Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Wednesday 19 June 2024

Morning (Time: 2 hours)

Paper reference **9BN0/03**

Biology A (Salters Nuffield)

Advanced

PAPER 3: General and Practical Applications in Biology

You must have: Ruler, HB pencil, scientific calculator and a copy of the scientific article adapted from the New Scientist and the Brazilian Journal of Medical and Biological Research (enclosed)

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- **Show all your working out** in calculations and **include units** where appropriate.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over

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P 7 4 4 5 8 R A 0 1 3 6

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Answer ALL questions.

Write your answers in the spaces provided.

1 One of the first plant species to colonise some habitats is thale cress (*Arabidopsis thaliana*).

The plant hormone IAA (auxin) is produced in the growing tips of plants such as thale cress.

(Source: Nigel Cattlin / Alamy Stock Photo)

(a) State what is meant by the term **colonisation of a habitat**.

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(b) One role of IAA is to stimulate the phototropic response of shoots.

Describe how IAA causes a phototropic response in the shoots of a plant.

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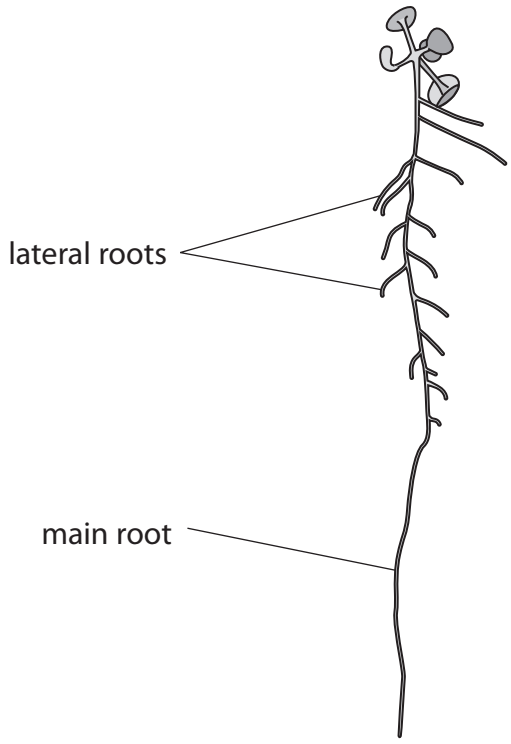
(c) Another role of IAA is to stimulate the growth of lateral roots.

The diagram shows the roots of thale cress.



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One type of receptor for IAA is coded for by the tir1 gene.

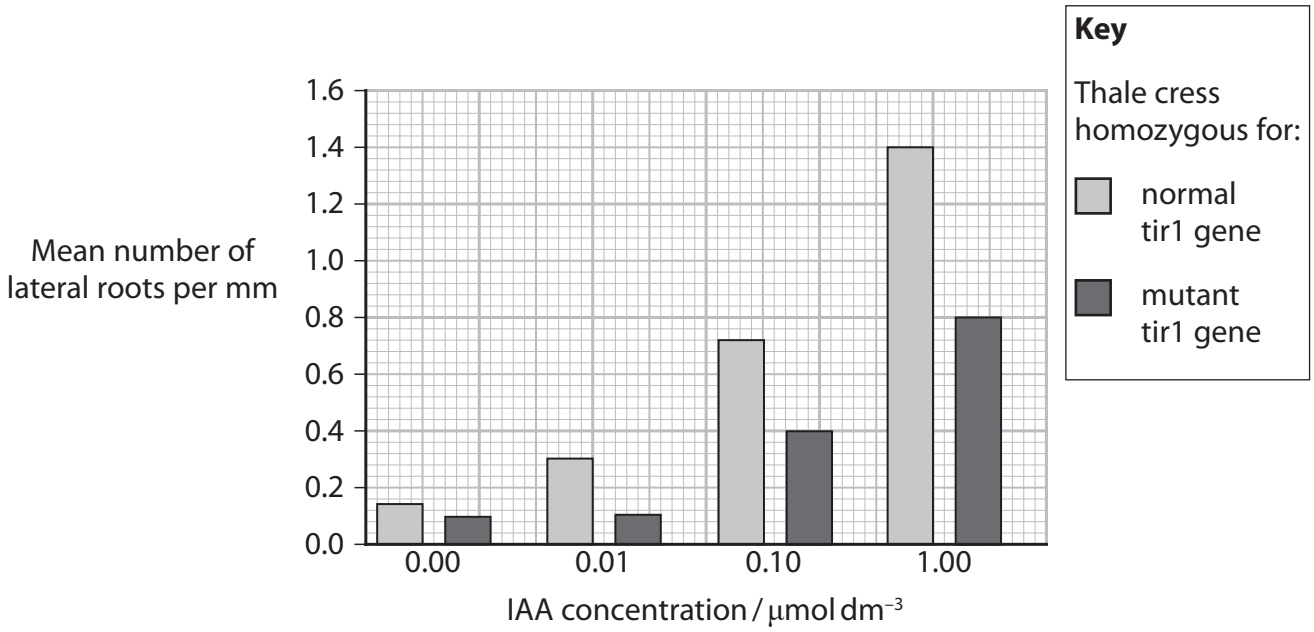
Scientists have investigated the effect of IAA on the growth of lateral roots in thale cress.

Plants homozygous for a normal tir1 gene and plants homozygous for a mutation in the tir1 gene were used in this investigation.

The plants were treated with different concentrations of IAA.

The mean number of lateral roots produced per mm of main root was recorded.

The graph shows the results of this investigation.



(i) Explain why the scientists used plants homozygous for the normal and the mutant tir1 gene in this investigation.

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(ii) Calculate the percentage decrease in mean number of lateral roots for thale cress with the mutant tir1 gene compared to thale cress with the normal tir1 gene at 1.00 μmol dm^{-3} of IAA.

(1)

Answer .....%

(iii) Deduce the effect of the mutation in the tir1 gene on the response of thale cress to IAA.

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(Total for Question 1 = 9 marks)

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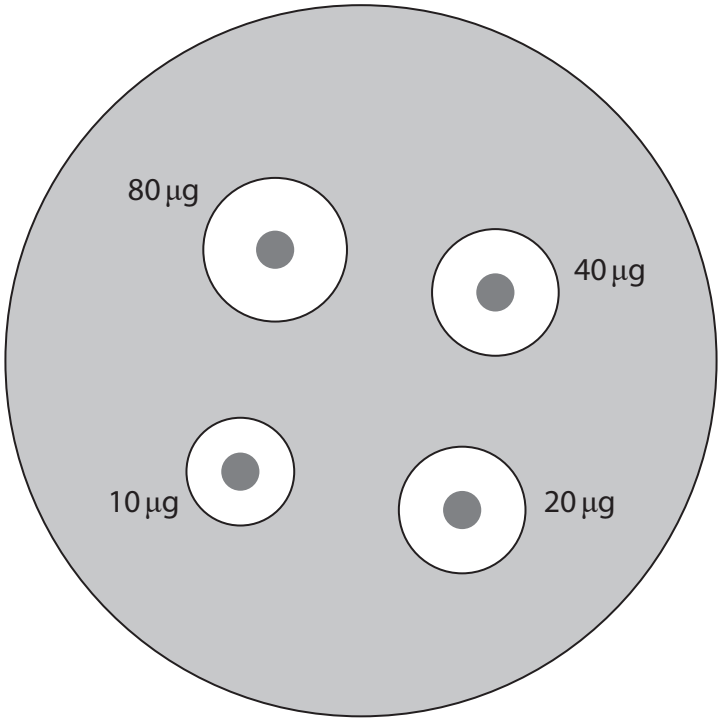
2 Pathogenic bacteria can become resistant to antibiotics.

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a bacterial pathogen that is resistant to many antibiotics.

Licochalcone A is a chemical isolated from the liquorice plant.

The antibacterial properties of licochalcone A have been investigated.

The diagram shows the effect of licochalcone A on a bacterial lawn prepared using MRSA.



Magnification ×1

(a) Complete the table using information from the diagram.

(2)

Mass of licochalcone A / μg	Diameter of clear zone / mm	Area of clear zone / mm²
10	14.5	165
20	16.5	214
40	16.5	214
80		

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(b) The bacteria used in this investigation are pathogenic.

Describe how filter paper discs containing licochalcone A can be safely placed on the bacterial lawn.

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(c) Explain how an anomalous result could be identified for this investigation.

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(Total for Question 2 = 7 marks)

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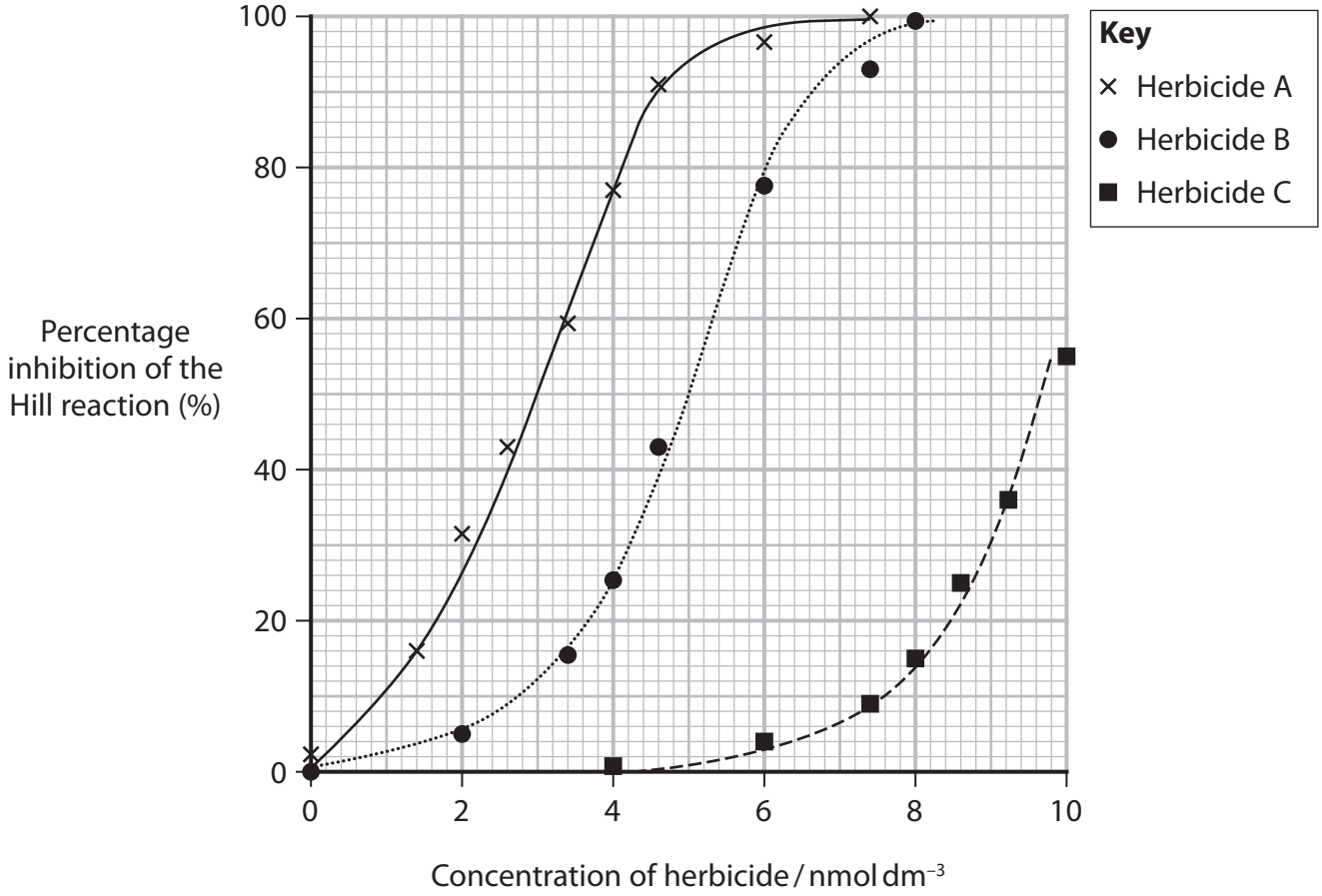
3 Photosynthesis takes place in chloroplasts.

(a) The light-dependent processes in photosynthesis can be investigated using the Hill reaction.

The graph shows the effect of three different herbicides, A, B and C, on inhibition of the Hill reaction in isolated chloroplasts.



(i) State the location of the light-dependent reactions in chloroplasts.

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(ii) Calculate the gradient of the slope for herbicide A at 50% inhibition of the Hill reaction.

Give your answer to two significant figures.

(2)

Answer.....

(iii) Describe the role of chlorophyll in the light-dependent reactions of photosynthesis.

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(b) Describe the role of RUBISCO in the light-independent reactions of photosynthesis.

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4 The photographs show two large marine animals, the great white shark and the humpback whale.

(Source: Sergey Uryadnikov/Shutterstock)

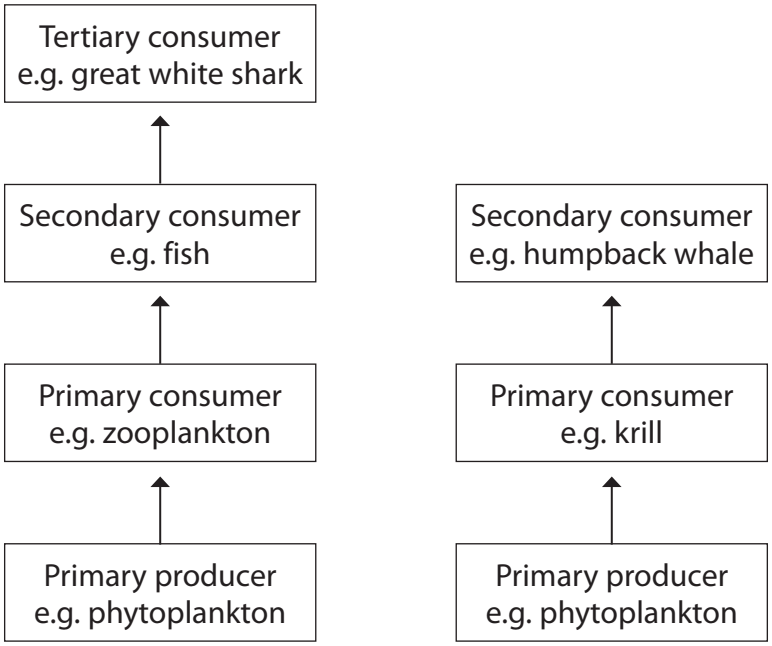
Great white shark

(Source: Mircea Costina / Alamy Stock Photo)

Humpback whale

A typical adult great white shark has a mass of approximately 600 kg.
Adult humpback whales have a mass of approximately 140 000 kg.

The diagram shows the trophic levels for two marine communities, one that includes the great white shark and one that includes the humpback whale.



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(a) Explain why an area of ocean can support a greater biomass of humpback whales than of great white sharks.

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(b) Phytoplankton are photosynthetic unicellular microorganisms.

Phytoplankton are primary producers in aquatic ecosystems.

(i) State the relationship between gross primary productivity and net primary productivity.

(1)

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(ii) The concentration of oxygen in water (dissolved oxygen) can be measured using an oxygen probe.

Explain how an oxygen probe could be used to estimate the effect of temperature on the gross primary productivity (GPP) of phytoplankton.

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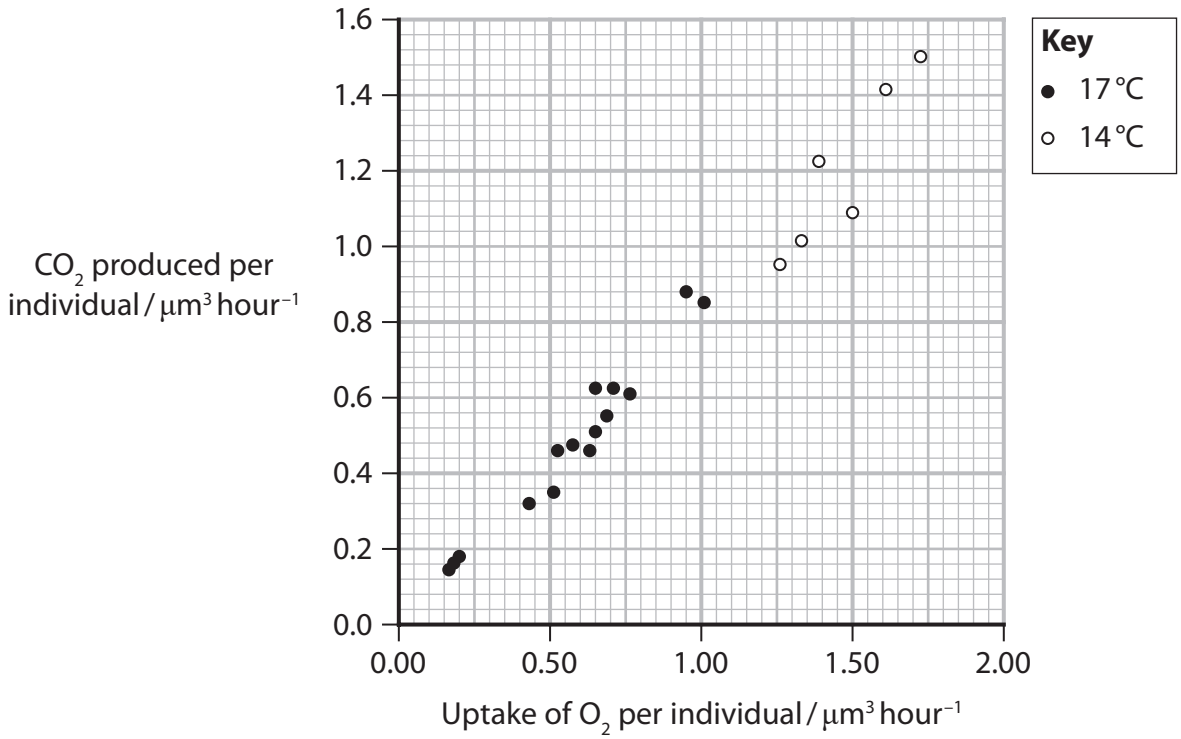
(c) Copepods are a group of zooplankton, small animals that feed on phytoplankton.

In an experiment, the production of carbon dioxide and the uptake of oxygen by copepods was measured at 14 °C and at 17 °C.

The results of the experiment are shown in the graph.



(i) Determine the mean ratio of carbon dioxide produced to oxygen consumed at 17 °C.

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(ii) Deduce **two** conclusions from the results of this experiment.

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(Total for Question 4 = 11 marks)

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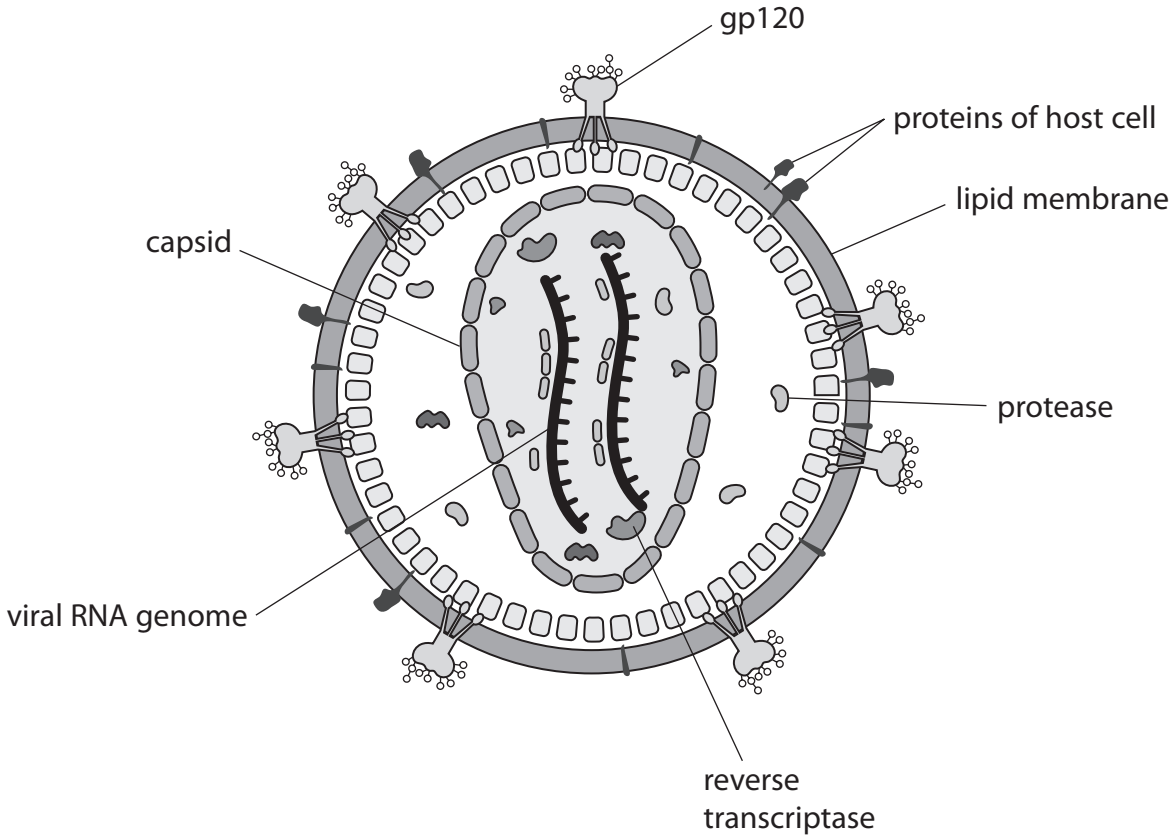
5 Human immune deficiency virus (HIV) can cause acquired immune deficiency syndrome (AIDS).

(a) The diagram shows an HIV virus particle.



(i) State the role of gp120 in the life cycle of the HIV virus.

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(ii) Give a reason why there are proteins from the host cell in the lipid membrane surrounding the virus particle.

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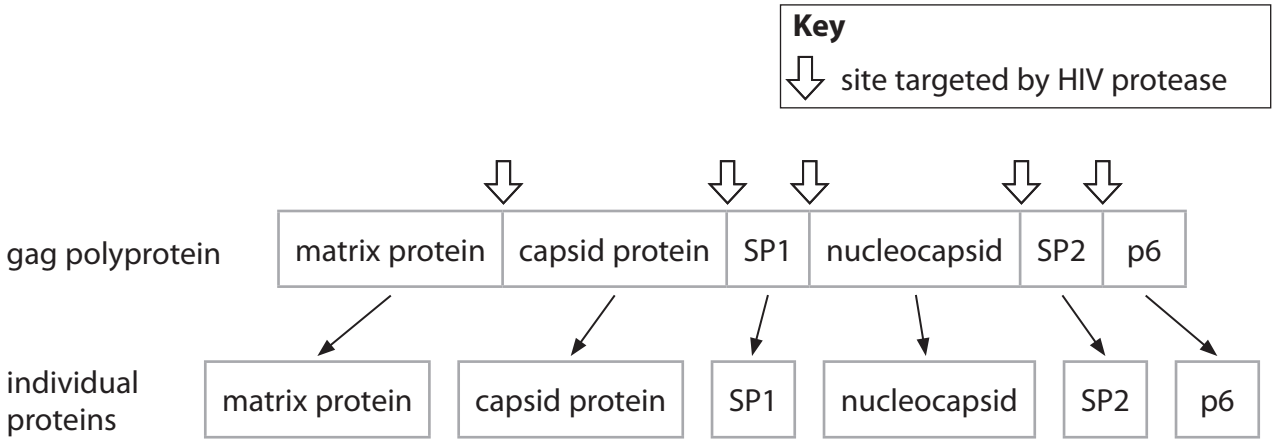
(b) During viral replication, virus mRNA molecules are translated into a virus polyprotein called gag. A polyprotein is a chain of smaller proteins.

This polyprotein is then split into individual proteins by the HIV protease.

The diagram shows the individual proteins produced from the polyprotein by HIV protease.



Deduce how HIV protease can split the gag polyprotein into individual proteins.

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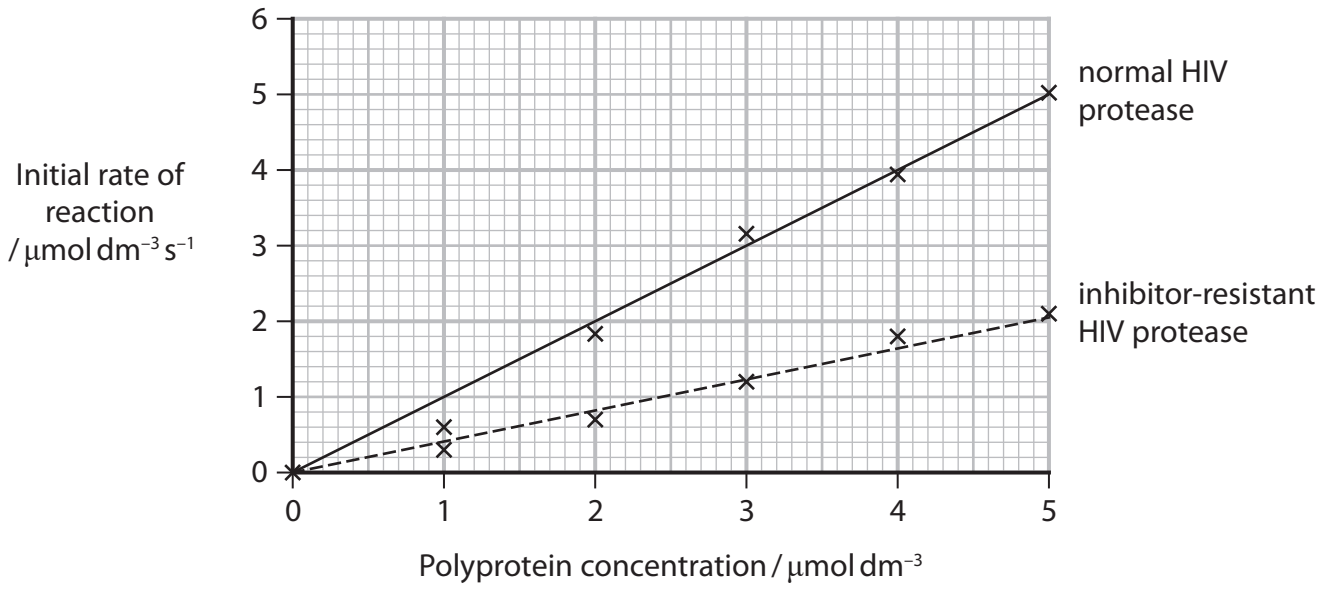
(c) HIV protease inhibitors are used in drugs to treat HIV infection.

In some individuals, the HIV has developed resistance to protease inhibitors.

The graph shows the effect of polyprotein concentration on the initial rate of reaction of normal HIV protease and inhibitor-resistant HIV protease.



(i) Calculate the initial rate of reaction in the inhibitor-resistant HIV protease for a polyprotein concentration of 7 μmol dm^{-3}.

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Answer .....

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(ii) Explain the importance of enzyme and substrate concentrations when comparing the initial rates of reaction of different enzymes.

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(Total for Question 5 = 10 marks)

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6 The drug MDMA (ecstasy) can cause damage to the brain.

(a) This damage can cause changes in behaviour. This drug affects serotonin synapses.

(i) Explain how MDMA changes the rate of transmission of nerve impulses across serotonin synapses.

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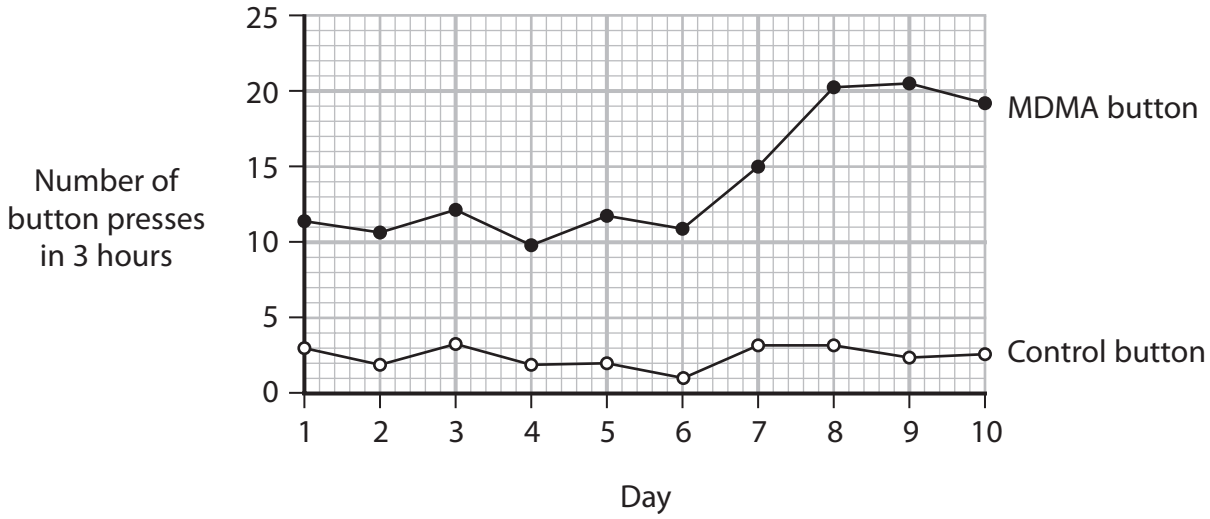
(ii) The effect of MDMA on the behaviour of mice has been investigated.

Mice were provided with access to two buttons, an MDMA button and a control button.

When they pressed the MDMA button they received a dose of MDMA.
When they pressed the control button they received a dose of salt solution.

The buttons were activated for one three-hour period each day.

The graph shows the results of this experiment.



Determine the effect of MDMA on the number of button presses made by these mice.

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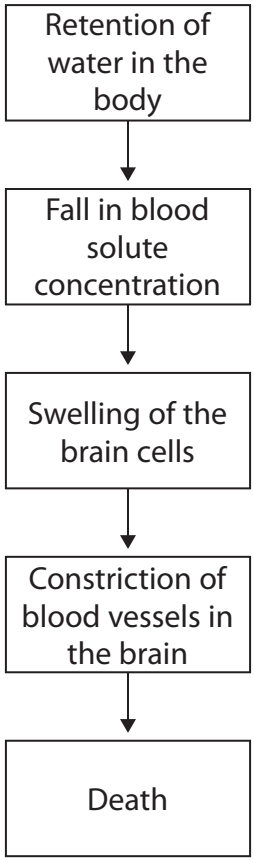
(b) MDMA is responsible for swelling of the brain resulting in death in some people.

The diagram shows how MDMA can cause brain swelling and death in some people.



Brain cells regulate their volume using active transport of sodium ions.

(i) State what is meant by **active transport**.

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(ii) Explain how the active transport of sodium ions can regulate brain cell volume.

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(iii) Explain why swelling of the brain cells will result in vasoconstriction.

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(iv) Explain why vasoconstriction will result in the death of brain cells.

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(Total for Question 6 = 16 marks)

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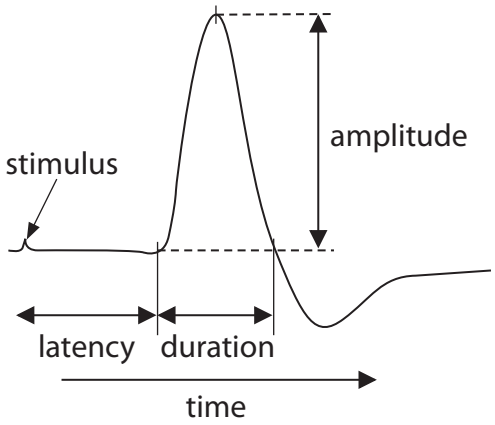
***7** Sports injuries can be treated to reduce pain caused by muscle cramp.

Ice massage, ice pack and cold-water immersion are three different types of treatment.

The compound action potential (CAP) is a measure of the sum of all action potentials in a muscle.

In one investigation, the effects of these treatments on the CAP in a leg muscle were investigated.

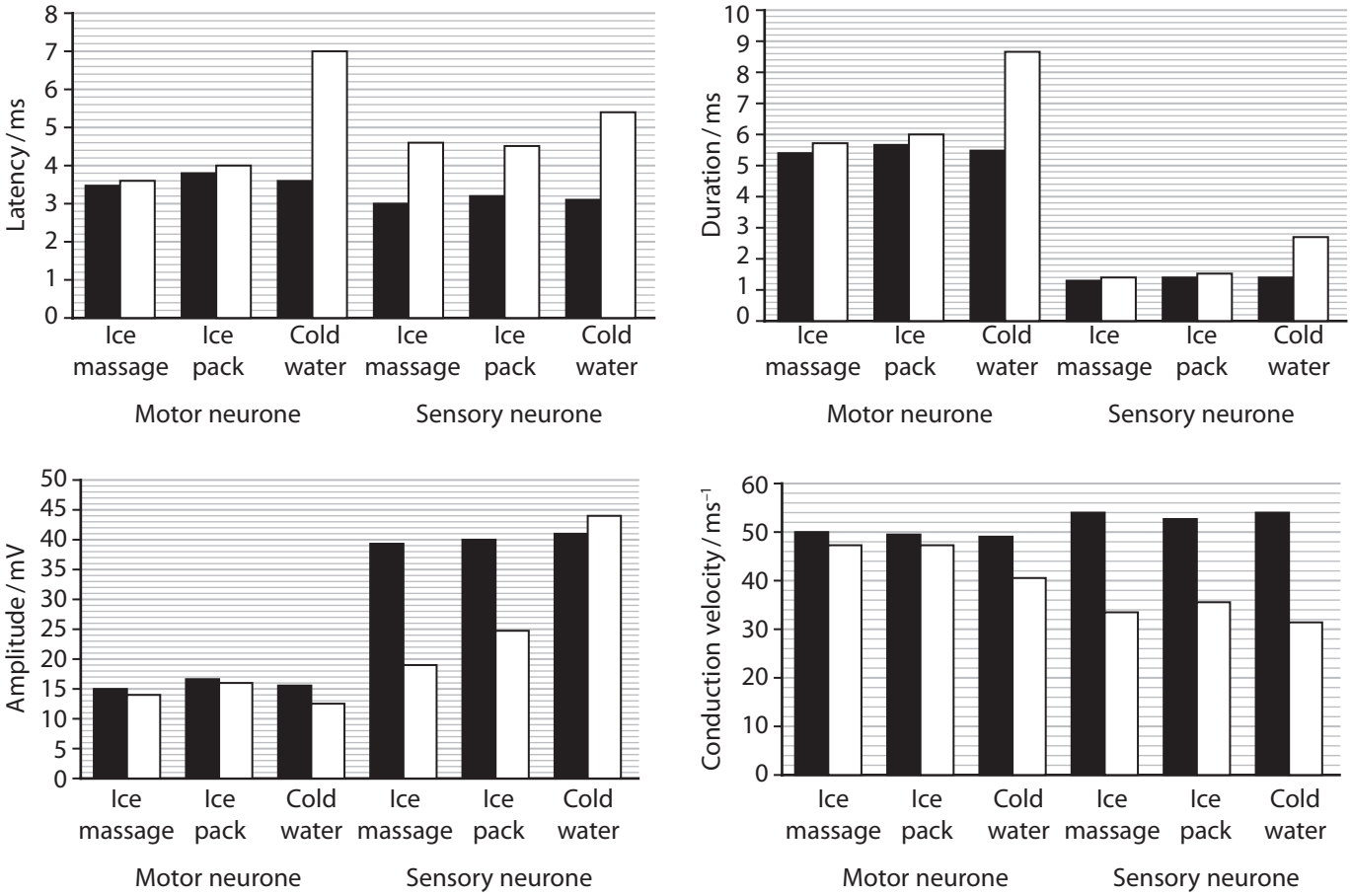
The diagram shows the latency, duration and amplitude for a CAP.



- Latency is the time taken from application of stimulus to the start of a CAP
- Duration is the length of time the CAP shows depolarisation
- Amplitude is the sum of depolarisation of all individual action potentials in the CAP
- Conduction velocity is the mean speed at which the CAP travels along the neurones.

The effects of the different treatments on the CAP for motor and sensory neurones are shown in the graphs.

Key ■ Pre-treatment □ Post-treatment



Assess the effect of different cold treatments on nerve conduction and the reduction of pain caused by muscle cramp.

Use all the information provided in the question as well as your own knowledge and understanding.

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(Total for Question 7 = 9 marks)

8 The scientific article you have studied was adapted from the *New Scientist* and the *Brazilian Journal of Medical and Biological Research*.

Use the information from the scientific articles and your own knowledge to answer the following questions.

(a) Explain why analysis of the amino acid sequence of the eye lens proteins can be used to determine the phylogenetic relationship of different sloths (Box 1).

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(b) Describe how the algae living on the hair of sloths can be shown to belong to one of four phyla (Box 2).

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(c) Describe how a spirometer could be used to estimate the metabolic rate of a sloth (paragraph 5).

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(d) Explain how the presence of different antibodies can be used to show that some viruses are specific to sloths and some are incidental (Box 3).

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(e) Sloths have 'the longest digestive process on record for a plant-eating mammal' (paragraph 7).

Deduce the advantage to the sloth of a slow digestive process.

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(f) Explain why 'maintaining a core body temperature is energetically expensive' for a sloth (paragraphs 8 and 9).

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(g) Sloths can warm up by climbing higher up into the canopy (paragraph 9).

State the type of adaptation that this represents.

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(h) Sloths spend a lot of time hanging upside down – 'constant grip is made possible by a lattice of tendons in the hands and feet that draw the digits closed' (paragraph 10).

Explain the advantage of using a lattice of tendons to draw the digits closed.

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(i) Sloth muscles 'contain a unique set of enzymes that confers tolerance to heavy accumulations of lactic acid' (paragraph 12).

Deduce how the enzymes in sloth muscles will differ from those in human muscles.

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(j) Sloths carry a 'community of commensal beetles, mites and moths'.

Explain what is meant by this phrase (Box 4).

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(k) Describe how sympatric speciation could have occurred in the moths living on sloths (Box 4).

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(Total for Question 8 = 30 marks)

TOTAL FOR PAPER = 100 MARKS

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Pearson Edexcel Level 3 GCE

Wednesday 19 June 2024

Morning (Time: 2 hours)

Paper reference **9BN0/03**

Biology A (Salters Nuffield)

Advanced

PAPER 3: General and Practical Applications in Biology

Scientific article for use with Question 8

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LIFE IN THE SLOTH LANE

Once defamed as slow and stupid, sloths are now recognised as masterworks of mammalian evolution – and we could all learn from their energy-saving tricks.

Sloths' exquisite adaptations have allowed them to survive for 30 million years.

Jonathan Ross ISTOCK PHOTO

1. GEORGES-LOUIS LECLERC, the Comte de Buffon, was the most famous naturalist on the planet in the middle of the 18th century, and he didn't think much of the New World. He proclaimed the Americas "degenerate", a sodden, miserable land filled with weak and inferior species. But Buffon reserved his most biting contempt for one creature in particular.

2. He wrote of their "too short" and "badly terminated" legs, of their "slowness, stupidity... and even habitual sadness". "These sloths," he continued, "are the lowest term of existence in the order of animals with flesh and blood. One more defect would have made their existence impossible."

3. Buffon couldn't have been more wrong. What he saw as shortcomings we now realise are exquisite adaptations that have allowed sloths to thrive in an exceedingly austere niche for at least 30 million years. In fact, the closer we look at sloth biology, the more we see just how hard evolution has had to work so that these notorious dawdlers can take it easy.

Box 1

Sloths are included, along with the armadillos and anteaters, in the Order Xenarthra (Edentata). Analysis of amino acid sequences of the eye lens proteins has confirmed earlier anatomical evidence indicating that the xenarthrans are an old offshoot of the eutherian stem that arose at least 75–80 million years ago. Initially all present-day sloths were considered to belong to the family Bradypodidae with two genera, Bradypus and Choloepus. However, a new classification has been proposed, which places the two-toed sloths in the family Megalonychidae and the three-toed sloths in the family Bradypodidae. It is thus now generally believed that the two living families of sloths have quite different phylogenetic origins and that Bradypus is derived from megatheroid and Choloepus from megalonychid sloths, their separate evolution beginning about 35 million years ago in the late Oligocene.

4. One reason we know so little about sloths is that they are surprisingly difficult to study. They live high in the canopies of South and Central America and are extremely hard to spot: they are small, they rarely move and their fur often gets matted with green algae, making them blend in with the leaves.

Box 2

Algae representing four phyla have been cultured from Bradypus, these being Chlorophyta, Chrysophyta, Cyanophyta and Rhodophyta.

During the dry season the hair of the sloths usually has a dirty brown coloration, but during long periods of rain it may show a very appreciable greenish tinge brought about by the increased presence of symbiotic algae. According to Britton, the algae may already be present in the hair of animals only a few weeks old and it has been suggested that they provide camouflage for the sloths, while obtaining shelter for themselves. Aiello discussed the different possibilities as to why sloth hair has evolved in such a way to encourage algal colonization. She does not believe that camouflage or thermal insulation are the only or necessarily the more important reasons and suggested that the algae may provide nutrition or a particular trace element. Lack of healthy algal colonies could thus provide an explanation why Bradypus does not survive long in captivity.

5. To figure out exactly how slow they are, in 2014, Jonathan Pauli at the University of Wisconsin-Madison and his colleagues went to Costa Rica to measure the metabolic rates of three-toed brown-throated sloths and Hoffmann's two-toed sloths. They found that while both species have extremely slow metabolisms, the three-toed sloth is a record-breaker. The rate at which it expends energy in the wild, known as the field metabolic rate, came in at 162 kilojoules per day per kilogram, meaning it has lower energy needs than any other mammal that isn't hibernating, including renowned slouches like koalas (410 kJ/day/kg) and giant pandas (185 kJ/day/kg).

Box 3

Seymour has reviewed the role of sloths as the possible hosts to a whole variety of arthropod-borne viruses (arboviruses), citing work carried out in Belém (Brazil), and in Panama. However, whether or not sloths are essential or only incidental to the natural cycle of an arbovirus, their long experimental viremias are remarkable and Seymour suggests that these may be due to the animal's low metabolic rate.

Seymour finally concluded that the wide variety of arboviruses isolated from sloths can be characterized according to antibody and virus isolation data as being sloth specific (Utinge, Utive and Changuinola viruses), incidental in sloths (such as the Venezuelan encephalitis viruses), or others (including the St. Louis encephalitis and Oropouche viruses) for which the role sloths play in the natural cycles is as yet uncertain. Simultaneous productive infections appear to be possible in these animals.

6. Part of the reason sloths are such extreme energy savers is their diet. They are arboreal folivores, meaning they live in trees and eat leaves. It is a deeply unpopular lifestyle choice, occurring in just 0.2 per cent of mammal species, and for good reason; leaves tend to be rather difficult to digest and contain few nutrients. Some tree-living leaf-eaters, such as howler monkeys, get around this by gorging on massive quantities of the stuff.

7. Sloths have adopted a different strategy: they nibble a bit here and there, making sure to keep their stomachs full. And they don't rush digestion. It can take anywhere from two days to nearly two months before swallowed food emerges again as dung, which makes this the longest digestive process on record for a plant-eating mammal. That is particularly weird when you consider that among mammals, the digestion rate typically depends on body size, with big animals taking longer to digest their food.

8. A long and winding alimentary canal isn't the only way sloths conserve energy. They also allow their body temperature to vary wildly compared with other mammals. Whereas humans hover within a degree of 38 °C, the three-toed sloths Pauli studied allowed swings of nearly 5 °C as the forest cooled or warmed around them. That saves a lot of energy, because maintaining a core body temperature is energetically expensive.

9. But sloths still need a way to warm up. Shivering, favoured by most warm-blooded animals, is for creatures with energy to burn. Instead, three-toed sloths climb higher into the canopy each morning to make the most of the sun's generosity. Sloths also can't jump.

10. But even beyond saving energy, the sloth's characteristic slow-motion upside-down walking might have another benefit: camouflage. One of the sloth's main predators, the harpy eagle, relies on seeing its prey move. Hanging upside down, completely still, for hours on end seems to do the trick. Sloths can do this in part thanks to their long, curved claws, which their giant ancestors used to excavate tunnels, but now operate more like coat hangers. The constant grip is made possible by a lattice of tendons in the hands and feet that draw the digits closed while at rest.

11. But there seems to be more to their muscular abilities than that. We usually think about muscles as doing one thing well, says Michael Butcher, a zoologist at Youngstown State University in Ohio. An Olympic weightlifter, for instance, has muscles capable of small, powerful movements, whereas a marathon runner's muscles are geared towards sustaining long periods of exertion. "But sloths break that rule," he says. They have an uncanny ability to resist fatigue, as well as a surprising amount of strength.

12. To better understand how they do it, Butcher dissected a dozen sloth cadavers. He was surprised to see they had very little muscle tissue – roughly 10 per cent less than you find in other arboreal mammals. But what muscle there is appears to be extraordinary. Most strikingly, sloth muscles seem to contain a unique set of enzymes that confers tolerance to heavy accumulations of lactic acid, which may help them resist fatigue as they hang out or move in super-slow motion.

Box 4

Sloths act as hosts to a wide variety of arthropods, which include biting and bloodsucking flies such as mosquitoes and sandflies, triatomine bugs, lice, ticks and mites. Sloths also carry a highly specific community of commensal beetles, mites and moths.

It has been suggested that the sloth moths may receive some protection from avian predators and possibly find nutrients in secretions of the sloth's skin and/or the algae present on the fur. Waage and Best reported that some three-toed sloths may carry in excess of 120 moths; lower numbers may occasionally be seen on two-toed sloths. They also pointed out that there is considerable sympatry amongst moth species found on sloths and that several different species may coexist on the same animal.

13. For all these fresh insights, there is still a lot to learn about sloths. We don't know why they climb all the way down to the forest floor to defecate, for instance, never mind why they bury the mess. It doesn't seem very frugal.

14. One thing is clear, though: the more we learn about these extraordinary creatures and their unhurried lifestyle, the easier it is to appreciate how diet and metabolism can drive evolutionary adaptation.

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