

Trophic levels and ecological pyramids

Revision notes · Trophic levels, pyramids of numbers, biomass and energy, and why energy transfer is inefficient so that food chains are short.

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). **Supplement** is Extended content, only examined on Papers 2 and 4.

Trophic levels and ecological pyramids Spec 19.2.11-19.2.19

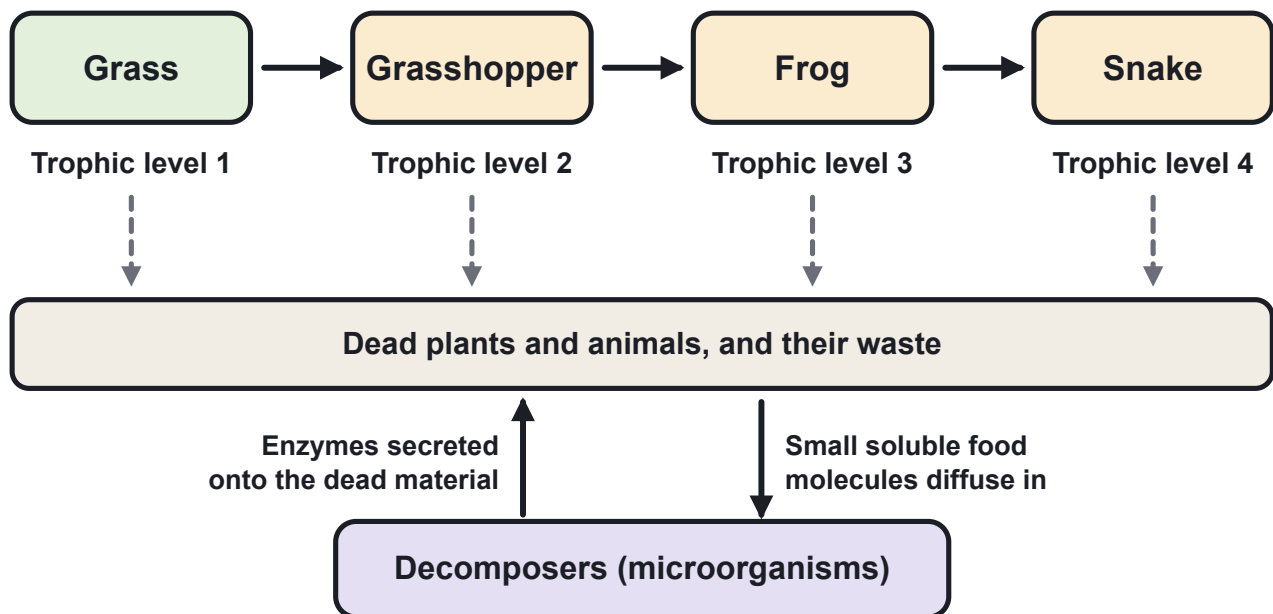
Trophic levels Spec 19.2.13, 19.2.14

Trophic level The position of an organism in a food chain, food web or ecological pyramid.

Trophic levels are numbered from the **producer** at the start of the chain. The same names are used in food webs, food chains and ecological pyramids.

Trophic levels		
Trophic level	Name	Example
1	Producers	Grass
2	Primary consumers	Grasshopper
3	Secondary consumers	Frog
4	Tertiary consumers	Snake
5	Quaternary consumers	Eagle

An organism in a food web may be at **more than one trophic level**. For example, an animal that eats both plants and herbivores is a primary consumer in one food chain and a secondary consumer in another. Decomposers feed on the dead remains from every trophic level.



Every trophic level ends up as dead material or waste, which decomposers feed on.

Common mistake: Producers are trophic level 1, so the primary consumer is level 2 and the secondary consumer is level 3. Do not count from the first animal.

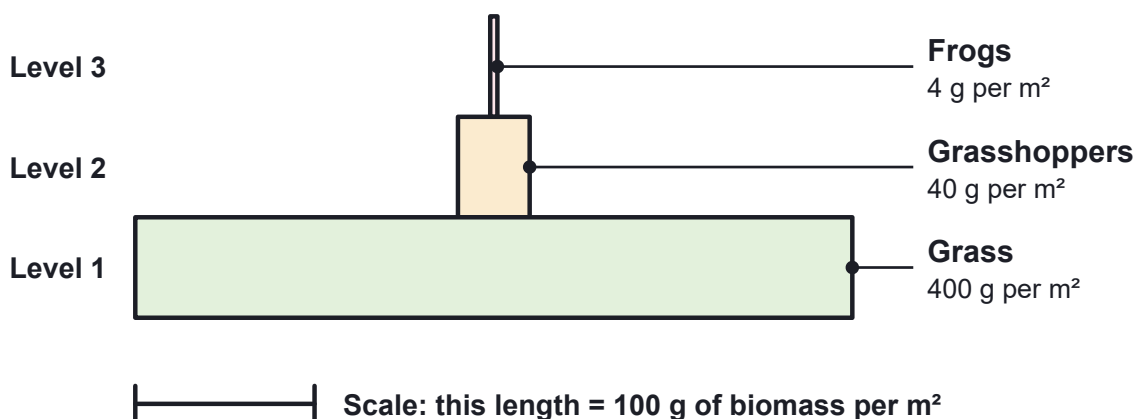
Pyramids of numbers and biomass Spec 19.2.11, 19.2.12

An ecological pyramid has one horizontal bar for each trophic level, with the producers at the bottom. The length of each bar is drawn to scale.

- A **pyramid of numbers** shows the number of organisms at each trophic level.
- A **pyramid of biomass** shows the mass of living material (biomass) at each trophic level, for example in g per m².

Drawing a pyramid

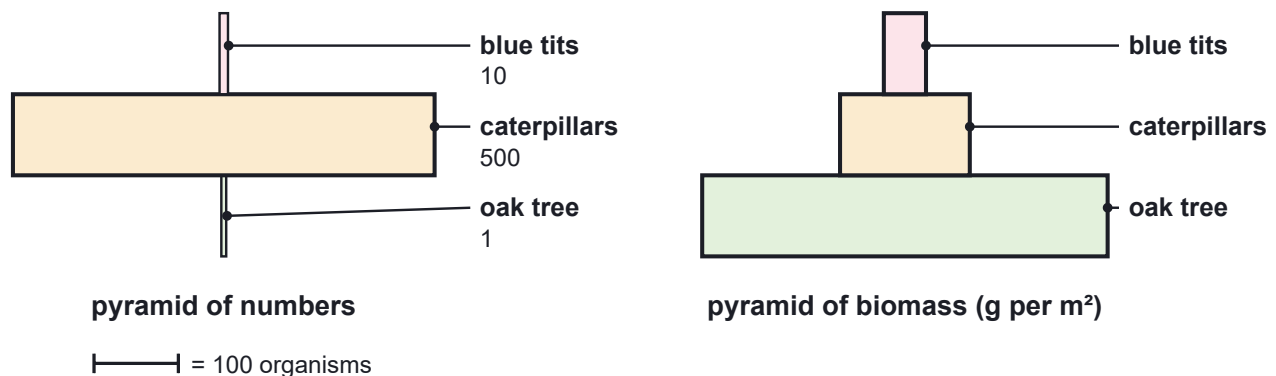
1. Choose a scale so that the longest bar fits on the page.
2. Draw a bar for each trophic level, with the producers at the bottom. Make the length of each bar proportional to its value.
3. Centre the bars on a vertical line and label each bar with the organism.



A pyramid of biomass for grass, grasshoppers and frogs, drawn to scale.

Pyramids of numbers can be the wrong shape

A pyramid of numbers does not always get narrower. One large oak tree can support hundreds of caterpillars, so the bar for the producers is shorter than the bar above it. The pyramid is not pyramid-shaped and is often described as **inverted**. The size of the organisms is ignored.



The same food chain: the **pyramid of numbers** is an odd shape because one large tree supports many caterpillars, but the **pyramid of biomass** is pyramid-shaped.

Advantage of a pyramid of biomass

A pyramid of biomass is usually a better way to represent a food chain than a pyramid of numbers, because:

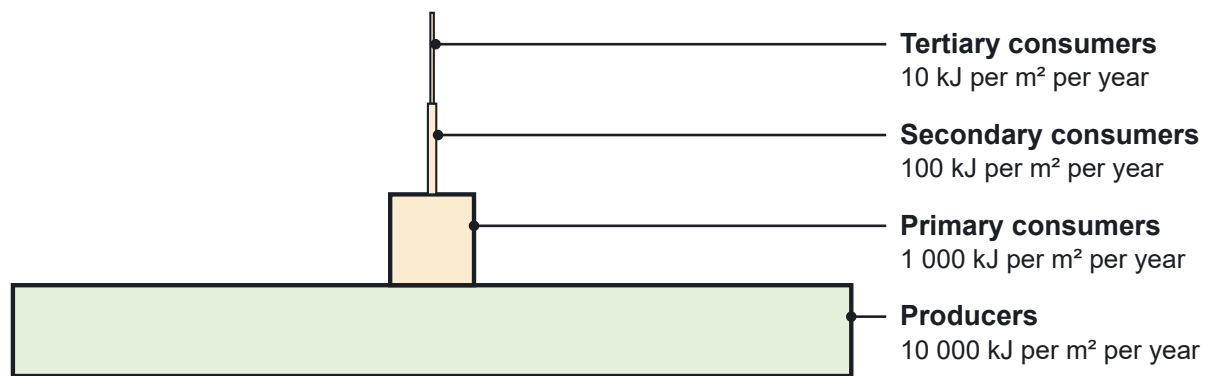
- it takes the **size of the organisms** into account, so one large tree is not shown as equal to one tiny insect;
- it is usually **pyramid-shaped**, because there is less biomass at each higher trophic level.

Exam tip: To explain an odd-shaped pyramid of numbers, say that the producer is one very large organism that supports many smaller consumers. Say that numbers ignore the size of organisms but biomass does not.

Pyramids of energy Spec 19.2.15, 19.2.16 Supplement

A **pyramid of energy** shows the **amount of energy** that flows through each trophic level in a given area over a period of time, for example in kJ per m² per year. It is drawn in the same way as the other pyramids, with the producers at the bottom and bars drawn to scale.

Example data for a pyramid of energy (practice values)	
Trophic level	Energy / kJ per m² per year
Producers	10 000
Primary consumers	1 000
Secondary consumers	100
Tertiary consumers	10



Scale: this length = 1 000 kJ per m² per year

A pyramid of energy is always pyramid-shaped. In this example only a tenth of the energy passes on to each higher trophic level.

Advantages of a pyramid of energy

- It is always **pyramid-shaped**, because energy is lost at each trophic level. It cannot be inverted.
- It takes into account the **size of the organisms**, unlike a pyramid of numbers.
- It shows the **rate** of energy flow, over a period of time. A pyramid of biomass shows only the mass at one moment (a pyramid of biomass can be inverted if organisms grow and reproduce quickly, for example algae in the sea).
- Different tissues contain different amounts of energy per gram (fat contains more than carbohydrate), so equal biomass does not always mean equal energy. A pyramid of energy compares the energy directly.
- It allows the efficiency of energy transfer between trophic levels to be compared.

Exam tip: Write the units as energy per area per time, such as kJ per m² per year. A pyramid of energy never has an inverted shape.

Why energy transfer is inefficient Spec 19.2.17, 19.2.18, 19.2.19 Supplement

Only a small fraction of the energy at one trophic level is transferred to the next. The transfer of energy from one trophic level to another is often not efficient, because energy is lost in these ways:

- Not all of an organism is eaten. Some parts, such as bones, roots and fur, are left uneaten.
- Some of what is eaten is not digested and is lost as **faeces** (egestion).
- Energy is lost in **excretion**, for example in urine.
- Energy is released by **respiration** to power life processes such as movement and, in mammals and birds, keeping warm. Much of this is lost as heat to the environment.

efficiency of energy transfer (%) = energy transferred to the next level ÷ energy available at the previous level × 100

Efficiency of energy transfer

The grass in a field stores 20 000 kJ of energy per m² per year. The cattle that eat it gain 1 600 kJ per m² per year. Calculate the efficiency of energy transfer from the grass to the cattle.

1. Efficiency = energy transferred ÷ energy available × 100

2. = 1 600 ÷ 20 000 × 100

3. = 8%

Answer: 8%

Food chains are short

Energy is lost at each trophic level, so less energy is available at each step. By the fourth or fifth trophic level there is too little energy left to support another population. This is why food chains usually have fewer than five trophic levels.

Eating plants or eating livestock

Humans can eat crop plants directly, or feed the crops to livestock and eat the livestock. It is more energy efficient to eat crop plants, because:

- there are fewer trophic levels in the food chain, so less energy is lost to the environment before it reaches humans;
- much of the energy in the crop fed to livestock is lost, for example in respiration, movement and keeping warm, and in faeces and urine, and is not stored in the meat or milk;
- so more people can be fed from the same area of land growing crops than from the same area used to grow food for livestock.

Common mistake: Do not say energy is 'lost' or 'used up' without saying how. Name the losses: heat from respiration, faeces, urine and parts not eaten.

Quick check

1. Define a trophic level.
2. Which trophic level do tertiary consumers occupy?
3. State one advantage of a pyramid of biomass over a pyramid of numbers.
4. **Supplement** State one advantage of a pyramid of energy over a pyramid of biomass.
5. **Supplement** Why do food chains usually have fewer than five trophic levels?

Quick check answers

Trophic levels and ecological pyramids

1. The position of an organism in a food chain, food web or ecological pyramid.
2. Trophic level 4.
3. It takes the size of the organisms into account, and is usually pyramid-shaped.
4. It shows the rate of energy flow over time, and is always pyramid-shaped.
5. Energy is lost at each level, so too little remains to support more.