Exercise walk-through

19.2.1

Ecological pyramids, energy transfer and human impact on a web

IGCSE Biology

You must be able to

- describe a food chain and a food web, and construct and interpret both
- describe a **producer** 生产者, a **consumer** 消费者, a **herbivore** 草食动物, a **carnivore** 肉食动物 and a **decomposer** 分解者
- describe a **trophic level** 营养级, and identify producers and primary, secondary, tertiary and quaternary consumers
- use food chains and webs to describe the impact of overharvesting a food species and of introducing a foreign species to a **habitat** 栖息地
- draw, describe and interpret pyramids of numbers, of **biomass** 生物量 and of energy, and discuss the advantages of each
- explain why the transfer of energy from one trophic level to the next is often not efficient

You must be able to

- explain, in terms of energy loss, why food chains usually have fewer than five trophic levels
- explain why it is more energy efficient for humans to eat crop plants than **livestock** 家畜 fed on crop plants

1 The method

Method — The words, in one place

word	meaning
producer	makes its own organic nutrients, usually by photosynthesis; every food chain starts with one
consumer	gets its energy by feeding on other organisms
herbivore / carnivore	a consumer that eats plants / that eats other animals
decomposer	gets its energy from **dead or waste** organic material
trophic level	the **position** of an organism in a chain: producer, then primary, secondary, tertiary and quaternary consumer

- An **arrow means energy passes this way**, so it points from the organism being eaten to the one that eats it. An arrow drawn the wrong way round loses the mark, however good the rest of the chain.
- Count trophic levels by counting the **organisms**, not the arrows: grass → rabbit → fox has **three**.

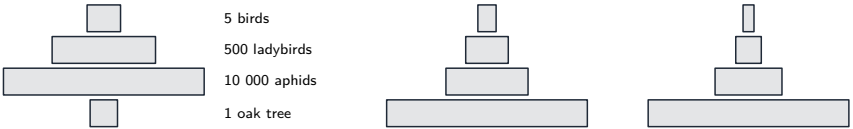
Method — The three pyramids, and which one is safe

Each bar is one trophic level, drawn to scale and stacked with the producer at the **bottom**.

- A **pyramid of numbers** counts organisms. It can come out the **wrong shape**, because one huge organism counts the same as one tiny one – a single oak tree at the base, feeding thousands of aphids above it.
- A **pyramid of biomass** uses the total **dry mass** at each level, so size is taken into account and the shape is almost always right. That is the advantage to quote.
- A **pyramid of energy** uses the energy passing through each level in a year. It is **never** inverted, because a level cannot pass on more energy than it received.

Method — The three pyramids, and which one is safe

Each bar is one trophic level, drawn to scale and stacked with the producer at the bottom



pyramid of numbers

bar width = the **number** of organisms

pyramid of biomass

bar width = the total **dry mass** of the organisms

pyramid of energy

bar width = the **energy** passing through, per square metre per year

A pyramid of *numbers* can come out the wrong shape, because one huge organism counts the same as one tiny one. Biomass fixes that, and a pyramid of *energy* is never inverted.

Method — Where the other 90% goes

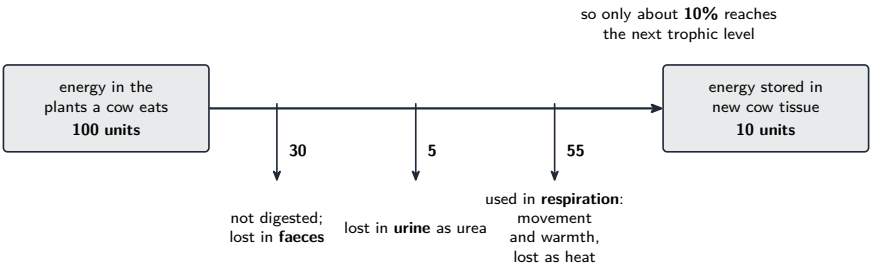
About **10%** of the energy in one trophic level reaches the next. An "explain why the transfer is inefficient" question wants the **named routes**, not the number:

1. energy used in **respiration**, for movement and for keeping warm, and then lost as **heat**;
2. undigested food lost in **faeces** 粪便;
3. **urea** 尿素 and other waste lost in **urine** 尿液;
4. parts that are **never eaten** at all – bones, hooves, roots, bark.

- That is also the answer to "why are there rarely more than five trophic levels": after four transfers there is too little energy left to support another population.

Method — Where the other 90% goes

An "explain why the transfer is inefficient" question wants the named routes , not the number



Name the routes, and the numbers add to 100. Parts that are never eaten at all – bones, hooves, roots, bark – are a fifth route, and lose more still.

Method — Why eating the crop beats eating the animal

Each transfer keeps about a tenth, so an **extra** trophic level costs a factor of ten.

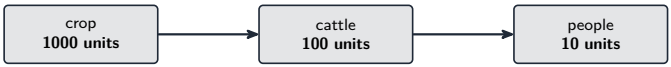
*The same field feeds about **ten times** as many people when the crop is eaten directly, because the energy passes through one fewer transfer and less is lost in the cattle's respiration, faeces and urine.*

Method — Why eating the crop beats eating the animal

Each transfer keeps about a tenth, so an extra trophic level costs a factor of ten.

eat the crop

feed the crop to cattle



Each transfer keeps about a **tenth** of the energy. One extra step therefore feeds about a tenth as many people from the same field.

Method — Reading a web for human impact

When a species is removed – by **overharvesting**, or out-competed by an **introduced species** 引入物种 – work outwards from it, one arrow at a time:

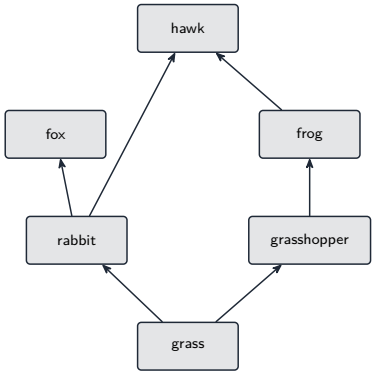
1. **What ate it?** Those populations fall, unless the web gives them another food.
2. **What did it eat?** That population rises, because less of it is being eaten.
3. **Who else ate the same food?** Those populations rise, because there is now less competition.

Worked example. Rabbits are hunted until very few remain. What happens to the foxes, and to the grasshoppers?

- **Foxes:** the rabbit is their only food in this web, so the number of foxes **falls**.
- **Grasshoppers:** they eat grass, and so did the rabbits, so there is **less competition** for grass and the number of grasshoppers **rises**.
- A third consequence follows: hawks lose one of their two foods, so they eat **more frogs**, and the number of frogs falls.

Method — Reading a web for human impact

When a species is removed – by overharvesting , or out-competed by an introduced species 引入物种 – work...



An arrow means **energy passes this way**, so it points from the organism being eaten to the one that eats it.

Remove one species and follow *every* arrow out of it, then every arrow into whatever ate it. Three different answers usually follow from one removal.

2 Practice

Practice 2.1 ▪ 2 marks

Describe what a decomposer is, and name one example.

Solution 2.1

Worked steps

- a decomposer gets its energy from **dead or waste organic material** B1
- for example a **bacterium** or a **fungus** B1

Practice 2.2 ▪ 2 marks

Using the food web in the worked examples, name one primary consumer and one secondary consumer.

Solution 2.2

Method: The words, in one place — p.5

Worked steps

- primary consumer: the **rabbit** or the **grasshopper** B1
- secondary consumer: the **fox** or the **frog** B1

Practice 2.3 ▪ 3 marks

A chain runs: oak tree → aphids → ladybirds → birds. Describe the shape of its pyramid of numbers, and explain why it has that shape.

Solution 2.3

Method: The three pyramids, and which one is safe — p.6

Worked steps

- the bottom bar is **very narrow** and the bar above it is **very wide**, so the pyramid is **inverted** at its base B1
- there is only **one** oak tree, but it supports thousands of aphids B1
- a pyramid of numbers counts organisms without taking their **size** into account B1

Practice 2.4 ▪ 2 marks

Explain one advantage of drawing a pyramid of biomass rather than a pyramid of numbers.

Solution 2.4

Method: The three pyramids, and which one is safe — p.6

Worked steps

- biomass uses the **total dry mass** at each level, so the size of the organisms is taken into account B1
- so the pyramid comes out the right shape even when one huge producer supports many small consumers B1

Practice 2.5 ▪ 3 marks

State **three** ways in which energy is lost between one trophic level and the next.

Solution 2.5

Method: Where the other 90% goes — p.8

Worked steps

- any **three** of: energy used in **respiration** and lost as **heat**; undigested food lost in **faeces**; **urea** lost in **urine**; parts **not eaten**, such as bones or roots B1 B1 B1

Practice 2.6 ▪ 3 marks

Explain why a field of wheat grown for people to eat feeds more people than the same field used to grow wheat for cattle that people then eat.

Solution 2.6

Method: Why eating the crop beats eating the animal — p.10

Worked steps

- eating the wheat directly means the energy passes through **one fewer transfer** B1
- at each transfer about **90%** of the energy is lost, in respiration, faeces and urine B1
- so about **ten times** as much of the field's energy reaches people, and more people can be fed B1

3 Exam-style

Exam-style 3.1 ▪ 1 mark

Which ecological pyramid can never be inverted, whatever the food chain?

A a pyramid of numbers

B a pyramid of biomass

C a pyramid of energy

D none of them

Solution 3.1

Method: The three pyramids, and which one is safe — p.6

A a pyramid of numbers

B a pyramid of biomass

C a pyramid of energy ✓

D none of them

Worked steps

C

- a level can never pass on more energy than it received, so each bar must be smaller than the one below it B1

Exam-style 3.2 ▪ 7 marks

Use the food web in the worked examples to answer this question.

Exam-style 3.2 (a) ▪ 2 marks

Name the producer, and state the trophic level of the frog.

Solution 3.2 (a)

Method: Reading a web for human impact — p.12

Worked steps

- producer: **grass** B1
- the frog is a **secondary consumer** B1

Exam-style 3.2 (b) ▪ 2 marks

Construct a food chain from the web that has **four** trophic levels.

Solution 3.2 (b)

Worked steps

- **grass** $\rightarrow$ **grasshopper** $\rightarrow$ **frog** $\rightarrow$ **hawk** B1
- arrows point from the organism eaten to the organism that eats it B1

Exam-style 3.2 (c) ▪ 2 marks

Hunters overharvest the rabbits until very few are left. Predict and explain what happens to the number of foxes.

Solution 3.2 (c)

Worked steps

- the number of foxes **falls** B1
- the rabbit is the fox's only food in this web, so the foxes have nothing else to eat B1

Exam-style 3.2 (d) ▪ 1 mark

Explain why the number of grasshoppers may rise.

Solution 3.2 (d)

Worked steps

- grasshoppers and rabbits both eat grass, so with fewer rabbits there is **less competition** for grass B1

Exam-style 3.3 ▪ 14 marks

The table shows the energy at each trophic level of a grassland, measured in kilojoules per square metre per year.

trophic level	**energy / kJ m^{-2} per year**
producers	20 000
primary consumers	1600
secondary consumers	140
tertiary consumers	11

Exam-style 3.3 (a) ▪ 3 marks

Draw a pyramid of energy for this grassland. Label each level.

Solution 3.3 (a)

Method: The words, in one place — p.5

Worked steps

- four bars, with the **producers at the bottom** and each bar **above** the one before B1
- the bars drawn **to scale**, so that 20 000 is by far the widest and 11 is barely visible B1
- each bar labelled with its trophic level B1

Exam-style 3.3 (b) ▪ 2 marks

Calculate the percentage of the producers' energy that reaches the primary consumers.

Solution 3.3 (b)

Worked steps

- divide the energy reaching the primary consumers by the energy in the producers M1

$$\frac{1600}{20\,000} \times 100 = \mathbf{8}\% \quad \text{A1}$$

Exam-style 3.3 (c) ▪ 3 marks

Explain why this percentage is so low.

Solution 3.3 (c)

Worked steps

- most of the producers' energy is **never eaten** – roots and dead leaves go to the decomposers B1
- of what is eaten, much is lost in **respiration** and given out as heat, and more is lost undigested in **faeces** and as urea in **urine** B1
- so only a small fraction is stored as new tissue and becomes available to the next level B1

Exam-style 3.3 (d) ▪ 2 marks

There is no quaternary consumer in this grassland. Use the figures in the table to explain why.

Solution 3.3 (d)

Worked steps

- the tertiary consumers receive only **11 kJ** per square metre per year B1
- about a tenth of that, roughly **1 kJ**, would reach a fourth consumer level, which is far too little to support a population of animals B1

Exam-style 3.3 (e) ▪ 2 marks

A farmer ploughs the grassland and grows wheat for people to eat instead of grazing cattle on it. Explain why the same area now feeds more people.

Solution 3.3 (e)

Worked steps

- people eating wheat are **primary consumers**, but people eating cattle are **secondary consumers** B1
- removing one transfer keeps about ten times as much of the field's energy, so more people can be fed from the same area B1

Exam-style 3.3 (f) ▪ 2 marks

A foreign species of beetle that eats grass is accidentally introduced to the grassland. Suggest what effect this may have on the primary consumers already living there.

Solution 3.3 (f)

Worked steps

- the beetle eats grass, so it **competes** with the rabbits and grasshoppers for the same food B1
- their numbers are likely to **fall**, because less grass is available to them B1