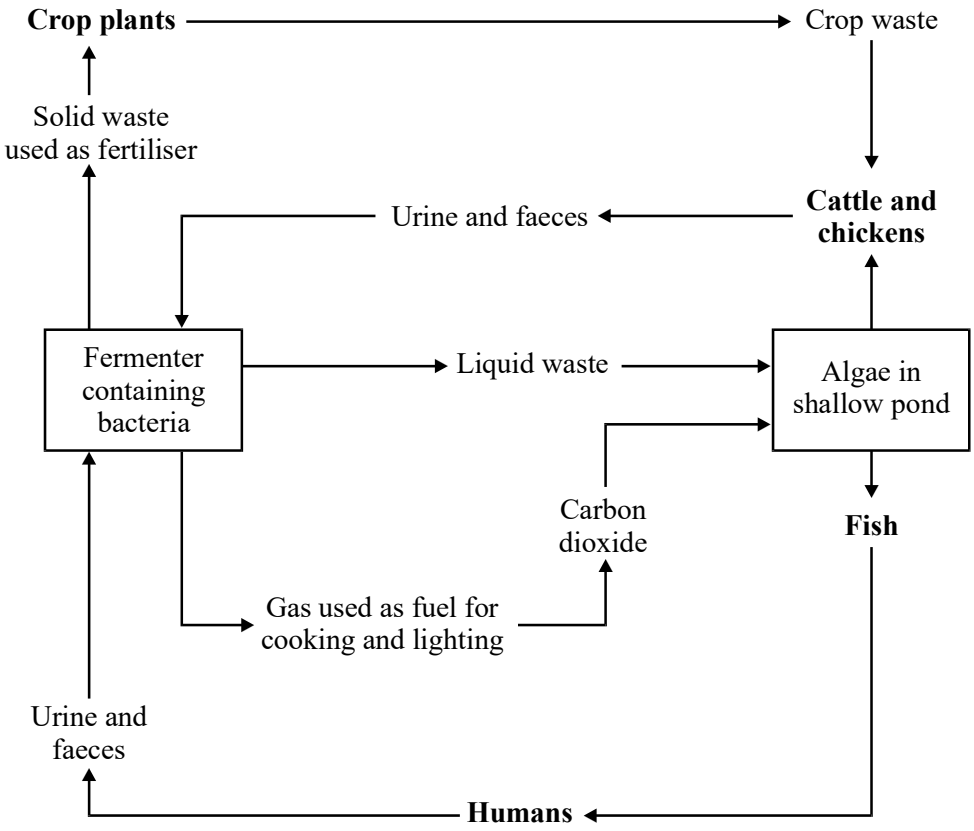
1. *Answers should be written in continuous prose. Credit will be given for biological accuracy, the organisation and presentation of the information and the way in which the answer is expressed.*

The diagram shows part of a system designed to meet all the basic needs of a family of four living in the tropics.



(a) The processes which naturally form part of the nitrogen cycle can make nitrogen contained in urine and faeces available to crop plants. Describe how these processes occur.

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(6)

(b) Explain the advantage in this system of:

(i) growing leguminous plants such as groundnuts or beans;

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(4)

(ii) stocking the pond with fish that feed on algae rather than with carnivorous fish.

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(3)
(Total 13 marks)

2. Spruce trees produce very large numbers of seeds. Most of these seeds die immediately, releasing nitrogen compounds into the soil. Swedish scientists investigated the effects of this on the growth of pine seedlings, in areas where the forest floor was free of moss plants and in areas where moss plants grew.

(a) Describe the part played by soil bacteria in making the nitrogen in compounds in the dead spruce seeds available to pine seedlings.

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(3)

(b) In areas where the forest floor was free of moss plants, the pine seedlings grew better in plots with added spruce seeds than they did in control plots. In areas in which moss plants grew, the difference in growth of the pine seedlings in plots with added spruce seeds was not statistically significant from those in the control plots. Suggest an explanation for the effect of the moss plants on the growth of the pine seedlings.

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(2)
(Total 5 marks)

3. Heather is a woody plant found in many moorland areas on higher ground in Britain. Grouse are chicken-sized birds which feed on the young shoots of heather. On many moorlands, the heather is managed to produce better conditions for grouse. This involves burning large areas. After burning, heather goes through the cycle of growth described below.

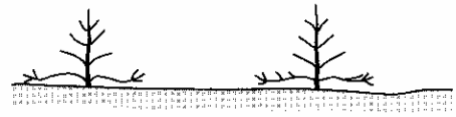
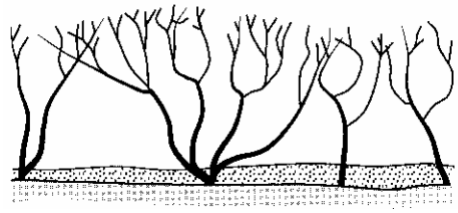
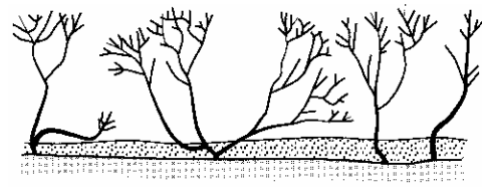
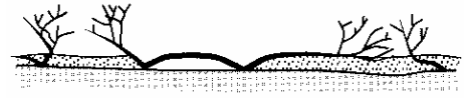
Pioneer phase 0-7 years	New plants grow either from seed or from stem bases undamaged by fire.	
Building phase 7-15 years	Phase of rapid growth producing dense cover of heather plants.	
Mature phase 15 - 25 years	Plants still growing but gaps start to appear in the canopy.	
Degenerate phase 25+ years	Branches break. Central part of plant dies although outer branches may remain alive.	

Table 1 summarises some data collected from a study of heather plants of different ages.

Age/years	Total biomass/g m^2	Biomass of green shoots/g m^{-2}	Percentage cover	Light at ground level as percentage of light in open
5	287	78	10	84
10	1508	203	85	5
20	1924	208	76	22
30	1043	n/a	34	56

Table 1

Key:
n/a = figures not available

(a) To determine the total biomass, quadrats were used to collect the heather samples. Describe the procedure you would have used to place these quadrats.

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(3)

(b) Describe how and explain why the diversity of plant species would be likely to change during the cycle of growth of the heather.

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(3)

(c) (i) Calculate the mean rate of increase in the biomass of green shoots between 10 and 20 years. Show your working.

Answer: .....

(2)

(ii) Explain why the mean rate of increase in the biomass of green shoots decreases with age.

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(2)

(iii) Management of heather by burning allows an area of land to support a larger population of grouse than if the heather is unmanaged. Use the information in **Table 1** to suggest why.

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(2)

Table 2 shows the nitrogen content of heather plants, leaf litter and the soil in plots of land at various stages after burning.

Time after burning/years	Nitrogen content/kg ha^{-1}		
	Heather plants	**Leaf litter**	**Soil**
3	59	28	5794
8	92	61	5952
15	192	58	5394

Table 2

(d) (i) Give **one** organic compound in which the nitrogen will be found in the heather plants.

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(1)

(ii) Give **one** ion in which the nitrogen will be found in the soil.

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(1)

(e) Explain how bacteria make nitrogen present in the leaf litter available to the heather plants.

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(4)

(f) It has been suggested that if heather moorland is to be managed by burning, this should take place before the heather is 15 years old. Use the information in **Table 2** to suggest why.

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(2)
(Total 20 marks)

4. *Read the following passage.*

In Uzbekistan, lorries bring them vast distances to improve the desert soil. In the Scottish hills, they helped a sheep farmer to increase the size of his flocks. The vital ingredient in both cases is an annelid, the earthworm. Scientists and farmers are only just beginning to appreciate the full value of this animal in maintaining the fertility of the soil.

When many of the larger species of earthworm burrow through the soil, they literally eat their way through it. The faeces they produce, known as worm casts, contain soil particles and undigested plant material. Fresh worm casts also contain enzymes such as protease, amylase, lipase and cellulase which continue to break down organic material after they have been lost from the body of the worm.

Earthworms play an important part in the cycling of organic matter. In European woodlands, a few common species such as *Lumbricus terrestris* feed on dead leaves. They are responsible for breaking up a large amount of the leaf litter into smaller fragments. They greatly increase soil fertility. At least part of this must be due to increases in the mineralised nitrogen that they make available for plant growth. Earthworm corpses decay rapidly. In one investigation, it was found that they had completely disappeared from the soil after three weeks at 12 °C. Of the nitrogen added to the soil as a result, 25 % was in the form of nitrates and 45% as ammonia. The average lifespan of an earthworm is about a year so this represents a substantial contribution to the cycling of nitrogen.

Earthworms also add nitrogen to the soil in their excretory products. The exact amount that they add depends on the activity of the worm. It seems likely that earthworms produce more excretory nitrogen when they are living on food reserves stored in their tissues than when they are actively feeding.

The ratio of carbon to nitrogen (the C : N ratio) in organic matter is of considerable importance because plants cannot absorb mineralised nitrogen unless the C : N ratio of the organic matter in the soil is in the order of 20 : 1 or less. The C : N ratio of freshly fallen leaves is much higher than this, being, for example 43:1 for oak. Earthworms feeding on leaf litter gradually lower its C : N ratio as they break the material down and use the products for respiration.

Source: adapted from C.A. EDWARDS and J.R. LOFTY, *Biology of Earthworms* (Chapman and Hall) 1977

Using information in the passage and your own knowledge, answer the following questions.

(a) Copy and complete the following table to show how the earthworm, *Lumbricus terrestris*, is classified.

Kingdom	
Phylum	
	Oligochaeta
	Opisthopora
	Lumbricidae
Genus	
Species	

(2)

(b) (i) Explain why digestive enzymes from the earthworm's gut are found in its faeces.

(2)

(ii) Describe briefly how you could show that fresh worm casts contain the enzyme, amylase.

(3)

(c) In an orchard where the trees had been sprayed with a fungicide for many years researchers found that there were very few earthworms but a normal population of soil microorganisms. The soil in this orchard was covered by a thick layer of dead leaves which were only decomposing slowly. In a nearby orchard which had never been sprayed, the leaves decomposed much faster. As a result, there was only a thin layer of decomposed leaves.
Suggest an explanation for the difference in the rate of decomposition of the leaves in the two orchards.

(2)

(d) Explain what is meant by:

(i) mineralised nitrogen (line 13-14);

(1)

(ii) excretory nitrogen (line 21).

(1)

(e) (i) Name **two** organic compounds in the body of a dead earthworm that would contain nitrogen.

(1)

(ii) Explain how bacteria in the soil make nitrogen in organic compounds in the body of a dead earthworm available to plants.

(3)

(f) In hot, dry weather an earthworm curls up into a ball and stops moving.

(i) How does this behaviour help the earthworm to survive these conditions?

(1)

(ii) Explain how earthworms still contribute to soil nitrogen even though they have stopped moving.

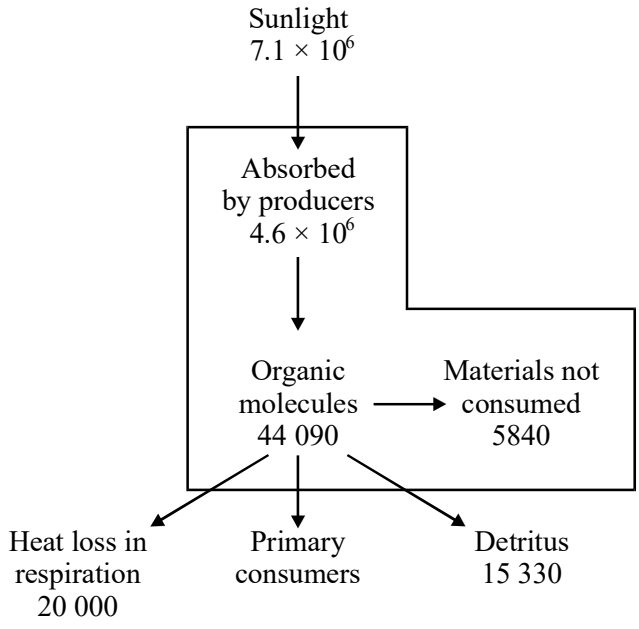
(1)

(g) Explain **two** ways in which earthworms can lower the C : N ratio of organic matter (line 27).

(3)

(Total 20 marks)

5. The diagram shows the annual transfer of energy in a forest ecosystem. The figures are in kJ m^{-2}.



(a) Although the producers absorb $4.6 \cdot 10^6$ kJm^{-2}, only about 1% of this is transferred to organic molecules. Suggest **one** reason for this.

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(1)

(b) Calculate the energy transferred to primary consumers in this ecosystem.

..... kJm^{-2}

(1)

(c) Nitrogen compounds in the detritus are broken down by bacteria to ammonium ions (NH_4^+). Describe how ammonium ions are converted into a form that can be readily absorbed by the producers.

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(3)
(Total 5 marks)

6. Read the following passage.

Deforestation, particularly in tropical rain forests, has proceeded at an alarming rate over the last 60 years. In addition to local decreases in biodiversity, there have been other, global, effects, especially on climate. Deforestation has been paralleled by an enormous rise in the burning of fossil fuels. These two factors have been important contributors to rising levels of carbon dioxide in the earth's atmosphere and increases in global temperatures.

Recent discussions on what to do about global warming have produced two new ideas. One is that farmers should plant trees on their land to act as carbon 'sinks'. These would offset increased carbon dioxide emissions by industry.

The second idea is that farmers should reduce the amount of ploughing they do. Ploughing allows air to enter the soil and helps with the recycling of both carbon and nitrogen. A reduction in ploughing would cut the oxidation of organic matter being stored in soils, which would then act as another carbon 'sink'.

Use information from the passage and your own knowledge to answer the following questions.

(a) Explain how deforestation could lead to decreases in biodiversity (line 2).

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(b) Explain how trees can act as carbon 'sinks' (line 7).

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(3)

(c) (i) Explain how a reduction in the amount of ploughing would lead to more carbon being stored in the soil (lines 9 – 12).

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(4)

(ii) Ploughing can increase the activity of nitrifying bacteria in the soil. Explain how ploughing can do this and how the activity of nitrifying bacteria can benefit crop plants.

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(5)

(Total 15 marks)

7. Read the following passage.

Early settlers used a technique known as 'slash and burn' to clear land for growing crops. Trees were cut down and burned and seeds of crop plants were scattered on the cleared land. After a few years, crop growth was usually so poor that people would move on and repeat the process. At low human population densities there was no long-term damage to the forest as the cleared areas of land had a chance to recover once people had left.

With an increase in human population, and over periods of time, large areas of forest have been destroyed. Modern developments have made possible greater yields from an area of land and farming has become more intensive. To maintain soil fertility, farmers now add fertilisers to the soil.

Use information from the passage and your own knowledge to answer the following questions.

(a) Explain how the process of 'slash and burn' would affect the availability of carbon in the atmosphere.

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(2)

(b) Explain how bare, cleared land could once again become forest.

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(3)

(c) Fertiliser, such as manure, contains ammonium compounds. Explain how the presence of soil bacteria and the use of manure improve crop yield.

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(6)

(d) Explain the advantages of conserving a forest ecosystem.

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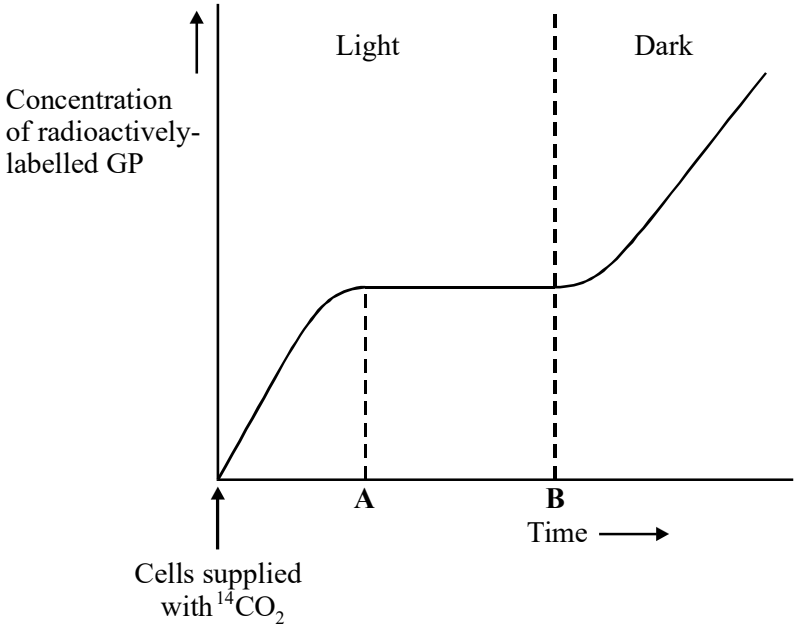
(4)

(Total 15 marks)

8. In an investigation, leaf cells were supplied with $^{14}CO_2$, carbon dioxide labelled with a radioactive isotope of carbon. These cells were kept in the light and allowed to photosynthesise. After a period of time, the light was switched off and the cells were left in the dark. The graph shows the concentration of radioactively-labelled glycerate 3-phosphate (GP) over the course of the investigation.



(a) (i) Describe how GP is formed from carbon dioxide in photosynthesis.

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(2)

(ii) In this investigation, the $^{14}CO_2$ was supplied in excess. Explain why the concentration of radioactively-labelled GP remained the same between times **A** and **B** on the graph.

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(1)

(b) Explain the change in the concentration of radioactive GP after the light was switched off.

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(3)

The table shows some results from an investigation of the concentration of carbon dioxide in samples of air taken from among the leaves in a potato crop.

Date	**Mean carbon dioxide concentration in parts per million between**	
	8 pm and 4 am	**8am and 4 pm**
10 July	328	309
20 July	328	299
30 July	326	284
10 Aug	322	282

(c) (i) The figures in columns 2 and 3 of the table were calculated from readings obtained at different times of the day. Explain why the figures in column 3 are lower than those in column 2.

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(2)

(ii) How would you expect the mean carbon dioxide concentration between 8 am and 4 pm to have differed if the air samples had been collected at soil level? Give a reason for your answer.

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(2)

(d) Suggest why, in this investigation, the investigators recorded the wind speed.

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(2)

(e) Some of the leaves from this crop die and fall to the ground. Describe how the carbon contained in the dead leaves becomes available and can be taken up by plants.

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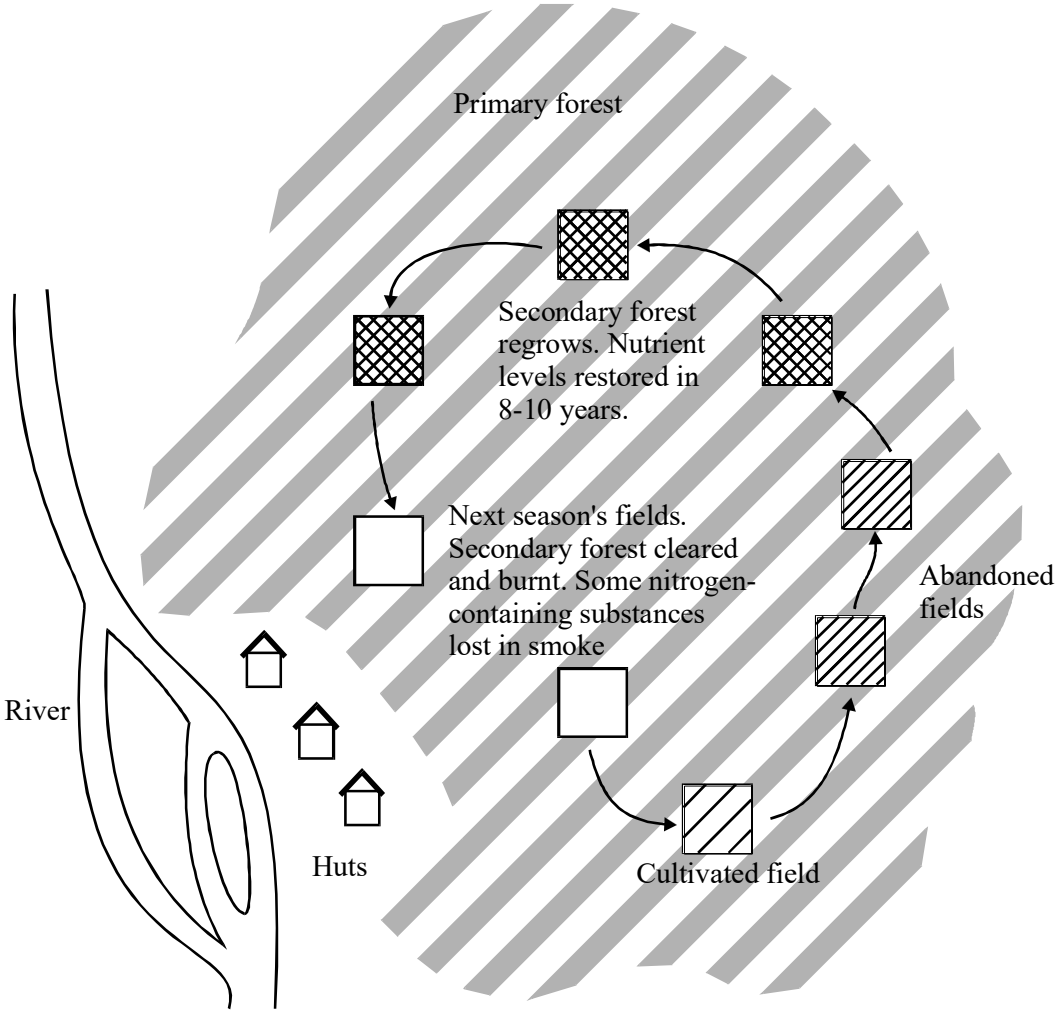
(3)

(Total 15 marks)

9. Some ways of clearing forest for agriculture are described as sustainable. The diagram shows one way in which agriculture can continue indefinitely on infertile forest soils.



(a) One way to catch flying insects is to trap them on a sticky surface.

(i) Describe how you could use sticky traps to compare the diversity of flying insects in the primary forest and in a cultivated field.

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(4)

(ii) Describe and explain how the diversity of insects in the primary forest would differ from the diversity of insects in the cultivated field.

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(4)

(b) Use your knowledge of nitrogen cycling to explain

(i) why crops can be grown in the cleared field for only two or three years;

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(2)

(ii) how the concentration of nitrates in the soil is restored 8 - 10 years after cultivation is abandoned.

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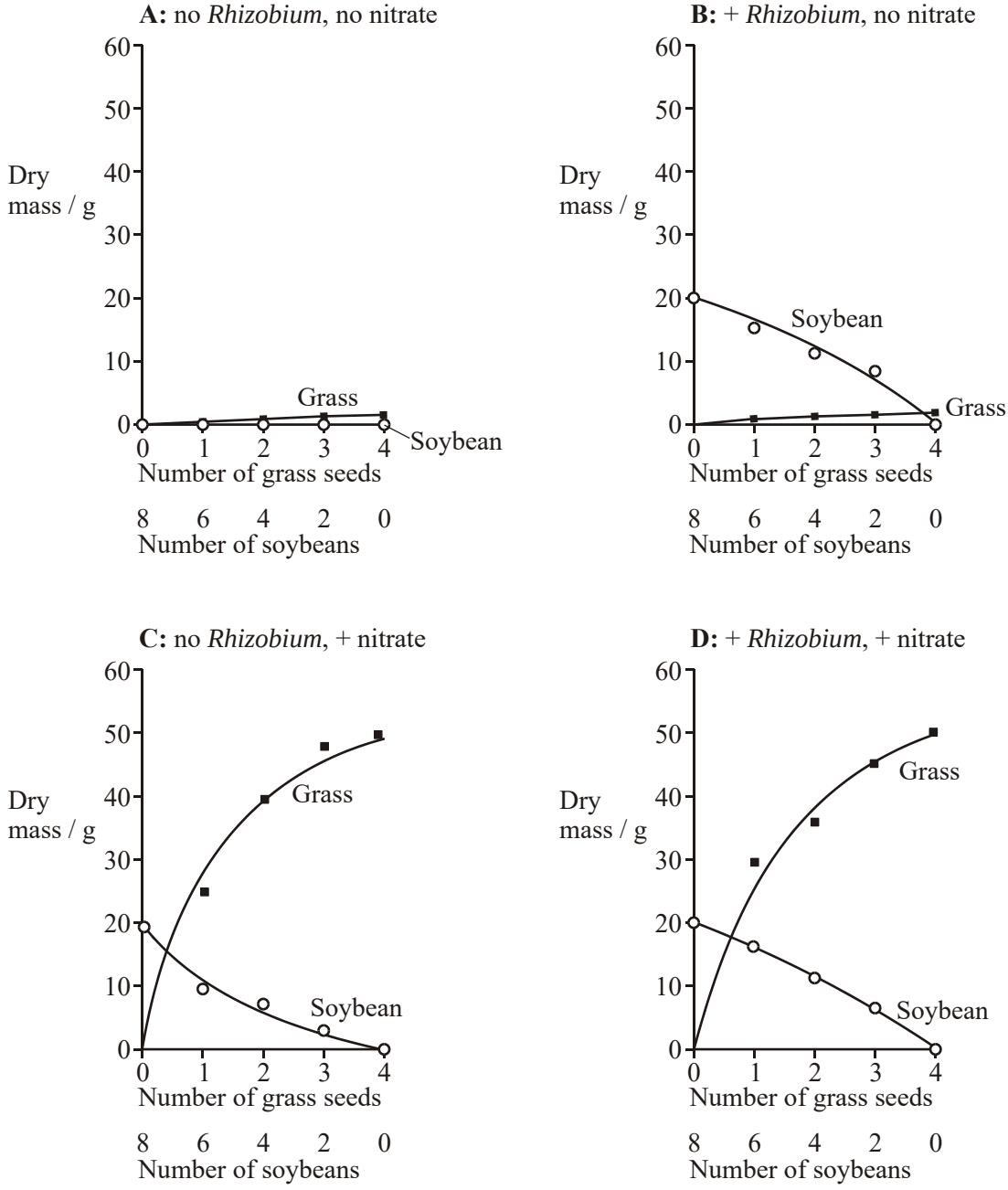
(5)
(Total 15 marks)

10. The soybean is a leguminous plant. The effect of nitrate fertiliser and of the nitrogen-fixing bacterium, *Rhizobium*, on the growth of soybeans and on the growth of one species of grass was investigated. The soybeans and grass seeds were sown together in pots of soil in five different proportions. They were then treated with different combinations of nitrate fertiliser and *Rhizobium* bacteria, as follows:

Batch **A**: no *Rhizobium*, no nitrate fertiliser
Batch **B**: *Rhizobium* added, no nitrate fertiliser
Batch **C**: no *Rhizobium*, nitrate fertiliser added
Batch **D**: *Rhizobium* added, nitrate fertiliser added

The dry masses of the soybean plants and of the grass were determined after 6 months of growth. The results are shown in the graphs.



(a) Did *Rhizobium* bacteria have any effect on the growth of the grass? Give evidence from graphs **C** and **D** for your answer.

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(1)

(b) Can the soybean make use of nitrogen supplied in the form of nitrate fertiliser? Give evidence from the graphs for your answer.

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(2)

(c) Describe and explain the effect of *Rhizobium* bacteria on the growth of soybeans.

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(3)

(Total 6 marks)

11. (a) Substances found in fallen leaves contain the elements carbon and nitrogen.
Explain how the activities of decomposers and nitrifying bacteria recycle the substances in fallen leaves for re-use by the trees.

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(7)

(b) Explain how the felling and burning of trees on a large scale could affect the concentration of carbon dioxide in the atmosphere.

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(2)

(c) Both rapidly-growing softwood trees and slow-growing hardwood trees grow in tropical rainforests. The seeds of both kinds of tree lie dormant on the floor of a mature forest and only germinate when exposed to light and warmth. However, the seedlings of many hardwood species grow more successfully beneath the protective canopy of the softwood trees.

When a small area of trees has been cut down, it can return naturally to tropical rainforest. Suggest and explain how re-establishment of the rainforest ecosystem may occur in such areas.

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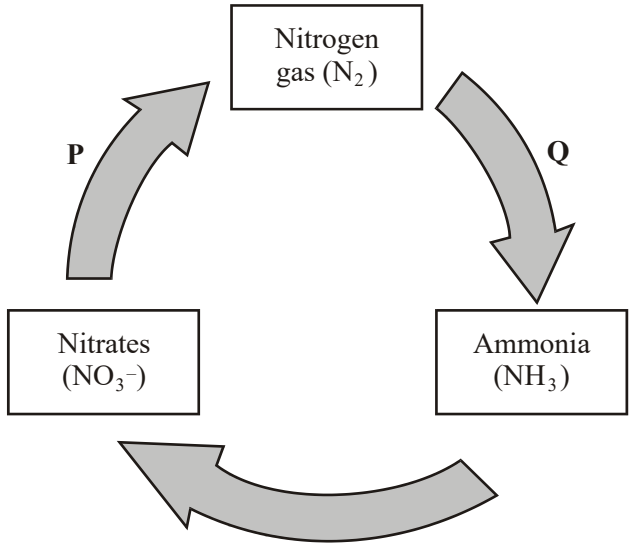
(6)
(Total 15 marks)

12. The diagram shows part of the nitrogen cycle.



(a) Name processes **P** and **Q**.

P .....

Q .....

(2)

(b) It is estimated that, each year, a total of 3×10^9 tonnes of ammonia are converted to nitrate. Only 2×10^8 tonnes of ammonia are produced from nitrogen gas. Explain the difference in these figures.

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(2)

(c) The conversion of ammonia to nitrate involves oxidation. What evidence in the diagram supports this?

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(1)

(Total 5 marks)

13. Deforestation often involves clearing large areas of forest for use as agricultural land.

(a) Deforestation reduces the diversity index of an area cleared in this way. Explain why.

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(2)

(b) Because the forest soil is often nutrient-poor, nitrogen-containing fertilisers may be applied to ensure good crop yields. Use your knowledge of the nitrogen cycle to explain the potential benefit of applying a fertiliser containing ammonium nitrate rather than one containing potassium nitrate.

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(3)

(Total 5 marks)

14. Detritivorous insects feed on the dead remains of plants. Some students estimated the numbers of detritivorous insects at two different sites in an ecosystem. They also obtained data about the net primary production of the sites to see if this influenced the numbers of insects present. Net primary production is a measure of plant biomass formed per year. The results are shown in the table.

Site	Number of insects per m^2	Net primary production / $g\ m^{-2}\ y^{-1}$
A	316	1440
B	90	550

(a) Explain how the students could use the mark-release-recapture technique to estimate the numbers of insects.

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(4)

(b) The students used the chi-squared (χ^2) test to test the hypothesis that there was no significant difference between the numbers of insects per square metre at sites **A** and **B**. The value they obtained was 125.8. They checked this value in χ^2 tables.

(i) How many degrees of freedom should they check against?

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(1)

(ii) What level of probability is normally used to judge whether a difference is statistically significant?

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(1)

(iii) The value of χ^2 for the 0.001 level of probability for this number of degrees of freedom is 10.8. What does the value obtained by the students suggest about the difference in numbers of the insects per square metre between the two sites? Explain your answer.

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(2)

(c) (i) Explain why the net primary production of an area does not represent the total amount of plant biomass formed per year by photosynthesis.

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(2)

(ii) Suggest how the difference in net primary production of sites **A** and **B** might explain the difference in the number of insects between the sites.

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(1)

(iii) Explain the role of bacteria in making carbon in dead plant remains available to plants.

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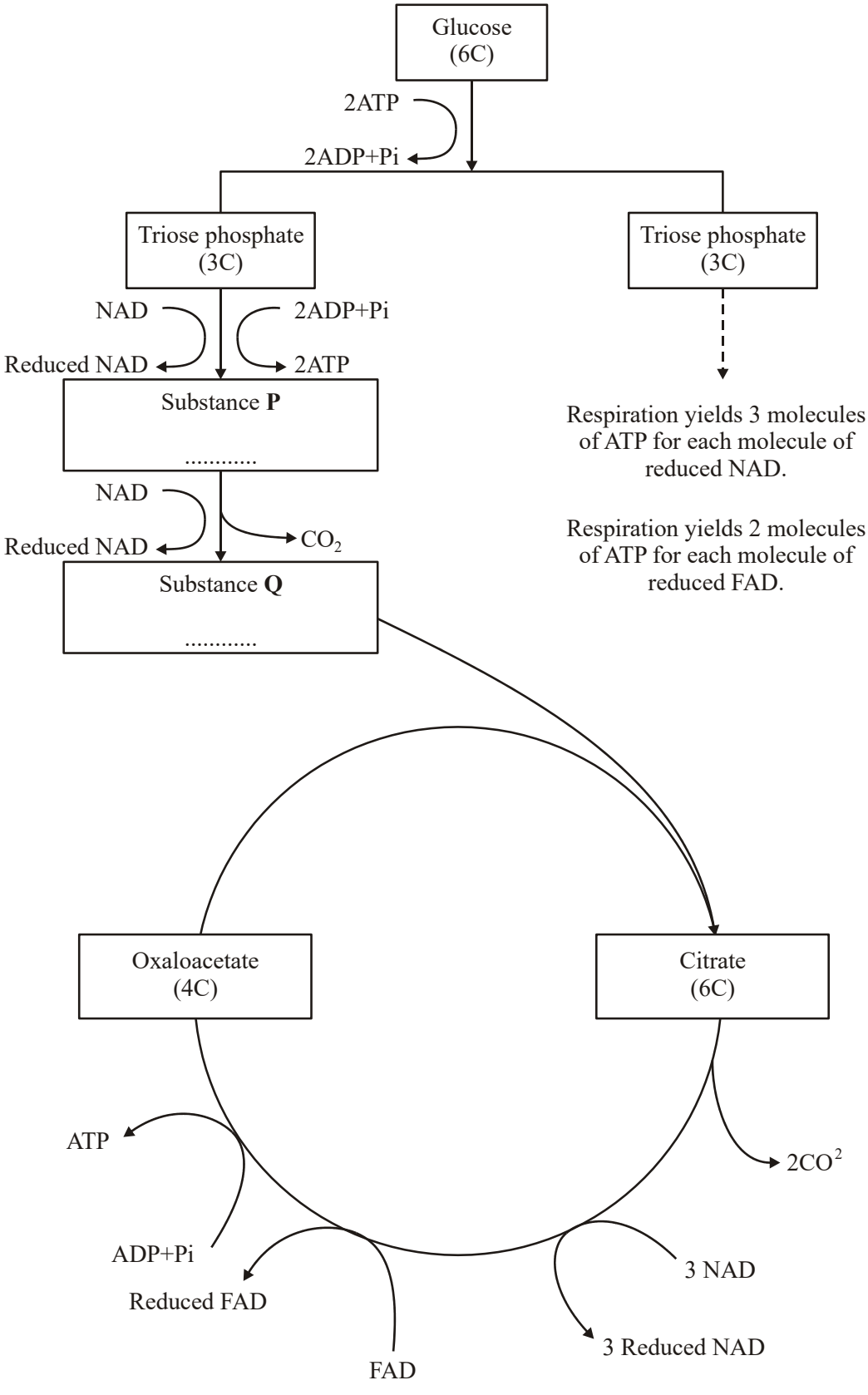
(4)
(Total 15 marks)

15. (a) The flow chart shows the main stages in aerobic respiration.



(i) Complete the flow chart by writing, in the appropriate boxes, the number of carbon atoms in substance **P** and the name of substance **Q**.

(2)

(ii) Some ATP is formed in the cytoplasm and some in the mitochondria. Use the information given to calculate the number of molecules of ATP formed in a mitochondrion from one molecule of glucose in aerobic respiration. Show how you arrived at your answer.

Answer.....

(2)

(iii) In the presence of oxygen, respiration yields more ATP per molecule of glucose than it does in the absence of oxygen. Explain why.

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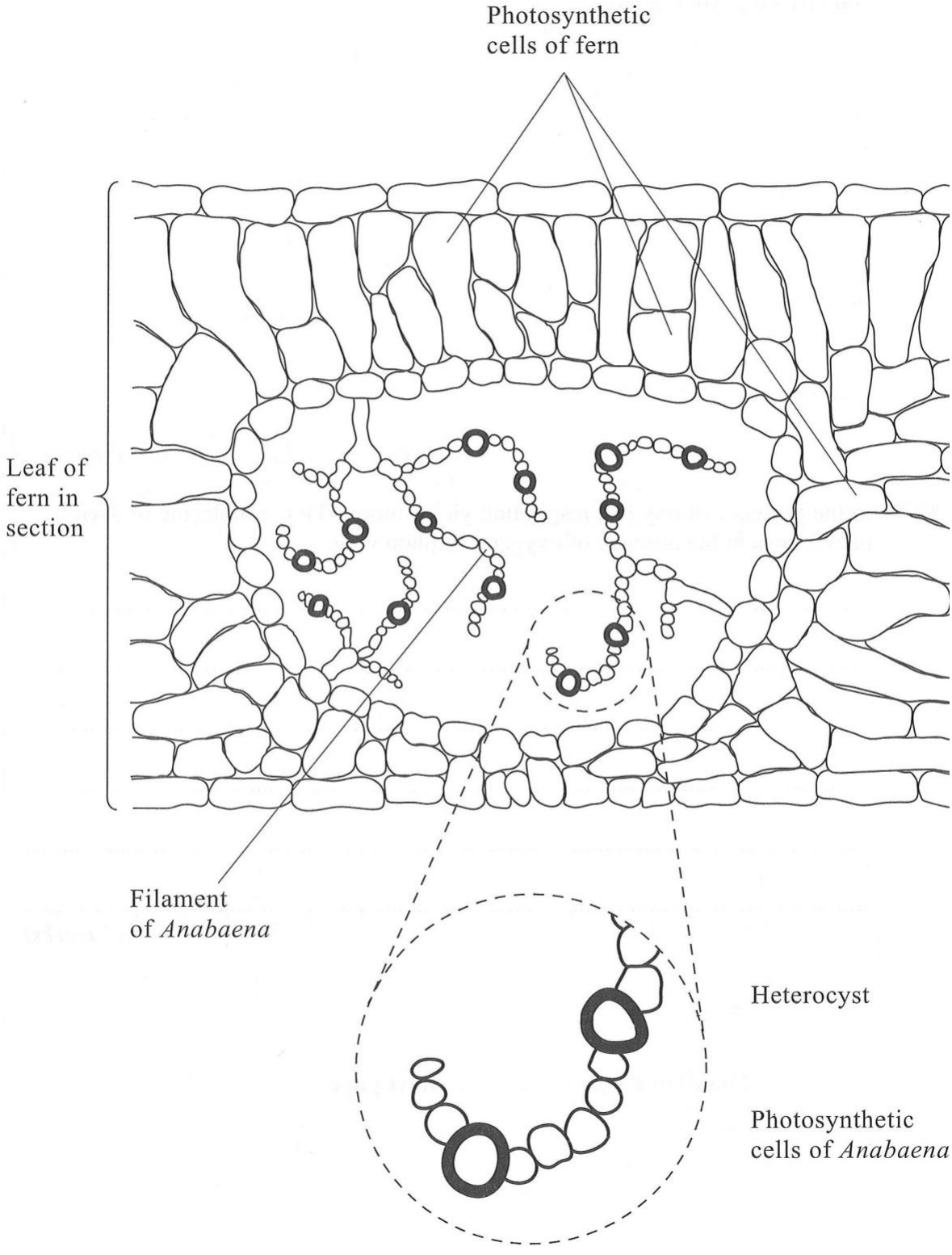
(3)

(b) *Anabaena* is a prokaryote found inside the leaves of a small fern. *Anabaena* can produce ammonia from nitrogen (nitrogen fixation). This reaction only takes place in the anaerobic conditions found in cells called heterocysts. Heterocysts are thick-walled cells that do not contain chlorophyll. The drawing shows the relationship between *Anabaena* and the fern.



(i) Suggest how the features of the heterocysts improve the efficiency of the process of nitrogen fixation.

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(3)

(ii) In China, the fern is cultivated and ploughed into fields to act as an organic fertiliser. Explain how ploughing the fern plants into the soil results in an improvement in the growth of the rice crop grown in these fields.

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(5)

(Total 15 marks)

16. In the activated sludge method of sewage treatment, organic matter in untreated sewage supplies nutrients to bacteria in the treatment tank. These bacteria include decomposers and nitrifying bacteria. The bacteria are eaten by ciliated protoctistans, which are, in turn, eaten by carnivorous protoctistans.

(a) (i) Sketch and label a pyramid of energy for the organisms found in the treatment tank.

(1)

(ii) Explain what causes this pyramid of energy to be this shape.

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(2)

(b) (i) Explain the roles of the decomposers and the nitrifying bacteria in converting nitrogen in organic compounds in the sewage into a soluble, inorganic form.

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(3)

(ii) Nitrifying bacteria are one kind of bacteria that are important in the nitrogen cycle; nitrogen-fixing bacteria are another kind. Describe the part played by nitrogen-fixing bacteria in the nitrogen cycle.

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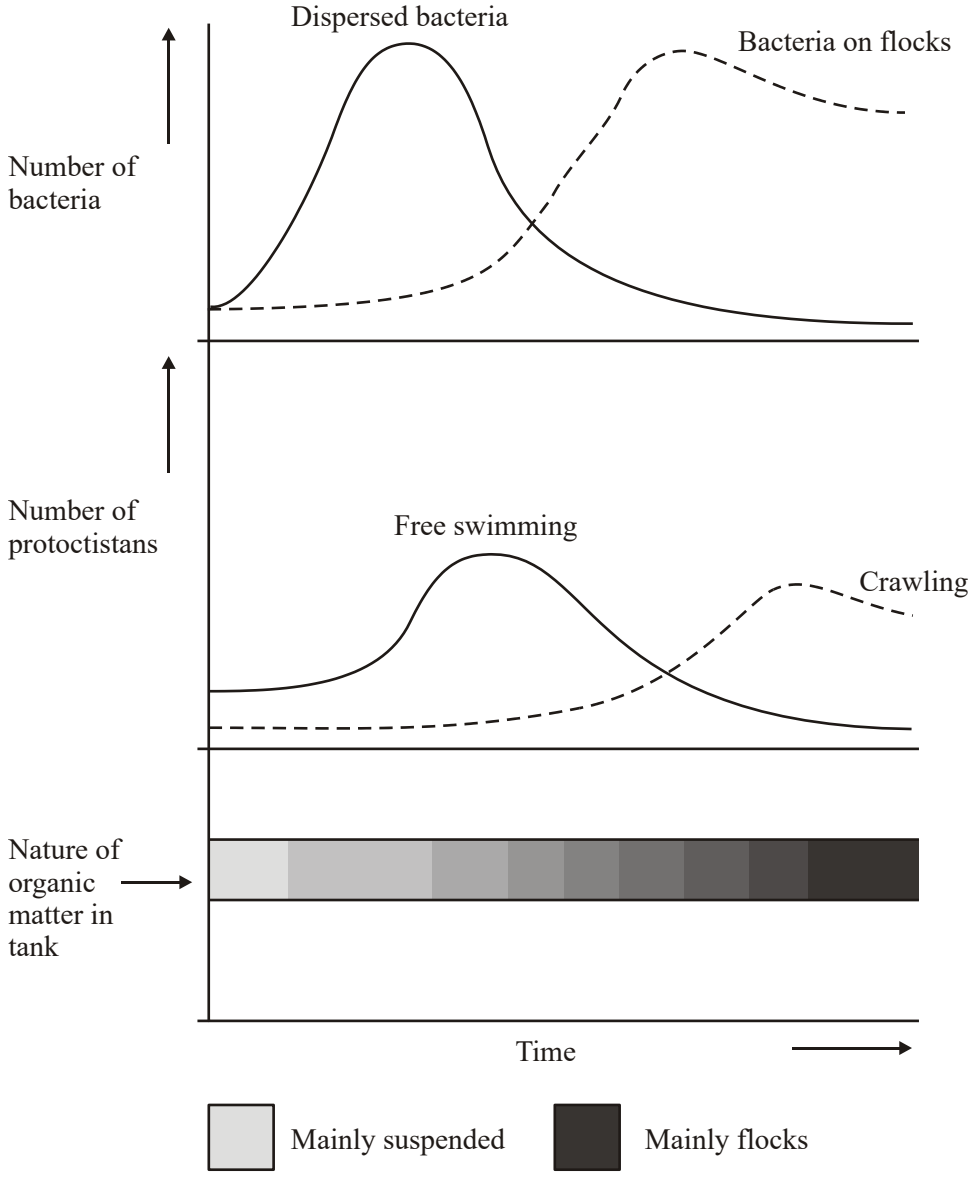
(2)

(c) The organic matter in untreated sewage consists of small particles, which are suspended in water. Activated sludge consists of solid lumps (flocs) of organic matter and bacteria. When the two are mixed in the treatment tank, bacteria from the flocs become dispersed in the water and feed on the suspended organic matter, converting it to flocs. Different types of ciliated protoctistans feed on the bacteria.

- Free-swimming protoctistans are able to move throughout the tank.
- Crawling protoctistans can only move over the surface of the flocs.

The diagram shows the change in the nature of the organic matter in the treatment tank and the changes in the numbers of the different types of organisms present.



(i) Explain the changes in the numbers of dispersed bacteria and the numbers of free-swimming protoctistans.

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(3)

(ii) Explain how the changes that occur in the treatment tank illustrate the process of succession.

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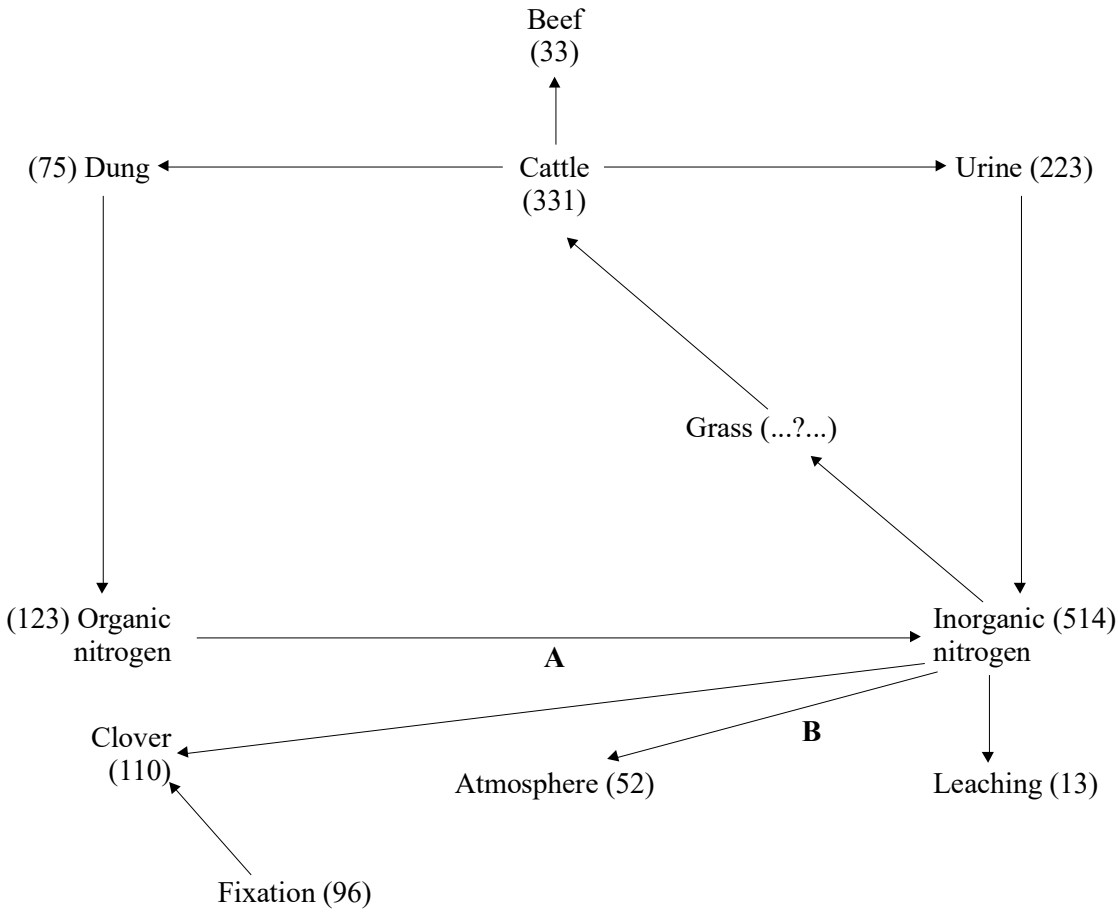
(4)

(Total 15 marks)

17. To manage grassland efficiently so that the maximum amount of beef is produced, it is important to understand how nitrogen is cycled. The diagram shows some steps in the flow of nitrogen. The figures in brackets show the approximate amount of nitrogen passing through that part of the cycle in kilograms per hectare per year.



(a) (i) Name a compound that could be classified as organic nitrogen.

.....

(1)

(ii) The annual flow of nitrogen through organic nitrogen could not have come from dung alone. Suggest another source of organic nitrogen.

.....

(1)

(b) (i) Name **one** of the types of bacteria involved in the process labelled **A**

.....

(1)

(ii) Name the type of bacteria involved in the process labelled **B**

.....

(1)

(c) From the figures given in the diagram, calculate the annual flow of nitrogen through 'grass'
Show your working.

.....

(2)

(d) Explain the advantage to cattle farmers of encouraging the growth of clover in grassland.

.....

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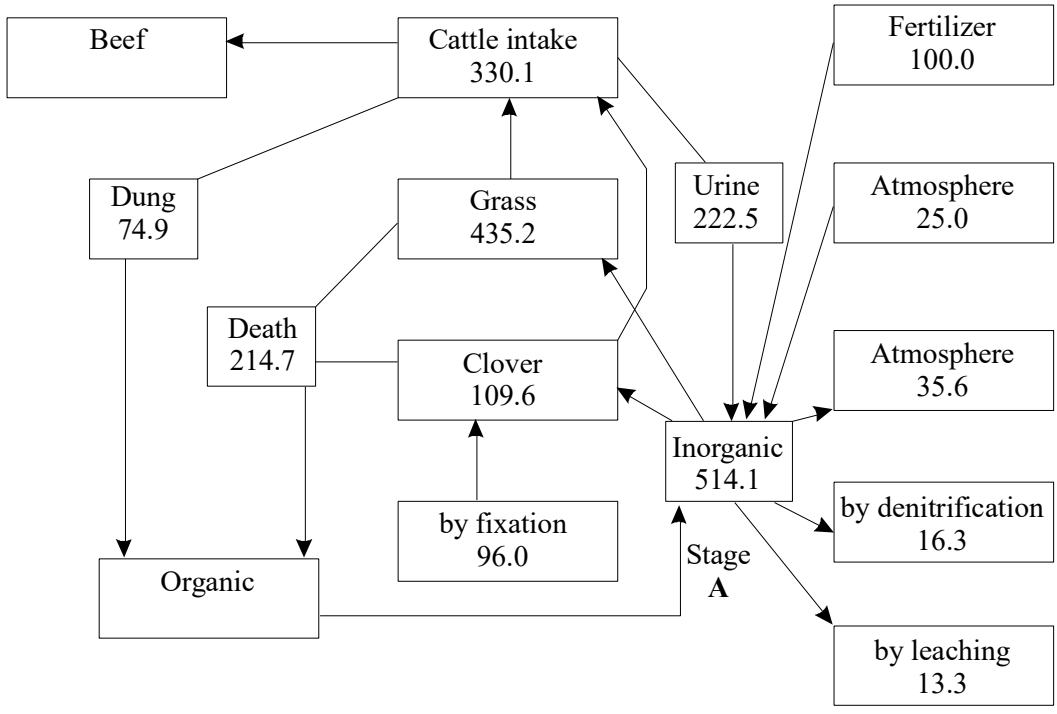
(2)
(Total 8 marks)

18. The diagram shows some of the data generated by a computer model of the nitrogen cycle for a permanent meadow on which beef cattle are raised.

The values given are in kg of nitrogen per hectare per year.



(a) (i) Calculate the mass of nitrogen incorporated into beef.

.....kg per hectare per year

(1)

(ii) What assumption did you make in calculating this figure?

.....

.....

(1)

(b) Stage **A** represents the conversion of organic nitrogen-containing compounds to inorganic compounds.

Describe the role of microorganisms in this process.

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(4)
(Total 6 marks)

19. (a) Growing the same crop over a large area year after year is known as monoculture. Explain why an outbreak of pests is more of a problem in monoculture than where a mixture of crops is grown.

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(3)

(b) (i) Insect pests have developed resistance to pesticides. If the resistance is due to a single gene, explain how resistant insects could be produced when both parents are susceptible to the pesticide.

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(3)

(ii) Other than resistance, give **two** disadvantages of using pesticides.

1 .....

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2 .....

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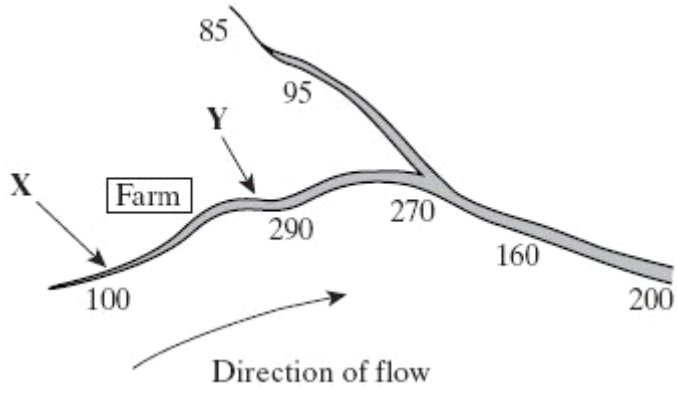
(2)

(Total 8 marks)

20. The diagram shows a river system in an area of farmland. The numbers show the nitrate concentration in parts per million (ppm) in water samples taken at various locations along the river. Concentrations above 250 ppm encourage eutrophication in the river.



(i) Explain how farming practices might be responsible for the change in nitrate concentration in the water between point **X** and point **Y**.

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(2)

(ii) Describe the effect the nitrate concentration may have in the river at point **Y**.

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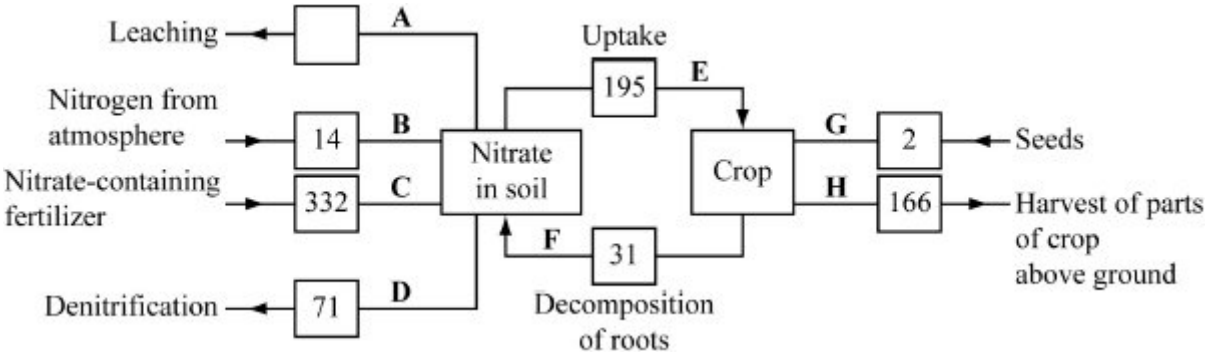
(5)
(Total 7 marks)

21. A wheat crop was grown in a field on a Dutch farm. When the wheat was harvested, all parts of the crop growing above ground were removed. The diagram shows the nitrogen cycle for this field. The figures are in kg of nitrogen per hectare per year.



(a) Give the letter of **one** pathway involving

(i) nitrifying bacteria

.....

(1)

(ii) nitrogen-fixing bacteria.

.....

(1)

(b) (i) Describe the part played by bacteria in pathway **D**.

.....

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.....

.....

(2)

(ii) This wheat crop was growing on clay soil. Clay is easily waterlogged. The figure for pathway **D** would be lower on a farm with sandy soil that does not become waterlogged. Explain why.

.....

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(2)

(c) (i) Calculate the maximum amount of nitrogen that could be leached from the soil where this crop was growing in a year.

Answer.....kg ha^{-1}

(1)

(ii) The information in the diagram could be useful to the farmer in reducing leaching. Explain **one** way in which it could be useful.

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(1)

(Total 8 marks)