

A-Level Biology – Energy Transfers

A-Level Biology (Edexcel/AQA/OCR, Year 2) · Total marks: 42 · Answers on the last page

This worksheet covers photosynthesis and respiration as energy transfers, and energy/nutrient flow through ecosystems including productivity calculations, trophic efficiency and the nitrogen and carbon cycles. A calculator is required. Allow about 45 minutes.

Section A – Photosynthesis, respiration and productivity (skills)

- Write balanced symbol equations for:
 - aerobic respiration
 - photosynthesis[2]
- Define gross primary productivity (GPP) and net primary productivity (NPP).
 - A crop has a GPP of $8000 \text{ kJ m}^{-2} \text{ yr}^{-1}$ and loses $3000 \text{ kJ m}^{-2} \text{ yr}^{-1}$ to respiration. Calculate its NPP.[4]
- The NPP of a grassland is $5000 \text{ kJ m}^{-2} \text{ yr}^{-1}$. Primary consumers in this grassland gain $100 \text{ kJ m}^{-2} \text{ yr}^{-1}$ in their biomass.
Calculate the percentage efficiency of energy transfer from the producers (NPP) to the primary consumers.[3]
- Explain how each of the following can limit the rate of photosynthesis: light intensity, carbon dioxide concentration, and temperature.[3]

Section B – Energy flow through ecosystems (exam-style)

- In a food chain, producers have a GPP of $15000 \text{ kJ m}^{-2} \text{ yr}^{-1}$ and lose $5000 \text{ kJ m}^{-2} \text{ yr}^{-1}$ to respiration. Primary consumers gain $1000 \text{ kJ m}^{-2} \text{ yr}^{-1}$ in biomass, and secondary consumers gain $200 \text{ kJ m}^{-2} \text{ yr}^{-1}$ in biomass.
 - Calculate the NPP of the producers.
 - Calculate the percentage efficiency of energy transfer from producers to primary consumers.
 - Calculate the percentage efficiency of energy transfer from primary consumers to secondary consumers.[6]
- Explain the role of decomposers (saprobionts) in an ecosystem, and explain why their activity is essential for continued primary productivity.[3]
- Describe the roles of named microorganisms in the nitrogen cycle in: (a) nitrogen fixation, (b) nitrification, (c) denitrification.[4]
- State three reasons why not all of the energy in one trophic level is transferred to the next trophic level.[3]

Section C – Nutrient cycling and extended application (challenge)

- Describe the main processes of the carbon cycle, and explain two ways in which human activity has altered the balance of carbon dioxide between the atmosphere and other carbon stores.[5]
- The producers in Question 5 have a GPP of $15000 \text{ kJ m}^{-2} \text{ yr}^{-1}$. The total solar energy incident on the same area is $2.0 \times 10^6 \text{ kJ m}^{-2} \text{ yr}^{-1}$.

Calculate the percentage of incident solar energy that is converted into chemical energy by photosynthesis (the efficiency of photosynthesis), and suggest one reason why this percentage is low.
[4]

11. The percentage efficiency of energy transfer from primary consumers to secondary consumers (20%, Question 5) is typically higher than the efficiency of energy transfer from producers to primary consumers (10%, Question 5).
Suggest one reason for this difference. [2]
12. Farmers can increase the efficiency of energy transfer to livestock (and hence increase yield) by keeping animals indoors in temperature-controlled, restricted spaces.
Explain how each of these two practices increases the efficiency of energy transfer to the animals.
[3]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$
 - $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ (using light energy)
- GPP is the total amount of chemical energy fixed by photosynthesis (converted from light energy) by producers per unit area/volume per unit time. NPP is the energy remaining in plant biomass after respiratory losses, $\text{NPP} = \text{GPP} - R$, and represents the energy available to primary consumers/for producer growth.
 - $\text{NPP} = 8000 - 3000 = 5000 \text{ kJ m}^{-2} \text{ yr}^{-1}$
- $$\text{efficiency} = \frac{100}{5000} \times 100\% = 2\%$$
- Light intensity: light provides the energy for the light-dependent reactions (ATP and NADPH production); at low light intensity there is insufficient energy to drive these reactions, limiting the overall rate. Carbon dioxide concentration: CO_2 is the substrate combined with RuBP in the light-independent reactions (Calvin cycle); at low CO_2 concentration this fixation reaction is slowed, limiting the rate. Temperature: photosynthesis depends on enzymes (e.g. RuBisCO); at low temperature enzyme activity and reaction rates are low, while at temperatures above the optimum enzymes begin to denature, reducing the rate.
- $\text{NPP} = 15000 - 5000 = 10000 \text{ kJ m}^{-2} \text{ yr}^{-1}$
 - $\frac{1000}{10000} \times 100\% = 10\%$
 - $\frac{200}{1000} \times 100\% = 20\%$
- Decomposers (bacteria and fungi) break down dead organic matter and waste products (e.g. faeces, fallen leaves, dead organisms) through extracellular digestion, releasing nutrients such as nitrate and phosphate ions back into the soil. This is essential because it recycles nutrients that would otherwise remain locked in dead biomass, making them available again for producers to absorb and use for growth (and hence for continued primary productivity).
- Nitrogen fixation: bacteria such as *Rhizobium* (in root nodules of legumes, mutualistic) and free-living *Azotobacter* convert atmospheric nitrogen gas (N_2) into ammonium compounds that plants can use.
 - Nitrification: *Nitrosomonas* oxidises ammonium ions to nitrite ions, and *Nitrobacter* oxidises nitrite ions to nitrate ions, which plants absorb through their roots.
 - Denitrification: bacteria such as *Pseudomonas denitrificans*, under anaerobic conditions (e.g. waterlogged soil), convert nitrates back into nitrogen gas, which is released into the atmosphere.
- Any three, e.g.: (1) Not all parts of an organism are eaten by the next consumer (e.g. bones, roots left uneaten). (2) Some material is not digested and is egested as faeces, so its energy is not absorbed. (3) A large proportion of absorbed energy is lost as heat from respiration (especially in endotherms/mammals and birds, which maintain a constant body temperature). (4) Energy is used for movement and other metabolic activities rather than being stored as biomass.
- Carbon dioxide is removed from the atmosphere by photosynthesis in producers, which is passed along food chains through feeding, and returned to the atmosphere by respiration of organisms and by decomposers breaking down dead organic matter. Over long timescales, some carbon is converted into fossil fuels (coal, oil, gas) or locked in carbonate rocks/shells. Human impact: (1) combustion of fossil fuels releases carbon dioxide that had been locked away for millions of years, increasing atmospheric CO_2 faster than it can be removed. (2) Deforestation reduces the number of

photosynthesising producers removing CO₂ from the atmosphere, and burning cleared vegetation releases additional stored carbon directly into the atmosphere.

10. $\text{efficiency} = \frac{15000}{2.0 \times 10^6} \times 100\% = 0.75\%$. This is low because much of the incident light is reflected, transmitted through leaves, of wavelengths not absorbed by chlorophyll, or missed entirely by leaves (does not fall on chlorophyll-containing tissue).
11. Plant material eaten by primary consumers (herbivores) contains a high proportion of cellulose and other structural material that is difficult to digest, so a greater fraction is egested undigested; animal tissue eaten by secondary consumers (carnivores) is generally easier and more completely digested and absorbed, so a greater proportion of the energy consumed is assimilated and available for growth.
12. Keeping animals in a temperature-controlled environment close to their optimum body temperature reduces the amount of energy the animal must use (via respiration, generating heat) to maintain its body temperature, so less energy is lost as heat and more can be stored as biomass. Restricting the space available to the animals reduces their movement, reducing the energy used in muscle contraction/locomotion, again leaving more energy available for growth and reducing the amount lost as heat.

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