3.5.3 Energy and Ecosystems

Name: _____

Reflection on Learning outcomes	☺ or ☹	**Target**
Explain how plants utilise the sugars from photosynthesis		
Explain what is meant by biomass and how it can be measured		
Suggest units for biomass		
Explain the process of calorimetry		
Evaluate the accuracy of results from simple calorimetry.		
Explain the concepts of Gross primary production and Net primary production		
Explain the concept of net production in consumers, linked to how energy losses along food chains		
Understand the mathematical relationship between the two and use it to calculate values when supplied with data		
Explain the reduction in energy/biomass along a food chain		
Apply knowledge to the context of exam questions.		
Explain the ways in which productivity is affected by simplifying food webs		
Explain the ways in which farmers are reducing respiratory losses within a human food chain		
Interpret and calculate data on efficiency when provided with appropriate information		
Evaluate the ethics of some of these farming practices.		

Outcomes:

- Explain how plants utilise the sugars from photosynthesis
- Explain what is meant by biomass, how it can be measured and suggest units for biomass
- Explain the process of calorimetry and evaluate the accuracy of results from simple calorimetry

How energy enters an ecosystem

Photosynthesis is the main route by which **energy** enters an **ecosystem.**

Definition: An ecosystem is formed from a community and the non-living (abiotic) components of its environment.

- In any ecosystem plants synthesise organic compounds from either **atmospheric CO_2** (for land-based plants) or **aquatic CO_2** (for aquatic plants and algae).
- The **light energy** is transferred to **chemical energy** in the **organic compounds** made in photosynthesis. Most of the sugars made in photosynthesis, such as **glucose**, are immediately used as respiratory substrates.
- The rest are used to make other carbohydrates such as **starch** and **cellulose** or other biological molecules such as **lipids** and **amino acids.**
- These biological molecules form the **biomass** (mass of living material in the plant) of the plants.

Q: Explain the relationship between photosynthesis, respiration and biomass by answering the question "Where does an oak tree get the materials it needs to grow from?"
Words: glucose, proteins, ATP, growth, biomass, fats, sugars, mitosis

1. Photosynthesis produces_____
2. Sugars are hydrolysed into_____
3. _____ is respired to produce _____
4. Energy/ATP used for_____
5. Energy is stored in _____

Measurement of biomass

Biomass is a measurement of

a) the mass of carbon, **per unit area**
   OR
b) the **dry mass** of tissue produced **per unit area** (more commonly used)

Dry mass gives you a measure of the *productivity* of an ecosystem. Productivity is a **RATE** so the biomass per unit area, **per unit time**. The **higher** the productivity the **higher** the biomass.

Measuring Dry mass

1. The sample of organism is dried in an oven (normally around 100°C).
2. The sample is weighed after a certain amount of time e.g. 24 hours.
3. The sample is **dried again** in the oven **and re-weighed** over and over until the **mass remains constant**, which means all the water has been removed.

Suggest the **units** for dry mass and learn!

_____

What is the advantage of using these units?

Collect all wheat in 1 metre^2, dry them at 80^{o}c, weigh them, and repeat process until no further change in weight. Then multiply answer by number of square metres in the field.

Why does this method help to provide a reliable measurement of the biomass? [2]

- Removes water
- Water content may vary in a plant

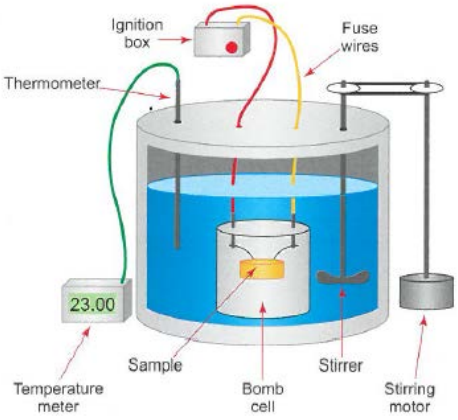
Why is this method not usually used in practice? [1]

- Destroys the sample

Calorimetry

Method for calorimetry

1. This is used to measure the chemical energy stored in organic material (biomass)
2. Organic material dried out
3. **Burnt in oxygen** in a combustion chamber.
4. The energy given off is used to heat **a known volume** of water.
5. Increase in temperature of water indicated energy contained in material.
6. The **units are Joules / kiloJoules (J/kJ)**



Exam Questions

Q1. Explain how you would obtain accurate results from simple calorimetry

_____

_____

_____

_____

_____(2)

Q2. Yield can be determined by measuring the dry mass of plants

a) Suggest how you could determine the dry mass of a sample of plant material.

_____

_____

_____

_____(2)

b) What is the advantage of using the dry mass and not the fresh mass to compare the yield of plants?

_____

_____

_____

_____ (2)

Q3. Ecologists developed a method for estimating the biomass of trees in a plantation. The plantation consisted of trees of the same species. They collected samples of wood from trees. For each sample they:

- determined the density of the freshly cut wood
- dried the wood in an oven at 103 °C for 24 hours
- determined the volume of the dried wood sample
- determined the density of the dried wood.

The table below shows data about one wood sample.

Volume of freshly cut wood sample / dm^3	**Density of freshly cut wood / g per dm^3**	**Volume of dried wood sample / dm^3**	**Density of dried wood sample / g per dm^3**
1.345	993.0	1.125	769.0

(a) The loss of mass of the wood sample was due to loss of water. Water has a density of 1 g per cm^3.

Use the data in the table to calculate the percentage of water in the freshly cut wood sample. Show your working.

Percentage of water = _____

(2)

(b) The ecologists dried the samples in an oven at 103 °C for 24 hours. Describe how the ecologists could have determined whether or not this drying removed all the water from a sample of wood.

_____

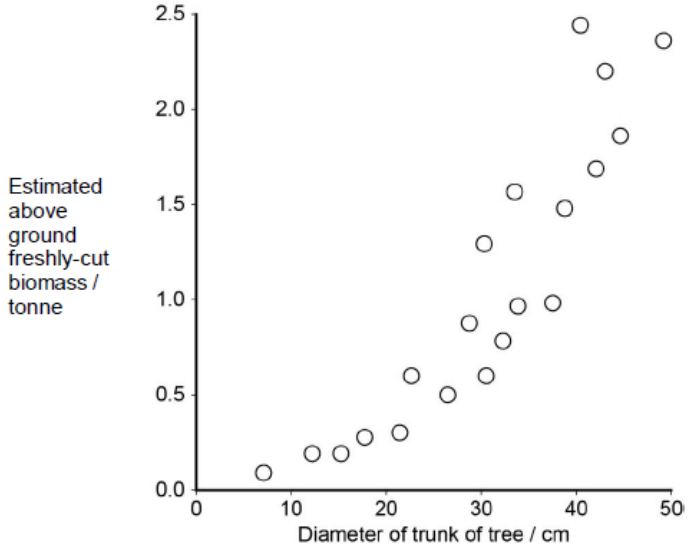
_____

_____

_____

_____**(2)**

(c) Ecologists then investigated the relationship between the diameter of the trunk of the trees and their biomass. The graph below shows their results. Each point is the result for **one** tree.



What does the graph show about the relationship between the diameter of the trunk of the trees and their biomass?

_____

_____

_____ **(2)**

(d) Plantations of trees are often created to remove carbon dioxide from the atmosphere, to help to balance the carbon dioxide released by burning fossil fuels.

For different species of tree, information is available for:

- the relationship between diameter of trunk and freshly cut biomass
- the percentage of water in fresh-cut wood
- the mean dried density of wood.

Using only the information provided in part **(c)**, suggest how the mass of carbon in the wood of a plantation of trees of a particular species could be estimated.

Start with measuring the diameter of a large number of trees.

Assume that the dry biomass of a tree consists of biological molecules that contain carbon.

_____

_____

_____

_____

_____

_____ **(4)**

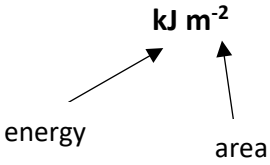
Outcome:

- Explain the concepts of Gross Primary Production (GPP) and Net Primary Production (NPP)
- Understand the mathematical relationship between the two, and use it to calculate values when supplied with data

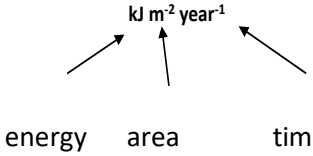
Energy flow through ecosystems

Definition:
Gross Primary Production (GPP) is the chemical energy store in plant biomass, in a given area, in a given time.

- GPP represents the total amount of **light energy** which is converted into **stored biomass** during **photosynthesis**.
- Units are the **energy stored as biomass**, **per area** or **volume**.



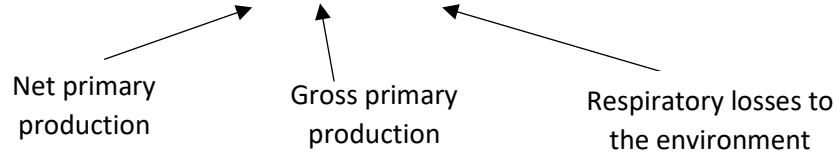
Note: Primary **productivity** is the **RATE** of chemical energy store in a plant biomass in a given area**, in a given time**



Definition:
Net Primary Production (NPP) is the chemical energy store in plant biomass after respiratory losses (**R**) have been subtracted.

- Plants **respire** to release energy from the biological molecules which make up the **biomass** made in **photosynthesis**, such as glucose.
- We therefore have to **minus** these **respiratory losses** of energy from the GPP.
- NPP is what is left after the plant has taken what it requires**.**
- NPP represents the potential food available to consumers.

NPP can be calculated using the formula: **NPP = GPP - R**



- This net primary production is available for **plant growth and reproduction**.
- It is also available for **other trophic levels** in the ecosystem such as **herbivores and decomposers**.

Exam tip: If an exam questions asks you about NPP or GPP, always write out the equation above. It is likely to get you one mark!

Outcomes:

- Explain the reduction in energy/biomass along a food chain

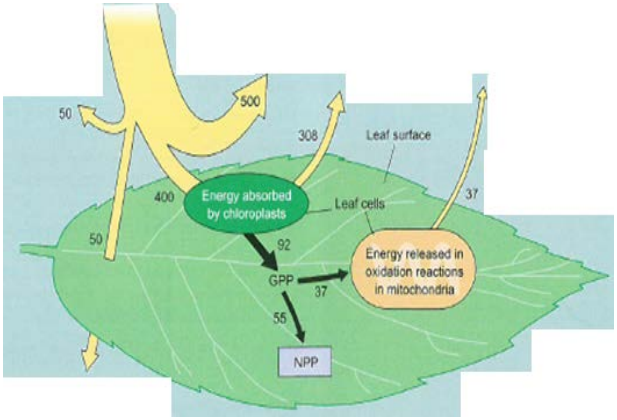
Factors affecting primary production

Production is related directly to the **rate of photosynthesis,** and so is affected by a wide range of biotic and abiotic factors.

Energy flow

What are the energy losses?

- The sun is the source of energy for ecosystems.
- However, only 1 % of this light energy is captured by green plants and converted to organic compounds, and so is available to organisms in the food chain.



Add the letters below to the correct places on the leaf to show the energy losses

A) Some is the wrong wavelength to be absorbed by chlorophyll.
B) Some energy is used in evaporating water from leaves
C) Some energy is reflected
D) Some energy is lost during photosynthetic reactions
E) Some energy is lost in respiration
F) Some energy is transmitted straight through leaf, missing the chloroplasts.

Food chains

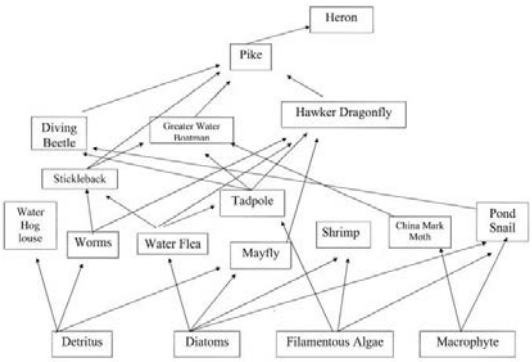
- A food chain shows the **flow of energy** between organisms. Each organism represents a **trophic level.** Decomposers are often not represented on a food chain.
- **Producers** start the food chain. They are photosynthetic organisms such as plants and form their own organic molecules (autotrophic).
- **Consumers** rely on an external source of organic compounds (heterotrophic) that they have to feed on. Animals are consumers.
- Primary consumers eat producers. Secondary consumers eat primary consumers. Tertiary consumers eat secondary consumers

Example of food chain with three trophic levels

Water lily (producer) → Water boatmen (Primary consumer) → Roach (fish) (Secondary consumer)

Food webs

- In a particular habitat many food chains can be linked together to form a food web.
- The more complex the food web means that any one change in a population will have less of an effect on the other populations, making it more stable.



Net Primary Production (NPP) in food chains

The NPP is the energy available to:

- **producers** for growth and reproduction.
- **primary consumers** when they eat the producers.
- **decomposers** when they feed on the dead producers/consumers.

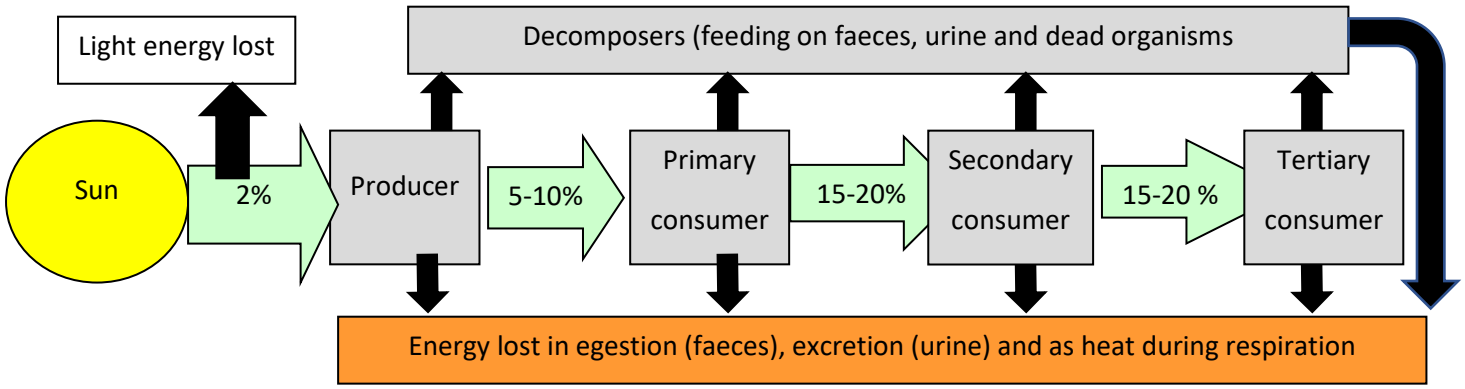
Only about 10% of the NPP is transferred to the consumer. 90% is lost because…

- Some of the organism is indigestible and the energy is egested as **faeces.**
- Some of the energy is excreted in **urine.**
- Some of the biological molecules taken in are **respired** and not incorporated into consumer biomass, this respired energy is lost as **heat.**

Exam tip: If an exam question mentions net primary production then you must write

NPP = GGP – R

This may get you a mark!



The % of energy transferred between the producer and primary consumer is less (5-10% compared to 15-20% between consumers) due to more indigestible matter in producers, such as cellulose, lost in faeces.

Exam Questions

Q4. Arbuscular mycorrhiza fungi (AMF) are fungi which grow on, and into, the roots of plants. AMF can increase the uptake of inorganic ions such as phosphate.

(a) Suggest **one** way in which an increase in the uptake of phosphate could increase plant growth.

_____

_____**(1)**

(b) Suggest **one** way in which AMF may benefit from their association with plants.

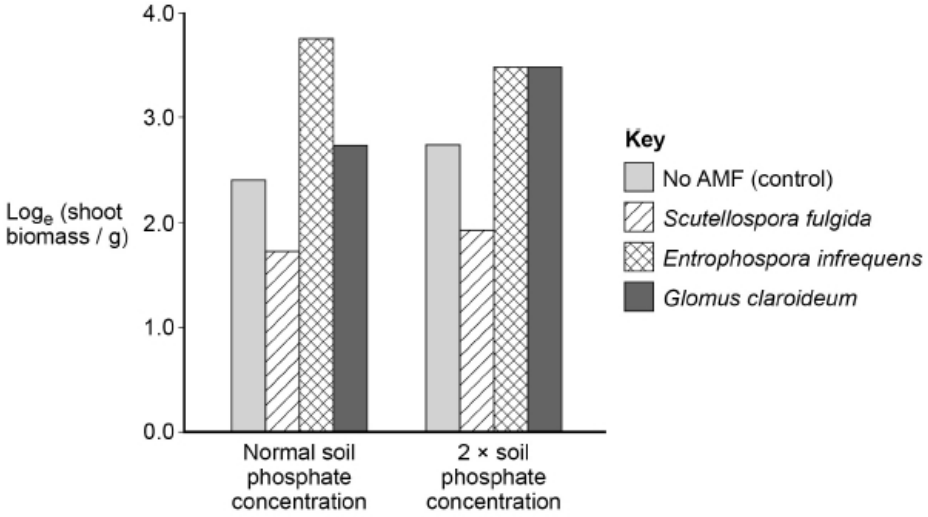
_____

_____**(1)**

(c) Scientists investigated the effects of different AMF species on the productivity of the plant community of a prairie grassland ecosystem when growing in/on soil containing different phosphate concentrations.

The scientists set up identical plots of prairie grassland soil containing seeds of the plant species found in the ecosystem. The scientists added different AMF species and different concentrations of phosphate to particular plots. Control plots without AMF species were also set up. After 20 weeks the scientists determined the shoot biomass for each plot.

The results the scientists obtained are shown in the graph.



Explain why an increase in shoot biomass can be taken as a measurement of **net** primary productivity.

_____

_____

_____

_____**(2)**

(d) Using the data from the graph in part (c), evaluate the effect on plant productivity of adding AMF species and adding phosphate to the soil.

_____

_____

_____

_____

_____

_____ **(4)**

(e) Using the e^x button on your calculator, determine the rate of shoot biomass production in grams per day for the control plot in soil with normal phosphate concentration.

Answer = _____ g day^{-1}

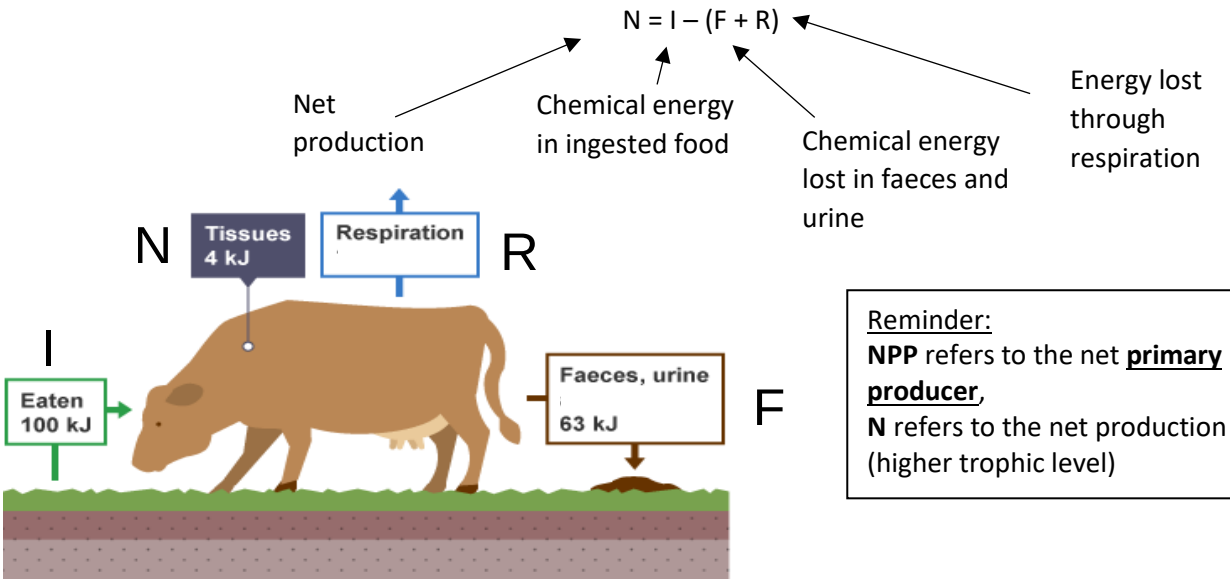
(2)

Outcomes:

- Explain the concept of net production in consumers, linked to how energy losses along food chains

Net production

N**et production (N) in a consumer** is the energy available to the next trophic level. The N reduces as you go from one trophic level to the next due to the energy loss at each level. N can be measured in a consumer as:



Reminder:
NPP refers to the net **primary** production in a **producer**,
N refers to the net production in a **consumers** (higher trophic level)

Secondary production refers to the net quantity of energy transferred and stored in the tissues of consumers (heterotrophs) (i.e. it is net production)

Definitions:
Primary productivity: The **rate** of primary production. It is measured as biomass in a given area in a given time e.g. in kJ m-2 year -1 or kJ ha^{-1} $year^{-1}$
Secondary productivity: The **rate** of secondary production. It is measured as biomass in a given area in given time e.g. kJ m^{-2} $year^{-1}$ or kJ ha^{-1} $year^{-1}$

Exam Tip:

- ha^{-1} $year^{-1}$ means per hectare per year
- 1 hectare is equivalent to 10,000m^2

Efficiency of energy transfer

To calculate the efficiency of energy transfer between trophic levels:

% efficiency of energy transfer = $\frac{\text{net production of trophic level}}{\text{net production of previous tropic level}}$ x100

e.g. The available energy, N, in a trout is 250 kJ m^{-2} $year^{-1}$ and the energy available to a human after eating it is 50 kJ m^{-2} $year^{-1}$. What is the efficiency of the energy transfer?

% efficiency of energy transfer = $\frac{50}{250}$ = 0.2 x 100 = 20%

Outcomes:

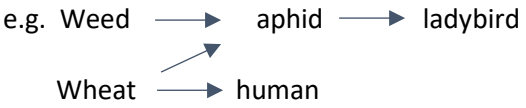
- Explain the ways in which productivity is affected by simplifying food webs

Increasing efficiency in food chains

Productivity is affected by farming practices designed to increase the efficiency of energy transfer to humans by:

- Simplifying food webs to reduce energy losses to non-human food chains
- Reducing respiratory losses within a human food chain

Simplifying food webs involves getting rid of food chains which do not include humans. This can increase the proportion of energy transferred to humans as less is eaten by other organisms.



In this example by removing the aphids, there is less **competition** between the aphids and the humans for the wheat as the aphids reduce the biomass of the wheat by eating it. The aphids can be removed in 3 ways:

- By using **chemical control**
  - Using an **insecticide** to kill the aphids directly.
  - Using an **herbicide** to kill the weeds which in turn removes interspecific competition for the crop for abiotic factors such as light and also removes a food source for the aphids reducing their numbers.
- By using **biological control**, such as adding ladybirds to the ecosystem which in turn eat the aphids.

Reducing respiratory losses

By **reducing rate of respiration** in livestock this will reduce R in the equation, increasing N. Less energy is lost through respiration and more is used for growth and biomass.

- **Movement can be restricted** by keeping animals in pens so less respiration occurs to release energy for muscle contraction.
- **Animals can be kept indoors or heated rooms** so less respiration occurs to generate heat to maintain body temperature.

Use the words below to fill in the blanks on the mark scheme perfect answers.

higher; respiration ; eat; consume; moving around; excretory; roots; herbivores; faeces; faeces; digest; digest; warm; hooves, horns, hair; respiration; energy; reflected; body temperature; chloroplast; respiration; wavelength; excretion; misses; faeces; eaten; heat; food;

Exam question: **Describe reasons for the low efficiency of energy transfer <u>from producer to primary cons</u>.**

1. The primary consumers _____ / cattle, do not eat all the grass (e.g. _____)
2. They do not _____ all the grass consumed (produce lots of _____)
3. Most of the energy they DO absorb is used in _____
4. A lot of the energy is used to keep themselves _____ by _____

Exam question: **Describe reasons for the low efficiency of energy transfer <u>between consumers</u>.**

1. Secondary consumers (us) don't _____ all the cow (e.g._____
2. We can't_____ everything we _____(produce_____)
3. There are losses in _____ materials – urine
4. Some is lost as heat from _____to the environment – the higher the body temp., the _____ the _____ needed to maintain it

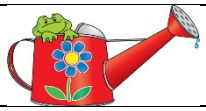
Exam question: **Describe reasons for the low efficiency of energy transfer through ecosystems-**

- Some light is r_____ / not of the appropriate _____
- Some light _____ leaves / does not strike _____
- There is _____ loss / energy is used to maintain _____ _____
- There is energy loss via _____
- There is energy loss via _____ / undigested _____ / some parts of organism are not _____
- There is loss via _____ / urine

Outcomes:

- Explain the ways in which farmers are reducing respiratory losses within a human food chain
- Interpret and calculate data on efficiency when provided with appropriate information
- Evaluate the ethics of some of these farming practices

Farming practices Read Toole and Toole, p.303-304.

Action to improve productivity	Reason
Add fertilisers to soil 	
Pesticides are added	
Weed killers/herbicides, are added	
Crops are selectively bred or genetically modified	
Use of greenhouses increase temperature, CO_2 concentration and light intensity 	
Ploughing/ aeration 	
Crops are protected by birds / pests / frost, by use of netting, covers	
Watering 	
Crop rotation	
Livestock is slaughtered when still growing 	
Livestock is fed on concentrate / a controlled diet	
Their movement is restricted	
They are kept warm 	
There is selective breeding	

Use of greenhouses and polytunnels

Limiting factor	Management in glasshouse/polytunnel
CO_2 concentration	Increased by burning propane in generator
Light	Light through glass Lights in the dark
Temp	Glass traps lights' heat Heating and cooling systems incl circulating systems.

The efficiency of a grazing animal

Scientists investigated the efficiency of an individual herbivore. They chose a bullock, because its energy transfer is not complicated by the milk producing process. Firstly, they needed to estimate the energy contained in the food eaten by the animal, which they did by taking samples of grass from a field. The plot selected was one hectare. One hectare measures 100m by 100m. It's about the size of a football or rugby pitch.

1. How many square meters in a hectare? [1] _____

2. The scientists selected 20 different plots of area $1m^2$ and collected all of the grass by mowing.

a. What percentage of the total plot was sampled? [1]

_____

b. Suggest why mowing was selected as collection method [1]

_____

3. The selected plots were chosen at random. Explain why this was important [1]

_____

4. Suggest how these plots could have been chosen. [1]

_____

5. The grass collected from the plots was first heated in an oven at 105°C until the weight was constant. Explain why this was [2]

_____

_____

6. Scientists obtained these results:

Mean mass of grass before drying/kg	Mean mass of grass after drying/kg
1.25	0.46

Calculate the percentage water content of grass. [2]

_____

_____

7. 100g of the dry plant material was placed into a bomb calorimeter which produced a mean value of 85Kj. Outline how a bomb calorimeter works. [3]

_____

_____

_____

_____

8. Look at figure A1. Use the equation N= I – (F+R) to calculate the net production of the bullock in kJ [2]

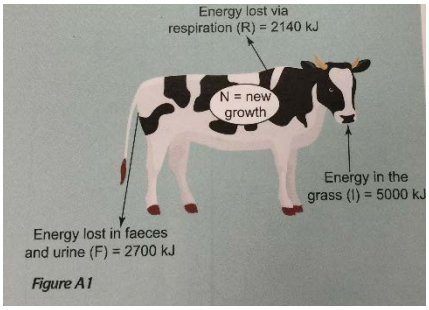


Figure A1

_____

_____

_____

_____

9. Calculate the overall efficiency of the energy transfer from producer to primary consumer. [2]

_____

_____

_____

_____

10. The energy transfer from primary to secondary consumer is general higher. Suggest a reason for this. [2]

_____

_____

_____

_____

_____

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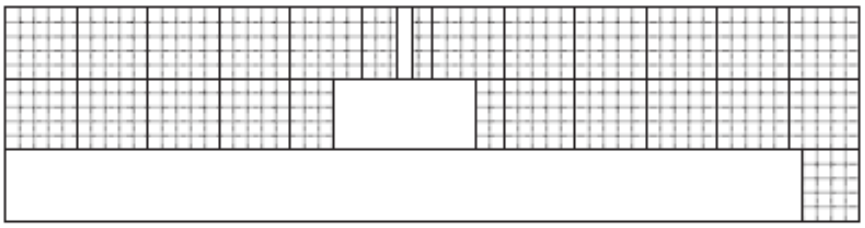
Exam Question

Q5. This is part of a food web from a pond ecosystem: single-celled algae → pond snail → fish

A pyramid of energy for this food web is shown below. The bars are drawn to the same scale.



(i) Use the pyramid of energy to calculate the percentage efficiency of energy transfer between producers and primary consumers. Show your working.

efficiency = ... %

(2 marks)

(ii) The average efficiency of energy transfer between producers and primary consumers in pyramids of energy is around 10 %.

Suggest why the efficiency of energy transfer from producers to primary consumers in this food web is higher than 10 %.

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(2 marks)

(iii) Energy from the sun may ultimately end up in dead plant matter. Describe how.

[2]

_____

_____

_____

_____

_____