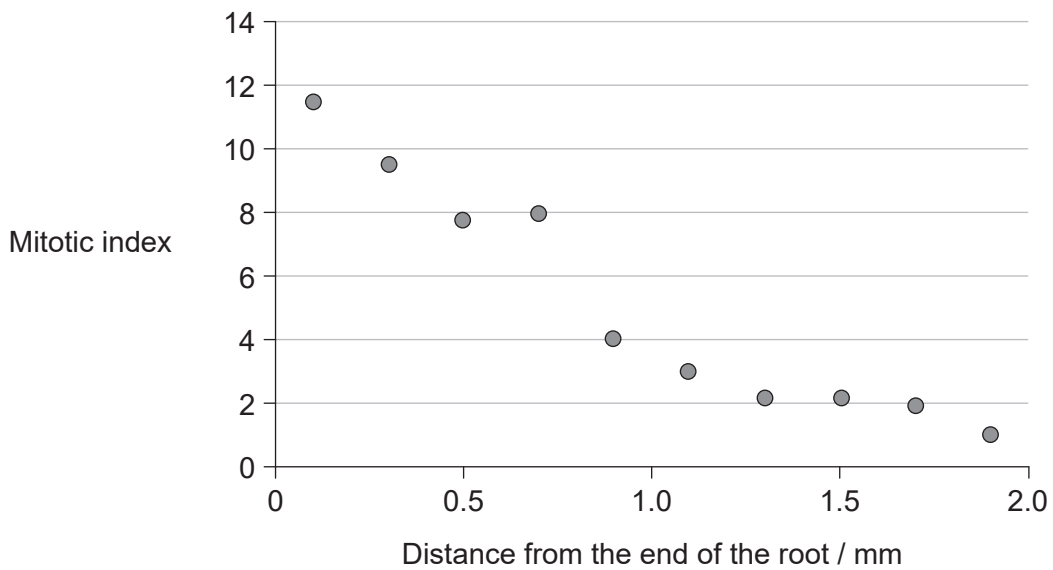
1 hour

---

**Instructions to candidates**

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The maximum mark for this examination paper is **[40 marks]**.

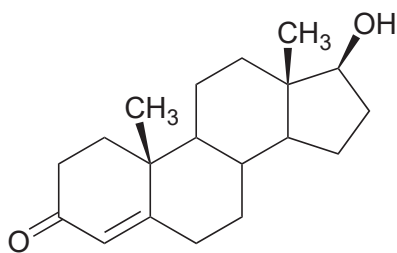
1. How is facilitated diffusion in axons similar to active transport?
  - A. They both require the energy of ATP.
  - B. They both move substances against a concentration gradient.
  - C. They both use sodium-potassium pumps.
  - D. They are both carried out by proteins embedded in the axon membrane.
  
2. How do both mitochondria and chloroplasts provide evidence for the endosymbiotic theory?
  - A. They have double membranes.
  - B. They have 80S ribosomes similar to prokaryotes.
  - C. They contain the same DNA as the nucleus of the cell.
  - D. They exist together in eukaryote cells for their mutual benefit.
  
3. The graph shows the mitotic index in the roots of lentil plants at different distances from the end of the root.



What can be deduced from the graph?

- A. As the distance from the end of the root increases, more cells are undergoing mitosis.
- B. At 0.5 mm from the end of the root, most of the cells are in prophase.
- C. There were fewer cells observed at 1.5 mm than at 0.5 mm.
- D. As the distance from the end of the root increases, the percentage of cells in interphase increases.

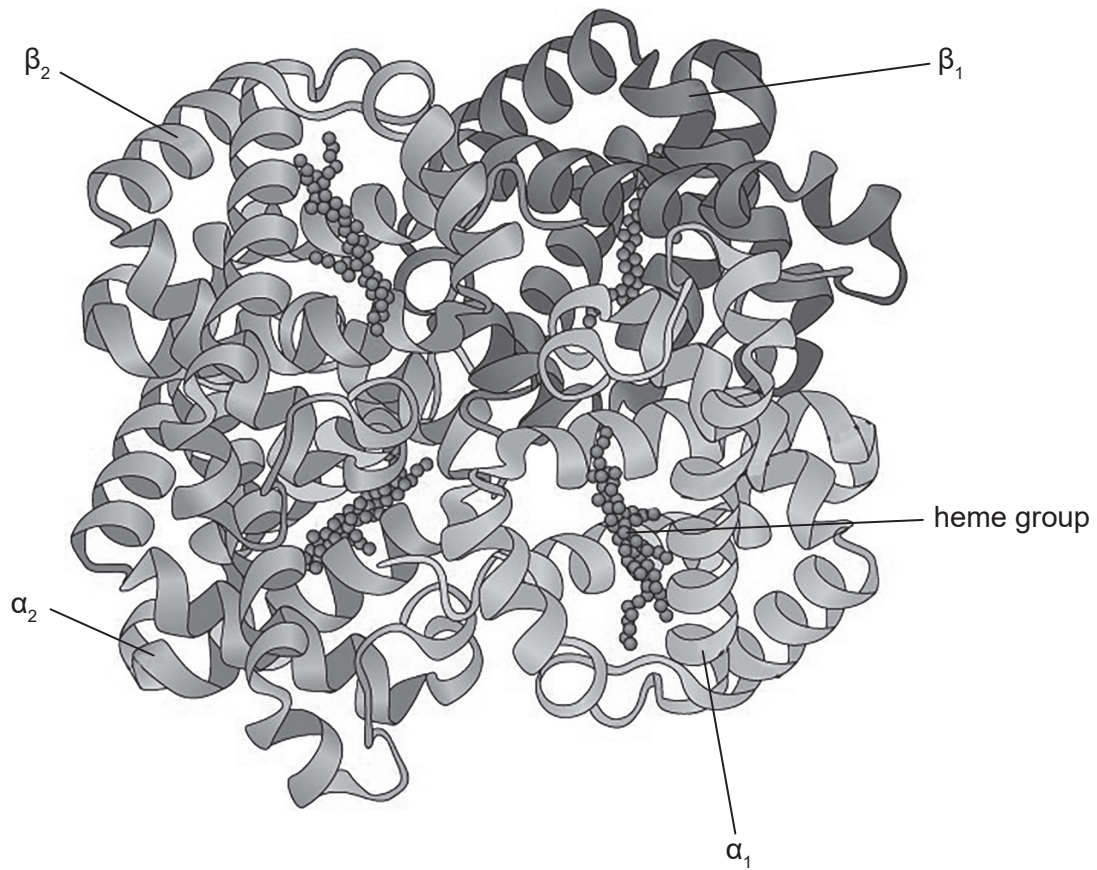
4. Which features of phospholipids give them their amphipathic properties?
- A. Basic phosphate groups and acidic lipids
  - B. Acidic phosphate groups and basic lipids
  - C. Hydrophobic phosphate groups and hydrophilic fatty acids
  - D. Hydrophilic phosphate groups and hydrophobic fatty acids
5. Testosterone is a hormone that is important for male reproductive development.



To which group of compounds does testosterone belong?

- A. Nucleotides
- B. Carbohydrates
- C. Lipids
- D. Amino acids

6. The image shows the structure of the protein hemoglobin.



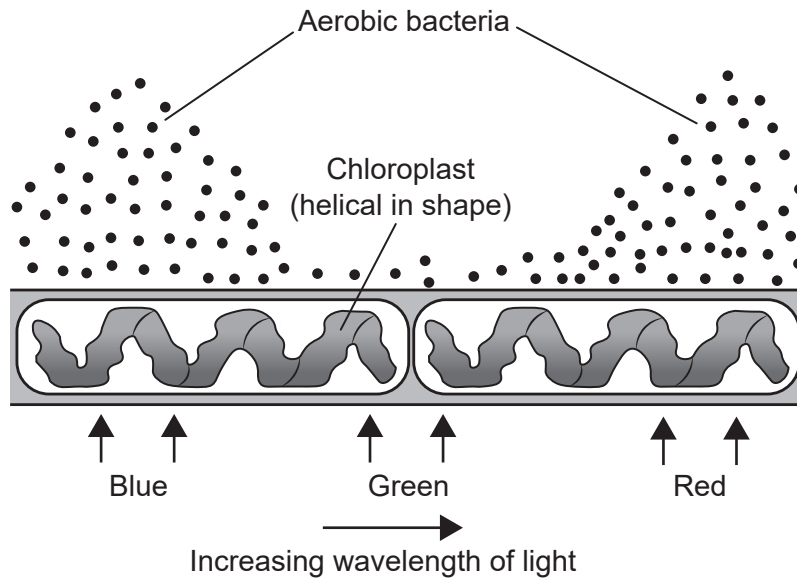
What level of protein structure bonds the  $\alpha$  and  $\beta$  chains together?

- A. Primary
- B. Secondary
- C. Tertiary
- D. Quaternary

7. The data shows part of the genetic code for mRNA. Which anticodon could be found on a tRNA molecule bonded to lysine?

UUU	Phenylalanine
UUC	
AAA	Lysine
AAG	

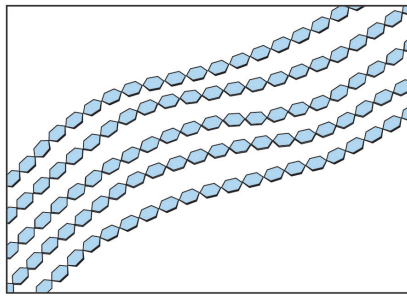
- A. AAG  
B. UUC  
C. TTT  
D. GAA
8. In 1882, Engelmann investigated photosynthesis by shining light of varying wavelength on a green alga. He observed where aerobic bacteria accumulated.



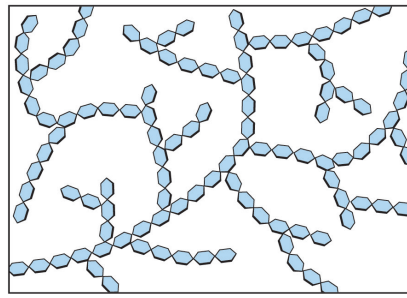
What can be deduced from this experiment?

- A. Only parts of the chloroplast contained chlorophyll.  
B. The distribution of bacteria indicates the action spectrum of photosynthesis.  
C. Most oxygen is released from the algae in green light.  
D. Chloroplasts reflect blue and red light.

9. The diagrams show how monosaccharide molecules are joined to form chains in two polysaccharides.



P



Q

Using the diagram and the table, which diagram and monosaccharide represent glycogen?

	Diagram	Monosaccharide that makes up the chain
A.	P	glucose
B.	P	maltose
C.	Q	glucose
D.	Q	maltose

10. John Cairns used the technique of autoradiography to produce photographs of DNA from the bacterium *E. coli*.

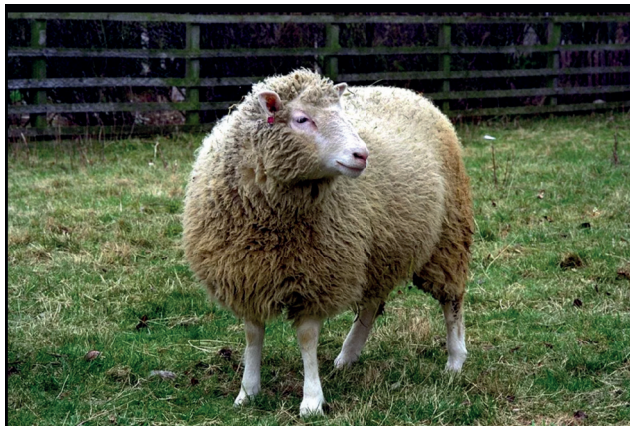


Which conclusion was drawn from his experiments?

- A. The DNA in all organisms is circular.
  - B. DNA in *E. coli* naturally contains thymidine.
  - C. DNA replication is conservative.
  - D. The DNA in *E. coli* is 900  $\mu\text{m}$  in length.
11. Down syndrome can be detected before birth by chorionic villus sampling. From where are the cells for this test taken?
- A. Amniotic fluid surrounding the fetus
  - B. Fetal digestive system
  - C. Tissue in the placenta
  - D. Lining of the uterus of the mother



12. Huntington's disease can develop in middle age and leads to death of brain cells. It is carried by an autosomal dominant gene. What can be deduced about a man who has the disease?
- A. Half of his children will get the disease.
  - B. Neither of his parents had the disease, but one must have been a carrier.
  - C. At least one of his grandparents must have had the disease.
  - D. His sons are more likely to have the disease than his daughters.
13. A nucleus was removed from a cell of sheep P and fused with a denucleated egg cell of sheep Q. This was transplanted into the uterus of sheep R, which gave birth to Dolly.



[Source: Photo courtesy of The Roslin Institute, The University of Edinburgh]

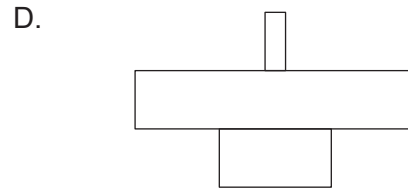
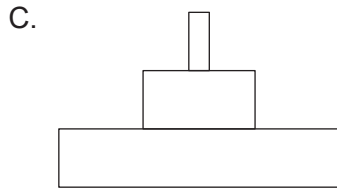
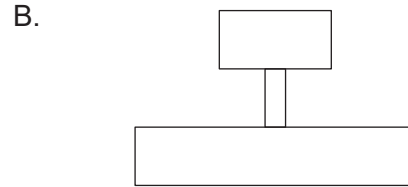
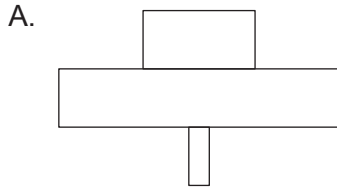
Which describes Dolly?

- A. A clone of sheep P, because Dolly was formed from the nucleus of its udder cell
- B. A clone of sheep Q, because Dolly was formed from one of its egg cells
- C. A clone of sheep R, because Dolly developed in its uterus
- D. Not a proper clone, as more than one sheep was involved in the development

14. In a woodland ecosystem, each tree provides food for numerous aphids which feed on the sap of the tree. The aphids are eaten by carnivorous beetles, as shown in the food chain.

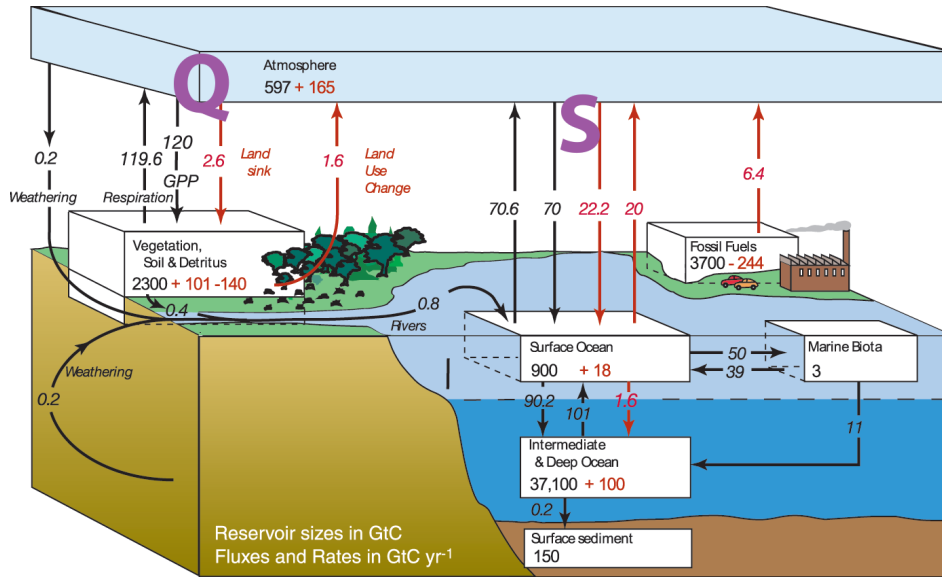
Oak Tree → Aphids → Beetles

Which pyramid of energy represents this relationship?



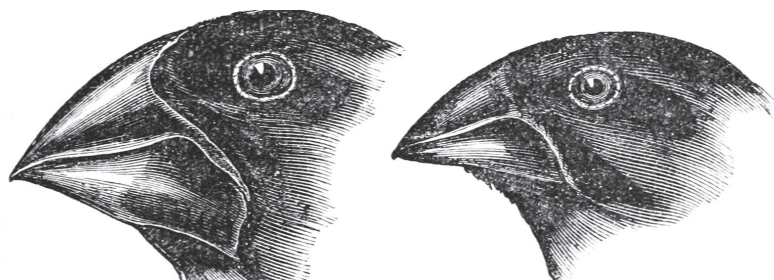
15. How do greenhouse gases contribute to global warming?
- A. They destroy the ozone layer, allowing radiation to reach the Earth's surface.
  - B. They prevent radiation from the Earth escaping into space.
  - C. They trap short wavelength radiation in the atmosphere.
  - D. They are a product of combustion, which generates heat.

16. The diagram shows the carbon flux in gigatonnes per year between some of the Earth's global reservoirs.



What can be deduced from the information in the diagram?

- A. Arrows S are mainly due to respiration of marine plants and animals.
  - B. Photosynthesis is a component of both arrows Q and S.
  - C. Every day, more carbon is removed from the ocean than is added.
  - D. Ocean carbon is stored as dissolved calcium carbonate.
17. Scientists studying ground finches (*Geospiza fortis*) on the island of Daphne Major in Galapagos found great differences in the shapes of the beaks.



What is the explanation for this variation in beak shape between the birds?

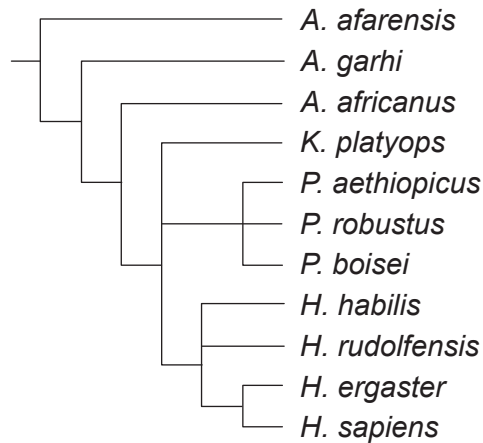
- A. Ground finches grow larger beaks if there is competition for food.
- B. They belong to different species.
- C. They are adapted for different diets.
- D. The more a beak is used by a ground finch, the larger it becomes.

18. To which phylum does the earthworm *Lumbricus rubellus* belong?



- A. Annelida
- B. Cnidaria
- C. Platyhelmintha
- D. Arthropoda

19. The cladogram shows one theory of how species of hominin evolved.



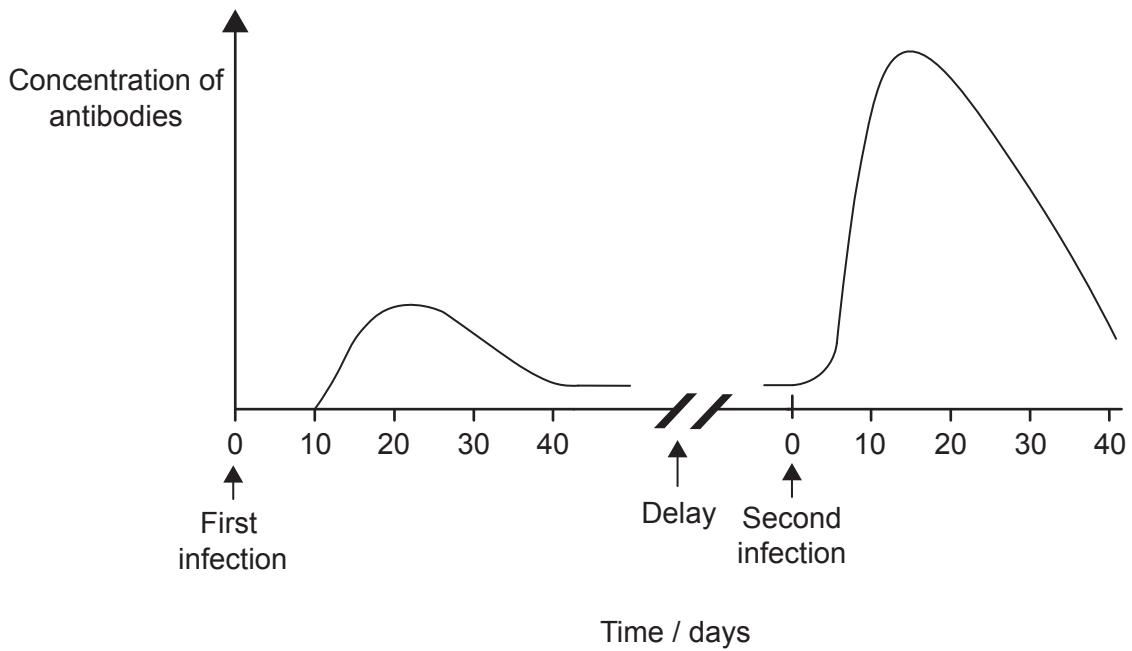
What can be deduced using the information in the cladogram?

- A. The closest species to *K. platyops* is *A. africanus*.
- B. *A. afarensis* is extinct.
- C. The DNA of *H. sapiens* is the same as that of *H. ergaster*.
- D. *H. sapiens* and *P. robustus* shared a common ancestor.

20. What occurs as a result of a cut in the skin of a finger?

- A. Prothrombin is transformed into thrombin.
- B. Fibrin is converted to insoluble fibrinogen.
- C. Platelets produce antibodies to prevent infection.
- D. Clotting factors are released from red blood cells.

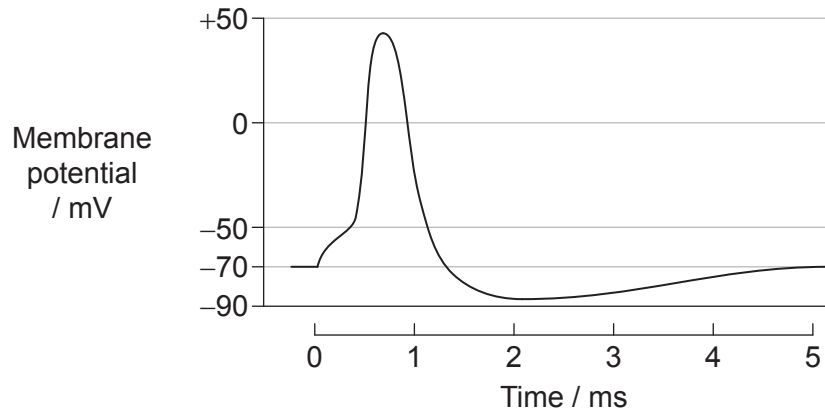
21. A person was infected with a pathogen and then later in life they were re-infected with the same pathogen. The graph shows the concentration of antibodies found in the blood that were produced in response to these two infections.



What is the reason for the faster rise in antibody concentration after the second infection?

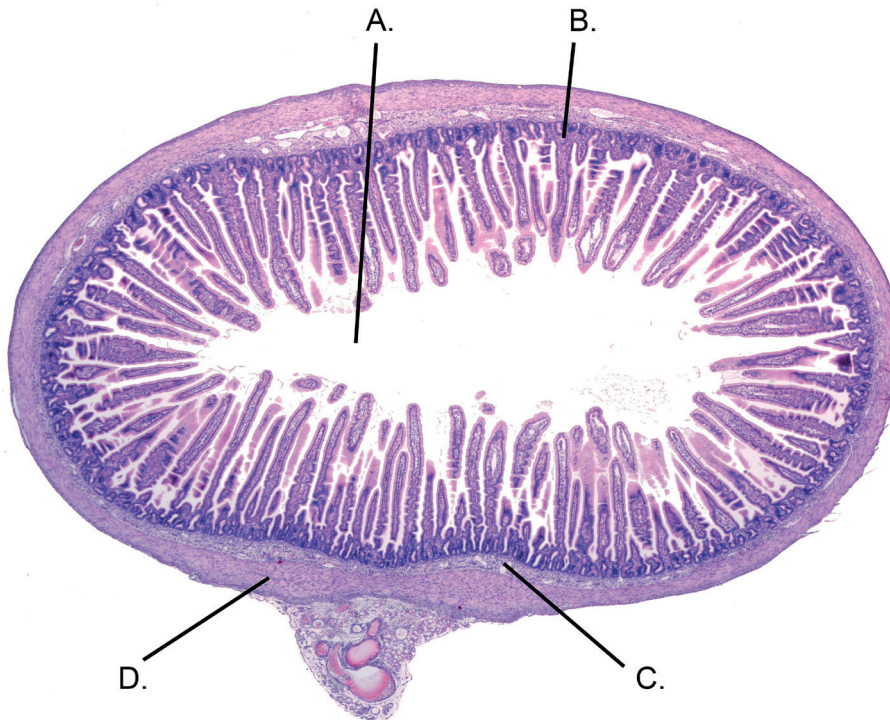
- A. The patient had previously been vaccinated with the antibody.
- B. Antibodies had been stored after the first exposure.
- C. Lymphocytes rapidly reproduced to form plasma cells.
- D. The second exposure was more infectious.

22. The graph shows changes in the membrane potential in an action potential.

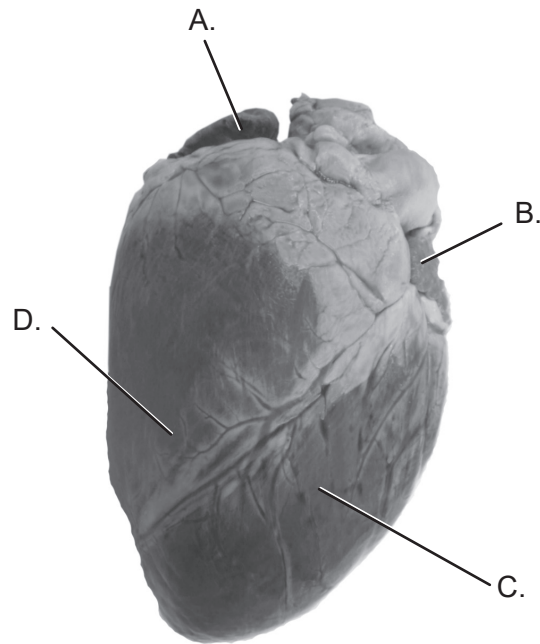


What is the approximate value of the threshold potential?

- A. -88 mV
  - B. -70 mV
  - C. -50 mV
  - D. +45 mV
23. The diagram shows a cross section through the small intestine of a mammal. Which label points to the mucosa?



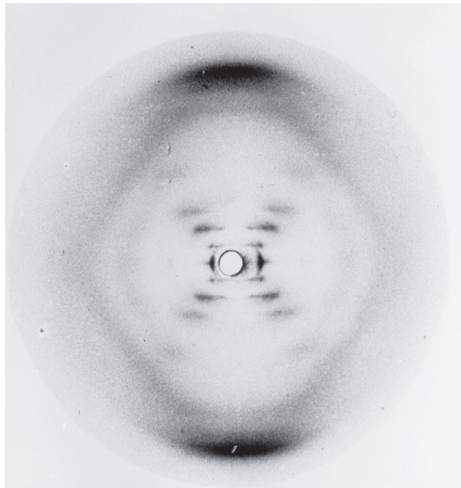
24. The image shows the four chambers of the mammalian heart viewed from the ventral side. The sinoatrial node is located in the wall of one of these chambers. Which chamber is it?



25. Leptin is a hormone which initiates the process to reduce food intake. What is the location of the glands that produce leptin and where are its target cells found?

	<b>Location of glands</b>	<b>Location of target cells</b>
A.	pancreas	hypothalamus
B.	pancreas	lining of stomach
C.	adipose tissue	lining of stomach
D.	adipose tissue	hypothalamus

26. Rosalind Franklin produced X-ray diffraction images of DNA.

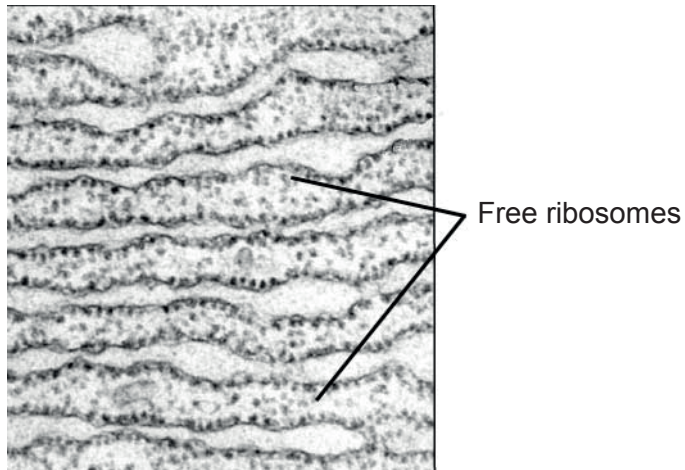


Which previously unknown aspect of DNA was deduced from these images?

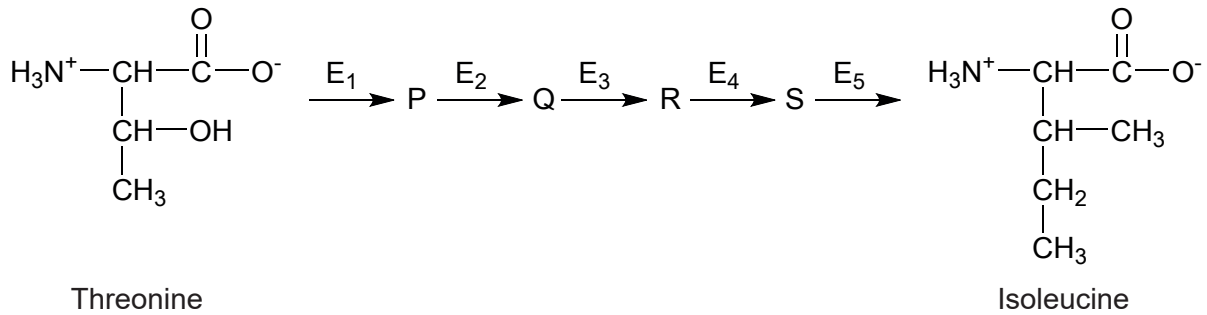
- A. Chromosomes are made of DNA.
  - B. Deoxyribose sugar is attached to a phosphate group.
  - C. The base A pairs with T and C with G.
  - D. The DNA molecule is a double helix.
27. What is the difference between the DNA of adult identical (monozygotic) twins?
- A. Order of genes
  - B. Sequence of nucleotides
  - C. Methylation pattern
  - D. Ratio of complementary base pairs



28. What is the primary function of the free ribosomes shown in the electron micrograph?



- A. Synthesize proteins to be used within the cell
  - B. Synthesize proteins for use in lysosomes
  - C. Carry amino acids to mRNA for protein synthesis
  - D. Synthesize proteins for secretion
29. Some bacteria can synthesize the amino acid isoleucine from threonine, a process involving five enzymes ( $E_1$  to  $E_5$ ) and four intermediary products (P, Q, R and S). The production of isoleucine is controlled by end-product inhibition.

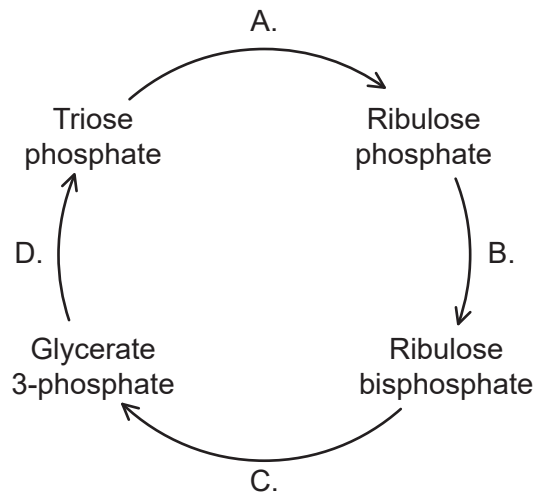


Which statement describes this end-product inhibition?

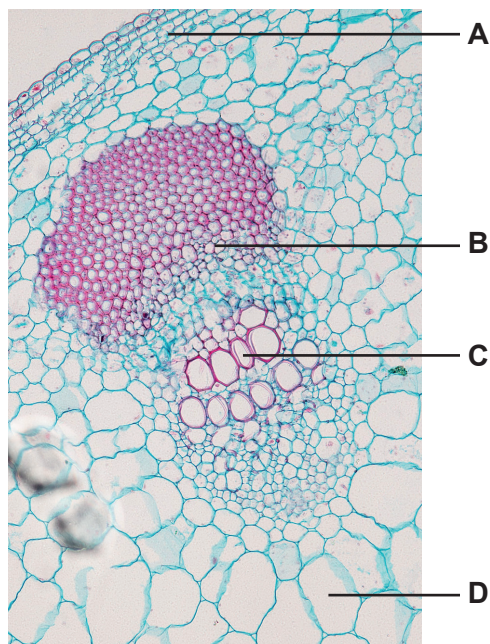
- A. If isoleucine accumulates, it inhibits the production of P.
- B. End-product inhibition causes a build-up of intermediary products.
- C. Isoleucine inhibits  $E_5$ , so no more isoleucine is produced.
- D. Isoleucine affects the structure of threonine.

30. Where are protons pumped, to allow chemiosmosis in aerobic respiration to occur?
- A. From outside the mitochondrion through the double membranes
  - B. From carrier to carrier in the inner mitochondrial membrane
  - C. From the matrix of the mitochondrion to the space between the membranes
  - D. From the space between the membranes to the cytoplasm outside the mitochondrion

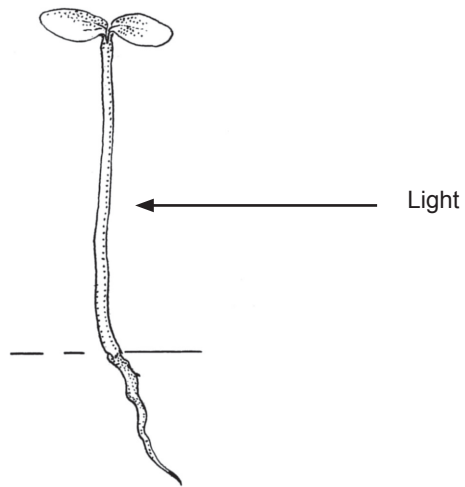
31. The diagram shows some of the intermediate compounds produced during the Calvin cycle. At what stage does carboxylation take place?



32. A plant is allowed to photosynthesize in an atmosphere containing radioactive  $^{14}\text{C}$ . Where in the plant stem would radioactive sugars be found?



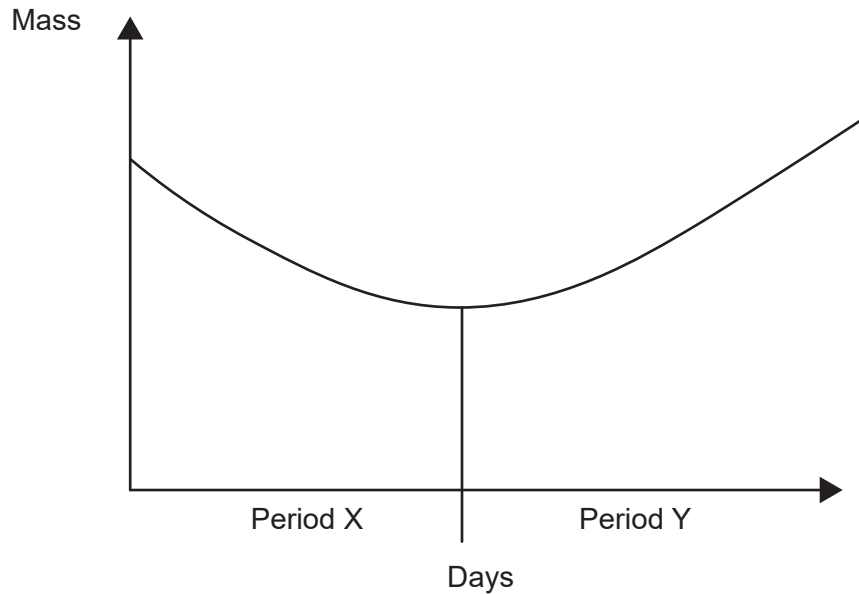
33. The diagram shows a plant shoot and the direction of the light which the shoot received.



What are the direction of movement and the effect of auxin in the tip of a plant shoot when receiving light from one side?

	<b>Direction of movement of auxin</b>	<b>Effect of auxin on cell elongation</b>
A.	Towards light	promotes
B.	Towards light	inhibits
C.	Away from light	promotes
D.	Away from light	inhibits

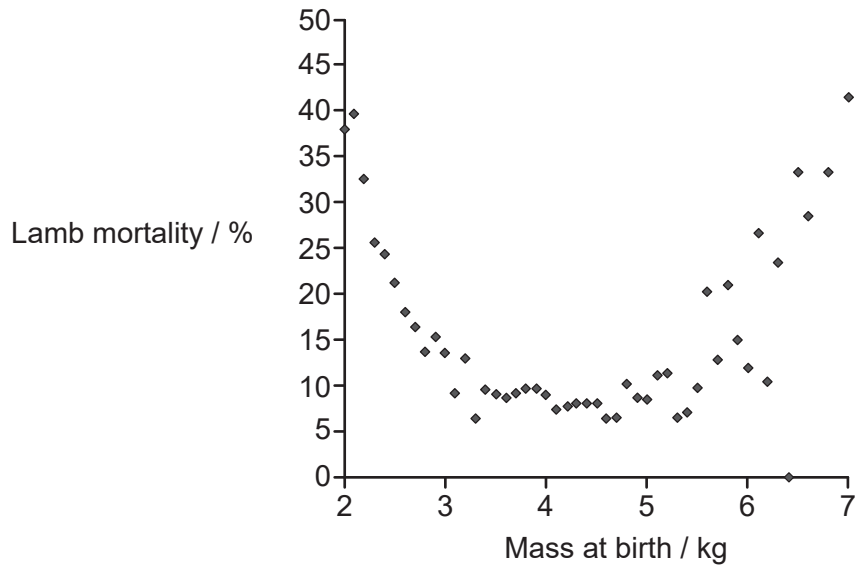
34. The graph shows how the mass of a bean seed from which all water has been removed (dry mass) changes during germination.



What can be deduced from the graph?

- A. The plant loses more water during period X than during period Y.
  - B. During period Y, photosynthesis occurs but not respiration.
  - C. During period Y, more CO<sub>2</sub> is fixed in photosynthesis than is released by cell respiration.
  - D. The seeds were not exposed to the correct temperature for germination during period X.
35. A dihybrid cross was carried out between two plants to determine whether the genes for seed shape and colour are linked. If the genes are unlinked, the expected ratio of 9:3:3:1 should occur. A chi-squared test was carried out on the observed results of the cross. The critical value for chi squared at the 5% level of significance in this test was 7.82. The calculated value for chi squared was 6.25. What can be concluded from this data?
- A. The results prove that the genes are linked.
  - B. The results prove that the genes are unlinked.
  - C. There is significant evidence that the genes are linked.
  - D. There is significant evidence that the genes are unlinked.

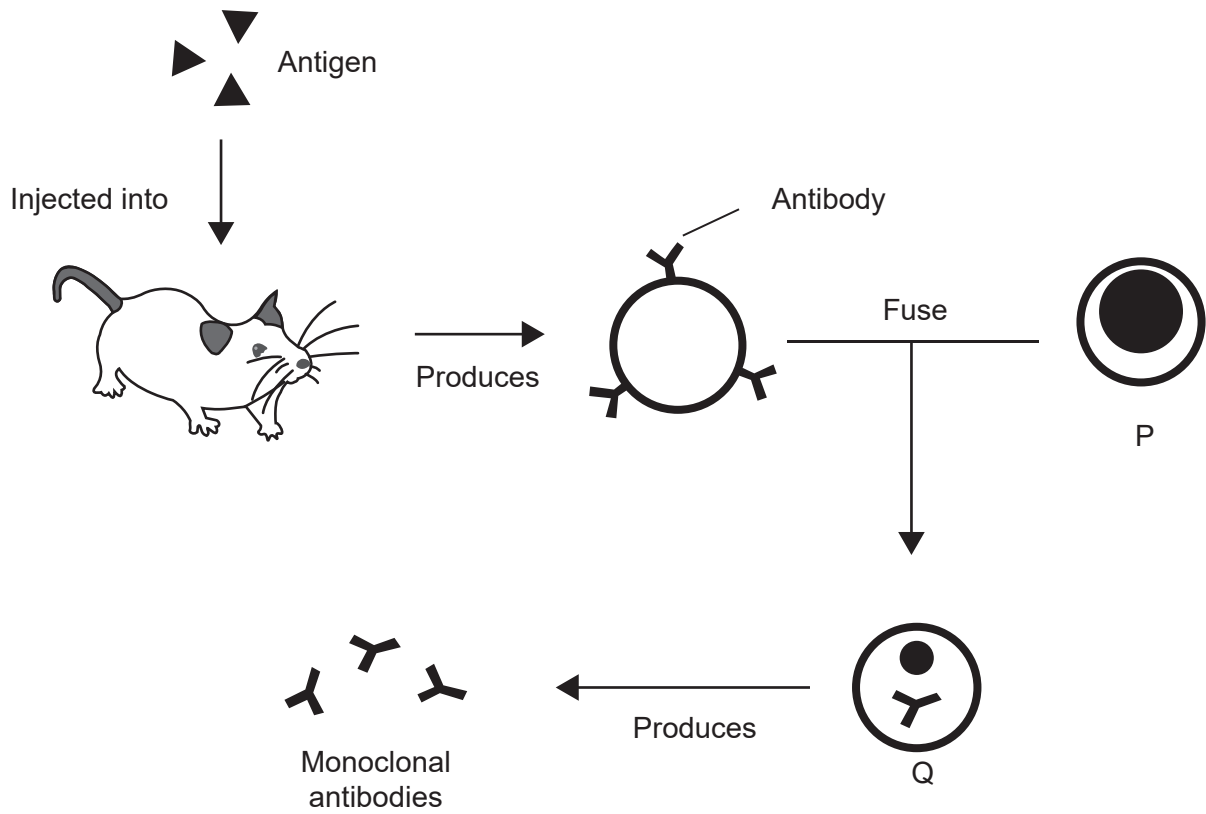
36. The graph shows the relationship between mass at birth and the percentage that die shortly after birth for Scottish Blackface lambs.



What type of selection for the lambs is shown in the graph?

- A. Disruptive selection, as there is a drop in mortality at intermediate birth masses
- B. Stabilizing selection, as lambs with low or high birth mass are less likely to survive
- C. Directional selection, as lambs with a high birth mass have high mortality
- D. There is no evidence in the graph of selection, as survival frequency is not shown

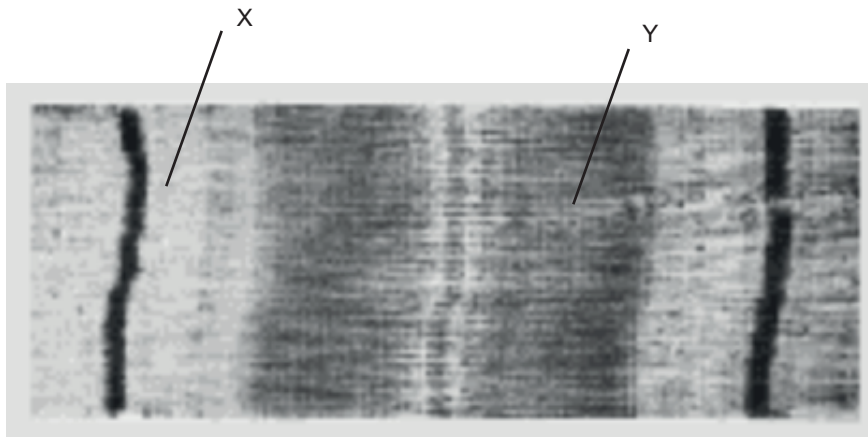
37. The diagram shows a method for the production of monoclonal antibodies.



What are cells P and Q?

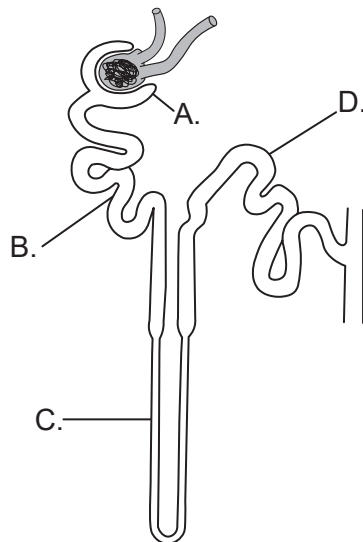
	P	Q
A.	Tumour cell	Hybridoma
B.	Tumour cell	Plasma cell
C.	T lymphocyte	Plasma cell
D.	T lymphocyte	Hybridoma

38. The image shows part of a myofibril from a relaxed muscle fibre.

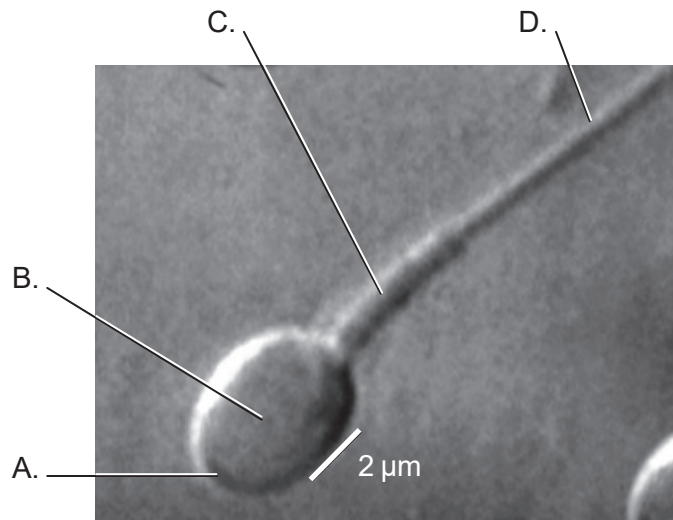


What occurs during muscle contraction?

- A. Myosin binding sites are blocked.
  - B. The bands labelled Y get shorter.
  - C. The bands labelled X get shorter.
  - D. Calcium ions bind to myosin.
39. Where in the nephron is most glucose reabsorbed?



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





## References:

3. *Physiologia Plantarum*, Volume 105, Issue 1, January 1999, Pages 171–178, Effect of microgravity on the cell cycle in the lentil root. F. Yu, D. Driss-Ecole, J. Rembur, V. Legué, G. Perbal. Wiley Online Library: <https://onlinelibrary.wiley.com/doi/abs/10.1034/j.1399-3054.1999.105125.x>
6. Hemoglobin molecule, Microbiology ID: e42bd376-624b-4c0f-972f-e0c57998e765@4.4 OpenStax Microbiology <https://cnx.org/contents/5CvTdmJL@4.4> and [https://commons.wikimedia.org/wiki/File:OSC\\_Microbio\\_07\\_04\\_hemoglobin.jpg](https://commons.wikimedia.org/wiki/File:OSC_Microbio_07_04_hemoglobin.jpg) Licensed under a Creative Commons Attribution 4.0 International License, <https://creativecommons.org/licenses/by/4.0/>.
8. Republished with permission of Oxford University Press, from *Plant Physiology and Development, Sixth Edition* by Lincoln Taiz, Eduardo Zeiger, Ian M. Møller, and Angus Murphy, 2015. Permission conveyed through Copyright Clearance Center, Inc.
9. Amelse, J. Achieving Net Zero Carbon Dioxide by Sequestering Biomass Carbon. *Preprints 2020*, 2020070576 (doi: 10.20944/preprints202007.0576.v1). Fig SI9. Distributed under a Creative Commons CC BY license Attribution 4.0 International (CC BY 4.0), <https://creativecommons.org/licenses/by/4.0/>.
10. © Cold Spring Harbor Laboratory Press. Autoradiography of bacterium *E. coli* DNA - micrograph, The Chromosome of *Escherichia coli*. Cairns, J.P., 1963. Cold Spring Harbor Symposia, *Quantitative Biology*, 28(44).
13. Photo courtesy of The Roslin Institute, The University of Edinburgh, Roslin, Scotland, UK, n.d. Dolly the Sheep in a field at The Roslin Institute. [image online] Available at: <https://www.livescience.com/57961-dolly-the-sheep-announcement-20-year-anniversary.html> [Accessed 23 March 2020].
16. Figure 7.3 and Table 7.1 from Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
17. Public domain.
18. Casselmann, H., 2011. *Lumbricus rubellus* HC1. [image online] Available at: [https://commons.wikimedia.org/wiki/File:Lumbricus\\_rubellus\\_HC1.jpg](https://commons.wikimedia.org/wiki/File:Lumbricus_rubellus_HC1.jpg) (CC BY-SA 3.0) <https://creativecommons.org/licenses/by-sa/3.0/deed.en> [Accessed 23 March 2020].
23. JOSE LUIS CALVO MARTIN & JOSE ENRIQUE GARCIA-MAURIÑO MUZQUIZ / [www.istockphoto.com](http://www.istockphoto.com).

24. Anatomy Corner, n.d. [*Elk heart*]. [image online] Available at: <http://anatomycorner.com/main/image-gallery/elk-heart/> [Accessed 23 March 2020].
26. © King's College, London. KCL Department of Biophysics KDBP/1/1.
28. J Gordon Betts, et al. *Anatomy and Physiology*. Houston Texas: OpenStax, 2013. <https://openstax.org/books/anatomy-and-physiology/pages/3-2-the-cytoplasm-and-cellular-organelles>. Image file available at [https://commons.wikimedia.org/wiki/File:0313\\_Endoplasmic\\_Reticulum.jpg#/media/File:0313\\_Endoplasmic\\_Reticulum\\_b\\_labeled.png](https://commons.wikimedia.org/wiki/File:0313_Endoplasmic_Reticulum.jpg#/media/File:0313_Endoplasmic_Reticulum_b_labeled.png). This file is licensed under the Creative Commons Attribution 3.0 Unported license. <https://creativecommons.org/licenses/by/3.0/deed.en>.
32. [sinhyu/123rf.com](http://sinhyu/123rf.com).
33. USDA-NRCS PLANTS Database. Available at: [https://commons.wikimedia.org/wiki/File:Alnus\\_seedling\\_drawing.png](https://commons.wikimedia.org/wiki/File:Alnus_seedling_drawing.png) [Accessed 30 November 2021].
36. Dwyer, C.M., Conington, J., Corbiere, F., Holmoy, I.H., Muri, K., Nowak, R., Rooke, J., Vipond, J. and Gautier, J.-M., 2016. Invited review: Improving neonatal survival in small ruminants: science into practice. *Animal*, 10(3), pp.449–459.
37. Adenosine, March 5, 2010. A general representation of the method used to produce monoclonal antibodies. [online] Available at: [https://en.wikipedia.org/wiki/Monoclonal\\_antibody](https://en.wikipedia.org/wiki/Monoclonal_antibody) (CC BY-SA 3.0) <https://creativecommons.org/licenses/by-sa/3.0/deed.en> [Accessed 27 March 2020]. Adapted.
38. Sarcomere. Sameerb. Available at <https://commons.wikimedia.org/wiki/File:Sarcomere.gif> [Accessed 30 November 2021].
39. National Institute of Diabetes and Digestive and Kidney Diseases, n.d. [*Nephron*]. [diagram online] Available at: <https://www.niddk.nih.gov/news/media-library/9164> [Accessed 23 March 2020].
40. 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](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>).