19.2.1 Ecological pyramids, energy transfer and human impact on a web

Name: _____ Class: _____ Date: _____ **Total: 37 marks**

KEY WORDS food chain 食物链 • food web 食物网 • trophic level 营养级 • pyramid 金字塔 • biomass 生物量

Objective

Sheet 19.2 gave you food chains, webs and trophic levels. This sheet is the rest of 19.2, and it is the part that carries the long questions: the three **ecological pyramids** 生态金字塔 and when each is the right one, exactly where the energy goes between levels, and what happens to a **food web** 食物网 when humans **overharvest** 过度捕捞 a species or introduce a foreign one. Every answer here is a chain of consequences read off a diagram. This sheet covers syllabus 19.2.

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
- 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 Worked examples

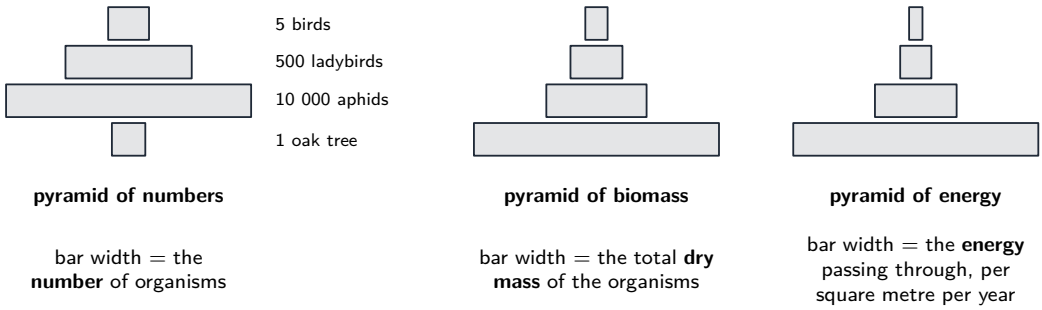
Study these first. Each one shows a **method** that a question later on this sheet needs.

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**.

The three pyramids, and which one is safe

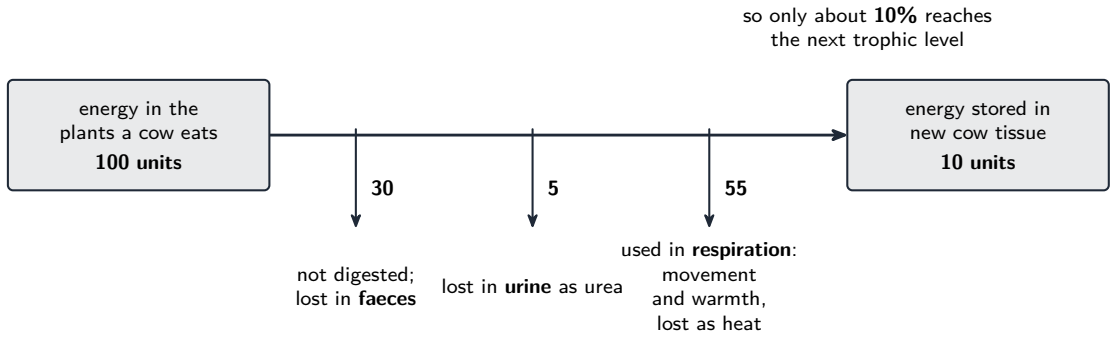


A pyramid of *numbers* can come out the wrong shape, because one huge organism counts the same as one tiny one. Biomass fixes that, and a pyramid of *energy* is never inverted.

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.

Where the other 90% goes



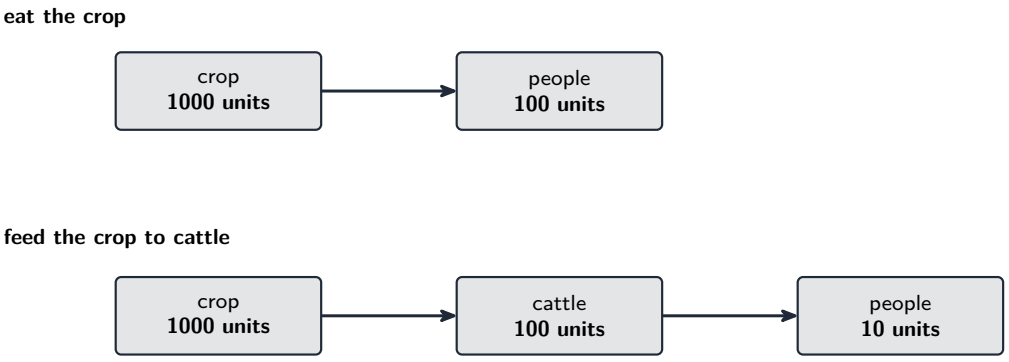
Name the routes, and the numbers add to 100. Parts that are never eaten at all – bones, hooves, roots, bark – are a fifth route, and lose more still.

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.

Why eating the crop beats eating the animal



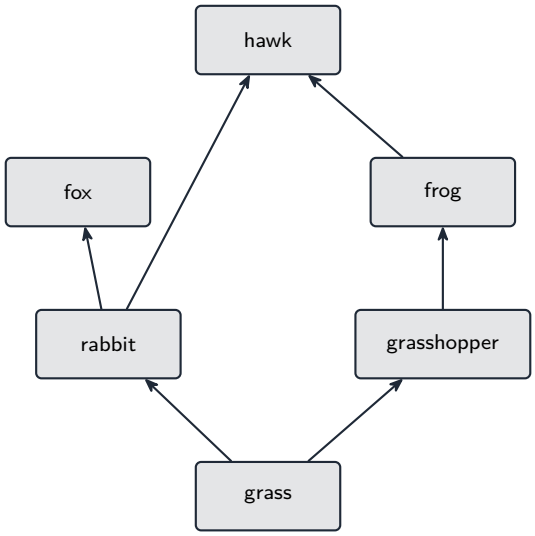
Each transfer keeps about a **tenth** of the energy. One extra step therefore feeds about a tenth as many people from the same field.

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.

■ Reading a web for human impact



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.

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.

2 Practice

Now use the methods above.

2.1 Describe what a decomposer is, and name one example. [2]

2.2 Using the food web in the worked examples, name one primary consumer and one secondary consumer. [2]

2.3 A chain runs: oak tree → aphids → ladybirds → birds. Describe the shape of its pyramid of numbers, and explain why it has that shape. [3]

2.4 Explain one advantage of drawing a pyramid of biomass rather than a pyramid of numbers. [2]

2.5 State **three** ways in which energy is lost between one trophic level and the next. [3]

2.6 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. [3]

3 Exam-style questions

3.1 Which ecological pyramid can never be inverted, whatever the food chain? [1]

A | B
C | D

A a pyramid of numbers
B a pyramid of biomass
C a pyramid of energy
D none of them

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

(a) Name the producer, and state the trophic level of the frog. [2]

(b) Construct a food chain from the web that has **four** trophic levels. [2]

(c) Hunters overharvest the rabbits until very few are left. Predict and explain what happens to the number of foxes. [2]

(d) Explain why the number of grasshoppers may rise. [1]

3.3 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

(a) Draw a pyramid of energy for this grassland. Label each level. [3]

(b) Calculate the percentage of the producers' energy that reaches the primary consumers. [2]

(c) Explain why this percentage is so low. [3]

(d) There is no quaternary consumer in this grassland. Use the figures in the table to explain why. [2]

(e) 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. [2]

(f) 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. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

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

2.2

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

2.3

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

2.4

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

2.5

- 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

2.6

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

3.1 C

- a level can never pass on more energy than it received, so each bar must be smaller than the one below it
- **A** is inverted whenever one large producer feeds many small consumers; **B** is almost always a pyramid but is not guaranteed; **D** is wrong because **C** is guaranteed

3.2

(a)

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

(b)

- **grass → grasshopper → frog → hawk**
- arrows point from the organism eaten to the organism that eats it

(c)

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

(d)

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

3.3

(a)

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

(b)

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

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

(c)

- most of the producers' energy is **never eaten** – roots and dead leaves go to the decomposers
- 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**
- so only a small fraction is stored as new tissue and becomes available to the next level

(d)

- the tertiary consumers receive only **11 kJ** per square metre per year
- 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

(e)

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

(f)

- the beetle eats grass, so it **competes** with the rabbits and grasshoppers for the same food

- their numbers are likely to **fall**, because less grass is available to them