

Answer Key: Energy Flow in Ecosystems

Course: Biology (Grades 9–12) Subject: Science For teacher use only

SCIENCE

How to use this key

Answers are grouped by section and question number. Many items are open-ended; accept any response that shows correct reasoning even if the wording differs. The energy calculations are worked out in full. Notes flag where more than one answer is defensible and list common misconceptions to watch for. Estimated grading time: ~6–8 min per packet.

START Notice & Wonder

grade for effort • ~2 min

- 1 Why are there so few top predators compared with plants?

Full credit for any reasonable notice + wonder. Ideal: Notice — "there are way more plants than hawks." Wonder — "why can't the land support as many hawks as grasshoppers?" Accept any on-topic wonder. *Science note (not required from students):* so little energy reaches the top trophic level (the 10% rule) that only a few top predators can be supported.

- 2 Where the energy comes from; what happens as it moves up.

Accept any reasonable prior idea. Target ideas: the energy originally comes from the Sun (captured by producers in photosynthesis); as it moves up, most of it is lost (as heat / used for life processes), so less is available at each higher level. Do not penalize incomplete prior knowledge here — this is a warm-up.

BUILD Read the Science

~1 min

- 3 Most/least energy; why the pyramid narrows.

Most energy: producers (grass), 10,000 kcal — the bottom level. **Least energy:** tertiary consumers (hawk), 10 kcal — the top level. **Why it narrows:** only about 10% of the energy at each trophic level is passed to the next; the rest (~90%) is lost as heat, so less energy is available at each step upward.

4 Classify the organisms.

- a) Grass — trophic level 1, producer (autotroph).
- b) Grasshopper — trophic level 2, primary consumer (herbivore).
- c) Hawk — trophic level 4, tertiary consumer (top carnivore).
- d) Soil fungi — decomposer (breaks down dead matter; acts on every level, so no single trophic-level number is required — accept "decomposer, not a numbered feeding level").

5 Calculate energy passed with the 10% rule (worked).

- 5a. $10,000 \text{ kcal} \times 0.10 = 1,000 \text{ kcal}$ passed to the primary consumers.
- 5b. $1,000 \text{ kcal} \times 0.10 = 100 \text{ kcal}$ passed to the secondary consumers.
- 5c. Yes — the calculated values (1,000 and 100 kcal) match Table 1. This tells students that this ecosystem follows the ~10% rule closely: each level holds about one tenth of the level below it. (Accept any answer noting the match and that ~90% is lost at each step.)

6 Percent transfer, shrews → hawk (worked).

Formula: percent transfer = (energy in higher level ÷ energy in lower level) × 100.
 $= (10 \text{ kcal} \div 100 \text{ kcal}) \times 100 = 0.10 \times 100 = 10\%$. This is consistent with the 10% rule. (Full credit for correct setup and 10%; accept "about 10%.")

7 Observation (O) vs. Inference (I).

- a) O — a value read directly (10,000 kcal).
 - b) I — a reasoned conclusion ("can only be a few hawks because...").
 - c) O — a value read directly (10 kcal).
 - d) I — a conclusion reasoned from the pattern (energy lost as heat is not shown as a single measured value; it is inferred from the drop between levels).
- Observation = measured/read directly; inference = a conclusion reasoned from evidence.*

8 Interpret the pyramid shape.

Full credit if the student ties the wide-bottom, narrow-top shape to energy loss between trophic levels via the 10% rule. Model: "The pyramid is wide at the bottom and narrow at the top because each trophic level only passes about 10% of its energy to the next (the 10% rule). Since ~90% is lost as heat at each step, far less energy is available higher up, so the top levels are small." Accept equivalent wording.

9 Predict the effect of removing a trophic level (grasshoppers).

(a) Grass: would likely increase / grow more at first, because far fewer grasshoppers are eating it.

(b) Hawks: would decline — with fewer grasshoppers, the shrews (secondary consumers) lose their food and decrease, so the energy reaching the hawks drops and their numbers fall.

Why: energy flows upward through the food chain; removing the primary consumers cuts the pathway that carries energy from producers to the higher levels. *Defensible alternate:* a student may note shrews could switch to other prey if available; accept if reasoned. Direction (grass up, hawks down) plus an energy-flow justification earns full credit.

10 Why are top-level consumers limited?

Model answer. Claim: Top-level consumers such as hawks are limited in number because only a tiny fraction of the ecosystem's energy reaches the top trophic level. **Evidence:** (1) In Table 1, producers have 10,000 kcal but the hawk level has only 10 kcal — 1,000 times less. (2) In Figure 1, each band holds about one tenth of the level below it (10,000 → 1,000 → 100 → 10 kcal). **Reasoning:** By the 10% rule, only ~10% of the energy at each trophic level passes to the next; the other ~90% is lost as heat. After three transfers only about 0.1% of the producers' energy remains, so there is enough energy to support only a few top consumers.

Defensible alternates: A student may cite the percent-transfer calculation from Q6 (10%) or the shape of the pyramid as evidence. Accept any claim supported by two correct numeric pieces of evidence and sound 10%-rule reasoning.

CER scoring rubric (3 points)

Score	Claim	Evidence	Reasoning
3	Clear claim: top consumers are limited by energy available at the top level.	Two accurate numeric pieces from Table 1 and/or Figure 1 (e.g., 10,000 vs. 10 kcal).	Correctly uses the 10% rule / trophic levels to explain why so little energy reaches the top.
2	Claim stated, mostly clear.	One solid numeric piece, or two with a minor error.	Some correct linkage but incomplete or a small misconception.
1	Vague or partly correct claim.	Evidence weak, non-numeric, or not from the sources.	Little or flawed reasoning; 10% rule not correctly applied.
0	No/incorrect claim.	No evidence.	No reasoning.

ACE Articulate / Connect / Extend.

Articulate: accept any accurate plain-language statement (e.g., "only about a tenth of the energy at one level gets to the next; the rest is lost as heat").

Connect: the cited pair must show a 10× drop, e.g., producers 10,000 → primary consumers 1,000 kcal, or 100 → 10 kcal.

Extend: any correct non-grassland food chain with ≥3 labeled trophic levels (e.g., algae → minnow → bass → osprey; or leaves → caterpillar → songbird → hawk). More than one answer is defensible.

EXTEND Early finisher & block extension (optional)

EF Design a pyramid for a new ecosystem.

Reward a coherent four-level pyramid with a real producer at the base, plausible organisms at each level, and energy values that drop by ~10× per step (any reasonable producer starting value). The "what if the top disappeared" sentence should note the level below would increase and/or the chain above collapses.

Block Multi-step ocean energy-loss chain (worked).

Starting producers (phytoplankton) = 50,000 kcal. Apply ×0.10 each step:

- Phytoplankton (producer): 50,000 kcal
- Zooplankton (primary consumer): $50,000 \times 0.10 = 5,000$ kcal
- Small fish (secondary consumer): $5,000 \times 0.10 = 500$ kcal
- Tuna (tertiary consumer): $500 \times 0.10 = 50$ kcal
- Shark (quaternary consumer): $50 \times 0.10 = 5$ kcal

Percent of original energy reaching the shark = $5 \div 50,000 \times 100 = 0.01\%$. Why sharks need a huge area: only one ten-thousandth of the producers' energy survives four transfers, so an enormous amount of phytoplankton (and ocean area) is needed to supply enough energy for even a small number of large top predators. (Full credit for correct chained multiplications and 0.01%.)

- **"Energy is recycled like matter."** *Matter* (nutrients/atoms) cycles and is reused by decomposers, but **energy flows one way** — in as sunlight, out as heat. Lost energy is not passed back up the pyramid.
- **"100% (or most) of the energy transfers to the next level."** Only about **10%** is passed on; ~90% is lost as heat and to life processes. Watch for students who multiply by the wrong factor in Q5–Q6.
- **"Bigger animals have more energy available to them."** The opposite is true: top predators sit at the *highest* trophic level, where the *least* energy is available. Their large size does not increase the energy reaching them — it is why so few can be supported.
- **"Decomposers are the top of the pyramid."** Decomposers act on every level and return matter to the soil; they are not a higher feeding step above the top predator.
- **Observation vs. inference (Q7).** Students often mark a reasoned cause or consequence ("can only be a few hawks because...") as an "observation." A "because..." or "would be..." statement is usually an inference.

Teacher follow-up based on likely errors

If many students say energy is recycled (misconception), contrast the one-way energy arrow with the matter cycle in a quick 5-minute discussion. If the 10% calculations in Q5–Q6 are shaky, model $\times 0.10$ (or $\div 10$) aloud with units. If Q9 (removing a level) is thin, re-anchor to the upward energy arrows in Figure 1. If CER (Q10) evidence is non-numeric, model citing the 10,000-vs-10-kcal contrast. The "energy is recycled" and "bigger = more energy" misconceptions are the highest-value items to address next class.