AP BIOLOGY • EXERCISE SHEET

8.2 Energy Flow Through Ecosystems

Name: ______________ Class: __________ Date: ____________ **Total: 45 marks**

KEY WORDS trophic level 营养级 • consumers 消费者 • food chain 食物链 • producers 生产者 • energy pyramid 能量金字塔 • biogeochemical cycle 生物地球化学循环 • autotroph 自养生物 • heterotroph 异养生物 • nitrogen fixation 固氮 • reservoir 库

Objective

Build the skills to answer exam questions on **energy flow** 能量流动 and **matter cycling** 物质循环 in ecosystems.

You must be able to:

- state the four ecological levels of organisation, in order
- explain the central contrast: **energy flows, matter cycles**
- describe the water, carbon, nitrogen and phosphorus cycles by their **reservoirs** 库 and **processes** 过程
- distinguish **autotrophs** 自养生物 from **heterotrophs** 异养生物, and name the five heterotroph types
- explain how a change in energy availability changes population size and the number and size of **trophic levels** 营养级
- explain why organisms need energy at all, and how energy availability shapes reproductive strategy

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ The sentence the whole topic hangs on

Energy flows through an ecosystem; matter cycles within it.

Energy enters as sunlight or chemical energy, passes along the trophic levels, and leaves as heat - it makes a **one-way trip** and must be resupplied continuously. Matter makes a **round trip**: the same carbon, nitrogen and phosphorus atoms move between reservoirs and organisms indefinitely. Each cycle therefore demonstrates the **conservation of matter**, and the cycles are **interdependent** - carbon cannot be fixed into a protein without nitrogen, and neither moves without water.

Write that contrast explicitly. An answer describing only "recycling" loses the energy half, and one describing only "energy is lost as heat" loses the matter half.

■ Reading a biogeochemical cycle

Every cycle is a set of **reservoirs** (where the element sits) and **processes** (what moves it between them). Reservoirs are **abiotic** (atmosphere, ocean, rock, soil) or **biotic** (living organisms).

Cycle	Largest reservoir	Processes to name
Water	oceans	evaporation, condensation, precipitation, transpiration
Carbon	ocean and rock; atmospheric CO_2 is the exchange pool	photosynthesis, cellular respiration, decomposition, combustion
Nitrogen	**the atmosphere** (about 78% N_2)	fixation, assimilation, ammonification, nitrification, denitrification
Phosphorus	**rock** - there is no atmospheric step	weathering, uptake by producers, consumption, decomposition

Two contrasts the exam returns to: the nitrogen cycle depends on **microorganisms in the soil** at nearly every step, and the phosphorus cycle has **no gaseous phase**, so it is slow and phosphorus is often the limiting nutrient.

■ Autotroph or heterotroph

- **Autotrophs** capture energy from a **physical** source (light) or a **chemical** source (inorganic compounds, as in deep-sea vents) and build their own organic molecules.
- **Heterotrophs** capture the energy already present in **carbon compounds** by consuming organic matter. Five types: carnivores, herbivores, omnivores, decomposers, scavengers.

Decomposers are the ones candidates forget, and they are the reason matter *can* cycle - without them, nutrients stay locked in dead tissue.

■ Energy availability changes an ecosystem

Organisms need energy to **organise, grow, reproduce and maintain homeostasis**. So a change in available energy does not stay in one species:

1. **Population size** rises or falls with the energy that reaches it.
2. **Trophic structure** changes - a drop in sunlight or in producer biomass reduces the **number and size** of the trophic levels above, because each level is supported by the one below.
3. **Reproductive strategy** can change - some organisms switch between asexual and sexual reproduction according to energy availability.

Example. Volcanic ash cuts the light reaching a lake for one season. Producer biomass falls; primary consumers starve or emigrate, so their population drops; the secondary and tertiary levels shrink or disappear entirely because the energy no longer reaches them. Matter is not destroyed - it is redistributed, much of it into the decomposers.

■ The energy that does not pass on

Only a small fraction of the energy at one level is stored as biomass available to the next; the rest is used for life processes and lost as heat. This is why an ecosystem needs a **continuous** energy input and why the levels above the producers are progressively smaller. Rough arithmetic with a 10% transfer: producers 10 000 kJ gives primary consumers about 1000 kJ, secondary about 100 kJ, tertiary about 10 kJ.

2 Practice

2.1 State the four ecological levels of organisation, from smallest to largest. [2]

2.2 Explain the difference between how **energy** and how **matter** move through an ecosystem. [3]

2.3 For each cycle, name the largest reservoir.

(a) Nitrogen. [1]

(b) Phosphorus. [1]

(c) Water. [1]

2.4 Name the process in the nitrogen cycle that does each of these.

(a) Converts atmospheric N_2 into a usable form. [1]

(b) Converts ammonium into nitrate. [1]

(c) Returns nitrogen to the atmosphere. [1]

(d) Releases ammonium from dead organic matter. [1]

2.5 Explain why the phosphorus cycle is slower than the carbon cycle. [2]

2.6 Classify each organism as an autotroph or a heterotroph, and where it is a heterotroph name its type.

(a) A vent bacterium oxidising hydrogen sulfide. [1]

(b) A fungus growing on a fallen log. [1]

(c) A vulture. [1]

(d) An oak tree. [1]

2.7 State **three** reasons an organism needs energy. [3]

2.8 If producers store 8000 kJ, estimate the energy reaching the secondary consumers and show your working. [2]

2.9 Explain why decomposers are essential for matter to cycle. [2]

3 Exam-style questions

3.1 Roughly how much energy passes from one trophic level to the next? [1]

- **A** 1%
- **B** 10%
- **C** 50%
- **D** 90%

3.2 Which statement about the nitrogen cycle is correct? [1]

- **A** the largest reservoir is soil organic matter
- **B** most steps are carried out by microorganisms in the soil
- **C** plants absorb nitrogen directly from the atmosphere
- **D** denitrification converts nitrate into ammonium

3.3 A biogeochemical cycle demonstrates the conservation of matter because [1]

- **A** energy is neither created nor destroyed
- **B** atoms move between reservoirs but are not created or destroyed
- **C** decomposers return all energy to the producers
- **D** each reservoir holds a fixed quantity at all times

3.4 A large-scale fertiliser run-off adds phosphate to a lake. Producer biomass increases sharply, then decomposers consume the dead algae and oxygen falls. This best illustrates that [1]

- **A** matter flows and energy cycles
- **B** a change in one cycle can disrupt the whole ecosystem
- **C** phosphorus has a large atmospheric reservoir
- **D** decomposers are autotrophs

3.5 A research team studies a temperate lake over four years. In year 1 the lake is

clear and supports algae, zooplankton, small fish and a top predator fish. In year 2 an upstream farm's fertiliser increases phosphate entering the lake tenfold. In year 3 the team measures a large increase in algal biomass, then a fall in dissolved oxygen and the death of most fish. By year 4 the algae have also declined.

(a) Identify the reservoir the added phosphate came from originally, and name the process that released it. [2]

(b) Explain, in terms of energy availability, why the top predator fish disappeared before the algae did. [3]

(c) The team argues that "the phosphorus was not lost from the lake, but the energy was". Evaluate this claim, referring to both matter cycling and energy flow. [4]

(d) Predict what happens to the nitrogen and carbon cycles in the lake during year 3, and justify each prediction. [4]

(e) The team proposes restoring the lake by removing the dead algal matter. Explain **one** benefit and **one** drawback of this intervention for the lake's nutrient cycles. [3]

Solutions

2.1 population, community, ecosystem, biome.

2.2 energy **flows** one way - it enters as light or chemical energy, passes up the trophic levels and leaves as heat, so it must be continuously resupplied; matter **cycles** - the same atoms move between abiotic and biotic reservoirs and are reused indefinitely; which is why each cycle demonstrates the conservation of matter while energy is not conserved in a usable form.

2.3 (a) the atmosphere. (b) rock. (c) the oceans.

2.4 (a) nitrogen fixation. (b) nitrification. (c) denitrification. (d) ammonification.

2.5 phosphorus has **no gaseous phase** and no atmospheric reservoir, so it is released only by the slow weathering of rock rather than by rapid exchange with the air as carbon is.

2.6 (a) autotroph - a chemical energy source. (b) heterotroph, decomposer. (c) heterotroph, scavenger. (d) autotroph.

2.7 any three of: to organise (build and maintain structure), to grow, to reproduce, to maintain homeostasis.

2.8 $8000 \times 0.1 = 800$ kJ to primary consumers; $800 \times 0.1 = 80$ kJ to secondary consumers.

2.9 decomposers break down dead organic matter, releasing the elements locked in it back into abiotic reservoirs where producers can take them up again - without this step matter would stay in dead tissue and the cycle would stop.

3.1 B - about 10%.

3.2 B. The atmosphere, not the soil, is the largest reservoir; plants cannot use atmospheric N_2 directly; denitrification converts nitrate to N_2, not to ammonium.

3.3 B. Conservation of matter is about atoms, not energy; and reservoirs certainly do change in size.

3.4 B. The added phosphate changes the phosphorus cycle, and the consequence spreads to oxygen, the carbon cycle and every trophic level.

3.5 (a) rock; weathering released phosphate into soil and groundwater, and the fertiliser concentrated it before it ran off into the lake.

(b) energy reaching each level is only a small fraction of the level below. The top predator sits at the highest level, so it depends on the largest number of transfers and receives the least energy, and it also has the smallest population and slowest reproduction. When oxygen loss killed the small fish, its energy supply was cut entirely, while the algae still had light and abundant phosphate and continued to grow.

(c) the claim is **largely correct**. The phosphorus is not lost: it moves from the water into algal biomass, then into dead organic matter and lake sediment - all still reservoirs within the lake, so the matter is conserved and can re-enter the cycle. The energy genuinely is lost: it entered as sunlight, passed through the algae and was released as heat by respiration and decomposition, and heat cannot be recaptured by the ecosystem. The one qualification is that some phosphorus does leave, in fish that die downstream or are removed, and some matter is buried in sediment for long periods - so "not lost" means "not destroyed", not "still available".

(d) **Nitrogen**: decomposition of the dead algae greatly increases ammonification, so ammonium rises; as oxygen falls, nitrification (which needs oxygen) slows while denitrification (which does not) increases, so nitrogen is returned to the atmosphere faster. **Carbon**: photosynthesis by the algal bloom initially removes CO_2 rapidly, then decomposition and respiration by the decomposers release large amounts of CO_2 and consume the oxygen, which is the direct cause of the fish deaths.

(e) Benefit: removing the dead algae removes the phosphorus and nitrogen stored in it from the lake entirely, so decomposition stops consuming oxygen and the bloom cannot be refuelled by released nutrients. Drawback: it also removes matter the lake's own cycles depend on, and it takes away the decomposers' energy source, so recovery of the normal food web may be slower - and it treats the symptom while the upstream run-off continues.