Diploma Programme
Programme du diplôme
Programa del Diploma

Biology
Standard level
Paper 3

Thursday 7 May 2015 (afternoon)

Candidate session number

1 hour

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- The maximum mark for this examination paper is **[36 marks]**.

Option	Questions
Option A — Human nutrition and health	1 – 3
Option B — Physiology of exercise	4 – 6
Option C — Cells and energy	7 – 9
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30 pages

2215 – 6018

Option A — Human nutrition and health

1. Low protein diets are a widespread problem in the developing world. A low protein diet in a pregnant mother could affect a developing fetus. Other mammals are used as a biomedical model for energy metabolism and malnutrition in humans.

In an experiment to study the effect of protein levels in the diet, pregnant mammals were fed diets with different ratios of protein to carbohydrate:

- low protein : high carbohydrate (LP),
- adequate protein : adequate carbohydrate (AP),
- high protein : low carbohydrate (HP).

The table shows the average birth mass of the offspring and the body mass gain of the mother during the pregnancy. The concentration of several substances in the plasma of the mothers was also recorded. LDL (low density lipoprotein) is considered "bad cholesterol" and HDL (high density lipoprotein) is considered "good cholesterol".

	Offspring birth mass / kg	**Mother's body mass gain / kg**	**LDL cholesterol / mmol l^{-1}**	**HDL cholesterol / mmol l^{-1}**	**Glucose / mmol l^{-1}**	**Urea / mmol l^{-1}**
LP	1.19	42.1	0.59	0.96	4.24	1.7
AP	1.41	68.3	0.70	0.87	4.04	3.0
HP	1.21	63.1	0.85	0.78	4.20	7.1

[Source: Adapted from: Metges, C.C., Lang, I.S., Hennig, U., Brüssow, K.-P., Kanitz, E. *et al*. (2012) Intrauterine Growth Retarded Progeny of Pregnant Sows Fed High Protein: Low Carbohydrate Diet Is Related to Metabolic Energy Deficit. *PLoS ONE*, **7**(2): e31390. doi: 10.1371/journal.pone.0031390. Table 6]

(a) Identify the substance that varies the most in the plasma of the mothers. [1]

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(b) Calculate the difference between birth mass of offspring whose mothers were fed the AP diet and the HP diet. [1]

. . . . . kg

(Option A continues on the following page)

(Option A, question 1 continued)

(c) Distinguish between LDL cholesterol and HDL cholesterol in relation to the diet. [1]

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(d) Explain the low birth mass of offspring born to mothers who were fed the LP diet. [2]

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(e) In many societies doctors may recommend an HP diet for pregnant humans. Using the data, evaluate this recommendation. [3]

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(Option A continues on the following page)

(Option A continued)

2. (a) (i) State **one** source of vitamin D in the diet. [1]

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(ii) State how vitamin D can be obtained other than through the diet. [1]

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(b) Distinguish between the composition of human milk and artificial milk. [2]

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(Option A continues on the following page)

(Option A continued)

3. (a) State **two** symptoms of type II diabetes. [2]

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(b) Explain the causes and consequences of phenylketonuria (PKU). [4]

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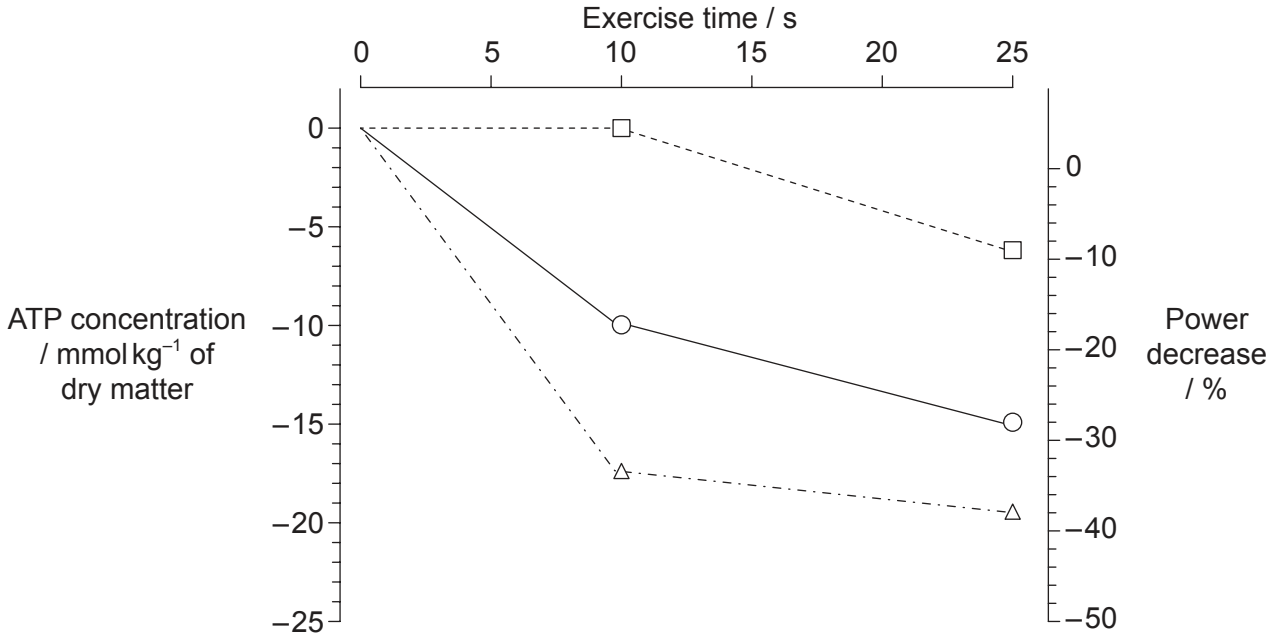
End of Option A

Option B — Physiology of exercise

4. Strenuous short-duration exercise requires a lot of energy in different muscle fibre types. This causes a reduction in the mechanical power output.

The graph shows the decreases in ATP concentration in different human muscle fibres during brief strenuous exercise. It also shows muscle fatigue, measured as the percentage decrease in power.



[Source: "Fiber Types in Mammalian Skeletal Muscles", Stefano Schiaffino and Carlo Reggiani, *Physiological Reviews* Published 1 October 2011 Vol. 91 no. 4, 1447–1531, Figure 13. DOI: 10.1152/physrev.00031.2010]

(a) Calculate the difference in ATP concentration between type I and type IIa muscle fibres after 25 seconds of exercise, giving the units. [1]

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(Option B continues on the following page)

(Option B, question 4 continued)

(b) Distinguish between power decline for the three types of muscle fibre. [3]

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(c) Suggest a reason for the ATP concentration remaining relatively high in type I muscle fibres during a 25 second period of exercise. [1]

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(d) Scientists have distinguished muscle fibres on the basis of their colour as red or white and their contractile properties as fast or slow. White fibres have a low myoglobin content, few mitochondria and fatigue quickly. Using the data, deduce with reasons, which muscle fibre type is most probably a white muscle fibre. [2]

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(Option B continues on the following page)

(Option B continued)

5. (a) Outline the function of myosin and actin in muscle contraction. [3]

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(b) State the function of the following structures in the human elbow.

(i) Synovial fluid [1]

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(ii) Biceps [1]

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(Option B continues on the following page)

(Option B continued)

6. (a) Define *tidal volume* and *ventilation rate*. [2]

Tidal volume:

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Ventilation rate:

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(b) Explain the processes that control changes in ventilation rate during exercise. [4]

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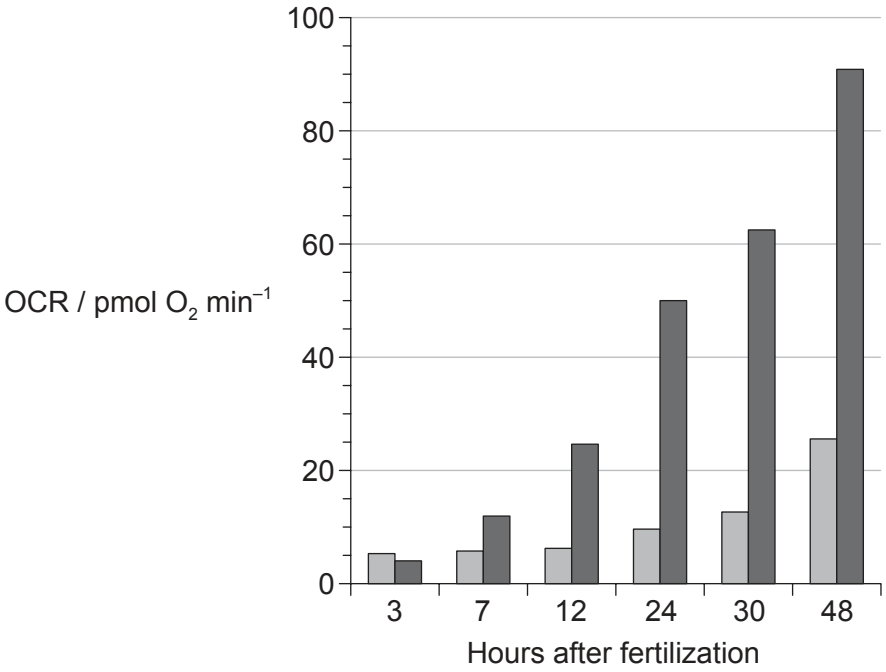
End of Option B

Option C — Cells and energy

7. Oxygen consumption by a tissue or organism arises from mitochondrial respiration and non-mitochondrial oxygen consumption. High oxygen levels in the cell can damage DNA, proteins and lipids. In early embryo development, elevated non-mitochondrial oxygen consumption acts as an essential mechanism for protection. The bar chart shows the oxygen consumption rates per embryo (OCR) measured in Zebrafish (*Danio rerio*) during embryo development in the hours after fertilization.



[Source: Adapted from: Stackley, K.D., Beeson, C.C., Rahn, J.J. and Chan, S.S.L. (2011) Bioenergetic Profiling of Zebrafish Embryonic Development. *PLoS ONE* **6**(9): e25652. doi:10.1371/journal.pone.0025652. Figure 3.]

(a) State the OCR in mitochondrial respiration 24 hours after fertilization. [1]

. . . . . pmol O_2 min^{-1}

(Option C continues on the following page)

(Option C, question 7 continued)

(b) Compare OCR due to non-mitochondrial oxygen consumption and mitochondrial respiration after fertilization. [2]

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(c) Suggest reasons for the rise in mitochondrial respiration in the 48 hours after fertilization. [2]

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(d) Non-mitochondrial oxygen consumption does not produce ATP and decreases in relation to mitochondrial respiration 48 hours after fertilization. Discuss the importance of non-mitochondrial oxygen consumption in a developing embryo. [1]

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(Option C continues on the following page)

(Option C continued)

8. (a) Outline primary and quaternary protein structures. [2]

Primary protein structure:

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Quaternary protein structure:

. . . . . .

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(b) List **three** limiting factors of photosynthesis. [3]

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2. . . . . .

3. . . . . .

(Option C continues on the following page)

(Option C continued)

9. (a) Outline the induced fit model for enzymes. [3]

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(b) Compare competitive and non-competitive enzyme inhibition. [4]

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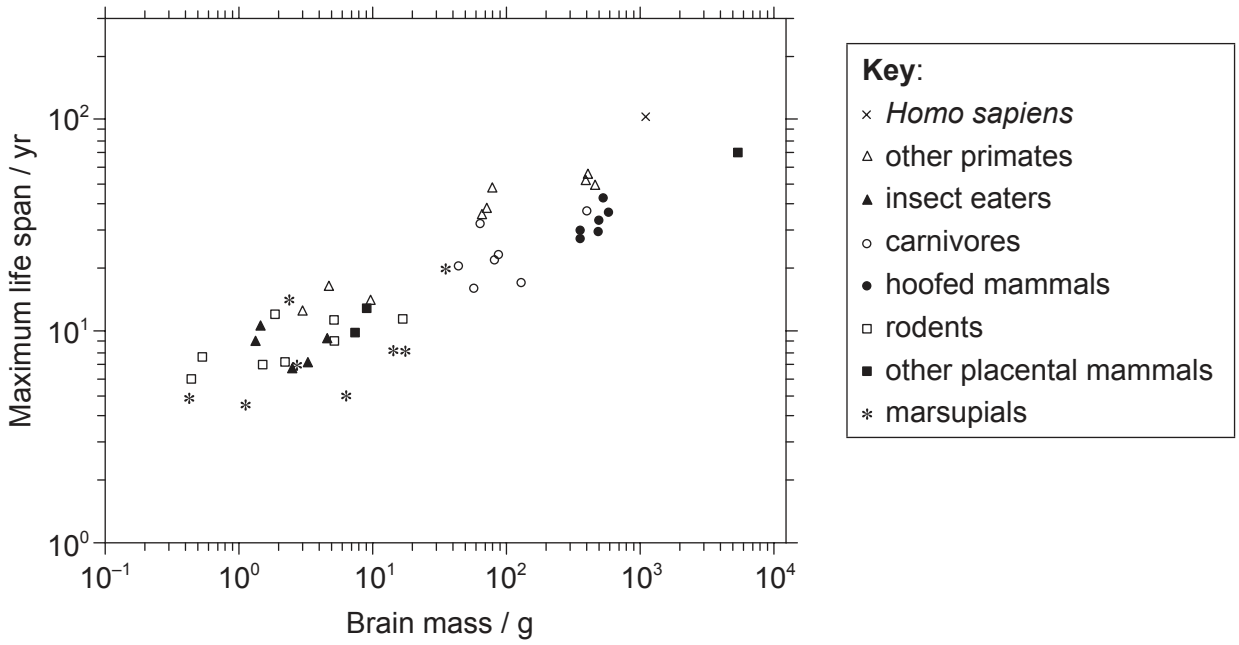
End of Option C

Option D — Evolution

10. The evolution of increased body size in mammals has been accompanied by an increase in life span. Another variable that could affect life span is brain size. Data was analysed from 47 mammalian species.



[Source: Hofman, M. A. (1993), Encephalization and the evolution of longevity in mammals. *Journal of Evolutionary Biology*, **6**: 209–227. doi: 10.1046/j.1420-9101.1993.6020209.x]

(a) State the relationship between brain mass and maximum life span. [1]

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(Option D continues on the following page)

(Option D, question 10 continued)

(b) Identify the group with the widest range of brain mass. [1]

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(c) Compare the brain mass and life span of primates and marsupials. [3]

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(d) Discuss how a larger brain size and longer life span might have contributed to the evolution of these species. [2]

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(Option D continues on the following page)

(Option D continued)

11. (a) Define *half-life of a radioisotope*. [1]

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(b) Outline the trends in hominid evolution illustrated by the fossils of *Australopithecus* and *Homo* species. [2]

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(c) State **one** example of balanced polymorphism and **one** example of transient polymorphism. [2]

Balanced polymorphism: . . . . . .

Transient polymorphism: . . . . . .

(Option D continues on the following page)

(Option D continued)

12. (a) Outline the contribution of prokaryotes to the origin of an oxygen-rich atmosphere. [2]

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(b) Discuss the endosymbiotic theory for the origin of eukaryotes. [4]

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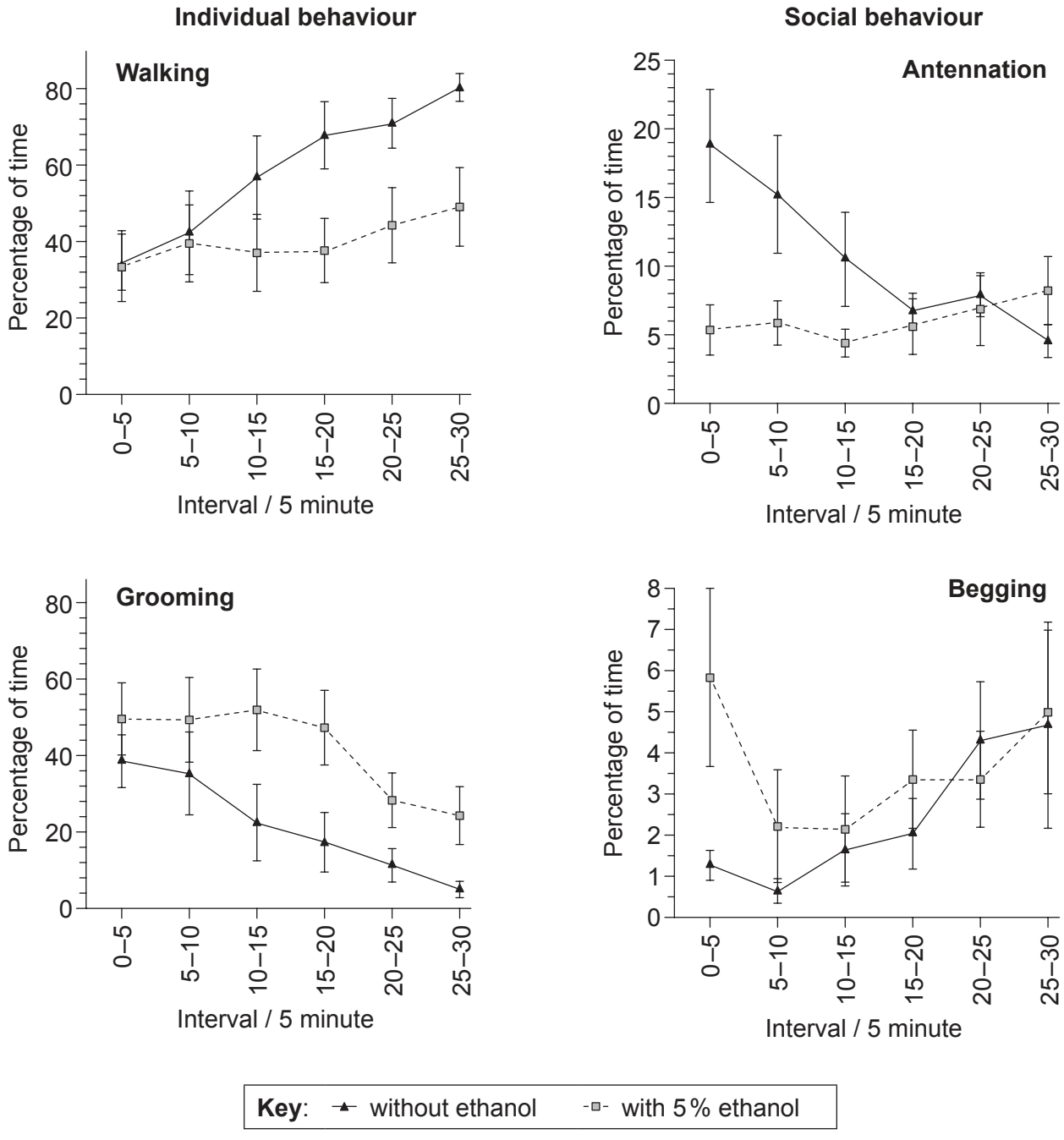
End of Option D

Option E — Neurobiology and behaviour

13. Honey bees (*Apis mellifera*) were fed with sucrose solution only or with low doses of ethanol in sucrose solution to examine how a slightly intoxicated state could affect their behaviour.

Individual behaviour involves walking and grooming while social behaviour includes contact of antennae between bees to show recognition (antennation) and asking other bees for food when hungry (begging). The graphs show individual and social behaviour changes observed in successive five minute intervals two hours after honey bees were fed sucrose solution either with or without ethanol.



[Source: Wright, G. A., Lillvis, J. L., Bray, H. J. and Mustard, J. A. (2012) Physiological State Influences the Social Interactions of Two Honeybee Nest Mates. *PLoS ONE* **7**(3): e32677.mdoi:10.1371/journal.pone.0032677. Figs 5 (A), (D), (E), (F)]

(Option E continues on the following page)

(Option E, question 13 continued)

(a) State the percentage of time the honey bees engaged in begging during the first five minute interval. [1]

Bees fed with ethanol: . . . . . %

Bees fed without ethanol: . . . . . %

(b) Describe the trends in antennation for honey bees fed with ethanol and without ethanol. [2]

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(c) Distinguish between the times spent walking and grooming for honey bees fed with ethanol and without ethanol. [2]

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(d) Evaluate the hypothesis that ethanol affects the social behaviour of honey bees. [3]

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(Option E continues on the following page)

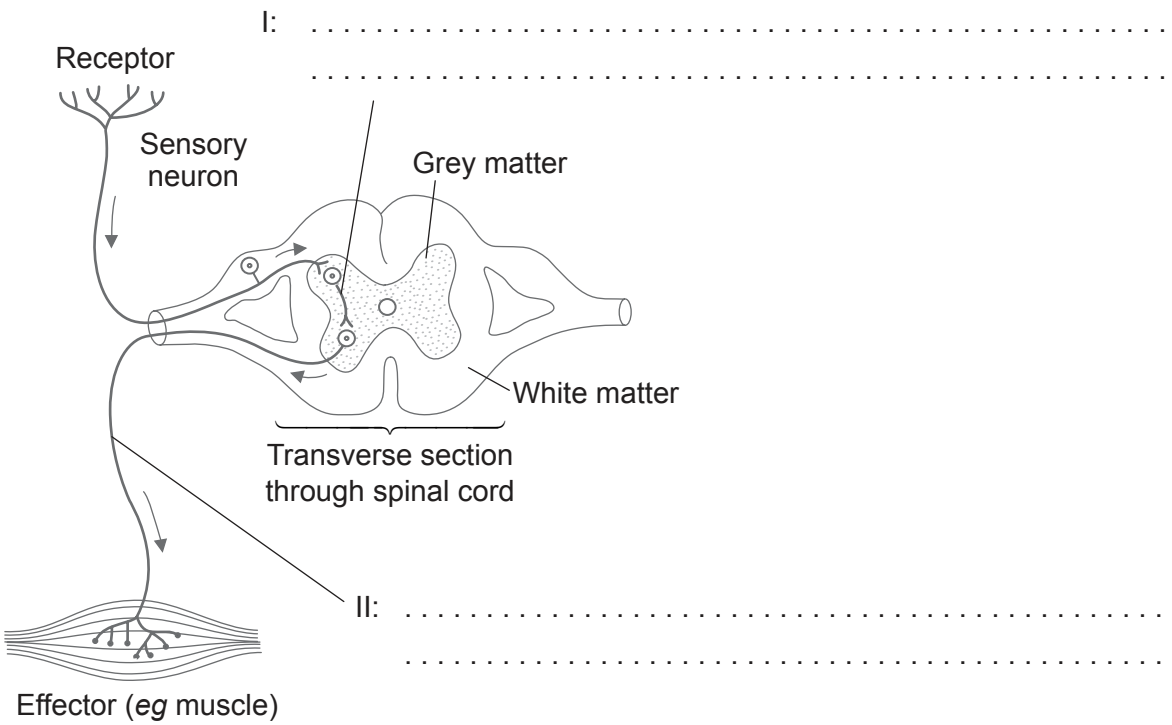
(Option E continued)

14. (a) State the type of receptors that detect smell and temperature. [2]

Smell: . . . . . .

Temperature: . . . . . .

(b) Annotate the diagram of the reflex arc to show the name and function of the neurons labelled I and II. [2]



[Source: © International Baccalaureate Organization 2015]

(Option E continues on the following page)

(Option E continued)

15. (a) Compare the effects of cocaine and THC. [4]

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(b) State **one** other example of an excitatory and an inhibitory psychoactive drug. [2]

Excitatory drug: . . . . . .

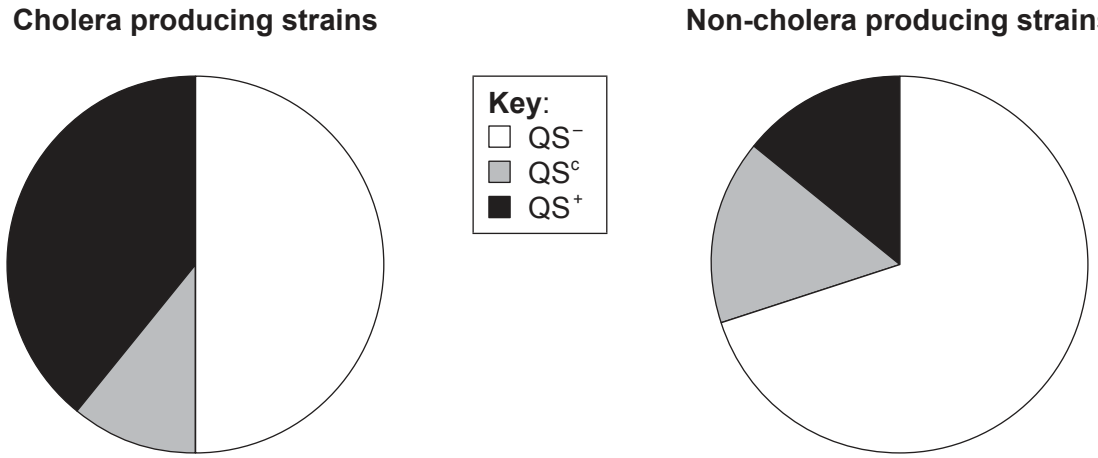
Inhibitory drug: . . . . . .

End of Option E

Option F — Microbes and biotechnology

16. *Vibrio cholerae* live in aquatic environments and cause cholera. Some *V. cholerae* form aggregates that show characteristics not seen in individual bacteria. The bacteria in these aggregates monitor the population densities by quorum sensing. They produce quorum sensing proteins (QS^+). Some *V. cholerae* strains do not produce quorum sensing proteins (QS^-) and some only produce quorum sensing proteins in low amounts (QS^c).

V. cholerae strains isolated in China were examined. The pie charts show the percentage of different quorum-sensing systems in strains that contain cholera toxin genes and in strains that do not contain cholera toxin genes.



[Source: © International Baccalaureate Organization 2015]

(a) State the percentage of cholera producing strains that do not produce quorum sensing proteins (QS^-). [1]

. . . . . %

(b) Determine the approximate percentage of non-cholera producing strains that produce quorum sensing proteins in low amounts (QS^c). [1]

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(Option F continues on the following page)

(Option F, question 16 continued)

(c) Compare the percentage of strains that do not produce quorum sensing proteins (QS^-) in strains with and without the cholera toxin genes. [2]

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(d) Deduce, using the data, whether the genes for quorum sensing and for toxicity of cholera evolved together. [1]

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(e) *Vibrio cholerae* is Gram-negative. Describe the structure of the cell wall of this bacterium. [2]

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(Option F continues on the following page)

(Option F continued)

17. (a) Outline how a defective gene can be replaced using viral vectors. [2]

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(b) State a use of species of *Aspergillus* and *Saccharomyces* in food production. [2]

Aspergillus:

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Saccharomyces:

. . . . . .
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(Option F continues on the following page)

(Option F continued)

18. (a) State the role of *Rhizobium*, *Nitrobacter* and *Azotobacter* in the nitrogen cycle. [3]

Rhizobium:

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Nitrobacter:

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Azotobacter:

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(b) Explain the production of methane from biomass. [4]

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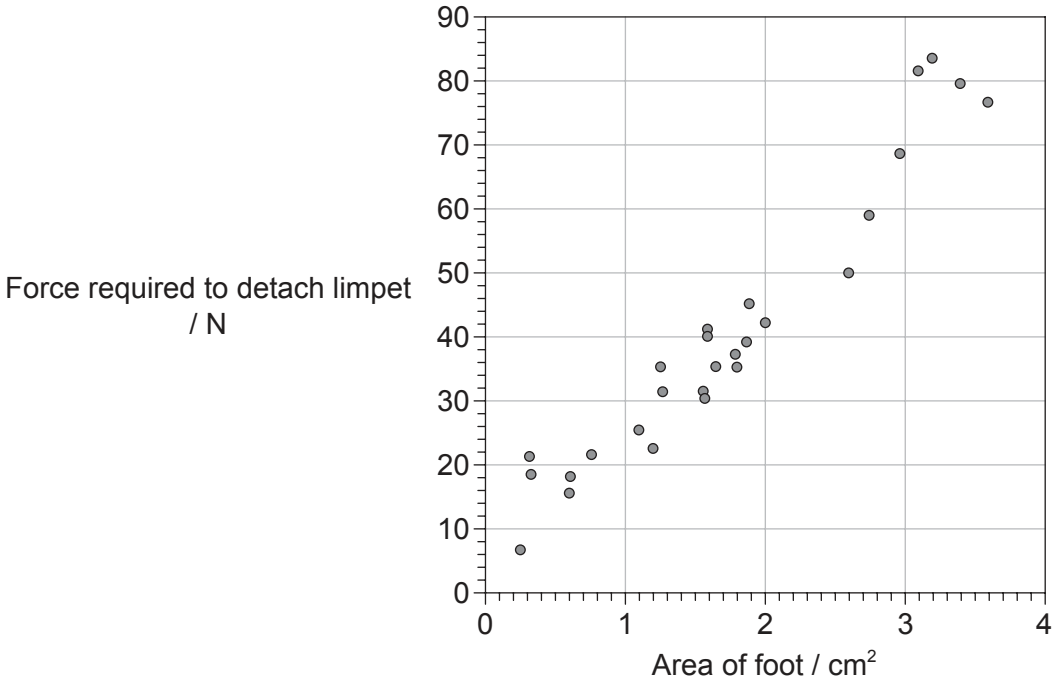
End of Option F

Option G — Ecology and conservation

19. Limpets (*Helcion pectunculus*) are marine molluscs that live in rock crevices (cracks and holes) in South Africa. In order to see whether the crevices protected the limpets from wave action, the force required to detach limpets in their natural habitat was measured. Once detached from the rocks, the area of the foot of each limpet was also measured.



[Source: David R. Gray and Alan N. Hodgson. THE IMPORTANCE OF A CREVICE ENVIRONMENT TO THE LIMPET HELCION PECTUNCULUS (PATELLIDAE). *J. Mollus. Stud*. (2004) **70** (1): 67–72 doi:10.1093/mollus/70.1.67]

(a) (i) State the force required to detach a limpet with an area of foot of 2 cm^2. [1]

. . . . . N

(ii) State the smallest area of foot necessary to resist a force of 50 N. [1]

. . . . . cm^2

(Option G continues on the following page)

(Option G, question 19 continued)

(b) Outline the relationship between area of foot and the force required to detach the limpet. [1]

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(c) Smaller limpets can only be found at the back of crevices. Discuss the reasons for this. [3]

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(d) Limpets tend to live towards the high tide zone. State the method used to determine the distribution of limpets between the low and high tide lines. [1]

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(Option G continues on the following page)

(Option G continued)

20. (a) (i) Calculate the Simpson diversity index from the data given for **one** community, using the formula provided. Show your working. [2]

The formula is $D = \frac{N(N-1)}{\Sigma n(n-1)}$

Species	Number (*n*)
Caddisfly larva (*Trichoptera*)	5
Cranefly larva (*Diptera*)	3
Damselfly larva (*Zygoptera*)	4
Mayfly larva (*Ephemeroptera*)	3
Stonefly larva (*Plecoptera*)	5

(ii) The same area was sampled the previous year and found to have a value for $D = 4.3$. Analyse the biodiversity of this community. [2]

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(Option G continues on the following page)

(Option G, question 20 continued)

(b) Identify the biome represented in the climograph. [1]

Graph removed for copyright reasons

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(Option G continues on the following page)

(Option G continued)

21. (a) Outline **one** example of biological control of a **named** invasive species. [2]

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(b) Explain the cause and consequences of biomagnification. [4]

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End of Option G

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