2.2 Energy and biomass in ecosystems

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS trophic level • producer • gross primary productivity • net primary productivity • ecological pyramid • bioaccumulation • biomagnification

Objective

Build the skills to answer exam questions on **energy** and **biomass** in ecosystems: trophic levels, ecological pyramids, **productivity** and **biomagnification**.

You must be able to:

- construct food chains and webs, and assign trophic levels
- explain energy loss between trophic levels and the shapes of ecological pyramids
- calculate gross and net productivity and transfer efficiency
- explain bioaccumulation and biomagnification of pollutants

1 Key knowledge and worked examples

Energy flow

Energy enters most ecosystems as sunlight, which **producers** turn into chemical energy by photosynthesis. It passes along food chains: producer → primary consumer → secondary consumer → tertiary consumer. At each step most energy is lost as **heat** from respiration, and in parts not eaten or not digested (the second law of thermodynamics: no energy change is 100% efficient). Only about 10% passes on, so food chains rarely have more than 4–5 trophic levels.

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productivity	meaning
gross primary productivity (GPP)	energy fixed by producers per area per time
net primary productivity (NPP)	GPP minus producers' respiration: NPP = GPP − R; available to consumers
gross secondary productivity (GSP)	food eaten minus faeces: energy **assimilated** by consumers
net secondary productivity (NSP)	NSP = GSP − R

$$\text{transfer efficiency} = \frac{\text{energy at the higher level}}{\text{energy at the lower level}} \times 100\%$$

pyramid	can it be inverted?
numbers	yes, e.g. one oak tree feeds thousands of insects
biomass	sometimes, e.g. phytoplankton in the sea at one moment
productivity (energy)	**never**: energy is lost at every level

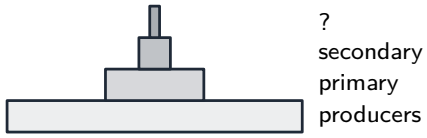
Biomagnification: a persistent pollutant that is not broken down or excreted (DDT, mercury) builds up in each organism (**bioaccumulation**) and becomes more concentrated at each higher trophic level, so top predators receive the highest doses.

Worked example. GPP = 20 000 and R = 12 000 kJ m^{-2} yr^{-1}: NPP = **8000** kJ m^{-2} yr^{-1}.

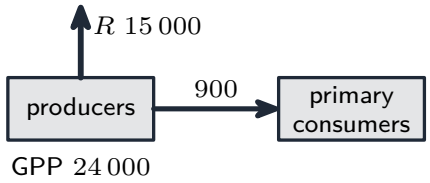
Answer shapes: show the subtraction or division with units; for pyramids, say what is measured.

2 Practice

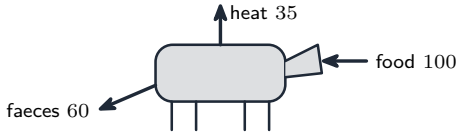
2.1 Explain why food chains rarely have more than five trophic levels. [2]



2.2 Grassland producers have a GPP of 24 000 kJ m^{-2} yr^{-1} and lose 15 000 kJ m^{-2} yr^{-1} in respiration. Primary consumers gain 900 kJ m^{-2} yr^{-1}. (i) Calculate the NPP. (ii) Calculate the transfer efficiency from NPP to primary consumers. [3]



2.3 A cow eats food containing 100 MJ. It loses 60 MJ in faeces and 35 MJ in respiration. Calculate its gross and net secondary productivity, and suggest why the NSP is so low. [3]



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3 Exam-style questions

3.1 An oak tree supports 2000 caterpillars, which are eaten by 20 birds.

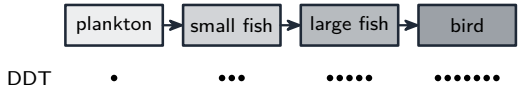


(a) Sketch the pyramid of numbers and the pyramid of biomass for this food chain. [2]

(b) Explain why the two pyramids have different shapes. [2]

3.2 The table shows the concentration of the pesticide DDT in a lake food chain.

organism	DDT (ppm)
water	0.00005
plankton	0.04
small fish	0.5
large fish	2.0
fish-eating bird	25

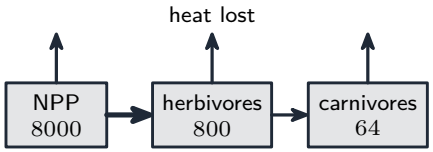


(a) Calculate how many times more concentrated the DDT is in the bird than in the plankton. [1]

(b) Explain how the DDT becomes so concentrated in the bird. [3]

(c) Suggest **one** effect on the bird population. [1]

3.3 The diagram shows energy flow in a temperate grassland, in kJ m^{-2} yr^{-1}: NPP 8000; primary consumers 800; secondary consumers 64.



(a) Calculate the efficiency of transfer from primary to secondary consumers. [1]

(b) Explain why a pyramid of productivity can never be inverted. [2]

(c) Using the data, discuss whether people should eat less meat to feed a growing population. [3]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

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

2.1

only about 10% of energy passes to the next level; most is lost as heat in respiration, or in waste and parts not eaten; after a few levels too little energy is left to support another population

2.2

(i) $24\,000 - 15\,000 = \mathbf{9000}$ kJ m^{-2} yr^{-1}; (ii) $\dfrac{900}{9000} \times 100 = \mathbf{10}\%$

2.3

GSP $= 100 - 60 = \mathbf{40}$ MJ; NSP $= 40 - 35 = \mathbf{5}$ MJ; grass is hard to digest, and keeping a large warm body moving uses much energy in respiration

3.1

(a) numbers: a narrow bar for the one tree, a wide bar for the caterpillars, a narrow bar for the birds; biomass: widest at the base, getting narrower at each level

(b) a pyramid of numbers ignores size: one tree is very large; biomass takes mass into account, and biomass falls at each level because energy is lost

3.2

(a) $25 \div 0.04 = \mathbf{625}$ times

(b) DDT is persistent and fat-soluble, so it is stored in body fat and not excreted (bioaccumulation); each organism eats many from the level below; so the DDT is passed on and concentrated at each level (biomagnification)

(c) eggshells become thin and break, so fewer chicks hatch and the population falls

3.3

(a) $64 \div 800 \times 100 = \mathbf{8}\%$

(b) it shows energy flow over time; energy is lost at every transfer, so each level must be smaller than the one below

(c) eating plants uses NPP directly: about ten times more energy per area than eating herbivores; so less land is needed per person; but some land (dry grassland, hills) cannot grow crops, and meat provides protein and incomes, so a reduction rather than an end may be best

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