

Classification + Evolution

Section Summary

Make sure you know...

- That organisms can be classified into a taxonomic hierarchy consisting of the following eight groups: domain, kingdom, phylum, class, order, family, genus, species.
- That the binomial system is used to give each organism a two part scientific (Latin) name — the first part is the name of the organism's genus and the second part is the name of its species — and that this helps to avoid the confusion of using common names.
- The defining features of the Prokaryotae, Protocista, Fungi, Plantae and Animalia kingdoms.
- That phylogeny is the study of the evolutionary history of groups of organisms (i.e. how closely related they are) and that it can be used to help classify organisms.
- That classification systems were originally based only on observable features, but that scientists now use a range of different evidence to classify organisms (including similarities in DNA base sequences and similarities in biological molecules, such as proteins).
- The similarities and differences between the 'three domain' and 'five kingdom' classification systems.

- That the three domain classification system was introduced because of new molecular evidence.
- That variation is the differences that exist between individuals and that it can occur within a species (intraspecific variation) or between species (interspecific variation).
- That continuous variation is where the individuals in a population vary within a range — there are no distinct categories.
- That discontinuous variation is where there are two or more distinct categories and each individual falls into only one of these categories.
- How to describe the differences between continuous and discontinuous variation using examples from plants, animals and microorganisms.
- That variation can be caused by genetic factors, environmental factors or a combination of both.
- How to use standard deviation to measure the amount of variation in a sample (how spread out the data is either side of the mean).
- How to use the Spearman's rank correlation coefficient to determine whether there is significant correlation between two variables.
- That an adaptation is a feature that increases an organism's chances of survival and reproduction, and also the chances of its offspring reproducing successfully.
- That adaptations can be behavioural, physiological or anatomical (structural).
- The reasons why organisms from different taxonomic groups may show similar anatomical features even though they're not closely related, including the example of marsupial moles and placental moles.
- The contributions of Charles Darwin and Alfred Russel Wallace to the theory of evolution by natural selection.
- How natural selection affects the characteristics of a population over time — including the roles of genetic variation, selection pressure and reproductive success.
- That fossil evidence, along with DNA and other molecular evidence, provides support for evolution.
- How insects evolving resistance to pesticides and microorganisms evolving resistance to drugs has implications for humans.

Classification + Evolution

- 1 The organism *Halobacterium salinarum* is classified as Archaea under the three domain system.
- (a) Fill in the blanks in the table below to show how *H. salinarum* is classified.

Domain	Archaea
Kingdom	Euryarchaeota
Phylum	Euryarchaeota
	Halobacteria
Order	Halobacteriales
	Halobacteriaceae
Species	

- (b) Under the five kingdom classification system, *H. salinarum* would have been classified as Prokaryotae. (2 marks)
- (i) Give **two** characteristics of the Prokaryotae kingdom. (2 marks)
- (ii) Explain why the three domain system does **not** contain the Prokaryotae kingdom. (2 marks)
- (iii) Give **one** similarity between the three domain classification system and the five kingdom classification system. (1 mark)

- 2 The **RuBisCO gene** is found in all plants.

When a new species of plant is being classified, this gene is often compared with the gene in other species to determine evolutionary relatedness.

- (a) Describe how a scientist could compare the RuBisCO gene in two different species of plant to determine how closely related they are. (2 marks)
- (b) Why is the RuBisCO gene useful for determining relationships between plant species? (1 mark)
- (c) The RuBisCO gene codes for an enzyme. Describe how a scientist could compare the RuBisCO enzyme in two different species of plant to determine how closely related they are. (2 marks)
- (d) Classification of plants was originally based only on observable features. Explain why taxonomists now consider other evidence when classifying plant species. (2 marks)

Classification + Evolution

- 3 **Fig. 3.1** shows the use of an anti-aphid pesticide on a farm and the number of aphids found on the farm over a period of time.

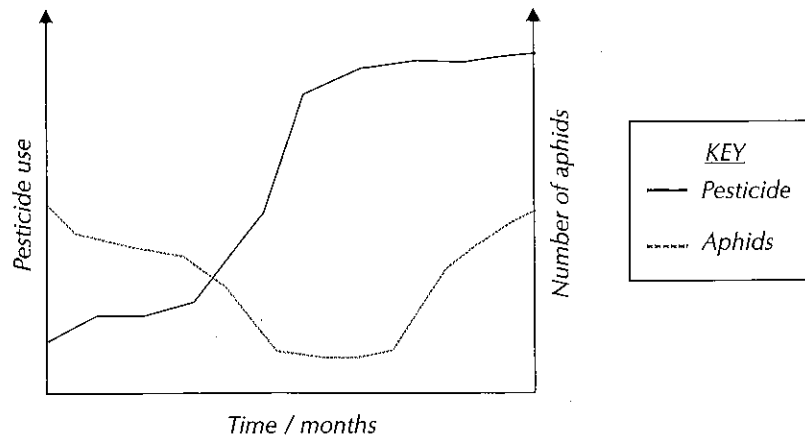


Fig. 3.1

- (a) (i) Describe the changes shown in the data in **Fig. 3.1**. (3 marks)
- (ii) Explain how the changes you described in **part i)** may have occurred. (4 marks)
- (b) Suggest **one** implication these changes may have for the farmer. (2 marks)
- 4 The bat *Anoura fistulata* has a very long tongue (up to one and a half times the length of its body). The tongue enables the bat to feed on the nectar inside a deep tubular flower found in the forests of Ecuador.
- (a) The bat's tongue is an **anatomical** adaptation to feeding on deep flowers.
- (i) What is an adaptation? (2 marks)
- (ii) Give **two** other types of adaptation an organism can have to its environment. (2 marks)
- (b) Describe how natural selection can explain the evolution of *Anoura fistulata*'s long tongue. (4 marks)
- (c) A team of biologists were trying to determine how recently *Anoura fistulata* diverged from another species of bat. Explain how molecular evidence could be used to determine how recently the species diverged from each other. (4 marks)

Classification + Evolution

1 a)

Domain	Archaea
Kingdom	Euryarchaeota
Phylum	Euryarchaeota
Class	Halobacteria
Order	Halobacteriales
Family	Halobacteriaceae
Genus	<i>Halobacterium</i>
Species	<i>salinarum</i>

(1 mark for each correct column)

- b) i) Any two from, e.g. no nucleus (1 mark) / unicellular (1 mark) / less than 5 μm (1 mark)
 ii) Under the three domain system, organisms that would be in the Prokaryotae kingdom are split into two separate domains/Archaea and Bacteria (1 mark). This is because of new evidence/molecular evidence that showed large differences between the two domains/Archaea and Bacteria (1 mark).
 iii) Any one from, e.g. the Protocista/Plantae/Fungi/Animalia kingdom is present in both systems (1 mark). / Four out of five kingdoms are present in both systems (1 mark). / The hierarchy below domain (e.g. kingdom, phylum, class, order, family, genus, species) stays the same (1 mark).

- 2 a) E.g. he/she could analyse the DNA base sequences of the genes (1 mark). The more similar the base sequences, the more closely related the plant species are likely to be (1 mark).
 b) It is present in all plants, so any two species of plant can be compared by looking at RuBisCO (1 mark).
 c) The amino acid sequences of the RuBisCO enzyme can be compared (1 mark). The more similar the amino acid sequences are, the more closely related the plant species are likely to be (1 mark).
 d) E.g. scientists don't always agree on the relative importance of different features (1 mark). Groups based solely on physical features may not show how closely related organisms are (1 mark).
- 3 a) i) At first, as the use of the pesticide increases, the number of aphids falls (1 mark). After a period of time, the number of aphids plateaus and pesticide use increases less steeply (1 mark). The number of aphids then begins to increase (1 mark).
 ii) E.g. the number of aphids fell as they were being killed by the pesticide (1 mark). Random mutations may have occurred in the aphid DNA, resulting in pesticide resistance (1 mark). Any aphids resistant to the pesticide were more likely to survive and pass on their alleles (1 mark). Over many generations, the number of aphids increased as those carrying pesticide-resistant alleles became more common (1 mark).
 b) E.g. if the aphids are resistant to lots of other pesticides as well as this one, it might take the farmer a long time to find one that works (1 mark) — in that time the entire crop could be destroyed (1 mark). / If the insects are resistant to specific pesticides, farmers might need to use broader pesticides (1 mark), which might kill beneficial insects (1 mark).
- 4 a) i) A feature of an organism that increases its chances of survival and reproduction (1 mark) and also the chances of its offspring reproducing successfully (1 mark).
 ii) behavioural (1 mark), physiological (1 mark)
 b) Individuals within the *Anoura fistulata* population showed variation in their phenotypes due to differences in their alleles (1 mark). The bats with longer tongues were more likely to survive, reproduce and pass on their alleles (1 mark). Over time the number of individuals with a longer tongue increased (1 mark). Over generations this led to evolution as the alleles that caused the longer tongue became more common in the population (1 mark).
 c) Always try to use the correct scientific language in your answers — here you should be talking about organisms passing on 'alleles', not 'features' or 'characteristics'.
 c) *Anoura fistulata*'s DNA base sequence could be compared with the other species' DNA base sequence (1 mark). Species that diverged away from each other more recently should have more similar DNA than those that diverged less recently (1 mark). Also, *Anoura fistulata*'s other molecules, such as proteins/antibodies, could be compared with the other species' proteins/antibodies (1 mark). Species that diverged away from each other more recently should also have more similar proteins/antibodies than those that diverged less recently (1 mark).

Biodiversity

- That biodiversity can be explored at the levels of habitat biodiversity (the number of different habitats in an area), species diversity (the number of different species and the abundance of each species in an area) and genetic diversity (the variation of alleles within a species or a population of a species).
- How to use sampling as a way of collecting data on biodiversity without having to count each individual organism in a habitat.
- That sampling can be random or non-random and that practical investigations can be carried out in the field by collecting random and non-random samples.
- How to carry out random sampling by using a grid and a random number generator, so that each random sample site has the same probability of being chosen.

- How to carry out non-random sampling to ensure all different areas in a habitat are sampled, including how to use systematic, opportunistic and stratified sampling.
- That species richness refers to the number of different species in an area and is measured by taking random samples of a habitat and counting the number of different species.
- That species evenness is a measure of the relative abundance of each species in an area and is measured by taking random samples of a habitat and counting the number of individuals of each different species.
- How to calculate Simpson's Index of Diversity using the formula: $D = 1 - (\sum(n/N)^2)$
- That habitats with a high Index of Diversity (a value close to 1) have a high biodiversity.
- That habitats with a low Index of Diversity (a value close to 0) are less stable and have a lower ability to cope with change, e.g. the introduction of a new predator, than areas of high biodiversity.
- That it is important to measure genetic diversity within isolated populations, e.g. zoos, rare breed populations and populations of pedigree animals.
- How to calculate genetic biodiversity using the formula: proportion of polymorphic gene loci = number of polymorphic gene loci ÷ total number of loci, and how to convert this into a percentage.
- That human population growth has affected biodiversity through habitat loss, over-exploitation, urbanisation and pollution.
- That monoculture has affected biodiversity through habitat loss, loss of local plants and animals and loss of heritage varieties.
- That climate change has affected biodiversity through changing environmental conditions.
- That maintaining biodiversity is important for ecological reasons (including protecting keystone species and maintaining genetic resources), economic reasons (including reducing soil depletion caused by continuous monoculture) and aesthetic reasons (including protecting landscapes).
- That *in situ* conservation involves protecting species in their natural habitat, whereas *ex situ* conservation involves protecting a species by moving part of a population from a threatened habitat and placing it in a new location.
- That *in situ* conservation includes establishing protected areas, such as wildlife reserves and marine conservation zones.
- That *ex situ* conservation includes breeding organisms in captivity (e.g. in zoos), then reintroducing them to the wild, and conserving organisms in botanic gardens and seed banks.
- That the Rio Convention on Biological Diversity (CBD) is an international agreement that aims to develop international strategies in the conservation of biodiversity and how to use animal and plant resources in a sustainable way.
- That the CITES (Convention on International Trade in Endangered Species) is an agreement designed to increase international cooperation in regulating trade in wild animal and plant specimens.
- That the Countryside Stewardship Scheme (CSS) is a local agreement to conserve wildlife and biodiversity by promoting specific management techniques to landowners.

Biodiversity

- 1 Domestic sheep are all members of the species *Ovis aries*. There are over 200 breeds of domestic sheep. The existence of these different breeds is an example of which type of diversity?
- A habitat diversity
 - B genetic diversity
 - C species diversity
 - D breeding diversity
- (1 mark)
- 2 A student is investigating the species diversity of insects in a 500 m² area of woodland.
- The student sampled the insect population by arranging a series of covered pitfall traps in the ground. The traps are designed so that insects fall into them while walking along the ground and are unable to escape.
- The student arranged the traps in a straight line along the edge of the woodland and left them overnight before coming back to count the insects she had caught.
- (a) Explain what is meant by the term 'species diversity'. (2 marks)
- (b) Give **two** reasons why the student did not obtain a representative sample of insects living in the woodland. (2 marks)
- (c) The student found that the woodland had a low species evenness. What does a low species evenness tell you about a habitat? (1 mark)
- (d) The student wants to compare the species diversity of insects in the woodland with the species diversity of insects on her local common. Suggest **one** thing the student must do when sampling insects on the common to ensure that her findings from both habitats are comparable. (1 mark)
- 3* Polar bears are a keystone species that play an important role in the maintenance of the Arctic ecosystem. They use the ice sheets that surround the Arctic shoreline to hunt for their main prey, seals. This helps to keep the populations of seals in check and also provides leftover food for scavengers such as the Arctic fox and Arctic birds.
- Suggest and explain the effect climate change might have on the population of polar bears and the effect this might have on the Arctic ecosystem. (6 marks)

*The quality of your response will be assessed in this question.

Biodiversity

4

A company wishes to clear part of a wood next to a town and build a new housing estate on the land. A study was conducted on the trees found in the town centre and in the wood. The results are shown in **Fig. 4.1**.

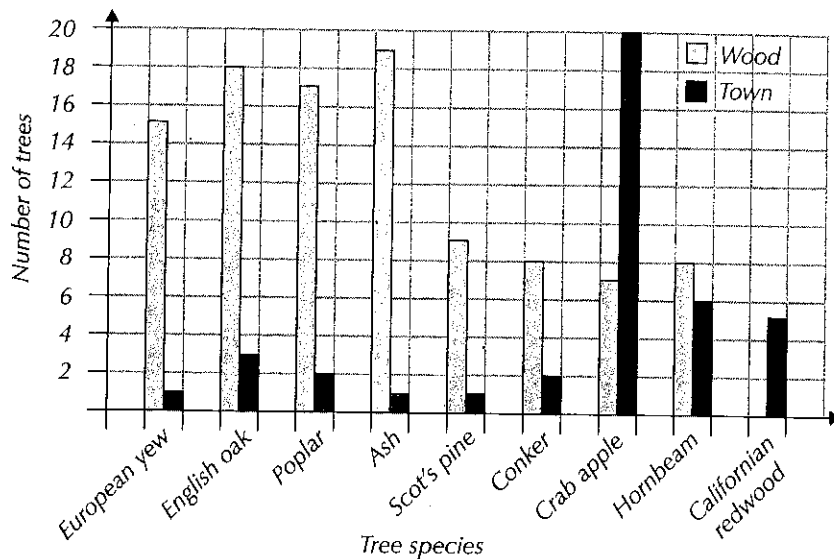


Fig. 4.1

- (a) Simpson's Index of Diversity can be calculated using the following equation:

$$D = 1 - (\sum (n/N)^2)$$

where n = Total number of organisms in one species

N = Total number of all organisms

Use the data in **Fig. 4.1** and the formula provided above to calculate Simpson's Index of Diversity for trees in the wood and in the town.

(4 marks)

- (b) Explain what your answers to part (a) tell you about the town habitat and the woodland habitat.

(2 marks)

- (c) The company discovers that the wood supports a small population of red squirrels, which are an endangered species.

Suggest **two** conservation measures that could be undertaken to protect the wood's red squirrel population if the development project goes ahead.

(2 marks)

Biodiversity

1 B (1 mark)

- 2 a) The number of different species (1 mark) and the abundance of each species in an area (1 mark).
 b) Any two from, e.g. the sample was biased/not collected at random/the sample was only collected from one area (1 mark). All the samples were collected on the same day/at the same time (1 mark). / The student's method only collected insects that live on the ground (1 mark).

- c) Any one from, e.g. that one or two species dominate the habitat (1 mark). / That insect diversity is low (1 mark).
 d) E.g. use the same sampling method/set up the pitfall traps in the same way (1 mark).

3 5-6 marks:

The answer gives a detailed explanation of how climate change may affect the population of polar bears and makes several suggestions as to how, due to their role as a keystone species, this will affect the Arctic ecosystem. The answer has a clear and logical structure. The information given is relevant and detailed.

3-4 marks:

The answer describes how climate change may affect the population of polar bears and makes one or two suggestions as to how this might have a knock on effect on the Arctic ecosystem.

Most of the information given is relevant and there is some detail involved.

1-2 marks:

The answer suggests how climate change may affect the polar bears. An effect this may have on other Arctic organisms may be mentioned.

The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.

0 marks:

No relevant information is given.

Here are some points your answer may include:

Climate change includes global warming (the increasing global average temperature), which could cause the ice sheets to melt. This could reduce the overall area of the ice sheets/break up the ice sheets, leaving the polar bears a smaller area in which to hunt. This could make it harder for the bears to find food as a result. The lack of food could lead to a decrease in the number of polar bears/a change in their distribution. A decrease in the number of polar bears could mean fewer seals are eaten, causing the seal population to increase. This could have knock-on effects for the populations of organisms eaten by the seals. A decrease in the population of polar bears may also reduce the amount of food available for scavengers such as the Arctic fox and Arctic birds. These scavenger populations may also decrease as a result.

4 a) Wood

$$D = 1 - \left(\left(\frac{15}{101} \right)^2 + \left(\frac{18}{101} \right)^2 + \left(\frac{17}{101} \right)^2 + \left(\frac{19}{101} \right)^2 + \left(\frac{9}{101} \right)^2 + \left(\frac{8}{101} \right)^2 + \left(\frac{7}{101} \right)^2 + \left(\frac{8}{101} \right)^2 + \left(\frac{0}{101} \right)^2 \right)$$

$$= 0.857 \text{ (3 s.f.)}$$

(2 marks for the correct answer, 1 mark for evidence of the correct calculation.)

Town

$$D = 1 - \left(\left(\frac{1}{41} \right)^2 + \left(\frac{3}{41} \right)^2 + \left(\frac{2}{41} \right)^2 + \left(\frac{1}{41} \right)^2 + \left(\frac{1}{41} \right)^2 + \left(\frac{2}{41} \right)^2 + \left(\frac{20}{41} \right)^2 + \left(\frac{6}{41} \right)^2 + \left(\frac{5}{41} \right)^2 \right)$$

$$= 0.714 \text{ (3 s.f.)}$$

(2 marks for the correct answer, 1 mark for evidence of the correct calculation.)

- b) Both areas have a relatively high index of diversity/an index of biodiversity close to 1 (1 mark). This means that both areas have a relatively high biodiversity and so are likely to be fairly stable habitats that are able to withstand change (1 mark).

- c) Any two from: e.g. the red squirrels could be relocated to a safer area. / The red squirrels could be bred in captivity and reintroduced into the wild elsewhere. / The remaining woodland could be made a protected area. (1 mark for each correct answer up to a maximum of 2 marks.)

There are lots of possible right answers here — just apply your scientific knowledge to the situation and make two sensible suggestions.

Communicable Diseases

Make sure you know...

- That a pathogen is an organism that can cause disease.
- That a communicable disease is a disease that can be spread between organisms.
- About the following communicable diseases (including the organisms they are caused by):
 - Tuberculosis, bacterial meningitis and ring rot are caused by bacteria.
 - HIV/AIDS, influenza and tobacco mosaic virus are caused by viruses.
 - Black sigatoka, ring worm and athlete's foot are caused by fungi.
 - Malaria and potato/tomato late blight are caused by protozoists.
- How communicable diseases can be transferred between organisms by direct transmission (directly from one organism to another) or indirect transmission (from one organism to another via an intermediate, such as spores or a vector).
- How transmission of pathogens can be affected by living conditions, climate and social factors.
- The primary non-specific defences against pathogens in animals, including the skin, mucous membranes, blood clotting, inflammation, wound repair and expulsive reflexes.
- The primary non-specific defences against pathogens in plants, including waxy cuticles, cell walls and callose deposition (physical barriers) and the production of chemicals (against pathogens and vectors).
- The structure of phagocytes and the process of phagocytosis (engulfment of pathogens).
- The roles of opsonins, phagosomes, lysosomes, antigen-presenting cells (APCs), neutrophils and cytokines in phagocytosis.
- The structure of T lymphocytes, how they are activated (clonal selection) and divide to produce clones (clonal expansion), and the roles of different types — T helper cells, T killer cells and T regulatory cells in an immune response.
- The structure of B lymphocytes, and how they are activated and divide to produce plasma cells and memory cells.
- That cells communicate by signalling using substances such as interleukins.
- How to examine and draw cells observed in blood smears.
- The structure of antibodies (proteins that bind to antigens), including constant and variable regions.
- How antibodies clear infections by agglutinating pathogens, neutralising toxins and preventing pathogens from binding to cells.
- What the primary immune response and secondary immune response are and how they work, including the role of memory cells in secondary immune responses.
- The similarities and differences between active, passive, natural and artificial immunity, including examples of each type of immunity.
- What an 'autoimmune disease' is and a named example of one (e.g. lupus or rheumatoid arthritis).
- How vaccines make people immune to disease by stimulating memory cell production.
- The role of vaccines in preventing epidemics, by creating herd immunity.
- What routine vaccinations are and why vaccines or vaccination programmes may change.
- The benefits (reducing death rates from bacterial disease) and risks (side effects, allergic reactions and increasing antibiotic resistance) of using antibiotics to manage bacterial infection.
- That widespread use of antibiotics began in the mid-20th century, following the discovery of penicillin.
- How bacteria develop antibiotic resistance by natural selection, including *Clostridium difficile* and MRSA as examples of antibiotic-resistant bacteria.
- Possible sources for medicines, including microorganisms and plants.
- Why it's important, in terms of drug development, to maintain biodiversity.
- What personalised medicine and synthetic biology are, and their potential in the future.

Communicable Diseases

1 Which of the communicable diseases below is caused by a fungus?

- A malaria
- B tomato late blight
- C ring rot
- D ringworm

(1 mark)

2 Tuberculosis (TB) is an infectious disease. More than one million people worldwide die from tuberculosis every year.

(a) Identify the type of pathogen that causes TB.

(1 mark)

(b) Fig. 1.1 shows the number of reported cases of TB in the UK between 2000 and 2009.

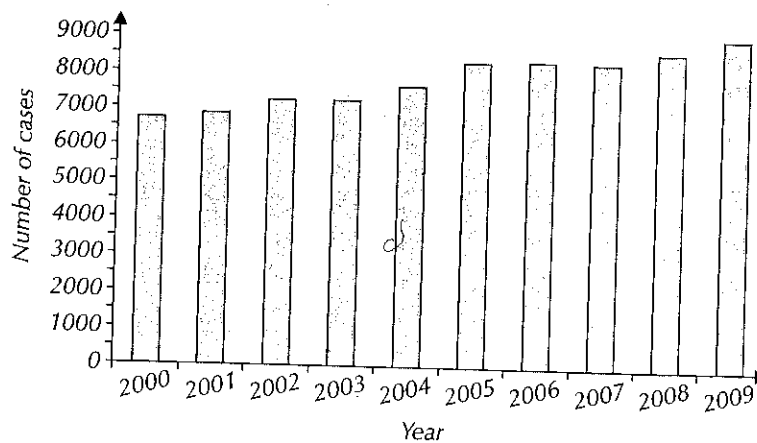


Fig. 1.1

(i) Describe the trend in the number of reported TB cases in the UK between 2000 and 2009.

(1 mark)

(ii) Calculate the approximate percentage increase in the number of cases of reported TB in the UK between 2003 and 2009. Show your working.

(2 marks)

(iii) A newspaper headline states that "The number of TB cases in England is predicted to rise by 33% by the year 2018". Discuss this claim using the information in the graph.

(3 marks)

Communicable Diseases

- 3 In 1918 there was a worldwide outbreak of influenza called 'Spanish flu'. The virus responsible was the **H1N1** strain — it had type 1 haemagglutinin (H1) and type 1 neuraminidase (N1) antigens on its surface.
- (a) When someone is infected with Spanish flu their immune system responds. The first stage of this response involves the phagocytosis of virus particles.
- (i)* Describe the sequence of steps in phagocytosis. (6 marks)
- (ii) What is the role of opsonins in phagocytosis? (1 mark)
- (iii) Outline the main stages of the immune response after phagocytosis. (5 marks)
- (b) Spanish flu circulated the globe for over a year. Explain why survivors of the Spanish flu did not contract it when exposed for a second time. (2 marks)
- (c) In 1957 there was another outbreak of influenza called 'Asian flu'. It was caused by the **H2N2** strain of influenza. Explain why survivors of the Spanish flu may have contracted Asian flu. (3 marks)
- (d) Every year new flu vaccines are developed. These contain antigens to multiple strains of influenza. Suggest why this is the case. (1 mark)

- 4 Diphtheria is an infectious disease caused by a pathogenic species of bacteria. Cases of diphtheria are now very rare since the introduction of a vaccination in the early 1940s.
- (a) (i) Explain how having a vaccination leads to the formation of memory B lymphocytes. (3 marks)
- (ii) Explain why individuals who don't have a particular vaccine will still gain some protection from the introduction of the vaccine. (3 marks)
- (b) Memory B lymphocytes differentiate into plasma cells which produce antibodies.
- (i) Name the **three** main regions of an antibody and give the function of each region. (3 marks)
- (ii) Tick the boxes to show which **three** of the following are functions of antibodies.

Agglutinating pathogens	Activating memory T lymphocytes	
Killing pathogens directly	Mutating pathogen DNA	
Neutralising toxins	Stopping pathogens binding to cells	

(3 marks)

*The quality of your response will be assessed in this question.

Communicable Diseases

1 D (1 mark)

Malaria and tomato late blight are caused by a protoctist and ring rot is caused by a bacterium.

2 a) a bacterium (1 mark)

b) i) The number of reported TB cases in the UK increased overall, from about 6750 cases in 2000 to about 9000 cases in 2009 (1 mark).

ii) $9000 - 7250 = 1750$

$(1750 \div 7250) \times 100$ (1 mark) = 24.1% (1 mark)

iii) E.g. although the number of TB cases has risen by about 33% between 2000 and 2009, it doesn't necessarily mean this trend will continue (1 mark). The graph shows the number of reported cases of TB, but the newspaper refers to the number of cases of TB — it may be that the reason for the increasing trend is just because more cases of TB are being reported (i.e. there's not an increase in overall number of cases) (1 mark). The graph shows the number of reported cases of TB in the UK but the newspaper refers to the number of cases of TB in England, so this prediction doesn't fit the data shown in the graph (1 mark).

Always read questions carefully — the introduction mentions that the graph shows the number of reported cases of TB in the UK. You'll miss this if you skim over the introduction and look at the graph first.

3 a) i) 5-6 marks:

All of the stages of phagocytosis are described thoroughly and in the correct order.

The answer has a clear and logical structure.

The information given is relevant and detailed.

3-4 marks:

Some of the stages of phagocytosis are described and most of them are in order, but the answer is incomplete.

The answer has some structure. Most of the information given is relevant and there is some detail involved.

1-2 marks:

A few stages of phagocytosis are described briefly and not necessarily in the correct order.

The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.

0 marks:

No relevant information is given.

Here are some points your answer may include:

When a phagocyte recognises the antigens on a pathogen, the cytoplasm of the phagocyte moves around the pathogen, engulfing it. This may be made easier by the presence of opsonins — molecules in the blood that attach to foreign antigens to aid phagocytosis. The engulfed pathogen is contained in a phagosome inside the phagocyte. A lysosome fuses with the phagosome and the lysosomal enzymes from the lysosome break down the pathogen.

The phagocyte acts as an antigen-presenting cell by presenting the pathogen's antigens on its surface, in order to activate other immune system cells.

ii) They aid phagocytosis by attaching to foreign antigens (1 mark).

iii) Receptors on the surface of T lymphocytes bind to the antigens presented by phagocytes, activating the T lymphocytes (1 mark). When B lymphocytes, which are covered in antibodies, meet an antigen with a complementary shape they bind to it (1 mark). This, along with substances released from T lymphocytes/T helper cells, activates the B lymphocytes (1 mark). The B lymphocytes then divide into plasma cells (1 mark). The plasma cells then produce antibodies specific to the antigen (1 mark).

b) After the first infection their B lymphocytes and T lymphocytes produced memory cells (1 mark). When they were exposed for a second time these memory cells divided into plasma cells and the correct type of T lymphocytes to quickly destroy the virus (1 mark).

c) The neuraminidase and haemagglutinin antigens on the Asian flu strain were different from the antigens on the Spanish flu strain (1 mark), so any memory cells created against H1N1 would not detect H2N2 (1 mark). So the immune system would have to start from scratch and carry out a primary immune response if exposed to Asian flu (1 mark).

Make sure you use scientific terminology in your answer, e.g. 'antigens' and 'primary immune response'.

d) To make people immune to more than one strain of flu (1 mark).

4 a) i) Vaccines contain antigens (1 mark) which activate T lymphocytes (1 mark). The antigens and T lymphocytes activate B lymphocytes, some of which differentiate into memory B lymphocytes (1 mark).

ii) They will benefit from herd immunity (1 mark). If most people in a community are vaccinated the disease becomes extremely rare (1 mark). This means people who haven't been vaccinated are less likely to get the disease because there's no one to catch it from (1 mark).

b) i) Variable region — forms the antigen-binding site (1 mark).
Hinge region — allows flexibility when the antibody binds an antigen (1 mark).
Constant region — allows binding to receptors on immune system cells (1 mark).

ii)

Agglutinating pathogens	✓
Killing pathogens directly	
Neutralising toxins	✓
Activating memory T lymphocytes	
Mutating pathogen DNA	
Stopping pathogens binding cells	✓

(1 mark for each correct answer, if more than three boxes are ticked remove 1 mark for each incorrect answer.)