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Diploma Programme
Programme du diplôme
Programa del Diploma

Biology
Higher level
Paper 2

18 May 2023

Zone A morning | **Zone B** morning | **Zone C** morning

Candidate session number

2 hours 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer two questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- The maximum mark for this examination paper is **[72 marks]**.

2223 – 6008

25 pages

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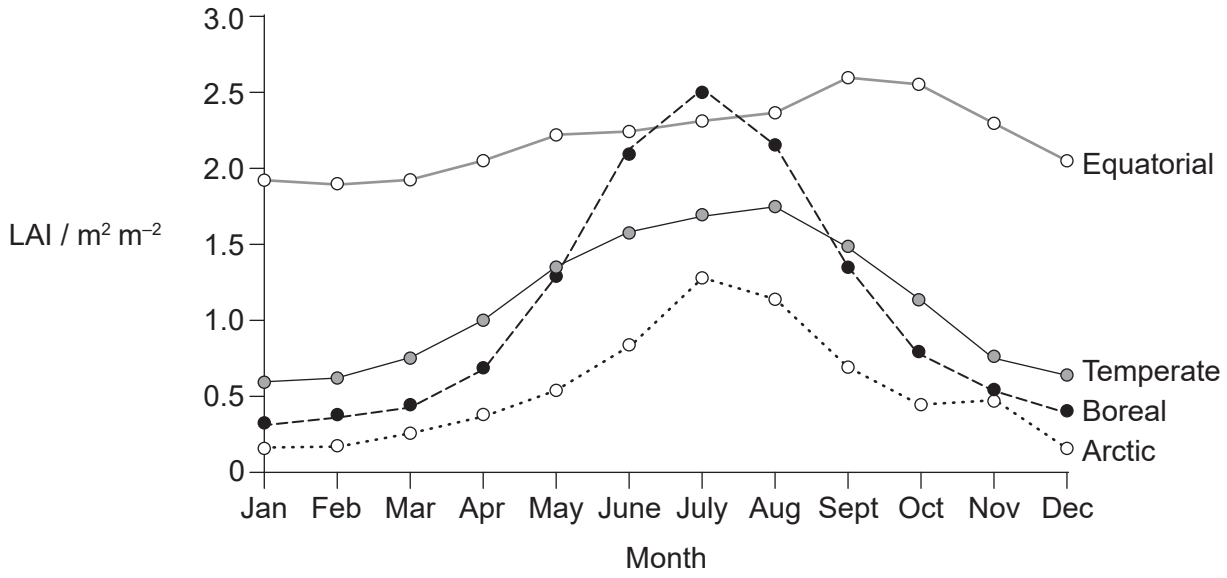
Section A

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

1. Remote sensing satellites are used to monitor the Earth's ecosystems. One measure of ecosystem status is leaf area index (LAI), which is the total area of leaves in square metres per square metre ($m^2\ m^{-2}$) of the Earth's surface. The graph shows LAI estimates, calculated using data from the Global Inventory Monitoring and Modelling System (GIMMS), during the period from 1981 to 2011. The data points are monthly averages in four latitudinal zones in the northern hemisphere.



[Source: Zhu, Z. et al., 2013. Global Data Sets of Vegetation Leaf Area Index (LAI)3g and Fraction of Photosynthetically Active Radiation (FPAR)3g Derived from Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI3g) for the Period 1981 to 2011. *Remote Sensing*, [e-journal] 5, pp. 927–948. https://doi.org/10.3390/rs5020927. Open access.]

(a) Compare and contrast the LAI data for the arctic and temperate zones. [2]

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(This question continues on the following page)

(Question 1 continued)

(b) Suggest reasons for the differences in LAI between the boreal and equatorial zones. [3]

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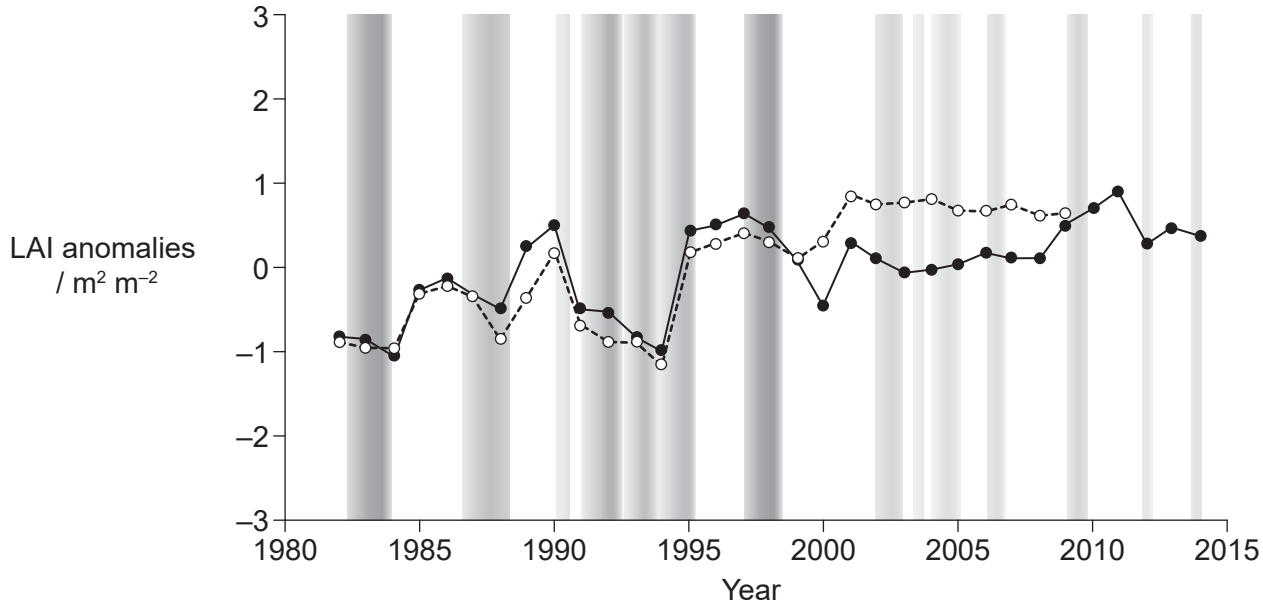
(Question 1 continued)

There is evidence of a change in mean LAI values on Earth over recent decades. Changes can be quantified by calculating LAI anomalies. These are differences between annual LAI values and the mean LAI for the entire given time period.

The graph shows global LAI anomalies for the period from 1981 to 2014, based on data from GIMMS. It also shows mean global LAI anomalies between 1981 and 2009, based on data from three other remote sensing programmes. Vertical bars show the timing of El Niño events. The darkness of the bars indicates the intensity of the El Niño events. The darker the bar, the more intense the event.



[Source: Material from: Zhu, Z., Piao, S., Myneni, R., et al., Greening of the Earth and its drivers, published 2016, *Nature Climate Change*, reproduced with permission of SNCSC.]

(c) Analyse the data shown in the graph for evidence of a relationship between LAI and El Niño events. [2]

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(Question 1 continued)

(d) The data in the graph show a long-term trend in global LAI.

(i) State the trend. [1]

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(ii) Global ecosystem modelling suggests that most of the change in LAI is due to increases in atmospheric carbon dioxide. Explain how rising atmospheric carbon dioxide (CO_2) concentration could cause the observed change in LAI. [2]

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(Question 1 continued)

The 2015 Paris Agreement sets out an international framework for avoiding dangerous climate change. A key aspect is conserving and enhancing sinks of greenhouse gases, including forests.

Free air carbon dioxide enrichment (FACE) experiments are being used to investigate whether increases in atmospheric CO_2 concentration will cause biomass increases in existing forests. Three FACE experiments have been running for at least ten years in young, developing forests. Photosynthesis rates are measured in 25 to 30 m diameter plots. In control plots, carbon dioxide concentrations remain at current atmospheric levels (ambient CO_2). In treatment plots, the CO_2 concentration is raised by 50 % (elevated CO_2).

The table gives some details of these experiments and the highest annual net primary production recorded during the period of the experiment. Net primary production is the mass of carbon absorbed and fixed by photosynthesis in plants that is not released due to plant respiration.

		Maximum annual net primary production / kg C m^{-2} y^{-1}	
Site of experiment	**Dominant tree species**	**Ambient CO_2**	**Elevated CO_2**
Rhinelander, Wisconsin	*Populus tremuloides* (deciduous angiosperm)	0.81	0.98
Oak Ridge, Tennessee	*Liquidambar styraciflua* (deciduous angiosperm)	1.00	1.26
Duke, North Carolina	*Pinus taeda* (evergreen conifer)	1.21	1.55

[Source: Walker, A.P., De Kauwe, M.G., Medlyn, B.E., et al., 2019. Decadal biomass increment in early secondary succession woody ecosystems is increased by CO_2 enrichment. *Nature Communications*, [e-journal] 10, 454. https://doi.org/10.1038/s41467-019-08348-1. Open access.]

(e) State the effect of elevated CO_2 on net primary production in these young, developing forests. [1]

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(f) Outline **one** benefit of conducting similar FACE experiments in multiple locations. [1]

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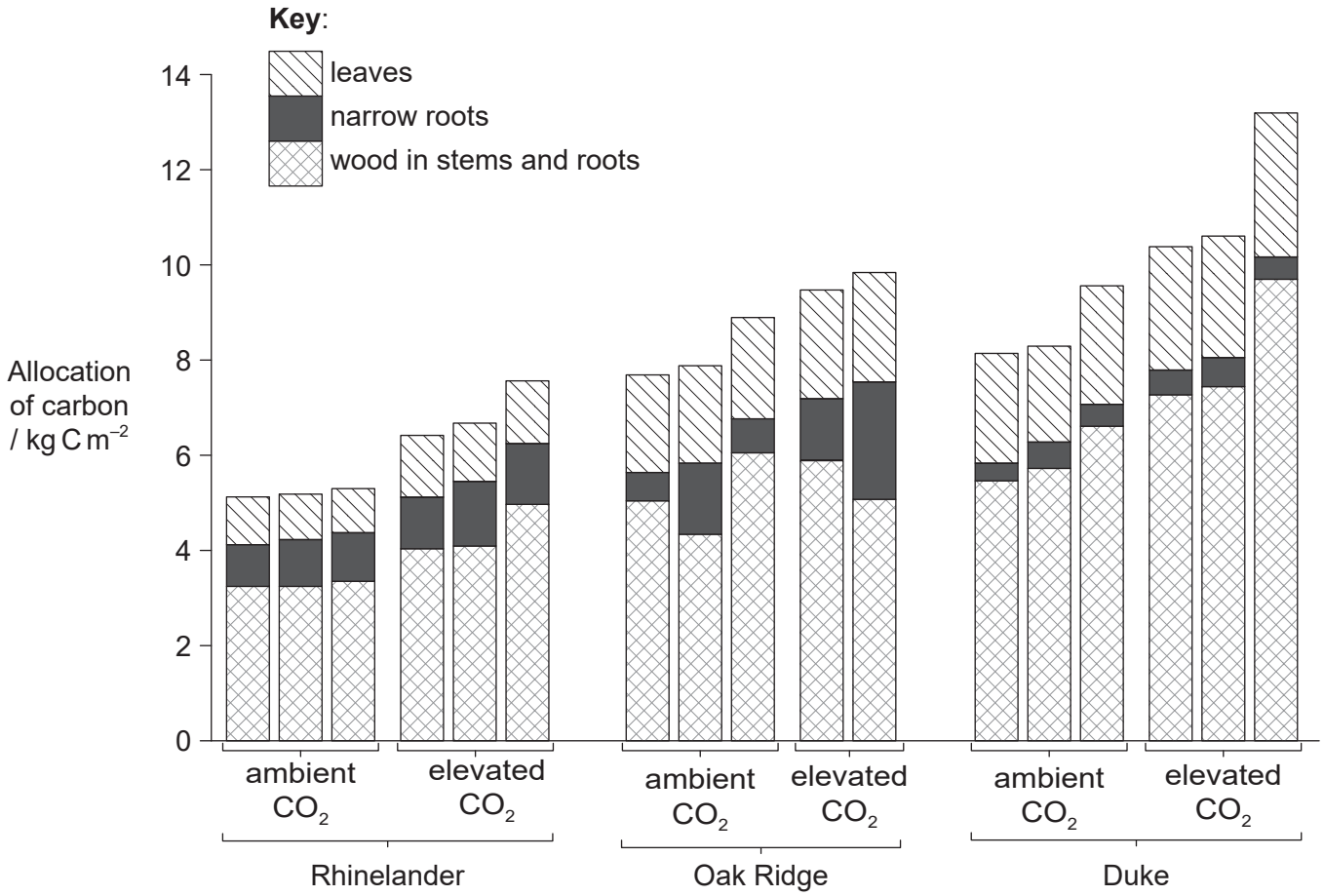
(Question 1 continued)

In each forest, there are two or three trial plots per CO_2 treatment. The bar chart shows the allocation of carbon from net primary production to different parts of the trees in these trial plots.



[Source: Walker, A.P., De Kauwe, M.G., Medlyn, B.E., et al., 2019. Decadal biomass increment in early secondary succession woody ecosystems is increased by CO_2 enrichment. *Nature Communications*, [e-journal] 10, 454. https://doi.org/10.1038/s41467-019-08348-1. Open access.]

(g) Evaluate the evidence from the bar chart that increases in carbon dioxide cause increases in carbon storage in young, developing forests. [3]

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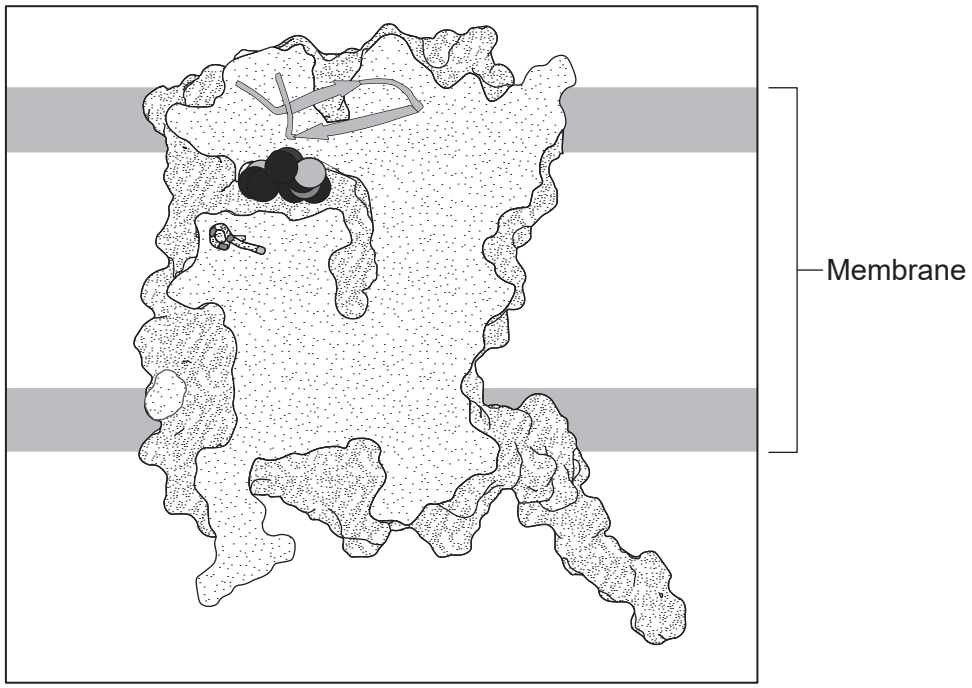
2. The diagram shows a section through the melatonin receptor, with melatonin attached to its binding site. Darker grey areas show the surface of the protein and paler areas are internal. The membrane in which this receptor is located is also shown.



(a) Draw **one** phospholipid molecule on the diagram to show a possible position in the membrane. [2]

(b) The receptor contains seven alpha helices and one other secondary structure. Deduce what this other secondary structure is. [1]

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(c) Discuss briefly whether amino acids on the surface of the protein are likely to be polar or non-polar. [2]

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(Question 2 continued)

(d) Outline the role of melatonin in humans. [2]

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will not be marked.

3. Antibiotics such as penicillin are secreted by fungi and other microorganisms in soil. By secreting them, a microorganism can inhibit the growth of a competitor.

In research published in 2014, nearly 3000 antibiotic resistance genes were discovered in soil microorganisms, giving resistance to 18 different antibiotics. The types of antibiotic resistance gene varied between soil types.

(a) Explain how natural selection could increase the prevalence of an antibiotic resistance gene in a species of soil bacterium. [3]

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(b) (i) There are viruses in soils that are pathogens of animals. Outline a reason for antibiotics in soil not eliminating these viruses. [1]

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(ii) Explain the reasons for antibiotics secreted into soil not harming insects or other animals in the soil. [2]

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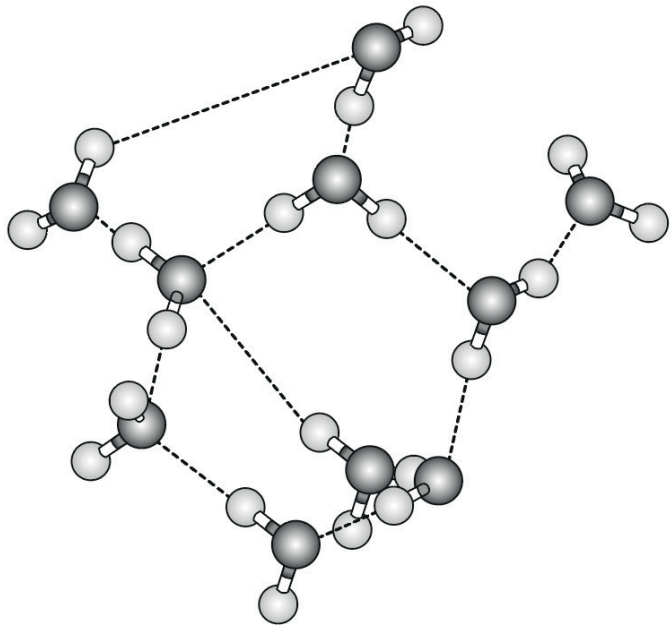
4. The diagram shows water molecules as they might be arranged in liquid water and the interactions between them.



(a) (i) State how many water molecules are shown in the diagram. [1]

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(ii) Identify the interactions that are shown between the water molecules. [1]

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(This question continues on the following page)

(Question 4 continued)

(b) (i) With reference to the diagram, explain how water in sweat evaporates. [2]

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(ii) Outline the reasons for secretion of sweat in humans. [2]

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5. The spider *Dolomedes plantarius* usually has white bands down the left and right sides of its body, but some individuals lack these bands. The photograph shows the banded form of *D. plantarius* with a ball of spiderlings.

Crosses were performed to investigate the inheritance of this trait, by allowing specific males and females to mate. Numbers of banded and unbanded spiderlings that hatched out from all the eggs laid by the female were recorded. Results are shown in the table.

		Progeny phenotypes		
Cross number	**Parental phenotypes ♀ × ♂**	**Banded**	**Unbanded**	**Proportion banded**
1	Banded × Banded	46	16	0.742
2	Unbanded × Banded	37	38	0.493
3	Unbanded × Banded	63	0	1.000
4	Unbanded × Unbanded			

(a) Explain the conclusion that can be drawn from Cross 1. [2]

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(Question 5 continued)

(b) Deduce reasons for the difference between the results of Cross 2 and Cross 3. [2]

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(c) There were 79 progeny in Cross 4. Predict the expected results by completing the table. [1]

(d) Identify, using **one** recognition feature visible in the photo, the phylum in which *D. plantarius* is classified. [1]

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Section B

Answer **two** questions. Up to one additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

6. Feedback mechanisms are used in living organisms both to promote and respond to change.

(a) Outline the role of ADH in osmoregulation. [4]

(b) Explain the regulation of metabolic pathways by end-product inhibition. [4]

(c) Describe the hormone feedback mechanisms that help to prepare a woman's body for pregnancy, sustain the pregnancy and then give birth. [7]

7. All living organisms contain chromosomes. In addition to acting as stores of genetic information, these chromosomes are involved in a range of active processes during the life of a cell and of an organism.

(a) Outline the changes to chromosomes that occur during prophase in the first division of meiosis. [4]

(b) Describe the processes that are carried out by enzymes that bind to DNA. [7]

(c) Explain the effects that the environment can have on DNA in living organisms. [4]

8. Fluids inside unicellular and multicellular organisms allow materials to be moved.

(a) Explain how vesicles are used by cells to move materials. [5]

(b) Describe the transport of carbon compounds such as sucrose and amino acids in phloem. [7]

(c) Outline how food is moved from the stomach to the large intestine. [3]

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References:

1. (a) Zhu, Z. et al., 2013. Global Data Sets of Vegetation Leaf Area Index (LAI)3g and Fraction of Photosynthetically Active Radiation (FPAR)3g Derived from Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI3g) for the Period 1981 to 2011. *Remote Sensing*, [e-journal] 5, pp. 927–948. https://doi.org/10.3390/rs5020927. Open access.

1. (c) Material from: Zhu, Z., Piao, S., Myneni, R., et al., Greening of the Earth and its drivers, published 2016, *Nature Climate Change*, reproduced with permission of SNCSC.

1. (e) Walker, A.P., De Kauwe, M.G., Medlyn, B.E., et al., 2019. Decadal biomass increment in early secondary succession woody ecosystems is increased by CO_2 enrichment. *Nature Communications*, [e-journal] 10, 454. https://doi.org/10.1038/s41467-019-08348-1. Open access.

1. (g) Walker, A.P., De Kauwe, M.G., Medlyn, B.E., et al., 2019. Decadal biomass increment in early secondary succession woody ecosystems is increased by CO_2 enrichment. *Nature Communications*, [e-journal] 10, 454. https://doi.org/10.1038/s41467-019-08348-1. Open access.

2. Material from: Stauch, B., Johansson, L.C., McCorvy, J.D., et al., Structural basis of ligand recognition at the human MT1 melatonin receptor, published 2019, *Nature*, reproduced with permission of SNCSC.

3. Material from: Forsberg, K.J., et al., Bacterial phylogeny structures soil resistomes across habitats, published 2014, *Nature*, reproduced with permission of SNCSC.

5. photo: Vėlavičienė, N., 2004. [Dolomedes.] [image online] Available at: https://commons.wikimedia.org/wiki/File:Dolomedes_fimbriatus.jpg. [Accessed 14 March 2022]. Licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license (https://creativecommons.org/licenses/by-sa/3.0/deed.en).

table: Baillie, A.L., Baillie, S.R. and Smith, H., 2019. The heritability of lateral banding in *Dolomedes plantarius*. *Arachnology*, [e-journal] 18(3), pp. 237–244. https://doi.org/10.13156/arac.2019.18.3.237.

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