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Biology Higher level Paper 3

17 May 2023

Zone A afternoon | Zone B morning | Zone C afternoon

Candidate session number

1 hour 15 minutes

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Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- The maximum mark for this examination paper is **[45 marks]**.

Section A	Questions
Answer all questions.	1 – 3

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Neurobiology and behaviour	4 – 9
Option B — Biotechnology and bioinformatics	10 – 15
Option C — Ecology and conservation	16 – 21
Option D — Human physiology	22 – 27



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will not be marked.



40EP02

Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. The micrograph shows part of a cardiac muscle cell.

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- (a) Calculate the width of the nucleus (N) between the two arrows. [1]

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- (b) Explain the changes that would occur in a cardiac muscle cell placed in a hypotonic solution. [2]

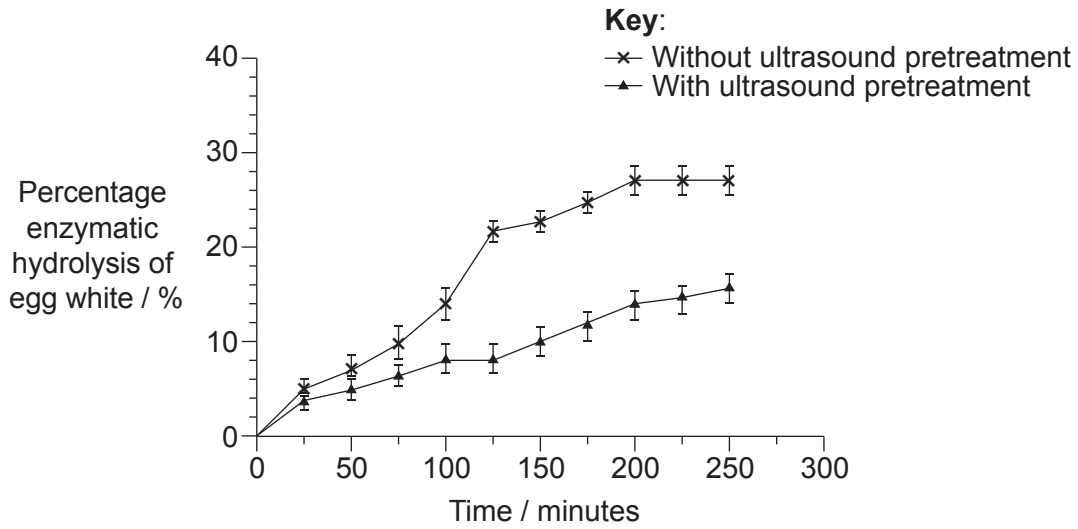
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40EP03

Turn over

2. A study investigated the effect of pretreating egg white proteins with ultrasound on how they were digested by enzymes. A series of 10% egg white solutions were exposed to ultrasound waves. Enzymatic hydrolysis of the egg whites with and without ultrasound pretreatment was then carried out using the enzyme alcalase in optimum conditions.



- (a) (i) State a variable that should be kept constant. [1]

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- (ii) Identify the independent variable. [1]

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(This question continues on the following page)



(Question 2 continued)

(b) Outline the steps to produce a 10% egg white solution. [2]

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(c) Each measurement was repeated several times. Explain the need for replicates of each treatment. [2]

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(d) Using the data, deduce whether pretreatment with ultrasound is effective for hydrolysing proteins. [1]

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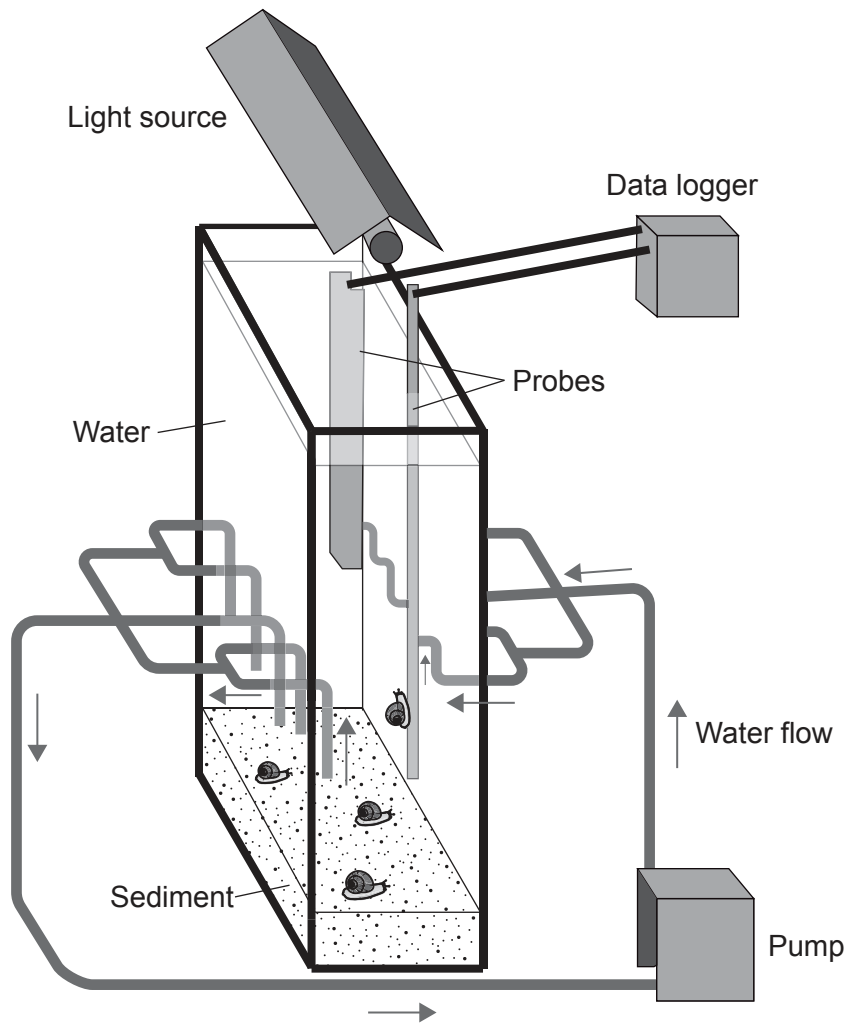
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40EP05

Turn over

3. Laboratory-scale mesocosms were built to investigate the effect of very small contaminants (nanoparticles) on ramshorn snails (*Planorbarius corneus*).



(a) State **two** variables measured by the probes.

[2]

- 1:
- 2:

(This question continues on the following page)



40EP06

(Question 3 continued)

(b) Suggest one advantage of using a mesocosm in this type of research. [1]

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(c) Outline the requirements for sustainability within a sealed mesocosm. [2]

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40EP07

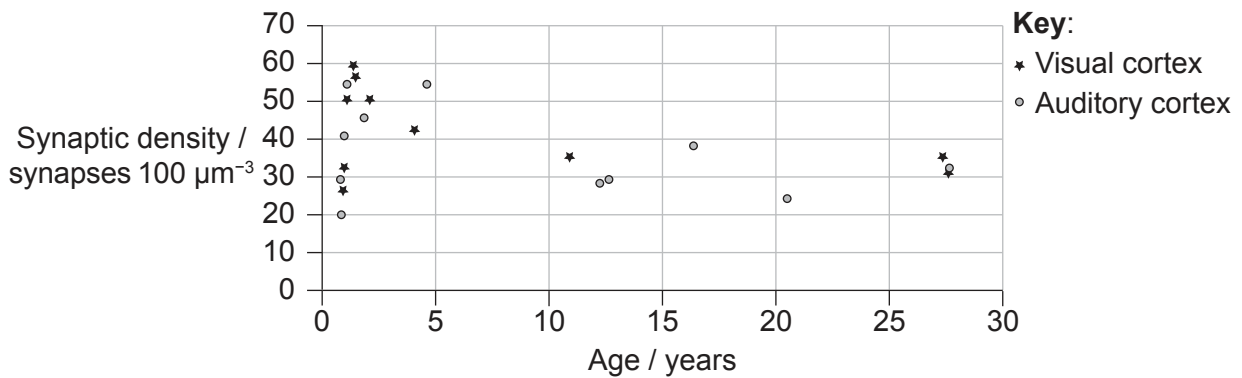
Turn over

Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Neurobiology and behaviour

- 4. After the age of 30, the number of synapses in the various parts of the human brain remain relatively constant. An electron microscope was used to measure the number of synapses in the auditory cortex and visual cortex of brains after autopsies. The graph shows the mean synaptic density in the auditory cortex and visual cortex below the age of 30.



- (a) The capacity to learn certain skills such as reading music and learning foreign languages is greater at an early age. Comment on this statement using the data shown in the graph. [2]

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- (b) Outline the process that reduces the number of synapses. [2]

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(Option A continues on the following page)

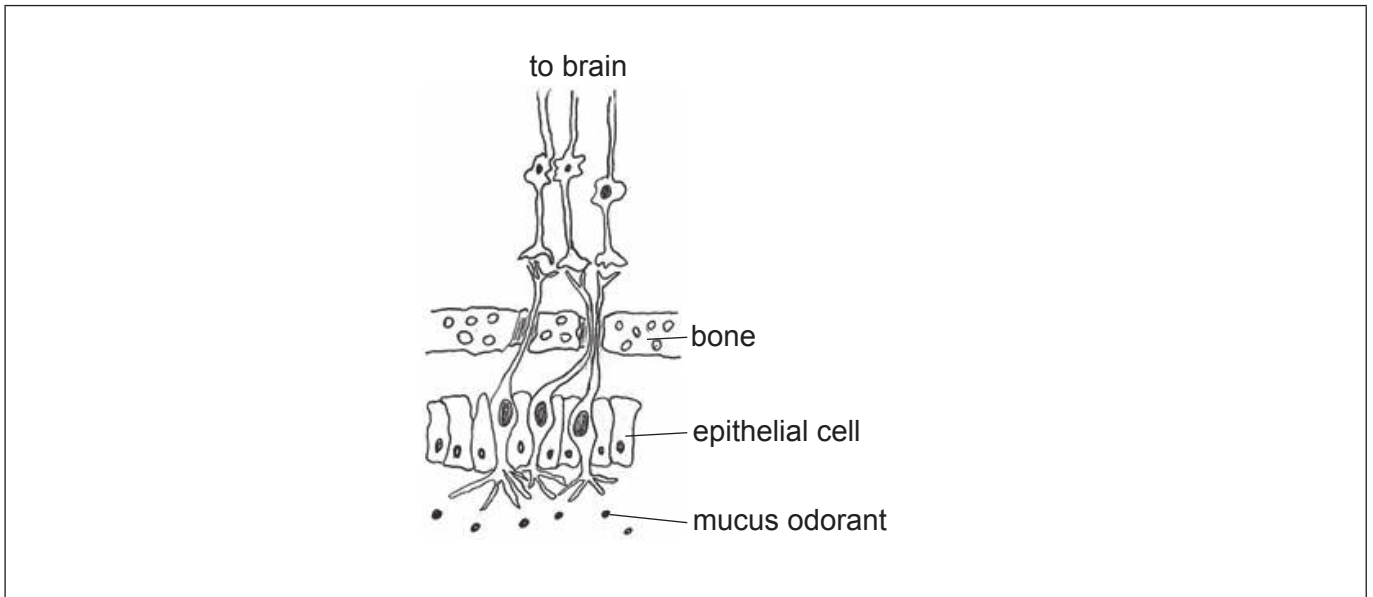


(Option A, question 4 continued)

- (c) State **one** method, other than autopsies, to identify the role of different brain parts. [1]

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- 5. Olfactory receptors are chemoreceptors in the nose that detect odorants. The diagram shows the cell organization of the main olfactory system.



- (a) On the diagram, label a chemoreceptor. [1]
- (b) Describe how olfactory chemoreceptors can detect different odorants. [2]

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- (c) State **two** types of receptors other than chemoreceptors. [2]

1:

2:

(Option A continues on the following page)

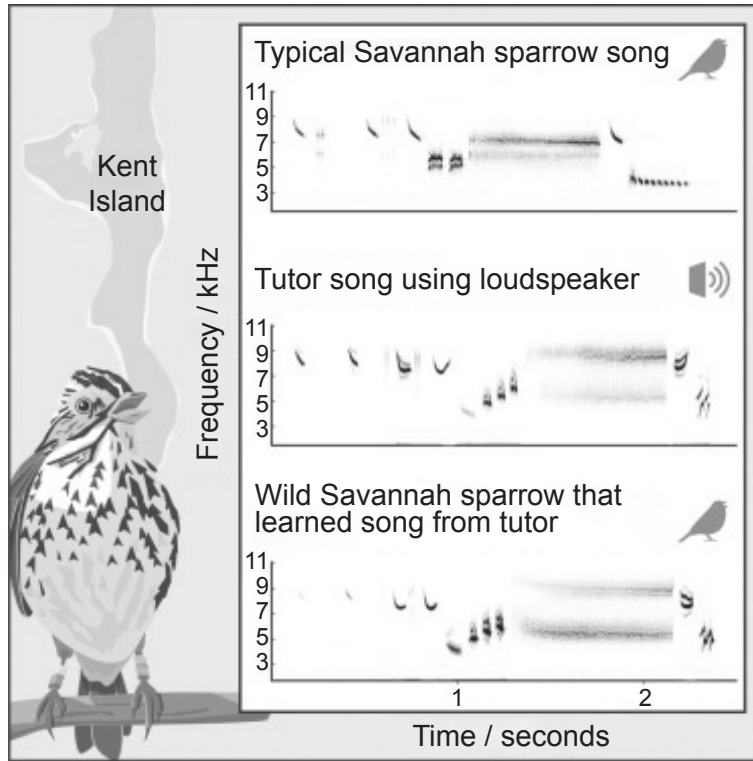


40EP09

Turn over

(Option A continued)

6. The learning of birdsong has been researched for many years. Savannah sparrows (*Passerculus sandwichensis*) were studied in their natural habitat on Kent Island, Canada. The data shows the spectrogram (sound recording) of the typical song for the species, a tutor song played to the birds using loudspeakers in their habitat and the song learned after listening to the tutor song.



- (a) Describe how the Savannah sparrows would acquire their song under natural conditions. [2]

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(Option A continues on the following page)



(Option A, question 6 continued)

- (b) The offspring of the sparrows that had been exposed to the tutor song were studied a year later. The newly hatched birds had no playback of a simulated vocal tutor, but the pattern was almost the same as that of the third graph (Wild Savannah sparrow that learned song from tutor pattern). Suggest what this pattern indicates about the learning of birdsong.

[2]

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(Option A continues on page 13)



40EP11

Turn over

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40EP12

(Option A continued)

7. Local anesthetics such as lidocaine have a history of efficacy and safety in medical and dental practice.

(a) Outline the effect of anesthetics on the nervous system.

[3]

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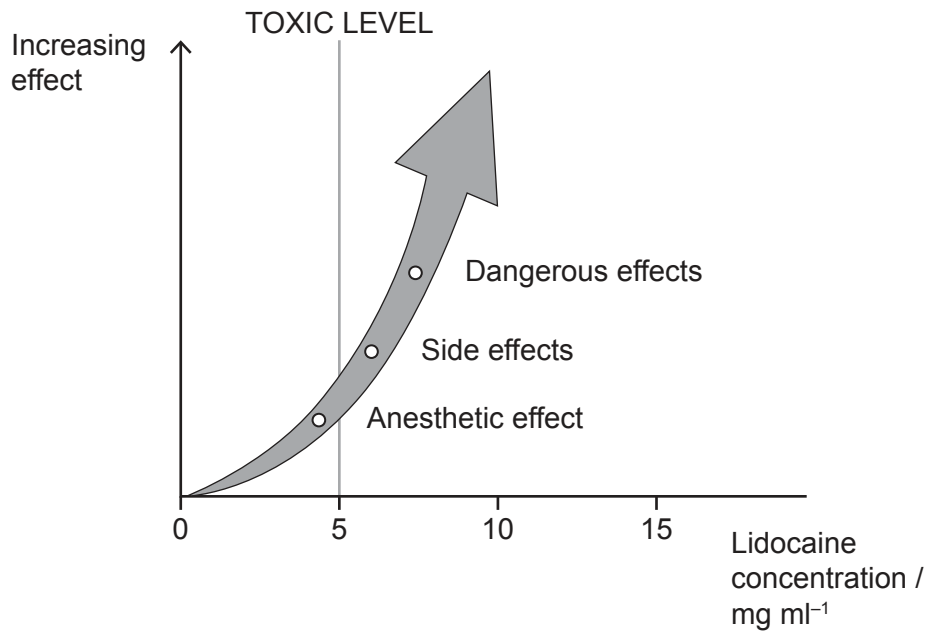
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As lidocaine is absorbed from the injection site, the concentration in blood plasma rises. If not properly administered, it can reach dangerous levels.



(b) Suggest **one** reason for the dangerous effects of high doses of anesthetics.

[1]

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(Option A continues on the following page)



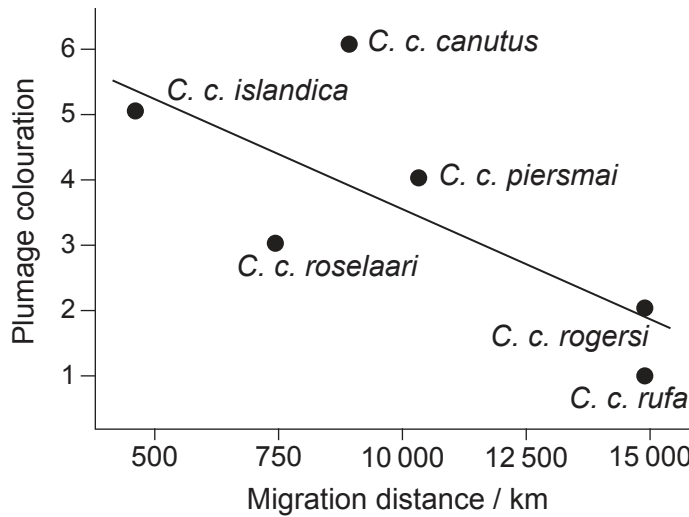
40EP13

Turn over

(Option A continued)

8. Breeding plumage can be an important signal for mate selection in birds. Breeding plumage in red knots (*Calidris canutus*) includes a rusty red colour. Red knots have six recognized subspecies, each with different migratory routes.

The scatter graph shows the overall migration distance and the breeding plumage colouration for different subspecies of red knots. The darkest plumage colouration is 6.



(a) (i) Identify the relationship between migration distance and plumage colouration. [1]

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(ii) Suggest **two** reasons, other than mate selection, for variation in plumage colouration in red knots. [2]

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(b) Explain the evolution of behaviour by natural selection. [3]

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(Option A continues on the following page)



40EP14

(Option A continued)

9. Explain how communication between neurons during synaptic transmission is achieved through neurotransmitters.

[6]

A large rectangular box with a dotted grid pattern, intended for the student to write their answer to question 9.

End of Option A



40EP15

Turn over

Option B — Biotechnology and bioinformatics

10. (a) Distinguish between batch and continuous fermentation. [2]

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Biogas production was investigated in batch and continuous fermentation. A semi-liquid mixture containing animal feces (slurry) was added to the continuous fermenter once a week.

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(b) (i) State **one** type of organism that can produce methane in a fermenter. [1]

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(Option B continues on the following page)



(Option B, question 10 continued)

(ii) Outline the need for slurry in the fermentation. [1]

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(c) Explain how growth of microorganisms in fermenters can become limited. [2]

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(Option B continues on the following page)



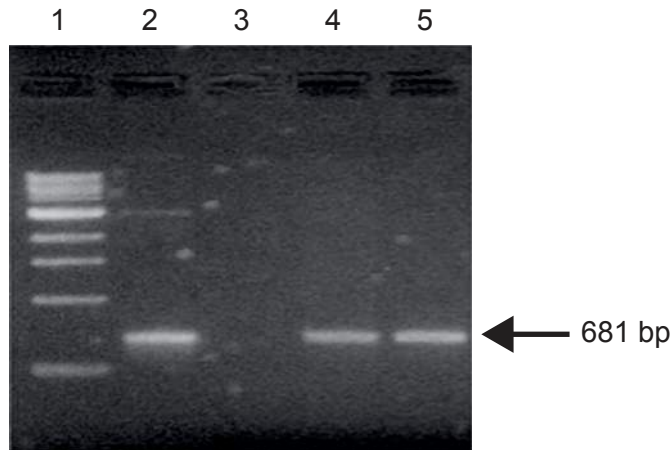
40EP17

Turn over

(Option B continued)

11. The surface antigen gene of hepatitis B virus (HBsAg) was cloned into plant cells using *Agrobacterium tumefaciens*. Plant cells were selected according to their resistance to kanamycin.

Transformed plant cells were analysed by PCR to see whether they contained the HBsAg gene of 681 base pairs (bp). The image shows the resulting electrophoretic gel with lane 1 showing the reference ladder (size markers), lane 2 a positive control and lane 3 a negative control. Lanes 4 and 5 show the PCR amplification of genomic DNA from transformed plant cells.



(a) Using the electrophoretic gel image, deduce with a reason whether the plant cell transformation was successful. [1]

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(b) Predict with a reason the DNA of the cells that could have been used as a negative control. [1]

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(c) Explain the use of kanamycin in the selection of transformed plant cells. [3]

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(Option B continues on the following page)

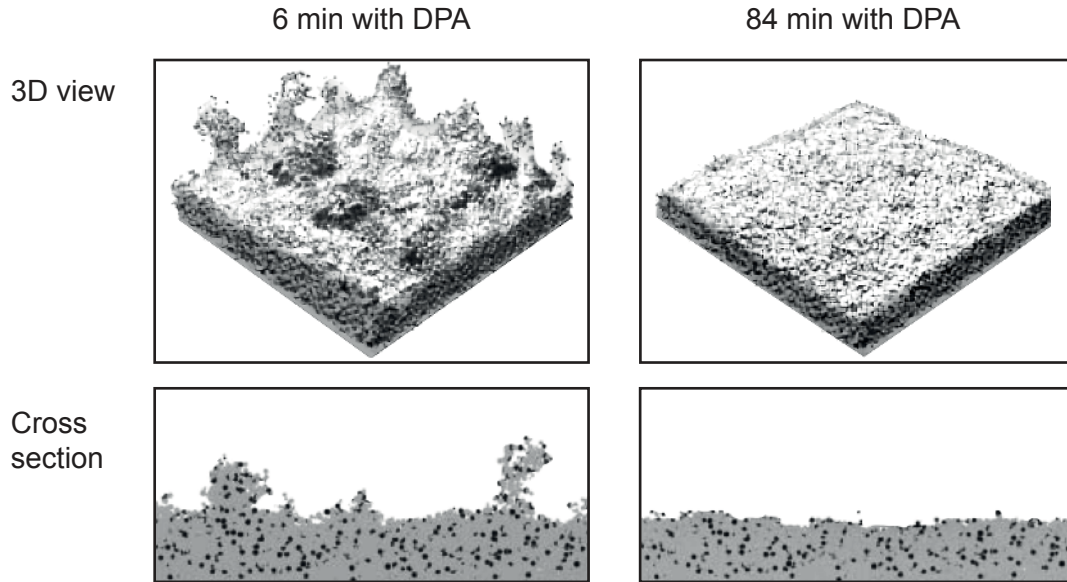


40EP18

(Option B continued)

- 12. A computer model simulation was proposed to assess the removal of extracellular polymeric substances (EPS) from biofilms by using a detachment-promoting agent (DPA).

Simulations on a 60-day-old biofilm after 6 minutes of treatment with DPA and on the same biofilm after 84 minutes of treatment with DPA are shown as a 3D view and a cross section. Dark grey represents bacteria and light grey shows the EPS.



- (a) State **one** reason, other than the formation of an EPS, for the high resistance to antimicrobial agents in biofilm microorganisms. [1]

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- (b) Scientists concluded from this simulation that the detachment of the EPS by DPA will help in the removal of the biofilm. Discuss the support for this conclusion shown by the data. [2]

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- (c) State the effect of the DPA on the bacterial concentration of the remaining biofilm. [1]

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(Option B continues on the following page)



40EP19

Turn over

(Option B continued)

13. Clinical genetic diagnostics detect DNA mutations ranging from single-nucleotide changes to whole-chromosome alterations.

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- (a) Identify the most precise method to detect a single-base substitution mutation. [1]

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- (b) Describe the advantage of microarrays over karyotyping in the detection of a genetic predisposition to or diagnosis of a disease. [2]

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- (c) Expressed sequence tags (ESTs) contain enough information to permit the design of precise probes for DNA microarrays. Describe ESTs. [2]

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(Option B continues on the following page)



40EP20

(Option B continued)

14. The sequence alignment shows the first 40 amino acids of adult and fetal hemoglobin in humans.



(a) State the number of amino acids that these sections of adult and fetal hemoglobin have in common. [1]

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(b) Describe how a sequence alignment can be obtained and used to compare proteins. [3]

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(Option B continues on the following page)



40EP21

Turn over

(Option B continued)

15. Explain how soybean crop plants can be genetically modified to become glyphosate-tolerant. [6]

A large rectangular area with horizontal dotted lines for writing.

End of Option B



40EP22

Option C — Ecology and conservation

16. The strawberry sap beetle (*Lobiopa insularis*) is one of the most important pests of strawberries. To investigate feeding preferences, strawberry plants with fruit at different maturation stages, green, semi-ripe and ripe, were exposed to sap beetles. The graph shows the percentage of strawberries that were damaged by sap beetles at different exposure times after infestation.

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(a) Distinguish between the trophic levels of sap beetles and strawberry plants. [1]

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(b) Sap beetles are attracted to volatile chemicals emitted by ripening fruit. Analyse the support for this conclusion shown by the data. [2]

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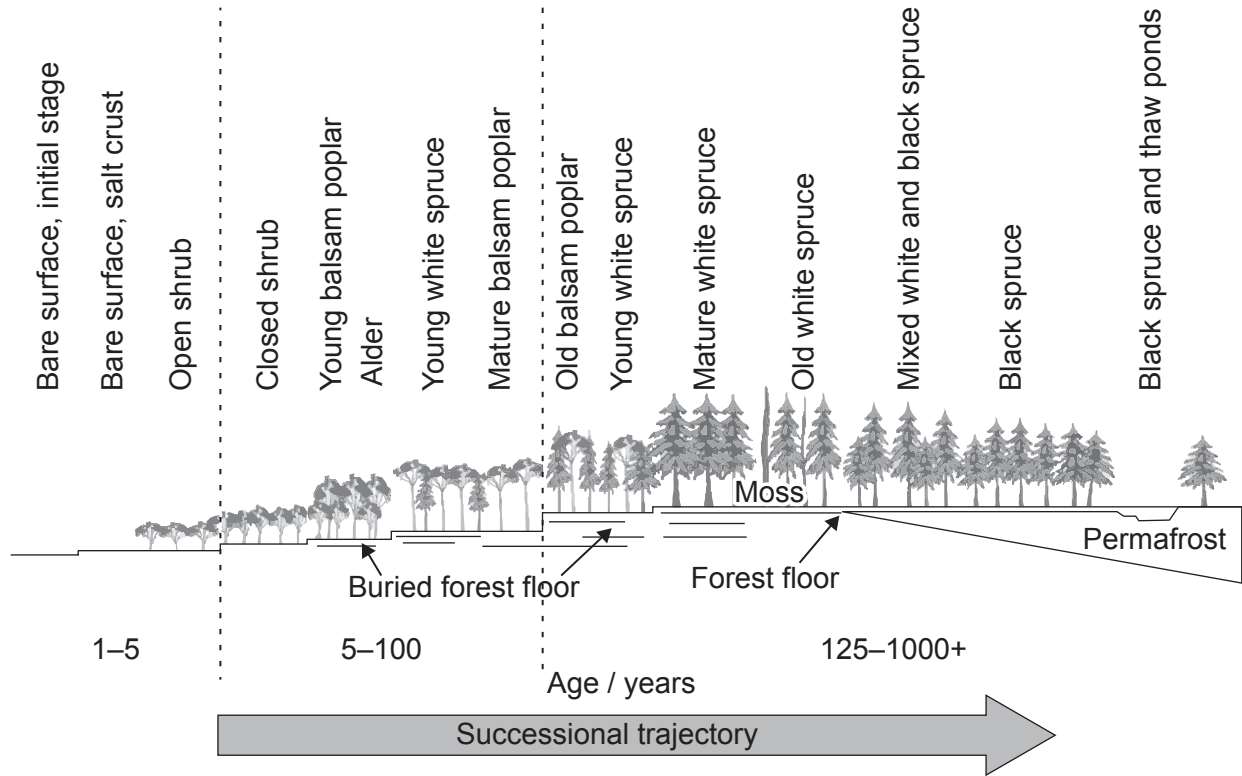


40EP23

Turn over

(Option C continued)

17. The diagram represents primary succession that occurs in an Arctic ecosystem, on a river floodplain in Alaska, USA. Permafrost is permanently frozen subsoil found in Arctic regions.



(a) Outline primary succession.

[1]

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(Option C continues on the following page)



40EP24

(Option C, question 17 continued)

(b) Describe two limiting factors on this ecosystem. [2]

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(c) Outline processes that must occur over time to produce deeper soil. [2]

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(Option C continues on the following page)



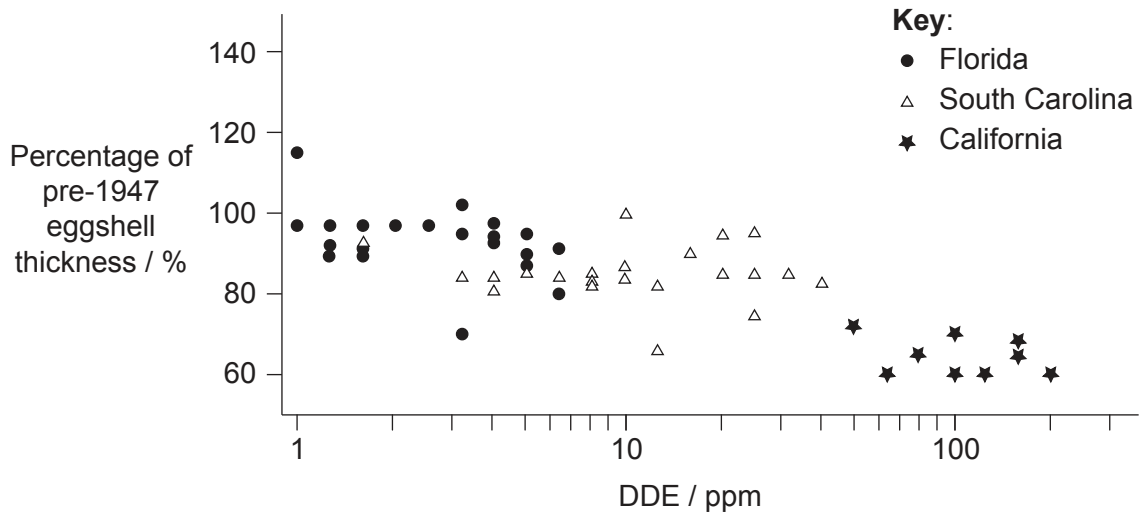
40EP25

Turn over

(Option C continued)

18. DDE (dichlorodiphenyldichloroethylene) is formed from the breakdown of DDT (dichlorodiphenyltrichloroethane). In a study done in 1969, eggs of the brown pelican (*Pelecanus occidentalis*) were collected from colonies in California, South Carolina and Florida, USA. The amount of DDE in each egg was quantified and the percentage of eggshell thinning was measured by comparison with the mean thickness measure before the use of DDT from 1947.

The graph shows the relationship between DDE concentration and eggshell thinning in each of the eggs studied.



(a) (i) State the relationship between DDE concentration and eggshell thickness. [1]

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(ii) Suggest **one** reason for a decline in the brown pelican population with the most eggshell thinning. [1]

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(Option C continues on the following page)



(Option C, question 18 continued)

- (b) Deduce, giving reasons, which brown pelican population decreased the most in the years following the study. [2]

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- (c) Outline the biomagnification of DDE in brown pelicans. [3]

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(Option C continues on the following page)

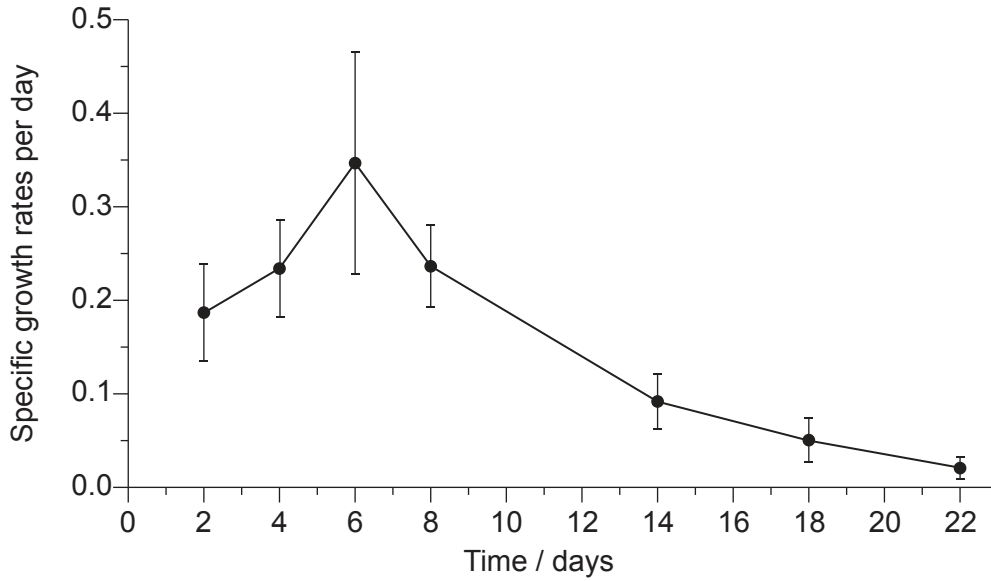


40EP27

Turn over

(Option C continued)

19. Duckweed (*Lemna gibba*) is a plant that grows on the surface of water. It was grown in cultures and the percentage increase in total area covered per day was obtained. The graph shows the specific growth rates per day for duckweed measured over 22 days.



Suggest reasons for the slowing down of duckweed population growth after day 6.

[3]

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20. The availability of nitrogen can affect the rate of an ecosystem's key processes.

(a) Outline the effect of nitrogen compounds from agricultural land leaching into a lake.

[3]

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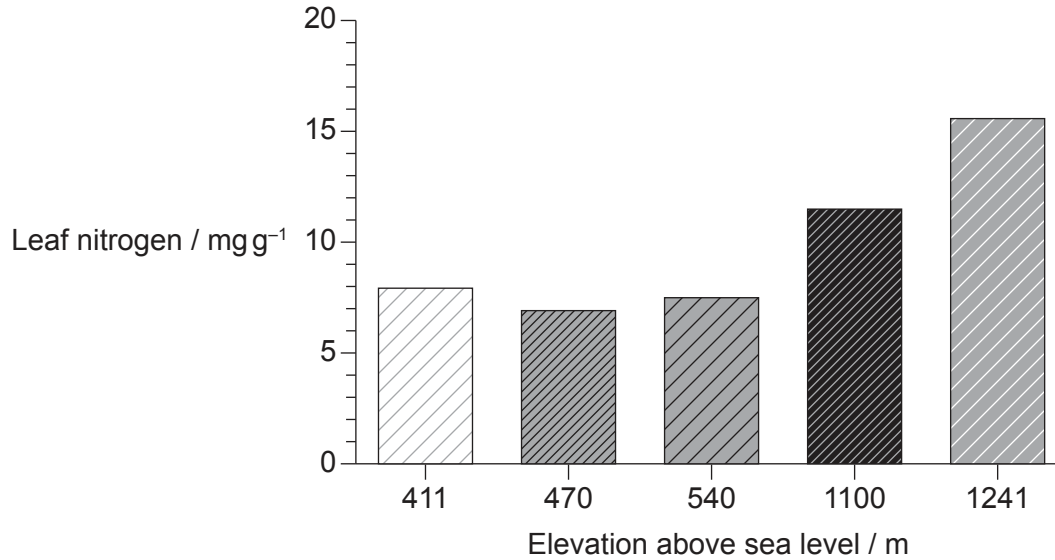
(Option C continues on the following page)



40EP28

(Option C, question 20 continued)

Nitrogen content was measured in leaves of insectivorous California pitcher plants (*Darlingtonia californica*) at five sites with different elevations above sea level along the California–Oregon border, USA. The bar chart shows the median of all measurements at each site.



(b) State the relationship between elevation and nitrogen concentration in leaves of pitcher plants.

[1]

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(c) Suggest **two** reasons, other than elevation, for the differences in nitrogen concentration in leaves of pitcher plants.

[2]

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(Option C continues on page 31)



40EP29

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40EP30

Option D — Human physiology

22. Children with congenital heart disease are usually malnourished and present some degree of functional and/or structural damage of organs. The table shows the percentage of children with congenital heart disease that are ingesting less, more or the recommended daily allowance (RDA) of energy and nutrients.

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(a) Predict with a reason the risk that a child with congenital heart disease might have

(i) scurvy. [1]

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(ii) anemia. [1]

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(Option D continues on the following page)



(Option D, question 22 continued)

(b) State one effect of a low intake of

(i) fibre:

[1]

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(ii) calcium:

[1]

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(c) Suggest **one** possible problem associated with a low fat intake.

[1]

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(Option D continues on the following page)



40EP33

Turn over

(Option D continued)

23. Acid conditions in the stomach favour some hydrolysis reactions and help to control pathogens in ingested food.

(a) Describe the production of acid in the digestive system. [2]

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(b) Outline the use of drugs to reduce the production of stomach acid. [2]

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The bacterium *Helicobacter pylori* is usually acquired in childhood, but acute *H. pylori* infection is rarely diagnosed until later years.

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(Option D continues on the following page)



40EP34

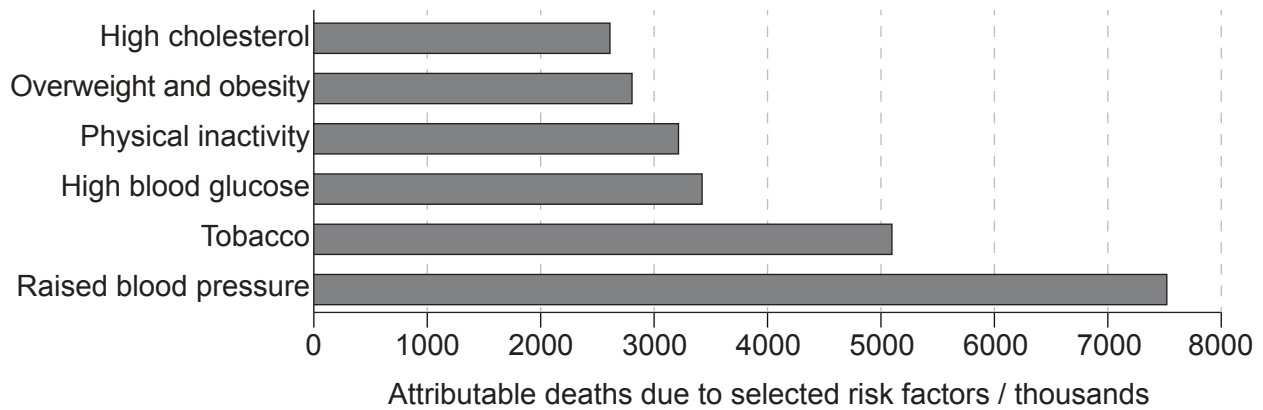
(Option D, question 23 continued)

- (c) Deduce with a reason whether the use of drugs will reduce the incidence of digestive system cancers according to the information in the diagram. [1]

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- 24. Scientific evidence demonstrates that reducing total cardiovascular risk results in the prevention of coronary heart disease. The chart shows attributable deaths in global population (in thousands) due to six leading cardiovascular risk factors.



- Describe how **two** named risk factors shown in the graph can lead to coronary heart disease. [2]

1:

.....

2:

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(Option D continues on the following page)



Turn over

(Option D continued)

25. The graph shows the mean plasma prolactin concentrations before, during and after breastfeeding in 18 lactating women 14 days after giving birth.

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- (a) Explain the production of prolactin in reference to its function in milk secretion. [2]

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- (b) State a hormone, other than prolactin, involved in milk secretion. [1]

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26. (a) Outline how red blood cells transport respiratory gases. [3]

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(Option D continues on the following page)



40EP36

(Option D, question 26 continued)

On an expedition to Mount Everest in 2005, the hemoglobin concentration in the blood of mountaineers was measured during a 15-day journey from Kathmandu (1400 m altitude) to an advanced base camp (5700 m altitude).

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- (b) Explain how the changes occurring in the hemoglobin concentration compensate for the consequences of high altitude for gas exchange. [3]

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- (c) Outline the recycling of red blood cell components in the liver. [3]

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(This question continues on page 39)



40EP37

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40EP38

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References:

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3. Material from: Auffan, M., Tella, M., Santaella, C., Brousset, L., Pailles, C., Barakat, M., Espinasse, B., Artells, E., Issartel, J., Masion, A., Rose, J., Wiesner, M.R., Achouak, W., Thiery, A. and Bottero, J.-Y., An adaptable mesocosm platform for performing integrated assessments of nanomaterial risk in complex environmental systems, published 2014, *Nature Scientific Reports*, reproduced with permission of SNCSC.
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40EP40

12. Used with permission *Microbiology Society*, from Xavier, J.B., Picioreanu, C., Rani, S.A., van Loosdrecht, M.C.M. and Stewart, P.S., 2005. Biofilm-control strategies based on enzymic disruption of the extracellular polymeric substance matrix – a modelling study. *Microbiology* 151, pp. 3817–3832; permission conveyed through Copyright Clearance Center, Inc.
17. Bonanza Creek LTER.
18. Material from: Blus, L., Gish, C., Belisle, A. and Prouty, R., Logarithmic relationship of DDE residues to eggshell thinning, published 1972, *Nature*, reproduced with permission of SNCSC.
19. Material from: Mkandawire, M. and Dudel, E.G., Assignment of *Lemna gibba* L. (duckweed) bioassay for in situ ecotoxicity assessment, published 2005, *Aquatic Ecology*, reproduced with permission of SNCSC.
20. Reproduced from Ellison, A.M. and Farnsworth, E.J., 2005. The Cost of Carnivory for *Darlingtonia californica* (Sarraceniaceae): Evidence From Relationships Among Leaf Traits. *American Journal of Botany* 92(7), pp. 1085–1093, with permission from Wiley.
24. Mendis, Shanthi, Puska, Pekka, Norrving, B, World Health Organization, World Heart Federation et al. (2011). *Global atlas on cardiovascular disease prevention and control* / edited by: Shanthi Mendis ... [et al.]. World Health Organization. Graph of attributable deaths due to selected risk factors.

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