1.5 Energy Transfers in and between Organisms: 1-hour Pack

AQA 7402 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A student calculated an energy budget for a population of voles. The voles had a food energy intake (I) of 15000 kJ m^{-2} $year^{-1}$. Energy lost in faeces and urine (F+U) was 9000 kJ m^{-2} $year^{-1}$, and energy used in respiration (R) was 5850 kJ m^{-2} $year^{-1}$.

(a) Using the equation P = I - (F+U) - R, show that the net production (P) of the vole population is 150 kJ m^{-2} $year^{-1}$. **(2)**

(b) State what happens to the energy in the net production (P) that is not consumed by the next trophic level. **(1)**

(c) Explain, in terms of energy flow, why only a small percentage of the Sun's energy incident on a habitat is ultimately fixed by photosynthesis. **(3)**

(Total for Question 1 is 6 marks)

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2 Required practical. A student used a respirometer to investigate the rate of oxygen consumption by blowfly larvae (maggots). The apparatus had two tubes connected to a manometer containing coloured fluid: one tube contained the maggots with soda lime, the other (the control tube) contained an equal volume of inert glass beads with soda lime. As the maggots respired, the coloured fluid in the manometer moved towards the tube containing the maggots.

(a) Explain the purpose of the soda lime in the apparatus. **(2)**

(b) Explain the purpose of the control tube containing inert glass beads. **(1)**

(c) The manometer capillary tube has an internal radius of 1.0 mm. During the experiment, the coloured fluid moved 30 mm along the tube in 5.0 minutes. Using volume = $\pi \times r^2 \times$ length, calculate the volume of oxygen consumed, in cm^3. Give your answer to 3 significant figures. **(2)**

(d) The mass of maggots used was 2.0 g. Using your answer to part (c), calculate the rate of oxygen consumption per gram of maggots, in $cm^3\ g^{-1}\ min^{-1}$. Give your answer to 2 significant figures. **(3)**

(e) Suggest one reason why the value calculated in part (d) might be an underestimate of the true rate of aerobic respiration of the maggots. **(2)**

(Total for Question 2 is 10 marks)

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3 In a woodland ecosystem, the producers had a gross primary productivity (GPP) of 18500 kJ m^{-2} $year^{-1}$. The producers used 11200 kJ m^{-2} $year^{-1}$ in respiration (R).

(a) Define the term 'net primary productivity' (NPP). **(1)**

(b) Calculate the net primary productivity (NPP) of the producers. Show your working. **(2)**

(c) The primary consumers in the woodland had a net productivity of 730 kJ m^{-2} $year^{-1}$. Calculate the percentage of the producers' NPP (from part b) that is transferred to primary consumers. **(2)**

(d) Suggest one reason why not all of the energy in the producers' net primary productivity is transferred to primary consumers. **(1)**

(Total for Question 3 is 6 marks)

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4 Photosynthetic efficiency and rates. A leaf disk experiment measures net photosynthetic O_2 production. At 400 micromol m^{-2} s^{-1} photon flux, a leaf area of 0.020 m^2 produces 1.80 x 10^{-4} mol O_2 in 10 minutes. Assume 8 photons are required to produce one O_2 in the light reactions (minimum quantum requirement).

(a) Calculate the total number of photons incident on the leaf area during the 10 minute period. **(3)**

(b) Using the quantum requirement given, calculate the theoretical maximum mol of O_2 that could be produced from the incident photons and compare with the observed 1.80 x 10^{-4} mol O_2. Hence calculate the light-use efficiency defined as (observed O_2 / theoretical max O_2) x 100%. Give the efficiency to 2 significant figures. **(4)**

(c) State one biological factor that could explain why observed O_2 production is much lower than theoretical maximum. **(1)**

(Total for Question 4 is 8 marks)

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5 A farmer wants to increase the efficiency of energy transfer to a herd of beef cattle. He is considering two intensive farming methods: (1) keeping the cattle indoors in temperature-controlled barns with restricted space to move; (2) treating the cattle with growth-promoting hormones. Discuss how each method could increase the efficiency of energy transfer to the cattle, and evaluate the ethical and environmental issues raised by these farming practices.

(Total for Question 5 is 6 marks)

6 Explain why the efficiency of energy transfer between successive trophic levels in an ecosystem is generally low, and explain why food chains rarely contain more than about five trophic levels.

(Total for Question 6 is 6 marks)

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Mark scheme · 1.5 Energy Transfers in and between Organisms: 1-hour Pack

Question 1

(a) 15000 - 9000 - 5850 (working shown) **M1**

(a) = 150 kJ m^{-2} $year^{-1}$ cso (answer given) **A1**

(a) Answer: 150 kJ m^{-2} $year^{-1}$ (given)

(b) it remains as dead organic matter and is broken down by decomposers/detritivores (returning carbon/nutrients to the abiotic environment, with further energy lost as heat via decomposer respiration) **B1**

(b) Answer: It is broken down by decomposers, returning nutrients to the environment.

(c) only certain wavelengths of light are absorbed by photosynthetic pigments (chlorophyll); other wavelengths (e.g. green light) are reflected or transmitted and not used **B1**

(c) much of the light reaching a habitat is not intercepted by chlorophyll/leaves at all (e.g. it reflects off non-photosynthetic surfaces, hits bare ground, or is absorbed by clouds/atmosphere before reaching plants) **B1**

(c) some absorbed light energy is lost as heat rather than being converted into chemical energy during the light-dependent reactions **B1**

(c) Answer: Wrong wavelengths are reflected/transmitted, much light misses chlorophyll entirely, and some absorbed energy is lost as heat rather than fixed.

Question 2

(a) soda lime absorbs the carbon dioxide released by the maggots during respiration **B1**

(a) so any change in gas volume/pressure detected is due only to the uptake of oxygen, allowing oxygen consumption to be measured **B1**

(a) Answer: Soda lime absorbs CO_2 so the fluid movement reflects O_2 uptake only.

(b) controls for (corrects for) fluid movement caused by changes in temperature or atmospheric pressure rather than by respiration, so the comparison is valid **B1**

(b) Answer: It corrects for fluid movement caused by temperature/pressure changes, not respiration.

(c) correct unit conversion: r = 1.0 mm = 0.1 cm, length = 30 mm = 3.0 cm **M1**

(c) volume = π x $(0.1)^2$ x 3.0 = 0.0942 cm^3 (awrt 0.094 cm^3) **A1**

(c) Answer: 0.0942 cm^3

(d) rate = volume / time = 0.0942 / 5.0 = 0.01884 cm^3 min^{-1} (ft from (c)) **M1**

(d) rate per gram = 0.01884 / 2.0 (ft from (c)) **M1**

(d) 0.0094 cm^3 g^{-1} min^{-1} (2 s.f.) awrt **A1**

(d) Answer: 0.0094 cm^3 g^{-1} min^{-1}

(e) small leaks at the joints/seals of the apparatus allow gas exchange with the atmosphere **B1**

(e) this reduces the pressure change detected, so less fluid movement occurs than would be expected from respiration alone, giving a lower calculated rate than the true rate **B1**

(e) Answer: Leaks in the apparatus reduce the recorded pressure change, so the calculated rate is lower than the true rate.

Question 3

(a) the rate at which energy (or biomass) is stored/made available to primary consumers, i.e. GPP minus respiratory losses (R): NPP = GPP - R **B1**

(a) Answer: NPP = GPP - R: the energy remaining after the producers' own respiratory losses.

(b) NPP = GPP - R = 18500 - 11200 **M1**

(b) 7300 kJ m^{-2} $year^{-1}$ cao (correct unit required) **A1**

(b) Answer: 7300 kJ m^{-2} $year^{-1}$

(c) (730 / 7300) x 100 (ft from (b)) **M1**

(c) 10 (%) cao **A1**

(c) Answer: 10%

(d) not all plant material is eaten (e.g. roots are inaccessible, or the plant is not found/eaten before it dies) and/or some ingested material is indigestible (e.g. cellulose/lignin) and egested as faeces rather than absorbed **B1**

(d) Answer: Some plant material is not eaten, or is egested undigested (e.g. cellulose), rather than absorbed by consumers.

Question 4

(a) method: photons per second per m2 x area x time = photon flux x area x time **M1**

(a) substitute: 400 micromol m^{-2} s^{-1} = 400 x 10^{-6} mol m^{-2} s^{-1}; time = 600 s **M1**

(a) 4.80 x 10^{-3} mol photons, cao **A1**

(a) Answer: 4.80 x 10^{-3} mol photons

(b) method: theoretical O_2 = mol photons / 8 **M1**

(b) calculate theoretical O_2 = 4.80 x 10^{-3} / 8 = 6.00 x 10^{-4} mol **M1**

(b) efficiency = (observed/theoretical) x 100 = (1.80 x 10^{-4} / 6.00 x 10^{-4}) x 100 **M1**

(b) 30% (to 2 sf), cao **A1**

(b) Answer: 30%

(c) possible factors such as photoprotection dissipating energy as heat, inefficiencies in electron transport, photorespiration, limited CO_2, or respiration concurrent with photosynthesis **B1**

(c) Answer: Photorespiration reduces net O_2 production.

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Question 5

Level 3 A detailed, well-linked discussion explains how both methods increase energy-transfer efficiency and gives a balanced evaluation of ethical and environmental issues, using accurate scientific terminology throughout. **5-6**

Level 2 Explains how one or both methods increase efficiency, with some evaluation of ethical or environmental issues; mostly clear but links between ideas may be incomplete. **3-4**

Level 1 Makes basic, largely unlinked statements about efficiency or about ethical/environmental issues, with limited detail or scientific reasoning. **1-2**

Level 0 No relevant content, or the response does not address the question. **0**

Indicative content:

- Keeping cattle indoors in a temperature-controlled barn reduces energy lost as heat to the environment (less energy needed for thermoregulation), so a greater proportion of the energy from food is available for growth/production of biomass
- Restricting movement reduces the energy used in respiration for muscle contraction and other activity, again increasing the proportion of ingested energy that can be converted into biomass (meat)
- Growth-promoting hormones can increase the rate of protein synthesis and growth rate, increasing biomass produced per unit of food consumed (improved feed conversion efficiency)
- Selective breeding for fast growth rate or good feed conversion could also be mentioned as a further method to increase efficiency
- Ethical issue: restricting movement and housing cattle in small pens may compromise animal welfare by preventing natural behaviour, potentially causing stress, injury or disease
- Ethical/health issue: use of hormones is controversial and banned in some regions (e.g. the EU) due to concerns over animal welfare and possible effects on human health from residues in meat
- Environmental issue: intensive indoor housing concentrates large volumes of waste (slurry), which can pollute watercourses (eutrophication) if not managed carefully
- Environmental issue: heating/maintaining barns and producing concentrated feed requires additional energy input and resources, which may increase the overall carbon footprint of production despite improved biological efficiency
- A balanced conclusion should weigh the gain in energy-transfer efficiency (and associated commercial benefit) against the animal welfare and environmental costs of intensive methods

Question 6

Level 3 A detailed and coherent explanation is given of why energy transfer between trophic levels is inefficient, and of why the number of trophic levels is limited. Ideas are logically linked using accurate scientific terminology throughout. **5-6**

Level 2 An explanation is given covering several reasons for energy loss and/or the limitation on trophic levels, generally clearly expressed, with mostly accurate terminology but some links between ideas may be missing. **3-4**

Level 1 Basic, generalised statements about energy loss are made (e.g. 'energy is lost as heat'), with little detail and limited or no reference to why trophic levels are limited. **1-2**

Level 0 No relevant content, or the response does not address the question. **0**

Indicative content:

- Not all biomass/organisms at one trophic level are consumed by the next trophic level; some organisms die without being eaten and are broken down by decomposers, so their energy passes to decomposers rather than to the next trophic level
- Some ingested material is indigestible (e.g. bone, cellulose, lignin) and is egested as faeces without being absorbed, so this energy is not available for growth
- Energy that is absorbed may be lost in excretory products (e.g. urea in urine) rather than being incorporated into biomass
- A large proportion of absorbed energy is used in respiration to generate ATP for movement, active transport and (in mammals and birds) maintaining a constant body temperature
- Energy used in respiration is ultimately released as heat to the surroundings and is not available to the next trophic level (in line with the second law of thermodynamics)
- As a result of these losses, typically only around 10% of the energy available at one trophic level is transferred to and incorporated into the biomass of the next
- Because energy availability falls sharply (geometrically) at each successive trophic level, after four or five transfers there is too little energy/biomass remaining to support a further viable population of consumers
- Top predators would need an impractically large feeding area/population of prey to obtain sufficient energy, which limits the number of trophic levels that can be sustained

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