Area of study 2 – Change over time

Section A (Multiple-choice questions)

Question 2.1

Members of the same species are

A. genetically identical.
B. always similar in appearance.
C. able to reproduce.
D. able to produce vigorous, fertile offspring.

Use the following information to answer Questions 2.2 and 2.3.

Two populations of frogs are separated by an area of dry ground. Both populations are quite distinctive. No individuals are present that show features of both populations.

Question 2.2

It is reasonable to assume that

A. the two populations are the same species.
B. the two populations are two separate species.
C. gene flow has occurred.
D. the two populations could be the same species.

Question 2.3

As there are no organisms that resemble both populations, it is reasonable to assume that

A. the selective pressures would be the same for both populations.
B. this is an example of allopatric speciation.
C. the differences are due to genetic drift.
D. the area of dry ground was not a physical barrier.

Question 2.4

An example of genetic drift is

A. the interbreeding of two populations.
B. the loss of an allele from a population by chance.
C. the sum of all variation in a population.
D. the phenotypic ratios in a population.

Question 2.5

A gene pool is

A. the interbreeding of two populations.
B. the loss of an allele from a population by chance.
C. the sum of all genetic make-up in a population.
D. the phenotypic ratios in a population.

Question 2.6

Gene flow is

A. the interbreeding of two populations.
B. the loss of an allele from a population by chance.
C. the sum of all variation in a population.
D. the phenotypic ratios in a population.

Question 2.7

An example of gene flow is

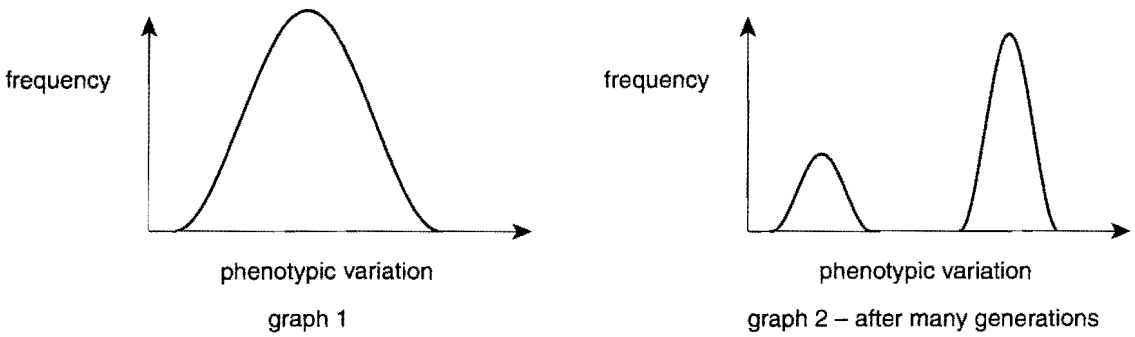
A. the arrival of a mainland species of bird to an offshore island.
B. the interbreeding of two species.
C. the loss of a particular feature from a population.
D. two distinct populations producing members with composite features.

Question 2.8

Organisms which are best suited to a particular environment

A. are able to change to suit their environment.
B. live longer than other members of that species.
C. contribute more offspring to the population.
D. are those that survive in the face of change.

Question 2.9.



The process which brought about the change illustrated by the above graphs is

A. geographic isolation.
B. mutation.
C. evolution.
D. natural selection.

Evidence for biological evolution and determination of evolutionary relationships

Question 2.10

An example of a fossil is

A. the impression of a rain drop preserved in rock.
B. an insect trapped in amber.
C. a bone found in rock, e.g. granite.
D. a cast of a worm's burrow.

Question 2.11

A suitable sediment required for fossilisation is

A. lava.
B. silt.
C. rock.
D. water.

Question 2.12

The mitochondrial DNA of a person comes from

A. the cytoplasm of both the ovum and sperm.
B. the ovum.
C. the sperm.
D. either the ovum or the sperm.

Question 2.13

Consider a family with two children: one boy and one girl. The mitochondrial DNA would be the same for the

A. mother and daughter only.
B. parents only.
C. father and both children.
D. mother and both children.

Patterns of biological change

Question 2.14

Allopatric speciation could be due to

A. a temporary physical barrier such as a flooded river plain, separating a population.
B. different behaviour patterns within a species, such as nocturnal or diurnal behaviour.
C. different mating calls within a population.
D. physical separation of a population, such as by a mountain range.

Question 2.15

Evidence of convergent evolution is the production of similar structures in two unrelated species. These structures are

A. polymorphic.
B. analogous.
C. homologous.
D. heterozygous.

Question 2.16

A source of variation which occurs in both humans and viruses is

A. sexual reproduction.
B. mutation.
C. non-disjunction.
D. crossing-over.

Question 2.17

Kangaroos and wallabies are classified as different species. They share a recent common ancestor.
The term which best describes the development of these species is

A. adaptive radiation.
B. genetic drift.
C. convergent evolution.
D. natural selection.

Hominin evolution and intervention

Question 2.18

A feature that hominins and primates share is

A. bipedal stance and gait.
B. a parabolic jaw.
C. culture.
D. opposable digits.

Question 2.19

A hominoid fossil was found and its age was estimated to be 2 million years old.
The method which could be used to determine the absolute age of the fossil would be

A. stratigraphic correlation.
B. radiocarbon dating.
C. PCR.
D. radioisotopic dating, e.g. using strontium.

Question 2.20

Homo neanderthalensis lived in Europe and western Asia between a quarter of a million years and 30 000 years ago.

If fossil remains of this species were compared to *Homo sapiens* it would be expected that *Homo sapiens* would have a relatively

A. larger brain.
B. more extensive parabolic jaw.
C. less prominent brow ridge.
D. broader jaw.

Question 2.21

An example of cultural evolution is

A. the decrease in body hair of humans.
B. different foods available in Australia compared to 50 years ago.
C. the ability of chimpanzees to problem-solve.
D. physical differences between human races.

Question 2.22

When an isolated group of organisms colonising a new area, has a disproportionate allele frequency compared to the greater population, this is an example of

A. genetic drift.
B. the founder effect.
C. gene flow.
D. allopatric speciation.

Question 2.23

The domestication of cattle is an example of

A. natural selection.
B. artificial selection.
C. genetic drift.
D. gene flow.

Section B (Short-answer questions)

Changing allele frequencies

Question 2.1

Electrophoresis has been used to examine the genetic variability in populations of cheetahs. The variability is very low when compared with most populations of other mammals. If you were to select two individual cheetahs at random, you are likely to find that they are genetically very similar.

a. What is genetic variability?

1 mark

b. Explain the significance of gene flow between populations of the same species on

i. the gene pools of each population.

ii. genetic variability within those populations.

1 + 1 = 2 marks

c. What impact would low genetic variability in a population such as the cheetah have on the species' survival?

2 marks

d. Suggest one practice that could be adopted by captive breeding programmes at zoos and fauna reserves to minimise low genetic variability in populations.

1 marks
Total 6 marks

Selection pressures and natural selection

Question 2.2

Enterococci are found naturally in the digestive tract of humans and other animals. Sometimes they are **pa**thogenic, e.g. they may cause infections in wounds, especially after surgery. They are naturally resistant to **ma**ny commonly used antibiotics and are treated with other antibiotics such as vancomycin. The problem is **tha**t some *Enterococci* such as *E. faecium* are also resistant to vancomycin. A number of vancomycin-**re**sistant *Enterococci* (VRE) have been found in patients in Australian hospitals during the last three years. **Th**ree strains of *E. faecium* resistant to vancomycin were found at a hospital in Newcastle (Australia) in 1996. **VR**E have been found in the USA since the late 1980s and more recently in European countries such as **Ge**rmany, Britain and Denmark.

a. Why is it a problem that *E. faecium* is resistant to vancomycin?

1 mark

In the USA, oral vancomycin is widely used for the treatment of infections such as *Clostridium difficile* colitis. Only severe cases are treated with this antibiotic in Australia. In Germany, Britain and Denmark, VRE have been found in pig and poultry (live and prepared meat) which have been farmed intensively and have been given a growth-promoting antibiotic which is chemically similar to vancomycin. This growth-promoting antibiotic is not used in the USA but has been used in Australia for many years. Experiments in Germany have shown that the strains of VRE in humans are different to those in other animals.

b. **i.** VRE might have been transmitted to the human gut via the food chain. State two pieces of evidence from the article which do not support this finding.

ii. What is the most likely reason for the emergence of VRE in the USA?

iii. Would your answer to **b. ii.** also explain the emergence of VRE in Australia? Explain and outline an alternative hypothesis if necessary.

2 + 1 + 2 = 5 marks

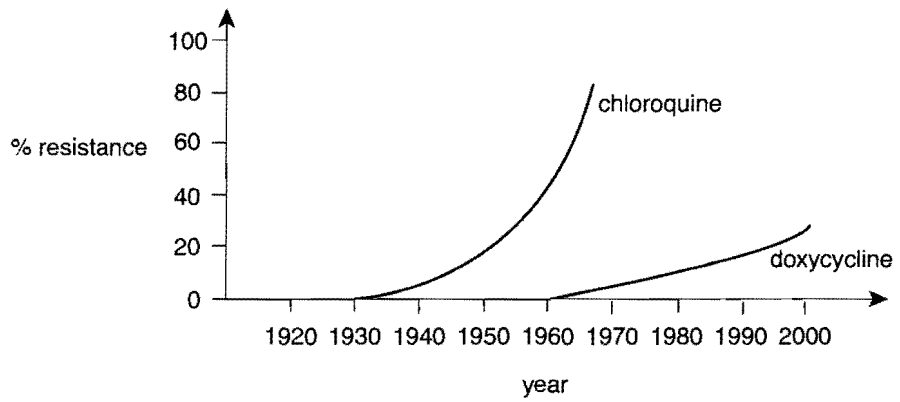
c. Outline the important steps occurring in natural selection that would increase the proportion of vancomycin-resistant *E. faecium* in the USA.

4 marks

Total 10 marks

Question 2.3

Malaria is a very common disease affecting many people in tropical areas of the world. Treatment of the disease is not easy, and it is far better to prevent the contraction of the disease by using readily-available drugs. Travellers to these particular areas take a course of tablets prior to visiting. Ongoing research has shown an increase in the incidence of malaria. Investigation of two of the more commonly used drugs, chloroquine and doxycycline, showed that the incidence of resistance to these drugs was increasing. The graph below shows the percentage of malaria parasites sampled that were resistant to each of these drugs.



a. What is the biological term that describes the change in resistance?

1 mark

b. **i.** What is the process that brought about this change?

ii. Explain how this change has been brought about.

1 + 4 = 5 marks

c. In many areas chloroquine is no longer prescribed to travellers.

Complete the graph for chloroquine for the years 1967 to 2000, and explain the reason for your answer.

2 marks

Total 8 marks

Question 2.4

In many species of animals, the members of each sex can be distinguished from each other by characteristics that are not directly related to their survival, gamete transfer or raising of their young. Examples of this include the different colours and tail feathers of peacocks and peahens, the larger build of a bull compared to a cow and the growth of antlers on male deer but not on female deer. This difference between the sexes of the same species is called sexual dimorphism.

a. In most cases it is the male that is more conspicuous, either in size, colour or with attachments such as antlers.

What advantage is gained by the male being more conspicuous than the female?

2 marks

b. **i.** Charles Darwin called this process sexual selection.

What would be the selective pressure in this situation? Explain.

ii. Is this a form of natural selection? Explain.

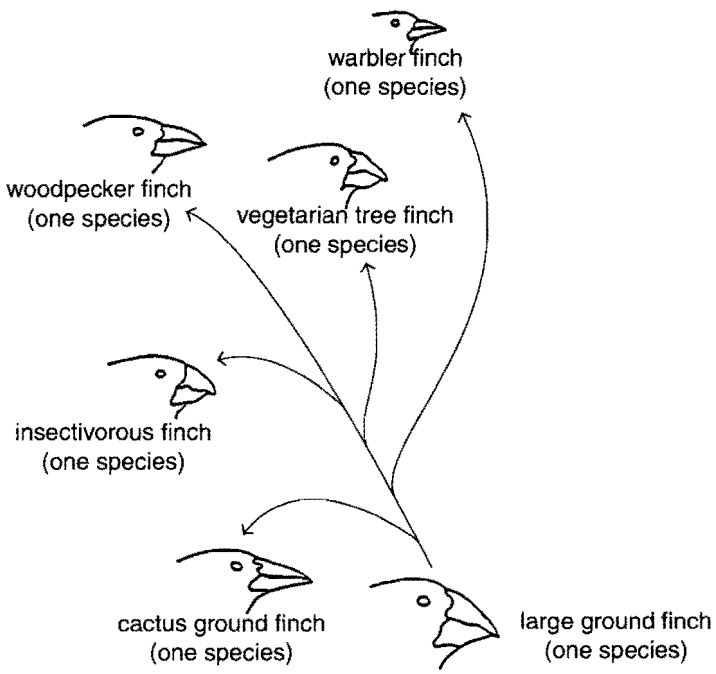
iii. Would these features of the males remain constant over generations? Explain.

iv. The term used by Darwin to describe the differences is sexual dimorphism.

Does this situation exist in humans? Explain.

2 + 2 + 2 + 2 = 8 marks
Total 10 marks

Question 2.5



The finches live on different islands, but are thought to have evolved from a common mainland ancestor. The species on each island are suited to the type of food present.

a. Would you expect the finches to be able to interbreed and produce viable offspring? Explain.

2 marks

b. What type of evolution is illustrated here?

1 mark

c. Is this an example of allopatric speciation? Explain.

2 marks

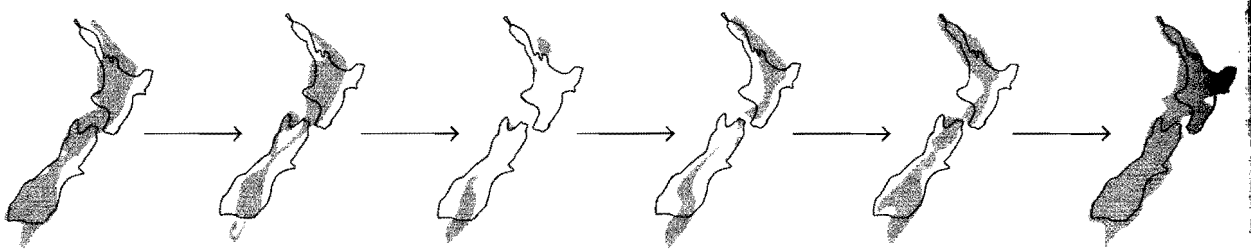
d. What chemical evidence could be used to show that the finch species evolved from a common ancestor? Explain.

2 marks
Total 7 marks

Question 2.6

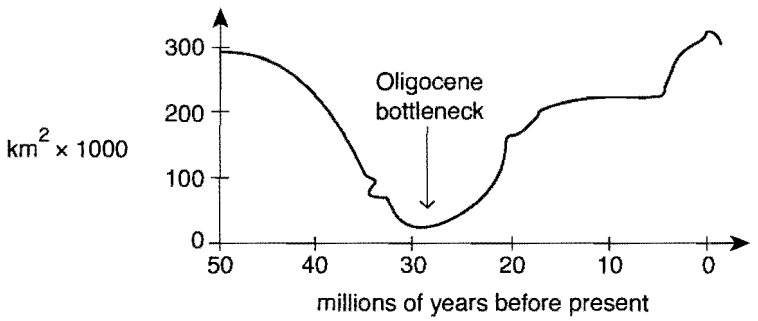
From 42 million years ago to the present time, the New Zealand landscape has changed quite significantly. The land was once quite flat with broad coastal plains and meandering rivers that were subject to periodic flooding by the sea. At times of peak flooding, New Zealand was reduced to a string of low-lying islands (as shown in the figure below). Geologists have studied the plant fossil record, ancient shorelines and the pattern of past climate and sea level changes to make these assumptions. Scientists believe that many endemic species were lost during these periods of flooding and those that survived suffered a 'genetic bottleneck'.

Changes in the New Zealand region since 42 million years ago, based on the modern day outline



Bortonian	Kaiatan	Duntroonian	Otajan	Waiauan	Otira
42 million years ago	37 million years ago	27 million years ago	20 million years ago	12 million years ago	0.015 million years ago

The graph below represents the changes in land area during this time.



a. **i.** What is meant by a 'genetic bottleneck'?

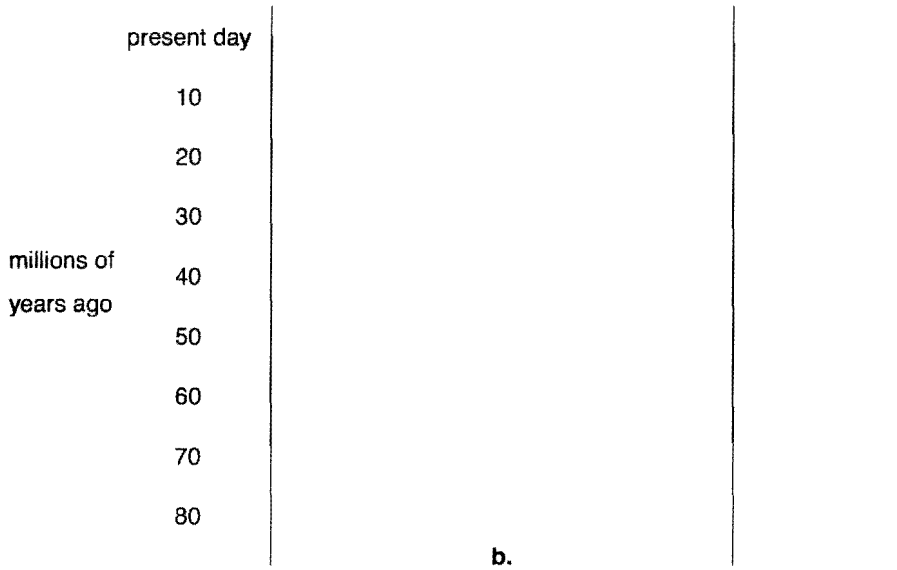
ii. How would geologists use the plant fossil record to support their ideas?

iii. What is the effect of a genetic bottleneck on the evolutionary process?

1 + 1 + 2 = 4 marks

To test the 'genetic bottleneck' theory, scientists have used special DNA techniques to extract DNA from three different New Zealand bird groups including three surviving kiwi species, five extinct moa and three types of wren. Analysis of genetic information preserved in these DNA sequences showed that all three groups of birds had much less genetic diversity within each group than would be expected if they had survived intact since New Zealand split away from Gondwanaland around 80 million years ago. It was concluded that the most recent species in each group had diverged from each other within the last 20 million years.

b. In the space allocated for **b.** below, draw a graph of the evolution of one of the three bird groups indicating the way in which the group may have evolved over time.



2 marks

c. In the space allocated for **c.** above, draw how your chosen group of birds may have evolved if the floodings had never occurred.

1 mark

d. Could scientists make a definite conclusion that one of the wren species is the same as that found 20 million years ago? Explain.

2 marks

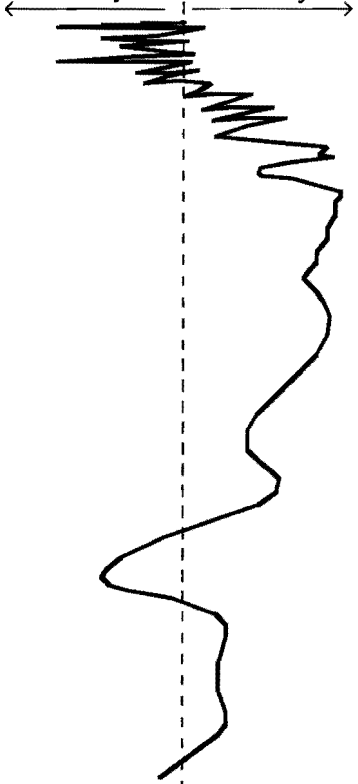
e. How would the scientists have ascertained that the groups of moas were related to each other without the use of DNA sequencing?

2 marks

Total 11 marks

Question 2.7

Information regarding the changes in the living and non-living components of the Earth has been collected by scientists in a variety of ways. Some of this information has been summarised in the table below, which shows the geological periods, average global temperature and significant events in the Earth's history.
(Not drawn to scale.)

Age (millions of years before present)	Period / Epoch	Average global temperature	Significant events in biogeography, fauna and flora
		warmer than today ← → colder than today	
	Quaternary		*Homo sapiens* appears
1.6	Pliocene		
5	Miocene		North and South America join
23	Oligocene		appearance of grasses
35	Eocene		India collides with Laurasia
57	Palaeocene		adaptive radiation of mammals
65	Cretaceous		mass extinctions (3) (including dinosaurs) Gondwanaland begins to break up flowering plants appear
150	Jurassic		birds appear Pangea begins to break up
210	Triassic		mammals appear
245	Permian		mass extinctions (2) extensive rainforests – tree ferns,
290	Carboniferous		club mosses and conifers appear
360	Devonian		mass extinctions (1) land vertebrates appear seed plants appear
410	Silurian		land plants appear
440	Ordovician		
510	Cambrian		chordates appear
570	Precambrian		

a. Palaeontologists piece together evidence about the flora and fauna that lived on Earth millions of years ago. They reveal that the kinds of organisms living on Earth have changed. Some species have appeared quite recently and are present today; others have appeared and disappeared millions of years ago.

i. What type of evidence would palaeontologists have used as a basis for their conclusions that dinosaurs existed on Earth in prehistoric times?

ii. What scientific technique were they able to use in order to state that mammals first appeared on Earth during the Triassic period?

1 + 1 = 2 marks

b. **i.** Which vertebrate group was the last to appear, and approximately when did it appear?

ii. There was a period when mammals were large with thick, long fur.

In which period was this most likely to have taken place? Explain.

2 + 2 = 4 marks

d. Use the information to draw an evolutionary tree, showing the evolutionary relationship between the dog, rabbit and kangaroo.

2 marks

e. Describe another form of evidence used to determine evolutionary relationships.

3 marks
Total 9 marks

Question 2.9

A tiny fossilised tooth was found in Queensland in a clay deposit which was 55 million years old. The tooth comes from an animal the size of a rat (*Tingamarra porterorum*) and it closely resembles the teeth from a condylarth, a mammal which lived in Europe and North America between 45 and 70 million years ago. Scientists believe that the tooth came from a placental mammal because of the position of the cusps. At the back of the tooth the central cusp, or hypoconulid, is isolated from the other two cusps. In a marsupial the hypoconulid is next to the entoconid, a cusp on the tongue side of the tooth. Scientists have also shown that the enamel of the tooth is similar in structure to the enamel of the tooth of a placental mammal.

a. Why are bones and teeth the most common parts of extinct mammals that are preserved as fossils?

1 mark

b. Could carbon–14 be used to estimate the age of the fossil? Explain.

1 mark

c. What evidence is there that the *Tingamarra porterorum* tooth is from a placental mammal?

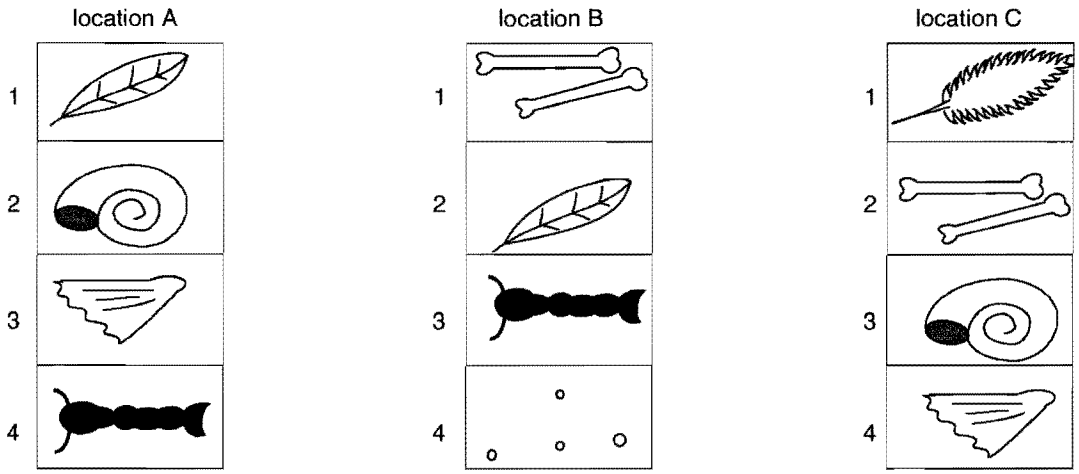
2 marks
Total 4 marks

Question 2.10

The theory of biochemical evolution hypothesises that life evolved from simple, unicellular organisms through a process of gradual change, into the myriad of life that now exists on Earth today. There are several lines of evidence that support this theory. Three of these are detailed below.

Evidence 1

The following diagram shows fossils found at various layers within three rock strata. The youngest fossils represented are believed to be about 150 000 years old.



a. What is a fossil?

1 mark

b. **i.** Which location appears to have the oldest fossils?

ii. Name and outline a method that could be used to confirm this.

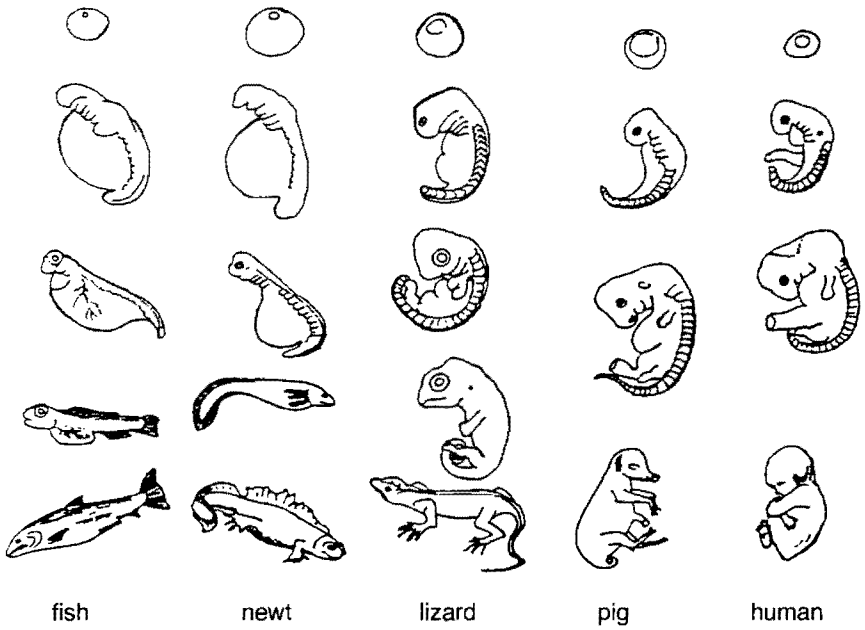
iii. What is an index fossil, and what are some useful features that it should have?

iv. Explain how scientists reach a conclusion about an animal's appearance when only hard parts of an organism fossilise.

1 + 2 + 3 + 2 = 8 marks

Evidence 2

The following diagram shows vertebrate embryos at various stages of development in a number of species.



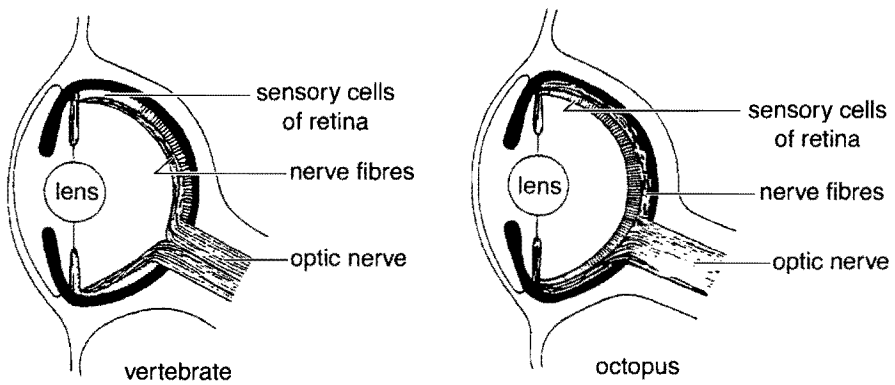
c. **i.** There are two main patterns of evolution: divergent and convergent.
Which type of evolution is indicated by the observations above?

ii. Define this type of evolution.

1 + 2 = 3 marks

Evidence 3

The diagrams below show the eye of a vertebrate and the eye of an octopus. The vertebrate has an inverted retina, meaning that the sensory cells of the retina lie beneath the nerve fibres. As a result of this the vertebrate eye has a blind spot. The octopus does not have an inverted retina as its sensory cells are above the nerve fibres. Consequently it does not have a blind spot.



d. **i.** What term is used to describe these structures?

ii. Explain your answer.

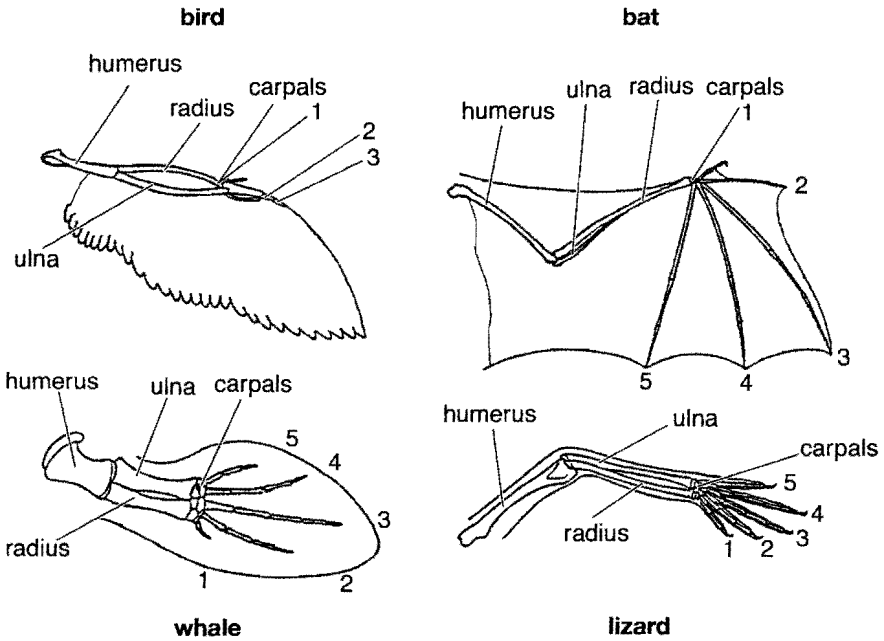
1 + 2 = 3 marks
Total 15 marks

Patterns of biological change

Question 2.11

The relationship between species is of great interest to researchers. Is *Homo sapiens* a direct descendant of an ape? Or are the two species descendants of a common ancestor? How closely is our species related to other species? What is our evolutionary pathway?

Much information has been derived from comparing structural features of living organisms. The similarity in the forelimbs of fish, amphibians, reptiles, birds and mammals is one piece of indirect evidence that has led these animals to be classified in the same group. The diagram below shows the arrangement of bones in the forelimbs of four vertebrates: bird, bat, whale and lizard.



a. What are the similarities in structure between different organisms called?

1 mark

b. Using the information in the diagram above, put forward an argument to support the theory that these animals are closely related.

2 marks

c. It has already been established that the bird, bat, whale and lizard have forelimbs that are structurally very similar. Why are they not identical?

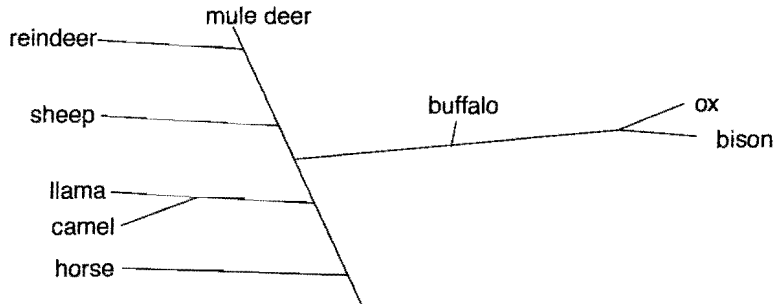
2 marks

Total 5 marks

Question 2.12

Scientists use a variety of information to understand the evolutionary relationships between species.

One of the sources of information has been through biochemical studies. A comparison of the sequence of amino acids in part of the fibrinogen molecules of mammals has resulted in the diagram shown below.



a. What name would palaeontologists give to this diagram?

1 mark

b. What assumption would the scientists have made prior to collecting fibrinogen samples from these mammals?

1 mark

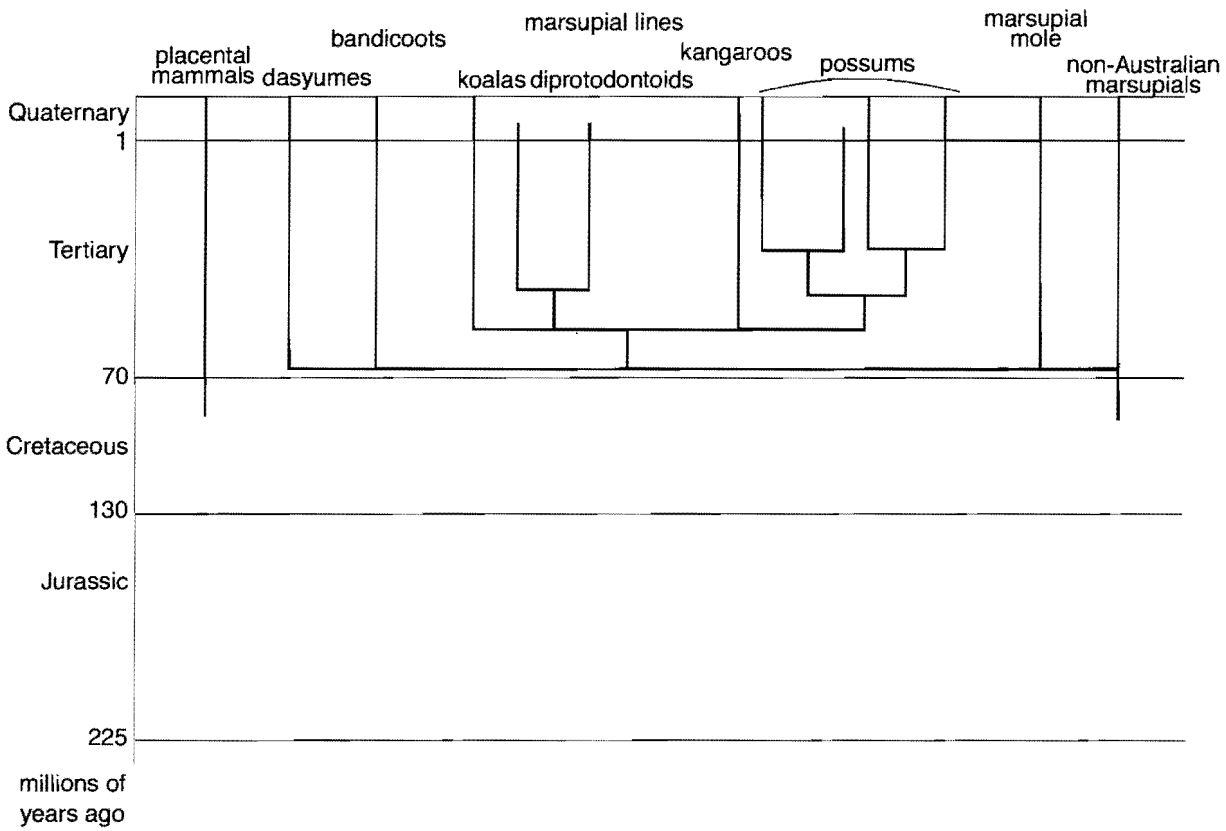
c. Would this technique be useful in tracing the evolution of a modern-day species, such as *Homo sapiens*, from its ancestral species? Explain.

2 marks
Total 4 marks

Divergent, convergent and parallel evolution

Question 2.13

Two hundred million years ago Australia was part of Gondwana, a large southern continent that included Africa, Antarctica and South America. Gondwana split up and Australia has been a separate continent for over 100 million years. In Australia there are many more species of marsupials than placentals. However, in North America the placentals dominate. It is believed that the two groups diverged from a common ancestor about 120 million years ago during the Cretaceous period. The following is a phylogenetic tree showing the types of mammals found in Australia today.



a. What type of evolution is shown by the marsupials? Explain, giving a specific example.

2 marks

b. On the diagram above, indicate with an × when the placental mammals and the marsupials split on the phylogenetic tree and Australia became isolated from Gondwana.

1 mark

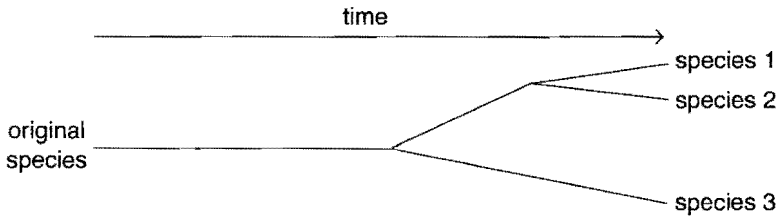
c. Many Australian marsupials are similar in form and habitats to placental mammals of North America. For example, the marsupial mouse, like the common mouse in North America, are small, agile climbers inhabiting low shrubs. Also, they are both nocturnal, similar in size and body shape and they often live in dense ground cover.

What type of evolution is described here? Explain.

2 marks
Total 5 marks

Question 2.14

The figure below is a flow diagram which represents the evolution of new species.



a. Explain the term 'evolution'.

1 mark

b. There are three different types of evolution: convergent, divergent, parallel.

Which of these forms of evolution is represented in the figure above?

1 mark

c. Complete the table below to show whether the following features are found in the evolution of new species. Place a tick (➳) in the appropriate box if the feature described is always associated with convergent, divergent or parallel evolution.

Feature	Convergent evolution	Divergent evolution	Parallel evolution
More species are present at the end of a period of time than at the beginning.			
The species present at the end of a period of time occupy similar habitats.			
Different environmental pressures cause this to happen.			
All new species originated from the same gene pool.			
Reproductive isolation is involved.			

5 marks

Total 7 marks

Hominin evolution and intervention

Question 2.15

Humans and their direct ancestors – hominoids (family *Hominidae*) and apes (family *Pongidae* and *Hylobatidae*) – are anatomically very similar to one another, which is why the members of these families are all grouped together as hominoids. There are, however, distinct differences between them.

a. State two differences between *Pongidae* and hominins.

2 marks

One way of investigating the question of hominoid evolution and ultimately that of human ancestry involves biochemistry. The similarity between organisms can be measured by comparing the sequence of amino acids in various proteins. This process can be used to assign relative dates to the times of separation of different evolutionary lines, especially when more than one protein has been compared.

For example, the alpha haemoglobin molecule of humans differs from that of gorillas in just one amino acid, and can be accounted for by a single base pair substitution. The haemoglobin molecules of humans and chimpanzees, however, are identical. The alpha chain of macaques (one of the groups of the Old World monkeys) differs from humans in five amino acids. For humans and rabbits, there are 28 differences.

b. Using the information above, draw a branching diagram that summarises the possible evolutionary relationships of humans, gorillas, macaques, chimpanzees and rabbits.

2 marks

Another method that can be used to analyse these evolutionary relationships and the sequences in which they diverged from one another is that of DNA hybridisation. Duplexes are formed when two single-stranded DNA polynucleotide chains are brought together. The greater the similarity between two DNA samples, the more extensive are the duplexes formed. When a sample of DNA from a different species is mixed with human DNA, the duplexes formed are incomplete and are called heteroduplexes. The DNA from the other organism 'competes' with the binding of human–human DNA samples. In such experiments the inhibition of human–human DNA binding by chimpanzee DNA samples is 98%, the inhibition of human–human DNA binding by macaque DNA is 93% and the inhibition of human–human DNA binding by mouse DNA is less than 50%.

c. If the evolutionary relationship suggested by the alpha haemoglobin sequences is correct, approximately what percentage of inhibition of human–human DNA binding would you expect by gorilla DNA?

1 mark
Total 5 marks

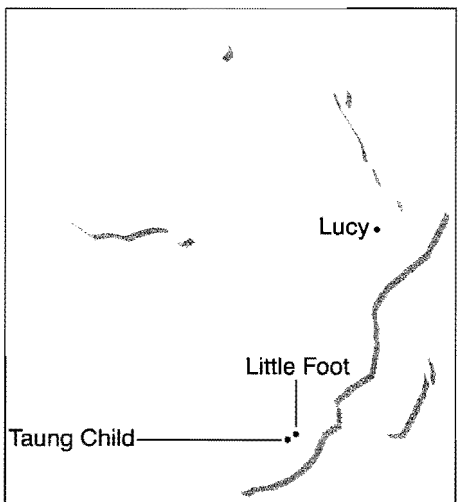
Question 2.16

Latest hominin fossil find will shed new light on our early ancestors

A collection of bones jutting from the walls of a South African cave should help determine when and how our early ancestors came down from the trees. Palaeontologists in Johannesburg have found the most complete skeleton of the ape-like hominins that preceded the genus *Homo*, to which we belong.

The remains, most of which are still buried deep in the Sterkfontein caves west of Johannesburg, are more complete than those of Lucy, the partial skeleton of *Australopithecus afarensis* found in the Hadar region of Ethiopia in 1974. Unlike those of Lucy, however, the new remains include an intact skull, and well-preserved leg and foot bones.

The bones have been dated at between 3.22 and 3.58 million years ago. If these dates are confirmed, the new find could be the earliest australopithecine ever found in southern Africa.



Locations of some important hominin fossil finds

The find was announced in December 1998 by Ronald Clarke. However, because most of the bones are still encased in rock, it is too early to identify the species. Clarke predicts that the skeleton will provide a wealth of information about the anatomy, behaviour and evolution of our early ancestors.

In 1924, the skull of an australopithecine infant, the Taung Child, was found on the edge of the Kalahari desert in northwest South Africa. This was the first significant hominin find on the African continent. The recent discovery by Clarke is thought to be the most important hominin fossil found since the Taung Child.

Clarke and his co-workers have already drawn controversial conclusions from a portion of the latest discovery. Four of the foot bones, which Clarke found while rummaging in a box of fossils in 1994, led the two scientists to declare that 'Little Foot', as the remains were whimsically named, had been capable of walking on two feet and also of climbing in trees.

a. Give two conditions for fossil formation.

2 marks

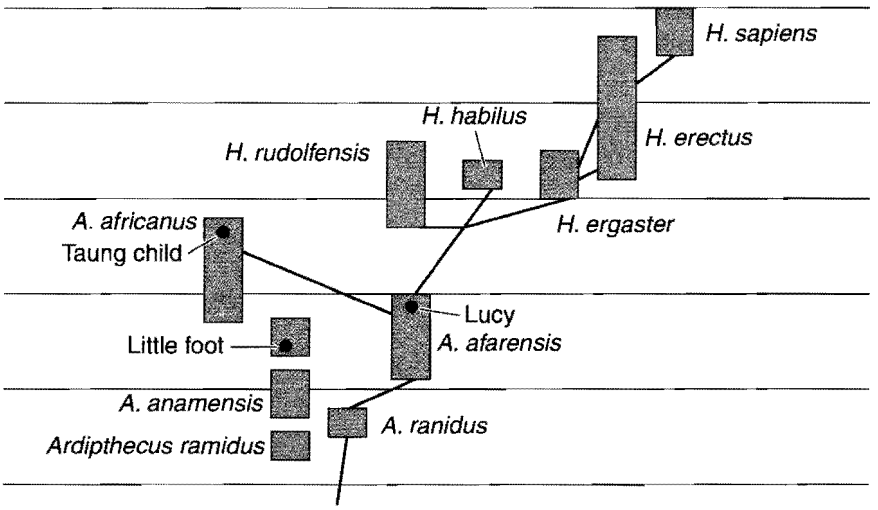
b. **i.** What important feature of hominins can be inferred by examination of well preserved leg and foot bones?

ii. List two other characteristics of hominins which distinguish them from other primates.

iii. If only a skull was found, is it possible to determine that if the organism stood and walked upright? Explain.

1 + 2 + 2 = 5 marks

c. Consider the following diagram.



What type of evolution is illustrated?

1 mark

Total 8 marks

Question 2.17

The table below shows a number of hominin species, the age of remains found by anthropologists and characteristics of each group.

Species	Age (years before present)	Brain size (mL)	Skull shape	Molar teeth (comparative size)
Australopithecus africanus	2 700 000	450	long skull, prominent brows	medium
Australopithecus robustus	1 500 000	500	long skull, prominent brows	very large
Homo habilis	1 700 000	650		large
Modern *Homo sapiens*	1000	1350	round skull, smooth brows	small
Homo erectus	1 000 000	950	long skull, prominent brow ridges	large
Neanderthal *Homo sapiens*	100 000	1400	long skull, prominent brow ridges	large

The evolution of modern humans is believed to have involved a gradual change along an evolutionary pathway involving the genus *Australopithecus*, *Homo habilis* and *Homo erectus*.

a. If *Homo erectus*, *Homo habilis* and Neanderthal *Homo sapiens* were all ancestors of modern *Homo sapiens*, suggest a likely sequence in which this evolutionary pathway occurred.

1 mark

b. Referring to the information provided, suggest which of the two species of *Australopithecus* was most likely to have been the direct ancestor to *Homo sapiens*. Give a reason for your answer.

2 marks

c. In the table above, the skull shape of *Homo habilis* has been omitted.

Describe the shape of skull you would expect to find in members of this species.

1 mark

Total 4 marks

Solutions

Unit 3: Signatures of life

Area of study 1 – Molecules of life

Section A (Multiple-choice questions)

Question 1.1 D
The other three are monosaccharides. Maltose and sucrose are disaccharides.

Question 1.2 A
The secondary structure is pleated or coiled, the tertiary structure is folded into a three-dimensional structure and the quaternary structure is when two or more protein molecules join together.

Question 1.3 C
An enzyme is a globular protein, which is three-dimensional: hence it is tertiary.

Question 1.4 C
Nucleic acids and proteins contain nitrogen but other biomacromolecules do not.

Question 1.5 D
Amino acids are complex carbon compounds. The other responses are inorganic.

Question 1.6 C
Prions do not contain any nucleic acids.

Question 1.7 B
All eukaryotic and prokaryotic cells have RNA, some viruses do contain RNA, but no prions do.

Question 1.8 A
All of those listed contain polypeptides (proteins).

Question 1.9 C
These are substances essential for particular enzymes to function. They are neither a substrate nor a product of the reaction. Enzymes lower activation energy.

Question 1.10 B
The diagram is of a nucleotide, the monomer of nucleic acids. Amino acids are the monomers of proteins. Monosaccharides of polysaccharides (complex carbohydrates and lipids) have no monomers, only subunits.

Question 1.11 A
When the DNA template is transcribed and copied, mRNA is produced.

Question 1.12 A
Mitochondria are the site of aerobic respiration, ribosomes synthesise proteins and the Golgi apparatus packages synthesised material into vesicles. Endoplasmic reticulum modifies synthesised proteins.

Question 1.13 D
Yeasts are heterotrophic; prions and viruses are non-trophic.

Question 1.14 C
The outer layer of a virus is a protein coat.

Question 1.15 A
A virus has either DNA or RNA in its core, but not both.

Question 1.16 D
Nuclei are present and it is therefore eukaryotic. No plant details are visible and the cells have a large **surface-area-to-volume ratio** for absorption (projections).

Question 1.17 D
The ribosomes read the mRNA code and link specific amino acids together, which are brought in by tRNA.

Question 1.18 C
Molecules are moving in, not out, as in exocytosis. Fluid-filled vesicles move by pinocytosis and active transport moves molecules through the membrane, not in vesicles.

Question 1.19 D
Mitosis and meiosis are the division of the nucleus (which is lacking in prokaryotic cells). Cytokinesis is the division of the cytoplasm.

Question 1.20 B
Ribosomes synthesise proteins. Endoplasmic reticulum modifies the protein and mitochondria provide the energy for synthesis.

Question 1.21 B
The complex preparation required for electron microscopy kills the specimen, which is seen as a black and white image. The high resolution is due to the use of a beam of electrons, rather than light.

Question 1.22 D
The product is being produced at a constant rate. There is still the capacity to increase further, at a greater substrate concentration.

Question 1.23 C
All active sites are continuously being filled and product formed. The rate at which this is happening is constant.

Question 1.24 C

All other variables would peak, but not lower again.

Question 1.25 A

The energy required for the reaction to get started is lowered by the presence of an enzyme. This is why the reaction is more likely to occur.

Question 1.26 D

A would not block the active site. **B** would not bind to the enzyme. Whilst **C** has a complementary shape, the charges would repel. **D** would attach and is able to bind to the active site.

Question 1.27 B

Anaerobic respiration produces alcohol and CO_2, usually occurs in the absence of oxygen and is independent of light. Anaerobic respiration in animals does not produce CO_2.

Question 1.28 C

Oxygen is not required for all cellular respiration, e.g. glycolysis. Aerobic respiration occurs in mitochondria and is more efficient than anaerobic respiration.

Question 1.29 B

The first stage of cellular respiration occurs in the cytoplasm. It is anaerobic and produces two ATP molecules.

Question 1.30 D

The matrix is the space within the mitochondria. Both the stroma and grana are part of the chloroplast.

Question 1.31 B

Bacteria lack membrane-bound organelles, so the reaction occurs in the cytoplasm.

Question 1.32 A

The transfer of the pyruvate into the mitochondria of all eukaryotic cells requires the expenditure of two ATP molecules. Aerobic respiration in bacteria occurs in the cytoplasm, so there is no expenditure of ATP.

Question 1.33 C

The complete oxidative breakdown of glucose releases 38 ATP molecules. Two ATP molecules are used to transfer the pyruvate into the mitochondria, so prokaryotes produce 38 ATP molecules and eukaryotes produce 36 ATP molecules.

Question 1.34 D

This stage of cellular respiration occurs in the mitochondria but does not use oxygen.

Question 1.35 C

This stage of cellular respiration occurs in the mitochondria but does use oxygen.

Question 1.36 B

The stroma is the fluid part of the chloroplast and the site of the light-independent reaction.

Question 1.37 B

The Calvin cycle is part of the light-independent reaction of photosynthesis and as a consequence occurs in the stroma of the chloroplast.

Section B (Short-answer questions)

Question 1.1

a. membrane [1]

b. All contain DNA in some form, have structural or functional proteins and some bacteria, such as cyanobacteria, can photosynthesise.

Com-ponent	DNA	Protein	Phospholipid bilayer	Chloro-phyll
A	✓	✓	✓	?
B	✓	✓	✓	–
C	✓	✓	✓	✓

[4]

c. i. chloroplast [1]

ii. Grana [1], site of the light-dependent reaction [1]. Water is split into H^+ and O_2 [1].

Question 1.2

a. i., iii. and iv. are polymers; ii. is not a polymer [2]. (½ mark for each correct answer.)

b. protein: amino acids; starch: glucose; and DNA: nucleotide [2]. (2 marks for all three correct answers; 1 mark for two correct.)

Note: Fatty acids and glycerol are not monomers of lipids, which therefore are not polymers.

Question 1.3

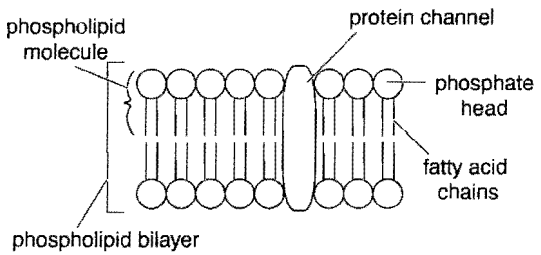
a. i. primary structure [1]

ii. secondary structure [1]

b. To stabilise and maintain the structure [1] of the molecule and hence enable functioning [1].

c. No [1]. As can be seen by the diagram, a much larger molecule must first be synthesised using the genetic code, and then this must be modified and folded to produce insulin [1]. The code produced for insulin would also produce a linear molecule, lacking the two chains linked by disulphide bonds [1].

Question 1.4



[2]

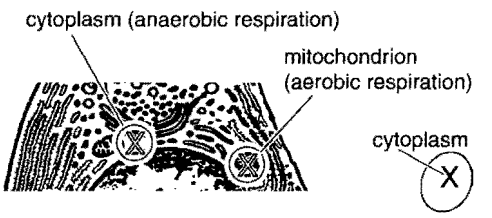
Question 1.5

a. Cell B is prokaryotic. It lacks internal detail [1] and is much smaller [1] than the eukaryote cell A.

b. i. Movement [1]. No. Cell A must be dead, as it is being viewed under an electron microscope [1].

ii. Ribosome [1]; function is protein synthesis [1]. Note that cell B lacks membrane-bound organelles.

c.



[1]

d. Biosynthesis, the large number of ribosomes on the extensive rough endoplasmic reticulum indicates synthesis of protein [1], the Golgi apparatus present packages the synthesised material into the numerous vesicles [1]. Exocytosis can be seen at the top of the cell [1].

Question 1.6

a. ATP is the immediate source of energy for cells [1]. Muscle cells require energy for contraction [1].

b. active transport [1]

protein channel [1]

Question 1.7

The dark reaction implies that the reaction only occurs in the dark, rather than not requiring light [1]. The reaction can proceed at any time, because it is independent of light [1].

Question 1.8

a. *A*: cell membrane [1], *B*: mitochondrion [1].-

b. *A*: Digested sugar, e.g. glucose, moves into the cell through the protein channels [1]. *B* provides energy via aerobic cellular respiration for transfer of sugar across the membrane (active transport) [1].

c. Glucose and galactose [1]. Less of these sugars is absorbed when the tissue has been poisoned with cyanide. Cyanide prevents aerobic respiration and kills cells, therefore no energy is available for active transport of these sugars [1].

d. Diffusion [1] is the movement of substances from a region where they are high in concentration to a region where they are lower in concentration [1].

e. protein channels [1]

f. The movement of substances from a high concentration to an area of low concentration assisted by carrier proteins in the cell membrane [1].

Question 1.9

a. unicellular organisms, kingdom *Protista* [1]

b. To expel excess water, which enters by osmosis [1].

c. i. No contractile vacuole activity as the organism would lose water [1].

ii. High activity as water would enter the organism from a region of low solute concentration and therefore the contractile vacuole would expel this excess water [1].

iii. There would be no activity as there would be no net movement of water as the solution is the same concentration as the organism [1].

Question 1.10

Plants have a sap vacuole, a large fluid filled organelle contributing to turgor and also storage, e.g. of water and ions [1]. Animals have small temporary vacuoles, food vacuoles that contain enzymes for intracellular digestion [1]. Protists have contractile vacuoles, which expel excess water that enters via osmosis [1].

Question 1.11

a. i. Beaker 1: colourless cells in distilled water [1]. (The *Chlorella* cells would possess a cell wall and not burst in a hypotonic solution.)

ii. Beaker 2: *Chlorella* cells in distilled water [1] (as the cells did not burst).

iii. Beaker 3: colourless cells in sodium chloride solution [1].

b. The cells in beaker 3 showed a decrease in cell volume because the solution surrounding these cells had a higher solute concentration than the cells themselves [1], so water moved out of the cell by osmosis to even-out the concentrations of sodium chloride inside and outside the cell [1].

c. The cells were of animal origin [1]. They ruptured in distilled water, due to movement of water into the cell by osmosis. Plant cells have a cellulose cell wall to prevent the cells from bursting [1].

Question 1.12

a. An enzyme [1] is an organic catalyst that decreases activation energy required for a reaction to occur, and therefore speeds up the rate of a reaction [1].

b. carbohydrates [1]

c. Any two of pH, temperature or starch concentration [2].

d. Accept any reasonable suggestion, for example:

1. Place 5 mL of starch suspension in each of three test tubes.
2. To the first test tube add 5 mL of distilled water (control 1).
3. To the second test tube add 5 mL of salivary amylase (control 2).
4. To the third test tube add 5 mL of salivary amylase and bubble cigarette smoke through a rubber tubing into it.
5. Test a sample from each test tube every 30 seconds, using iodine to indicate the level of starch present. When the iodine no longer changes to a blue/black colour all of the starch has been converted to maltose. Time how long it takes for each test tube to do this.
6. Repeat experiment.

Marking: control set up [1], logical method [1], controlled variables [1], repeats [1].

e. i. There is the risk of catching diseases from other students by using human saliva, e.g. colds, flu or hepatitis [1].

ii. The use of commercially produced/sterile amylase could be used which would pose no problems. Alternatives also could be the use of second-hand data or computer models [1].

Question 1.13

a. substrate [1]

b. i. amino acids [1]

ii. ribosome [1]

c. High temperature permanently changed the active site of the enzyme [1]; the enzyme is denatured [1].

Question 1.14

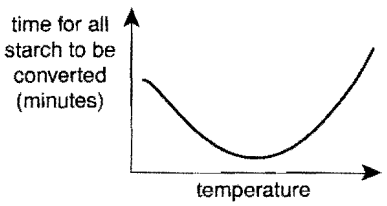
a. The pH of the solution [1].

b. Amount of substrate (starch), amount of enzyme (amylase) [1].

c. The optimum is pH 8 [1]. At this pH, the reaction was completed in the shortest time [1].

d. No [1]. Glycogen would have a different three-dimensional shape to starch, hence it would not fit into the active site of the amylase enzyme [1].

e.



[1]

Question 1.15

a. **i.** Ribosomes in the cytoplasm [1].

ii. nucleus [1]

b. Amylase catalyses the breakdown of stored starch to simple sugars [1] which can be used in respiration to release energy needed for germination [1].

c. As the concentration of gibberellin increases so does the amylase production [1].

d. **i.** The presence of abscisic acid reduces the level of amylase production [1].

ii. Very low levels [1]. Amylase action is essential for germination and high levels of abscisic acid reduces amylase production [1].

Question 1.16

The Krebs cycle occurs within the mitochondria at the **matrix** [1]. It produces **less** [1] ATP than the electron transport system and **does not [1] require** oxygen.

Question 1.17

a. lactic acid [1]

b. **i.** glycolysis [1]

ii. cytoplasm [1]; two ATP molecules [1]

c. **i.** electron transport system [1]

ii. The amount is 34 ATP molecules, 36 are produced, however two ATP molecules are required for the pyruvic acid to enter the mitochondrion [1].

d. A total of 38 ATP molecules are produced, two in glycolysis and a further 36 aerobically. There is no loss of two ATP molecules as bacteria do not have mitochondria [1].

Question 1.18

a. diffusion [1]

b. Calvin cycle/light-independent reaction [1]

c. Chlorophyll is needed for photosynthesis (and radioactive CO_2 usage). The yellow zones do not have chlorophyll, hence no photosynthesis occurs here, thus radioactivity levels are lower than in the green zone, where photosynthesis can occur if light is available [1].

d. Some radioactive photosynthetic product may have been transported to this area from the green zone.

OR

Some radioactive CO_2 would diffuse to the cells in this area, although not a lot as it is not being used in photosynthesis [1]. This is more likely given the results in leaf B.

e. Leaf B is a control, and is used to **compare** with leaf A to show that no photosynthesis would occur in leaf B, as it was kept in the dark [1].

Question 1.19

a. $6CO_2 + 12H_2O \xrightarrow[\text{light energy}]{\text{chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$ [2]

b. Light is not a limiting factor [1]. Limiting factors such as the number of chloroplasts, availability of water and carbon dioxide cause the graphs to plateau [1].

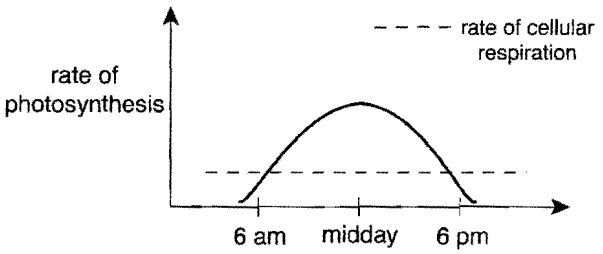
c. At very high temperatures, enzymes within the plant cell may become denatured and reduce the rate of photosynthesis.

OR

At very high temperatures, the stomata of the plant may close to reduce transpiration, so there is less CO_2 for use in photosynthesis [1].

d. A low amount of CO_2, when compared to experiment 3 which has a high CO_2 concentration [1].

e.



[1]

All living cells respire at all times; in plant cells this is relatively constant [1].

Question 1.20

a. Any one of:

- phospholipid in plasma membrane
- energy source for cellular respiration
- storage (of energy) [1]

b. fatty acid chains and a glycerol molecule [2]

c.

	Hydrolysis/ condensation	Water input/ output	Exergonic/ endergonic	Catabolic/ anabolic
X	condensation	output	endergonic	catabolic
Y	hydrolysis	input	exergonic	anabolic

Area of study 2 – Detecting and responding

Section A (Multiple-choice questions)

Question 2.1 C
The signal is changed/transduced into a cellular response by a series of events. Negative feedback is the mechanism of homeostasis. Reflex arcs and stimulus response are both types of nervous pathways.

Question 2.2 B
Testosterone is a steroid, a lipid-based hormone which passes through the phospholipid bilayer (not protein channels) and into the cytoplasm. This complex passes into the nucleus and initiates protein synthesis.

Question 2.3 D
Apoptosis is programmed cell death and is determined by signals from the cell itself.

Question 2.4 D
For a tumour to grow, the rate of apoptosis must be less than the rate of cells produced by mitosis.

Question 2.5 A
Cytokinins are plant hormones. Interferon is produced by viral-infected cells. Antibodies are produced by B cells.

Question 2.6 C
Exercise primarily requires oxygen and a change in CO_2 is what is detected and responded to, as this is critical to pH and hence to all enzyme activity.

Question 2.7 C
A hormone is a chemical produced in one part of the body and transported to another, where it produces a response.

Question 2.8 B
It conveys information to other members of the same species.

Question 2.9 A
When the two graphs are compared, experiment 2 has increased leaf growth, when compared to the intact plants, experiment 1.

Question 2.10 B
Auxin produced by the apical bud inhibits growth of lateral buds.

Question 2.11 C
Abscisic acid is involved in dormancy, vernalisation, abscission and stomatal rhythm.

Question 2.12 D
Gibberellins are involved in cell division and elongation.

Question 2.13 B
Ethylene is involved in fruit ripening.

Question 2.14 C
This is an abbreviated form of abscisic acid.

Question 2.15 B
Toxins are often heat stable, bacteria can multiply at low temperatures, viruses do not produce toxins.

Question 2.16 B
Antibodies are specific proteins produced by B cells in response to an antigen.

Question 2.17 C
Prions do not have a cell wall or nucleic acids. They are protein particles.

Question 2.18 B
Mast cells produce histamines in response to allergens.

Question 2.19 A
Histamines are responsible for the allergic response e.g. itchy eyes etc.

Question 2.20 B
Macrophages engulf and destroy cell contents. T_C cells destroy cancer cells and are cytotoxic. They also act against other eukaryotic cells mainly infected with viruses. B plasma cells produce antibodies.

Question 2.21 D
Specific antigens stimulate B cells to replicate and produce plasma cells to produce antibodies.

Question 2.22 C
See explanation to Question 2.20.

Question 2.23 A
See explanation to Question 2.20.

Question 2.24 B
The immunity is passive as the foetus has not made the antibodies.

Question 2.25 D
A is natural immunity, B and C are active.

Question 2.26 A
The alteration to the pathogen is important so as not to cause disease.

Question 2.27 B
In the humoral response, macrophages detect and present antigens which are then detected by T_h cells, which in turn activate B cells to produce antibodies.

Question 2.28 C
T_c cells attack eukaryotic cells thereby causing rejection, not to be confused with 'detection'.

Question 2.29 C

A facultative parasite can live in a suitable host or in a medium such as blood or a sugar solution. They survive or die depending on environmental conditions.

Question 2.30 A

An example is thrush developing when resistance is lowered due to stress, etc. Opportunistic pathogens do not always have a variety of hosts.

Section B (Short-answer questions)

Question 2.1

a. *A*: receptor (heat) [1]
B: sensory neuron [1]
C: interneuron or intermediate neuron [1]
D: synapse [1]
E: motor neuron [1]

b. The reflex arc is a faster response and may therefore reduce injury [1].

c. The action potential moves via diffusion of a transmitter substance [1].

d. The brain is not involved in the reflex action [1].

Question 2.2

a. **i.** neurotransmitter [1]

ii.

	Effect is sustained	Needed in high concentration at its site of action
hormone	yes	no
compound X	no	yes

[2]

b. **i.** Ribosomes on endoplasmic reticulum [1].

ii. Golgi body [1]

c. **i.** exocytosis [1]

ii. diffusion [1]

iii. The random movement of molecules from a region of high concentration to a region of low concentration to establish equilibrium [1].

d. An inhibitor [1] could block/compete with transmitter for the receptor site [1]. An anaesthetic [1] stops transmission by blocking the receptor site [1].

Question 2.3

a. **i.** hormones [1]

ii. Any two of:
- travels in bloodstream
- produced by one organ and acts on another
- only activates target cells
- active in small quantities

or any other reasonable answer [2].

b. The maintenance of a relatively stable internal environment despite a changing external environment [2].

c. Have two groups of animals, one experimental group and one control group. Expose the experimental group to the oestrogen mimic [1]. Do not expose the control group to the mimic, but keep all other variables between the two groups constant (i.e. species, age, diet, health, physical environment etc.) [1]. Look for lower fertility in the experimental group compared with the control group [1].

Question 2.4

a. A chemical produced in one part of an organism, transported to another part where it acts [2].

b. Protein-based hormone [1].

c. Insulin binds to receptors on the plasma membrane [1]. This opens specific protein channels which allows glucose to move into the cell [1].

Question 2.5

enzymes – specifically proteases [1]

Question 2.6

a. A chemical excreted by an individual, which has an effect on (communicates to) another individual [1] of the same species [1], e.g. ants will leave a trail for other ants to follow to food or, if alarmed, will produce a chemical to alert other ants. Dogs and cats use chemicals in their urine to mark their territory [1].

b. **Advantages**: can last a long time, can travel large distances, are species specific, will not necessarily alert predators [2].
Disadvantages: can be over-marked by other members of the species, will be washed off with rain or blown over a wide area leading to confusion [2].

Question 2.7

a. axon terminal [1]

b. (synaptic) vesicles [1]

c. **i.** exocytosis [1]

ii. The vesicles fuse with the cell membrane and the contents of the vesicle leaves the cell [2].

d. diffusion [1]

e. They have specific receptors for the neurotransmitter on their cell membranes [1].

Question 2.8

a. Directional plant growth in response to a stimulus [1].

b. Two of the following: light, water, gravity or touch [2].

c. For example, it causes plant cells that are away from the light to elongate and hence cause the shoot to bend towards the light [1].

Question 2.9

a. photoperiodism [1]

b. Short day or long night plants [1].

c. For example:
Variable: temperature [1]. Many plants at each temperature, all other factors consistent [1]. Repetition of results [1].

Question 2.10

a. To increase access to light to increase photosynthesis [1].

b. Auxin reduces growth of lateral shoots, therefore maintains apical dominance [1]. When auxin is applied to the cut apex, as in group 4, lateral shoots do not grow very much in comparison to group 2, therefore the apical dominance is maintained [1].

c. Gibberellic acid encourages lateral shoot growth [1]. In group 3, when gibberellic acid was added to the cut apex, there was increased lateral shoot growth in comparison to group 2 [1].

d. The apical bud tips [1]. Removal of the bud in group 2 leads to increased lateral shoot growth compared to group 1 where this is still intact, or compared to group 4 where the auxin has been added to the cut apex [1].

e. In the phloem [1]. (There is also some transport in the xylem.)

Question 2.11

a. A chemical messenger produced in response to a stimulus and transported to another location where it triggers a response [1].

b. growth hormone (auxin, IAA, cytokinin) [1]

c. phloem [1]

d. While the growth hormone is at high levels, the leaves remain attached to the plant [1]. The increase in ABA seems to lead to the leaf drop occurring [1].

e. Apply ABA to crops before they are fully ripe, so they can be picked while still firm and they are easier to transport, or so that all picking can occur at the same time [1].

f. It triggers the stomata to close, reducing transpiration (water loss) in the hottest part of day [1].

Question 2.12

a. **i.** B: more colonies grew around this disc compared to the others [1]. Smaller radius of inhibition.

ii. A: this disc had the least number of colonies around it [1]. Larger radius of inhibition.

b. The antibiotic diffuses evenly in all directions from the disc, forming a clear circular region [1].

c. No [1]. Viral growths require living cells, e.g. eggs or an organism. They cannot be grown on agar plates [1].

d. No [1], because different bacteria have different resistance or sensitivity to different antibiotics [1].

e. As there are potentially pathogenic organisms present [1], it is important that the agar plates are sealed and disposed of, e.g. by sterilisation or incineration [1].

Question 2.13

a.

Structure	Bacteria	Fungus	Virus
cell wall	present	present	absent
genetic material	DNA	DNA	DNA or RNA
membrane-bound organelles	absent	present	absent

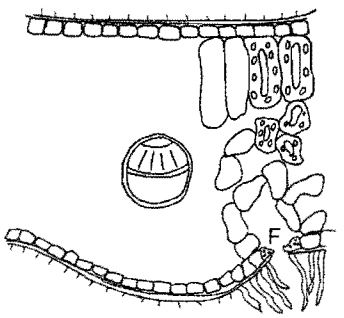
[3]

b. Organisms causing disease may be in the aphid's saliva; hairs prevent contact of aphid's saliva with the leaf [1].

c. To reduce water loss [1].

d. To reduce water loss [1] and prevent entry of pathogens [1].

e.



[1]

f. The cuticle is a waxy layer and so the enzymes could dissolve the cuticle, thus allowing the fungi to enter the leaf [1].

Question 2.14

a. A material, e.g. attenuated, dead or alive, or toxins that promote a rapid immune response [2].

b. antigen/pathogen [1]

c. **i.** Fungi are living and need to respire [1].

ii. No; bacteria do not have mitochondria [1].

d. $6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6O_2 + 6H_2O$ [2]

e. **i.** antibodies [1]

ii. Antibodies combine with a specific type of antigen and renders them harmless [1].

iii. Antibodies are specific for a particular antigen [1].

Question 2.15

a. brown ear tick [1]

b. To attack the live parasite [1].

c. Correct: An infected rabbit was transported to the mainland [1].
Incorrect: A vector such as a mosquito carried the virus to the mainland [1].

Question 2.16

a. Vasodilation occurs to bring in phagocytes [1].

b. **i.** After some time the antibody concentration decreases and memory cells need to be stimulated [2].

ii. B cells (plasma) [1] produce antibodies [1]. T cells [1] help B cells and destroy invading cells [1].

Question 2.17

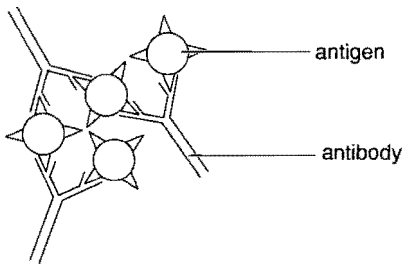
a. Specific antibodies are produced by B plasma cells [1]. Memory of antibodies is retained by memory cells, so when they are next exposed the immune system can respond quickly and accurately to the antigen [1].

b. natural active immunity [1]

c. **i.** *A*: antigen [1]; *B*: antibody [1].

ii. *A* is a protein or carbohydrate marker on the outside of cells [1].
B is a protein molecule with a variable and a constant region [1].

iii. It allows an antibody to join to two antigens, agglutinating cell-bound antigens or neutralising bacterial exotoxins or viruses [1].



[1]

d. i. Two of:
- bacteria are cellular, viruses are not;
- bacteria have a cell membrane, viruses have a protein coat;
- bacteria have circular DNA, viruses have either DNA or RNA;
- bacteria have ribosomes, viruses do not; or
- any other reasonable answer [2].

ii. Antibiotics interfere with cell wall production and hence stop reproduction, or they inhibit protein synthesis or enzyme action but viruses do not have cell walls and they do not metabolise [2].

Question 2.18

a. Orally, in food or drink, through an open wound, or through respiratory pathways [1].

b. B plasma cells (lymphocytes) [1]

c. Receptors on the surface of the B cell recognise surface proteins on the bacterium as an antigen (non-self) [1]. This stimulates the B cell to divide many times (with the help of the T helper cells), producing both plasma and memory cells. Memory cells persist and remain in the bloodstream and especially in the lymph nodes [1] so that when the bacterium infects this individual the memory cells will be quickly stimulated to produce antibodies to kill off *H. pyloria* before disease symptoms arise [1].

d. It is important to understand that if you disagree with an issue it is necessary that you can put forward valid suggestions.

Any answer suggested could be based on economic/commercial, freedom of will, moral/religious or other grounds.

One could argue that there is a risk to the child. Or it is against the parent's beliefs. Or that the cost to the government is too great, versus the benefits gained [1].

Question 2.19

a. A chemical (may be whole or part of a pathogen – or a toxin produced by it) that the body or immune system detects as foreign (non-self) [1].

b. A protein molecule that combines specifically with a particular antigen. Produced by B cells of the immune system [1].

c. A white blood cell, involved in immune response (B or T cells) [1].

d. A white blood cell, formed from B lymphocyte, that produces and releases antibody molecules [1].

e. A chemical released by virally infected cells that may act on other cells, making them immune to viral attack [1].

Question 2.20

a. Any two of:
- cilia lining the nasal cavity and trachea may trap bacteria and other potential pathogens before they enter the respiratory tract;
- mucous secreted by cells lining the respiratory tract may trap pathogens;
- coughing removes mucous that may contain pathogens;
- acid in the stomach may help destroy pathogens ingested with food; or
- any other reasonable answer [2].

b. White blood cells [1]. Leucocytes – phagocytes may engulf pathogens or toxins, antimicrobial substances act to inhibit or destroy pathogens. (Antibody production/immune response is the third line of defence.)

c. Lasting protection against a particular pathogen or disease [1]. It is acquired naturally after an individual is exposed to a particular antigen (on or produced by a pathogen) and produces memory cells (either B or T_C cells) that are stored in the lymph nodes [1].

d. Long-term immunity can be acquired artificially by injecting an individual with a vaccine that contains dead or weakened (attenuated) pathogens, or the specific antigen if it is known. This stimulates the immune system to produce antibodies against this pathogen (virulent form) and store memory cells without actually experiencing the disease itself [1].

e. Passive immunity is when ready-made antibodies are injected into the bloodstream of an infected individual [1]. It is useful in treating diseases where death or serious repercussions usually occur before the immune system has had time to react to the antigen involved. Immunity only lasts about 28 days as the immune system did not make these antibodies, therefore no memory cells will be stored [1].

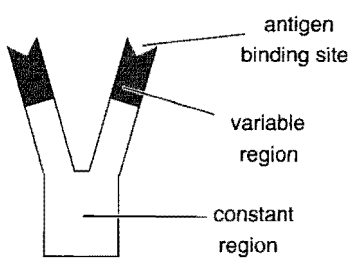
Question 2.21

a.

Cell type	Function
B cell	activated by antigens, defence against viruses/bacteria
B memory cell	long-lived cells capable of responding to antigens rapidly differentiating into plasma cells
T_H cell	activate B cells and T_C cells
B plasma cell	stimulated by antigen, rapidly produces antibodies
T_C cell	destroys eukaryotic cells
macrophage	engulf and destroy infected cells

[6]

b.



[2]

An antibody is a protein produced by B plasma cells. It has a constant region and a variable region – the antigen binding site [1].

c.

Pathogen	Example of disease	Distinguishing feature of pathogen	Treatment
prion	CJD, mad cow disease	only contain protein, no nucleic acid	none
fungus	tinea, candida	cell wall, larger than others, eukaryotic	fungicide
virus	cold, warts	protein coat, RNA **or** DNA	no specific treatment
bacteria	sore throat, wound infection	prokaryote, small cellular	antibiotic

[12]

Unit 4: Continuity and Change

Area of study 1 – Heredity

Section A (Multiple-choice questions)

Question 1.1 C
Introns are removed, a methyl group is added and premRNA is produced.

Question 1.2 D
The DNA is temporarily unwound by enzymes and complementary bases are added to each original strand.

Question 1.3 B
Codons in mRNA have U instead of T, and TAC codes for 'start', so there would only be three amino acids for this section. TAC codes for Met only in the body of DNA, not at the beginning.

Question 1.4 C
Alternative forms of genes are alleles, made of DNA, which code for protein. Alleles can be expressed individually, e.g. those on the X chromosome of a male; however, usually both alleles are expressed if the organism is homozygous or if the condition is co-dominant or incomplete dominance.

Question 1.5 A
The diagram shows one chromosome, made of two chromatids, which is one chromosome of an homologous pair.

Question 1.6 C
DNA polymerase catalyses the replication of DNA. As DNA replication occurs from the 5′ to 3′ end, the 3′ to 5′ is discontinuous in its replication and the segments must be joined by DNA ligase, after synthesis.

Question 1.7 C
The current is running from top to bottom and the shortest fragment, CFTR mutation, travels furthest from the well.

Question 1.8 C
PCR makes multiple copies of DNA, and gel electrophoresis separates DNA by length. Transformation is the movement of genes between species.

Question 1.9 B
As a plasmid is circular, when it is cut three times it will only produce three pieces. If it was linear then four pieces would result from three cuts.

Question 1.10 D
All cells have 22 homologous pairs of autosomes and females have an homologous pair of X chromosomes. In males the sex chromosomes are not homologous.

Question 1.11 B
Gametes only have one chromosome from each pair of homologous chromosomes. Non-disjunction would give species members different numbers of chromosomes. Different alleles are present in homologous chromosomes.

Question 1.12 D
Four genetically similar haploid cells are made. DNA is replicated during the S phase of interphase when the chromosomes are not visible, then homologous chromosomes pair and line up.

Question 1.13 A
Non-disjunction, crossing-over and production of haploid cells occur in meiosis.

Question 1.14 B
The order of the cells if undergoing meiosis is II, I, III. Cells I and III are only possible in meiosis, not mitosis.

Question 1.15 B

Bacteria are reproduced by binary fission. Yeast, fungi and animals all use mitosis for cell division. Mitosis is nuclear division. Prokaryotes do not have a nucleus.

Question 1.16 A

The trait cannot be sex-linked dominant as all daughters of an affected father would show the trait and II–3 does not. The condition is dominant as two affected parents have two unaffected children. I–1 and I–2 are both heterozygous.

Question 1.17 C

II–1 is affected, ∴ it has a $\frac{2}{3}$ chance of being heterozygous ($\frac{1}{4}$ are normal and $\frac{1}{3}$ of the affected are homozygous).

Question 1.18 A

II–3 is homozygous normal, as is her husband. There is no chance their children will be affected.

Question 1.19 B

Autosomal dominant and sex-linked recessive do not fit for pedigree III. Sex-linked dominant does not fit for any pedigree.

Question 1.20 A

Chromosome morphology would be quite different between different species, which cannot interbreed. An even polyploid number indicates fertility.

Question 1.21 B

All body (somatic) cells have 60 chromosomes. Gametes, i.e. sperm and ova, have 30 chromosomes. Non-disjunction occurs in meiosis. During anaphase and telophase, 120 chromosomes would be present in the cell.

Question 1.22 B

Most mutations are harmful. UV tends to produce somatic mutations and carcinogens cause cancer, but that is not the reason for calling UV a mutagen. It is a mutagen because it promotes mutation.

Question 1.23 A

This is continuous variation, e.g. human height, and is under the control of many genes, each with potentially many alleles. The phenotype is the result of the interaction between genotype and the environment. If the environment was different, the phenotype would be altered.

Question 1.24 D

The genotype for a human are one of $\mathbf{I^AI^A}$, $\mathbf{I^Ai}$, $\mathbf{I^BI^B}$, $\mathbf{I^Bi}$, $\mathbf{I^AI^B}$ and **ii**. Cats have one of $\mathbf{C^AC^A}$, $\mathbf{C^BC^B}$ and $\mathbf{C^AC^B}$. Possible phenotypes for humans are A, B, AB and O. Possible phenotypes for cats are A, B and AB. However, the notation of A and B for cats does not imply the same phenotype in humans and cats.

Question 1.25 B

Two homozygous offspring would be produced and 2 heterozygous offspring are produced.

Question 1.26 C

The two homozygotes have different phenotypes, as do the heterozygotes.

Question 1.27 C

Different letters represent incomplete dominance (**A**). **B** represents complete dominance.

Question 1.28 D

Linked genes are shown as a fraction where the allele for one gene A is linked to the allele from another gene B. Possibilities are therefore $\frac{\mathbf{Ab}}{\mathbf{ab}}$ or $\frac{\mathbf{Ab}}{\mathbf{aB}}$.

Question 1.29 C

Man, heterozygous i.e. **Aa**. Woman, **aa** normal.

Question 1.30 B

Aa × **aa**

½ **Aa** ½ **aa**

Question 1.31 C

50 plants produce yellow and wrinkled seeds, 150 would produce yellow and round seeds, and 150 would produce green and wrinkled seeds. The remaining 450 would be green and round. The ratio would be 9 round green : 3 round yellow : 3 wrinkled green : 1 wrinkled yellow.

Question 1.32 C

$\frac{1}{4}$ of the plants would produce wrinkled seeds.

The cross of **Rr** × **Rr** produces round seeds to wrinkled seeds in a ratio of 3 round : 1 wrinkled.

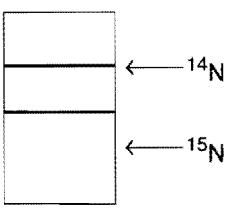
Section B (Short-answer questions)

Question 1.1

a. DNA replication occurs in the S phase of the cell cycle in interphase, preceding meiosis or mitosis [1].

b. DNA replication is semi-conservative therefore new molecules contain one parental strand (^{15}N) and one new strand (^{14}N) [1]. Therefore new DNA would produce a band that lies in-between the ^{14}N and ^{15}N bands [1].

c.



[1]

Four DNA molecules now exist, two made of only ^{14}N and two containing a mix of ^{14}N and ^{15}N producing two bands as shown in the diagram [1].

Question 1.2

Universal: The same triplets code for the same amino acids in all organisms [1].

Degenerate: A given amino acid may be coded for by more than one codon [1].

Non-overlapping: An mRNA sequence AUGAGCGCA is not read AUG/UGA/GAC but only as AUG/AGC/GCA. i.e. the bases are read in groups of three [1].

Question 1.3

a. **i.** nitrogenous bases found in DNA [1]

ii. cysteine, arginine, glutamic acid, serine, threonine, glycine and serine [2]

iii. There is more than one possible codon for the same amino acid here [1]; two different codons have both resulted in serine being in the chain [1].

b. 375 [1]. Three per amino acid = 369 + 6 for the stop and start codon [1].

c. three sequential bases of transfer RNA (tRNA) [1]

Question 1.4

a. regulator gene [1], as it controls the expression of another gene [1]

b. a structural gene [1]

c. transcription [1]

d. When lactose is present it binds to lac regressor protein and can't bind to the promoter [1]. Therefore the gene is activated [1] and lactase is produced [1].

Question 1.5

a. transcription [1]

b. Ribosomes read the mRNA codons and bind with complementary anticodons on tRNA molecules in an order determined by the DNA [1]. Amino acids carried on the tRNA line up in the correct order and join together by peptide bonds to form a particular polypeptide [1].

c. The same DNA sequence will code for the same proteins in all organisms; therefore the haemoglobin gene, when transferred into a pig, will still produce human haemoglobin [1].

OR

The DNA of all organisms contains nucleotides of the same structure, therefore human haemoglobin genes can be inserted in pigs and they will still produce human haemoglobin [1].

Question 1.6

a.

		children		
mother	father	A	B	C
—— ——	——	—— ——	——	—— ——
——	—— ——	——	——	—— ——
——	——	——	—— ——	
——	——	——	——	——

[1]

b. adenine, thymine, cytosine and guanine [2]

c. point mutation [1]

d. Tatiana, Marie and Alexis [2]

e. Each strand of the original DNA acts as a template for the synthesis of a new strand [1]. Hence each daughter DNA is composed of one original strand and one new strand [1].

f. **i.** Recessive [1], as unaffected parents can produce an affected child OR any other reasonable answer [1].

ii. X-linked [1], as carrier mothers pass it on to their sons OR there is a high proportion of males affected OR any other reasonable answer [1].

Question 1.7

a. nucleotides [1]

b. **i.** Any three of

- RNA has uracil, DNA has thymine;
- RNA has ribose sugar, DNA has deoxyribose sugar;
- RNA is single-stranded, DNA is double-stranded;
- mRNA is shorter than DNA. Mature mRNA does not contain introns;
- mRNA may be found in nucleus and cytoplasm, while genomic DNA is only found in nucleus;
- OR any other reasonable answer [3].

ii. transcription [1]

c.

DNA sequence	A	G	C	T	T	C	G	G	G	T	G	G
mRNA sequence	U	C	G	A	A	G	C	C	C	A	C	C

[1]

d. codon [1]

e. serine, lysine, proline and threonine [2]

f. ribosome [1]

g. arginine, serine and proline [2]

h. deletion [1]

Question 1.8

a. A segment of DNA coding for the production of a particular protein or polypeptide [1].

b. two copies [1]

c. DNA unwinds in the region of the gene exposing one of the strands as a template for the transcription of a single stranded complementary mRNA molecule [1]. mRNA moves and attaches to a ribosome in the cytoplasm exposing two 3-base codons [1].

The mRNA is then translated into a polypeptide: tRNA molecules carrying specific amino acids bind to their complementary codons at the ribosome. The amino acids form peptide bonds which result in a polypeptide chain – the P34H protein [1].

d. **i.** TAC GGT TTC ACC CAT ACG
ATG CCA AAG TGG GTA TGC
(Both strands must be included.) [1]

ii. No [1]. The genetic code is degenerate, therefore specific amino acids may be coded for by more than one codon [1].

e. **i.** An environmental factor that causes a permanent change in a DNA sequence [1].

ii. The second codon would change from CCA to UCA. As it is the first base in the codon that is changed it is likely that the amino acid specified will change, resulting in a different primary structure of the protein [1]. This may change the function of the protein, resulting in a different phenotype in the organism [1].

iii. The sixth codon would change from UGC to UGU. As this is the third base of the codon it is more likely to not result in a different amino acid, due to degeneracy of the genetic code [1]. Therefore, it would probably result in the same protein and, hence, it would have no effect on the phenotype of the organism [1].

Question 1.9

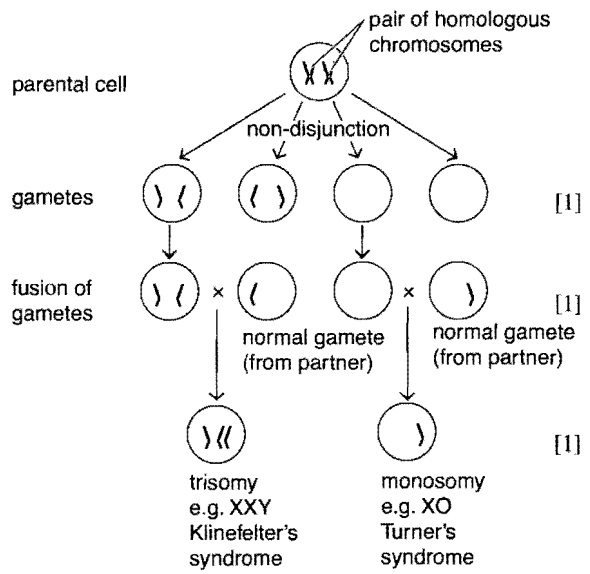
a. i. Mutagens, e.g. x-rays, UV radiation and certain chemicals such as benzene [1].

ii. Sample 1: single base insertion leading to a frameshift [1].

Sample 2: three base duplication or trinucleotide repeat [1].

iii. A frameshift alters all subsequent amino acids and results in a greatly altered protein. A three base duplication causes more copies of one of the amino acids to be produced, but subsequent amino acids are not affected, and the resulting protein may be only slightly changed [2].

b. Students may describe how either of these conditions may arise.



Question 1.10

a. Transcription occurs in the nucleus, where a complementary copy of the DNA coding strand is made [1], assisted by the enzyme RNA polymerase. Pre-mRNA is produced. This undergoes post-transcriptional modification: where transcribed introns are removed, poly(A) tail and methyl cap are added. The product is messenger RNA, mRNA [1].

b. Translation occurs at the ribosomes, in the cytoplasm. Transfer RNA, (tRNA) molecules with complementary anticodons to the codons of mRNA [1] carry specific amino acids. Transcription begins at the start codon and continues until the stop codon is reached. The product is a polypeptide [1].

Question 1.11

a. Yeast DNA is contained within a nuclear membrane (eukaryotic), whereas bacterial DNA is not [1].

b. i. a restriction enzyme, also known as a restriction endonuclease [1]

ii. ligase [1]

c. Only those yeast cells that have taken up the plasmid will survive when exposed to ampicillin; this enables the selection of the genetically altered yeast [1].

d. Yeast and bacteria reproduce rapidly and make many identical copies of themselves in a short time, desirable if we wish to harvest the gene or gene product [1]. Rats do not reproduce rapidly and do produce variation in the offspring [1].

e. Issues could be

- concern that the introduction of a new gene may increase the engineered organisms' ability to reproduce;
- the transformed genes could cross species barriers;
- there could be a risk to humans.

The important part about issues is not whether they are valid, but that there are concerns expressed by the public, which need to be addressed [1].

f. A vector is the term used to describe the plasmid [1].

g. transformed [1]

h. One of heat shock or electric shock, which temporarily opens the bacteria's plasma membrane and facilitates the uptake of the gene [1].

Question 1.12

a. Body cells are also known as somatic cells [1].

b. The disease is recessive. The evidence is that the person suffering from the condition is homozygous for the gene and as a normal allele is inserted [1], it must be dominant to be expressed [1].

c. gene therapy [1]

d. The process outlined at 1 is the gene delivery system, which involves transfection where a virus (for example) is used to transfer the DNA [1].

e. All the cells would contain the normal allele as they are clones [1], produced by mitosis [1].

Question 1.13

a. The place where endonucleases cut DNA is a specific base sequence called the recognition site [1].

b. The ends produced are blunt [1] or sticky [1].

Question 1.14

a. Liposomes do not contain their own DNA and therefore the risk of disease is reduced compared to the adenovirus [1]. The liposome readily assimilates with the cell membrane and allows the new DNA to pass into the recipient [1].

b. i. There is the potential risk of illness caused by the adenovirus [1].

ii. The adenovirus would have its DNA modified so that it could not reproduce [1].

Question 1.15

a. meiosis [1]

b. i. 24 [1]

ii. non-disjunction [1]

iii. 47 [1]

c. The cells replicate by mitosis [1], so all body cells are genetically identical [1].

Question 1.16

a.

Mitosis	Meiosis
×	✓
×	✓
×	✓
×	✓
✓	✓
×	✓
✓	×
✓	✓

[4]

b. Any three of
- random arrangement and segregation of homologous chromosomes at metaphase I;
- cross-overs at prophase I;
- daughter cells resulting from meiosis are not identical;
- mutation may occur during DNA replication, crossing-over or segregation of chromosomes. [3]

c. The random choice of mates [1], and the random fusion of gametes [1], both contribute to variation amongst the offspring.

d. Meiosis (metaphase II) [1]. The chromosomes have no pair indicating that the initial division of homologous pairs has already occurred [1].

Question 1.17

a. Chromosome replication and DNA synthesis occur in S [1].

b. Each strand of DNA acts as a template for new nucleotides to be added [1]. The result is two hybrid double-stranded molecules [1].

c. Cytokinesis is the process where the cytoplasm is divided after nuclear division [1].

d. **i.** The cell cycle occurs in the meristem, in buds and root tips, i.e. the growth regions of the plant [1].

ii. In plant cells the cell membrane does not invaginate as in animal cells but a new cell wall (cell plate) forms and separates the cytoplasm [1].

Question 1.18

a. **i.** cell 3 [1].

ii.

Cell number	Tissue
1	any tissue
2	ovaries or testes

[2]

The diagram represents a gamete and the other cells in the gonads are diploid.

b. The number of chromosomes in the offspring is uneven (4 + 3 = 7) [1], therefore their chromosomes can't pair at meiosis, so no gametes are produced [1].

Question 1.19

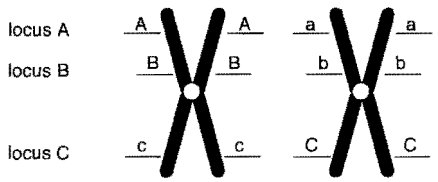
a. P – centromere [1].

Q – chromatid [1].

R – one chromosome, one of an homologous pair of chromosomes [1].

S – a pair of homologous chromosomes [1].

b.



(Note: must be the same allele on each homologous chromosome. Other combinations are possible.) [3]

Question 1.20

a. Essential genes are lost from the genome OR loss of bases which alters the DNA sequence resulting in a non-functional protein [1].

b. At metaphase I of meiosis, homologous pairs of chromosomes line up together on the equator [1]. One chromosome of each pair is drawn to the centriole at the opposite ends of the cell [1], at metaphase II the chromatids separate ensuring one copy of each chromosome in each daughter cell [1].

c. Non-disjunction [1]. Both chromosomes of the pair migrated to the same end of the spindle OR chromatids did not separate at the second division of meiosis [1].

d. It had been expelled from the cell OR was not in the original sperm cell [1].

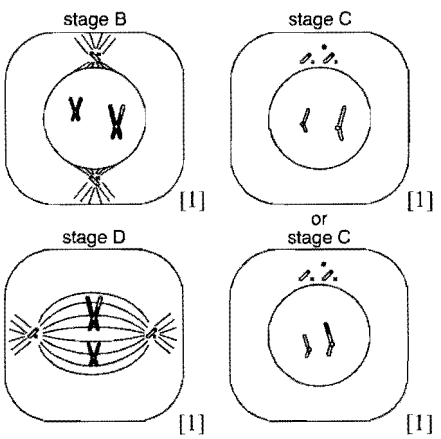
Question 1.21

a. A, B, D then C [1].

b. Meiosis [1]. Any two reasonable answers, for example
- Stage A: homologous chromosomes pair up [1].
- In stage C, there are half as many chromosomes per cell as in stage A [1].

c. testis and ovary [1]

d.



Question 1.22

a. any cell other than gametes [1]

b. **i.** six [1]

ii. three [1]

c. An allele of a gene carried on the X chromosome [1].

d. an alternative form of a particular gene [1]

e.

Phenotypes of parent flies crossed	Genotypes of offspring	Phenotypes of offspring
white-eye male × red-eye female	X^RX^r	red-eye female
	X^RY	red-eye male
white-eye female × red-eye male	X^RX^r	red-eye female
	X^rY	white-eye male

[4]

f. $X^RX^r \times X^RY$

$\downarrow$

$X^RX^R, X^RY, X^RX^r, X^rY$ [2]

2 red-eye females : 1 red-eye male : 1 white-eye male [2].

Question 1.23

a. A gene is a part of a chromosome, or section of DNA, that codes for a particular protein product. Separate alleles are alternative forms of a gene [2].

b. The physical site on a chromosome where a particular gene is located [1].

c. Genotype refers to the alleles carried for a particular trait (i.e. an individual's genetic make-up) [1], whilst phenotype refers to the expression, or appearance, of a particular trait in an organism's particular environment [1].

Question 1.24

a. Recessive [1]. An affected child is born (e.g. IV–4) to two unaffected parents [1].

b. Dominant [1], as an unaffected child (e.g. IV–6) is born to affected parents [1].

c. Let **A** = normal for trait one, **B** = affected for trait two
a = affected for trait one, **b** = normal for trait two

	IV–3	×	IV–5	
(genotypes)	**Aabb**	↓	**aaBb**	[1]
(gametes)	½ **Ab**, ½ **ab**	↓	½ **aB**, ½ **ab**	[1]
(offspring)	1 **AaBb** : 1 **Aabb** : 1 **aaBb** : 1 **aabb**			[1]

Question 1.25

a. X^A and X^a [2]. X^A = normal; X^a = red-green colour-blind.

b. **i.** X^aY
ii. X^aX^a
iii. X^AY
iv. X^aY *½ mark per part* [2].

c. Paternal [1]. Female is colour-blind therefore she must have inherited this from her mother as her father does not have the characteristic (he only has one X chromosome, therefore he will express whatever allele he has for colour vision) [1].

Question 1.26

a. Feature 1: Individual II–3 does not have the trait, hence the trait cannot be X-linked recessive [1].
Feature 2: Individual II–2 has the trait, hence the trait cannot be X-linked recessive [1]. All daughters of an affected father (II–5) have the trait, but not his son.

b. Hypophosphataemia X^H. No hypophosphataemia X^h [1].

c. **i.** X^hY [1]
ii. X^HX^h [1]
iii. Feature 1: Individual II–3 does not have the trait [1].
Feature 2: Individual II–4 does not have the trait [1].

d. **i.** 0 [1]
ii. ¼ [1]
iii. 1 [1]

Question 1.27

a. X-linked recessive [1]. Female carriers exist who do not show the trait, but there are no male carriers [1].

b. Any symbols that show the trait as being on an X chromosome e.g. X′ – trait, X and Y – normal [1].

c. X′Y (must use same symbols as **b.**) [1].
This is an affected male; this means he must be XY, and as he shows the trait he must have the X′ [1].

d. X′X [1].

e. P. genotypes X′X × X′Y
gametes (X′ + X) × (X′ + Y)
F_1 genotypes X′X′ : X′Y : X′X : XY [1].
F_1 phenotype ½ of the boys and ½ of the girls will show the trait [1]. In all ½ of the offspring.

f. Pedigrees enable us to observe the inheritance of a trait over several generations. They can be used to detect the mode of inheritance of a particular allele when large numbers of offspring cannot be obtained [1].

Question 1.28

a. incomplete dominance [1]

b. **BB** = black, **BW** = blue, **WW** = white
P. genotypes **BW** × **BB**
gametes (**B** + **W**) × (**B** + **B**)
F_1 genotypes ½ **BW** : ½ **BB** [1]
Offspring will be ½ blue and ½ black [1].

c. Parents must either be **BB** and **BB**, or **WW** and **WW** [1]. **BB** × **BW**, **WW** × **BW**, **BW** × **BW** will all produce some blue offspring [1].

Question 1.29

a. **i.** Autosomal [1], it is not X-linked as I–2 would pass the trait on to both his daughters [1].
ii. **W**: white forelock, **w**: normal hair (OR any suitable symbols, except X and Y) [1].

b. **ww** [1]

c. I–2 OR II–3 [1]

d. **i.** **Ww** and **ww** [1]
ii. ½ OR 50% [1]
iii. ½ OR 50% [1]

Question 1.30

a. **P** = purple allele, **p** = white allele
(or any suitable symbols, except X and Y) [1].
e.g. purple parent genotype = **PP**
white parent genotype = **pp**

b. Heterozygous [1]. The F_1 plants received one **P** allele from the purple parent and one **p** allele from the white parent, hence their genotype must be **Pp** [1].

c. **i.** Dominant refers to a trait that is expressed equally in the homozygote and the heterozygote. The dominant allele is said to 'over-ride' the expression of the recessive allele in a heterozygote [1].

ii. **P** (purple allele), as the F_1 plants all had purple flowers, even though they were heterozygous [1].

d. No [1]. Two thirds of the purple F_2 plants are heterozygous, as shown in the cross below.

F_1 purple flowers × purple flowers

Pp × **Pp**

(gametes) ½ **P** ½ **p** × ½ **P** ½ **p**

1 **PP** : 2 **Pp** : 1 **pp**

3 purple flowers : 1 white flowers [1]

Question 1.31

a. i. grey coloured, curly hair [1]

ii. **G** = grey **g** = cinnamon
C = curly **c** = straight [1]
GGCC × **ggcc** all offspring will be **GgCc** [1]

b. i. Linked genes are found on the same chromosome and therefore tend to be inherited together [1].

ii. Parents: **GgCc** × **ggcc**

gametes	GC	Gc	gC	gc
all **gc**	GgCc	Ggcc	ggCc	ggcc

[1]

Phenotype ratio is 1 : 1 : 1 : 1; therefore expect roughly 70 of each [1].

iii. The breeder's hypothesis is supported by these results because the rats produced are in large numbers and do not show the expected ratio if not linked [1].

Question 1.32

a. Let **G** = grey and **g** = white seed coat colour;
I = inflated pods and **i** = constricted pods.
Grey seed coat and constricted pods will have a genotype of **Ggii** or **GGii** [1].
In order to obtain pea plants with grey seed coat and constricted pods, the grey seed coat parent will have at least one **G** allele, and both parents will need to be **Ii** for pod shape [1].

b. Yes, because the ratio of 300 : 100 (3 : 1) is the same as the expected ratio for monohybrid cross [1].
If there was no linkage, a standard dihybrid ratio of 9 : 3 : 3 : 1 would be obtained [1].

Question 1.33

a. i. two [1]

ii. **B** = black, **b** = red **S** = solid, **s** = spotted (or any suitable symbols, except X and Y) [2]

b. i. not linked [1]; F_2 ratio is 9 : 3 : 3 : 1 [1]

ii. The genes are on separate chromosomes [1] as they assort independently [1].

Question 1.34

a. Heterozygous rats (A): **KkLl**
Recessive phenotype rats (B): **kkll** [1]

b. Rat A gametes: **KL Kl kL kl** [1]
Rat B gametes: all are **kl** [1]

c. rat A **KkLl** × rat B **kkll**

	KL	Kl	kL	kl
kl	KkLl	Kkll	kkLl	kkll

gametes: ¼ **KL** : ¼ **Kl** : ¼ **kL** : ¼ **kl** × gametes: all **kl**

1 **KkLl** : 1 **Kkll** : 1 **kkLl** : 1 **kkll**

diagram [1]
calculation (such as Punnett square) [1]
genotypes and ratios [1]

d. No, they do not agree, as there is not a 1 : 1 : 1 : 1 ratio for all genotypes [1].
This suggests that these two genes are not segregating independently and are probably linked (on the same chromosome) [1].

Area of study 2 – Change over time

Section A (Multiple-choice questions)

Question 2.1 D

They are genetically similar, similar in appearance and by definition are able to produce vigorous, fertile offspring.

Question 2.2 D

As the two populations are separate and there are no individuals which appear to be the product of matings, there has been no gene flow. Unless the two populations are brought together and produce vigorous, fertile offspring, it is not possible to give a definite answer.

Question 2.3 B

The two populations are separated by a physical barrier, the dry ground. As the two populations are geographically isolated, allopatric speciation can occur. Genetic drift may produce a change in allele frequency by chance, but not distinctive features on its own.

Question 2.4 B

The loss of an allele from a population by chance. Genetic drift is only a factor in small populations.

Question 2.5 C

Option **C** gives the definition for a gene pool.

Question 2.6 A

Option **A** gives the definition for gene flow.

Question 2.7 D

Organisms must be of the same species and gene flow is interbreeding, not arrival or immigration.

Question 2.8 C

Most organisms can't change to suit their environment, they have adaptations which suit their environment. Living longer and surviving are important but the most important point is to reproduce.

Question 2.9 D

The original population may be geographically separated; however, different environments, with different selective pressures, must act on each population. Suitable variations will be favoured, possibly mutations, by the process of natural selection, which will lead to evolution.

Question 2.10 B

The cast is not a fossil. An impression of a bone would be found in the rock, not the bone itself. A fossil is evidence of past life.

Question 2.11 B

Lava destroys evidence of life, water is not a sediment and rock may be formed after sedimentation.

Question 2.12 B

Mitochondrial DNA is in the cytoplasm of the ovum and therefore is inherited solely from the mother.

Question 2.13 D

The mitochondrial DNA is passed from the mother to all her children in the cytoplasm of the ovum fertilised to make each child.

Question 2.14 D

Allopatric speciation occurs when a population is physically separated for many generations. Behaviour and mating calls may lead to speciation, but this is not allopatric.

Question 2.15 B

The structures may be similar and yet have evolved independently. They are analogous, which is evidence of convergent evolution. Homologous structures are evidence of divergent evolution.

Question 2.16 B

The only process that could occur in a virus is mutation, as they do not undergo meiosis.

Question 2.17 A

As they have a recent common ancestor, the evolution is diverged. The change is due to natural selection, but the best description is adaptive radiation, which is a subset of divergent evolution.

Question 2.18 D

Options A–C are only for humans. Humans have opposable thumbs and apes have both opposable big toes and thumbs.

Question 2.19 D

Carbon dating is only useful for objects up to 50 000 years old. Stratigraphic correlation is useful only to give a **relative** age. PCR is used to amplify DNA and is not relevant here.

Question 2.20 C

The brow ridges provided extra strength to the skull to support larger jaw muscles. These would be less prominent. Both species would have parabolic jaws. The width of the jaw is natural variation and it is the relative size of the brain, and in particular the size of the cerebral cortex, that is important.

Question 2.21 B

Cultural evolution is only found in humans. It is our interaction with the environment and the changes that occur as a result of this.

Question 2.22 B

Genetic drift is the random change in allele frequency in a usually small, isolated population. Gene flow is interbreeding between populations, and allopatric speciation occurs when two groups are physically separated and no gene flow occurs, and over time two species develop.

Question 2.23 B

Man has chosen individuals with suitable features and has bred them.

Section B (Short-answer questions)

Question 2.1

a. Genetic variability occurs when members of a population differ in one or more inherited characteristics [1].

b. **i.** Where gene flow occurs, the type and frequency of alleles will be similar in both populations [1].

ii. Gene flow allows the introduction or loss of alleles from a particular population [1].

c. It would reduce the species' chances of survival [1]. The genetic similarity would reduce the probability of the presence of a favourable characteristic in the population if there was an environmental change [1].

d. Zoos and fauna reserves often operate a semen exchange programme to reduce in-breeding OR any other reasonable answer [1].

Question 2.2

a. A new antibiotic will need to be produced otherwise the *E. faecium* populations cannot be controlled and hence the pathogenic properties cannot be restricted and people may die [1].

b. **i.** 1. The growth-promoting antibiotic was not used in the USA and VRE has been found in the USA since the late 1980s [1].
2. Experiments in Germany have shown that the strains of VRE in humans are different to those found in other animals [1].

ii. The overuse of oral vancomycin for the treatment of infections [1].

iii. No. Only severe cases were treated with the antibiotic in Australia [1]. VRE have been transmitted to the human gut via the food chain in Australia, as this strain may be different [1].

c. 1. Initially there were VRE and VSE (vancomycin susceptible *E. faecium*) in the USA [1].
2. Vancomycin was administered orally and hence VSE decreased in numbers and VRE survived [1].
3. VRE reproduced and passed the resistant genes onto their offspring and so on [1].
4. Hence the proportion of VRE increased in the population [1].

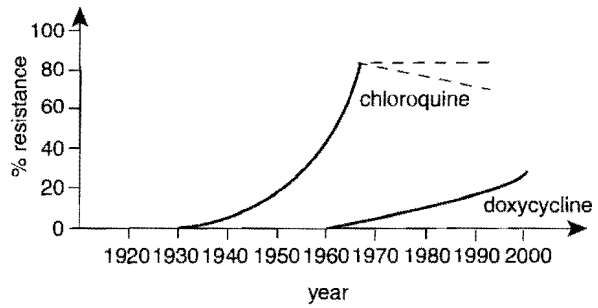
Question 2.3

a. evolution [1]

b. **i.** natural selection [1]

ii. A variation in initial population [1]; the selective pressure of anti-malarial drugs [1]; the most resistant survived and reproduced [1]; and the population became predominantly suited [1].

c.



Any reasonable answer, e.g.

- if the resistance remains constant, it is not affected by natural selection;
  OR
- if the resistance decreases, resistance is not a selective advantage. [1]

Question 2.4

a. They must compete for females and more chance of mating [1]. The more conspicuous males are more likely to gain the attention of the female and mate [1].

b. **i.** Female members of the species would be the selective pressure [1]. They would choose which male would mate with them by their characteristics e.g. the size of antlers [1].

ii. Yes, this is a form of natural selection [1]. Those organisms most suited, e.g. those with larger antlers, are selected to breed. These characteristics enable them to survive and reproduce. Hence the population would have a larger proportion of these characteristics [1].

iii. The features would not be expected to remain static over time [1]. It would be expected that sexual selection will always be occurring and over generations. For example the size of antlers could increase as the proportion of large antlers in a population increases [1].

iv. To a degree, the situation exists in humans [1]. For example, males are generally taller and have more developed musculature than females. These differences become more pronounced after puberty [1].

Question 2.5

a. No [1]. The finches belong to different species, and are by definition unable to reproduce vigorous fertile offspring. There would be differences between the species that would prevent interacting and interbreeding, such as different mating calls [1].

b. divergent evolution [1]

c. No, in allopatric speciation the population must be physically separated [1]. In this case the populations are separated on the islands due to the food available. They could easily interact if suitable food was available on each island [1].

d. DNA hybridisation studies could be carried out [1]. The DNA from each species would be made single-stranded and the percentage of hybridisation (complementary base pairing) could be compared. The greater the hybridisation, the greater the relationship [1].

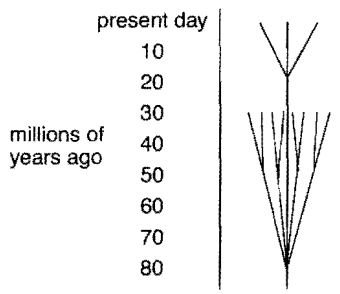
Question 2.6

a. **i.** Populations were reduced to such low numbers that they lost much of their genetic variability [1].

ii. They would compare them to present-day plants and relate fossil structures to their expected location [1].

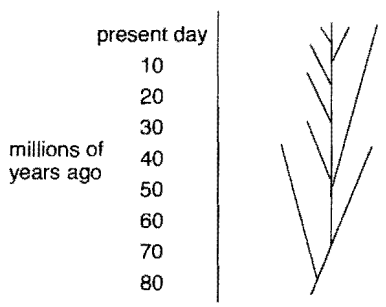
iii. Genetic variation is greatly reduced [1]; therefore evolution is slowed or stopped for a particular species [1]. The species is more susceptible to extinction.

b. The graphs should show an expansion of the number of species up to 30 million years ago, at which time the bottleneck should appear [1], with the appropriate number of species appearing from 20 million years ago [1], e.g. for kiwis.



b.

c. The diagram should not show the bottleneck. Continuous evolutionary expansion should occur [1].



d. No [1]. It is not possible to mate the species to determine if they can produce vigorous fertile offspring [1].

e. Two of: comparing structures, immunological comparison, comparison of geographical distribution [2].

Question 2.7

a. **i.** the discovery of dinosaur fossils [1]

ii. Radioisotope dating [1]. (Carbon dating enables estimates of age up to 50 000 years and so would not be appropriate for dating in millions of years.)

b. **i.** Birds were the last vertebrates to appear [1], and this occurred about 200 million years ago [1].

ii. The Quaternary period [1]. The only time after mammals evolved that average global temperatures were colder than today was during the Quaternary period [1].

c. i. A large number of species die out at the same time [1].

ii. If the climate becomes warmer and the species does not have members who have inherited characteristics that can tolerate the warmer conditions [1] then no individuals will survive to produce the next generation, or if a species on which they rely (such as for food) does not have members that possess inherited characteristics that enable them to survive the warmer conditions, no individuals may survive [1].

iii. No [1], there was not a **sharp** decrease in the average global temperature at the time of mass extinction 3, which included the dinosaurs [1].

iv. Any one of
- An increase in competition with mammals for food;
- A rise in sea level drowned them;
- A meteorite impact caused volcanic eruptions which released poisonous gases or dust which blocked out the sun;
- OR any other reasonable answer. [1]

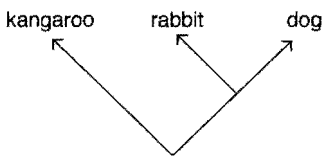
Question 2.8

a. duck [1]

b. If the environment of the two organisms were similar [1], there would be no difference in the selection pressure acting [1].

c. It suggests that this molecule was present in the earliest species (common ancestor) [1].

d.



[2]

e. Any one of the following:
- Comparative anatomy – homologous structures.
- DNA hybridisation – DNA which is complementary from a different species.
- Fossils – study of similarities in fossils.
- Comparative embryology – study of similarities in embryos of a different species.

Name [1]; *Description* [1].

Question 2.9

a. Bones and teeth are mainly composed of a hard mineral substance. Teeth also have a hard enamel coating [1], which means that they are less likely to decay or weather away.

b. No. Carbon dating can only be used for biological material up to a maximum age of 50 000 years [1]. (^{14}C has a half-life of 5730 years.)

c. In *Tingamarra porterorum* the hypoconulid is isolated from the other two cusps and is in the middle of these cusps, whereas in marsupials the hypoconulid is next to the entoconid [1]. The enamel of the tooth is similar in structure to the enamel of the tooth of a placental mammal [1].

Question 2.10

a. The remains or evidence of an organism preserved in rock or other substance [1].

b. i. B [1]

ii. One method is to use radioisotopic dating using an element with a known long half-life, e.g. uranium, which has a half-life of 4.5 billion years [1]. Using the ratio of uranium to lead present or use the ratio of argon to strontium present [1]. (Carbon dating cannot be used as the fossil is older than 50 000 years.)

iii. An index fossil is one which is found in different locations and can be used as a comparison [1]. It is important that it is easily identifiable [1] or that its distribution is widespread. It is also important that it readily fossilises and that the organism from which it was produced lived for a reasonable length of time [1].

iv. Scientists infer the appearance based on present day organisms [1] and they can also look at other features, such as the attachment of muscles, the density of bones and the size of the bones to determine the appearance [1].

c. i. divergent [1]

ii. The organisms have a common ancestor [1], but develop different characteristics due to be being exposed to different selective pressures [1].

d. i. analogous [1]

ii. Structures with a similar function and appearance [1], but with differences in their basic structure, indicating different ancestors [1].

Question 2.11

a. homologous structures [1]

b. Their bone structure is similar [1] in that they all have a humerus, radius, ulna and carpals [1].

c. Their structures have become modified through natural selection [1] so that each species has a forelimb that is suited to a particular use [1].

Question 2.12

a. evolutionary tree OR phylogenetic tree [1]

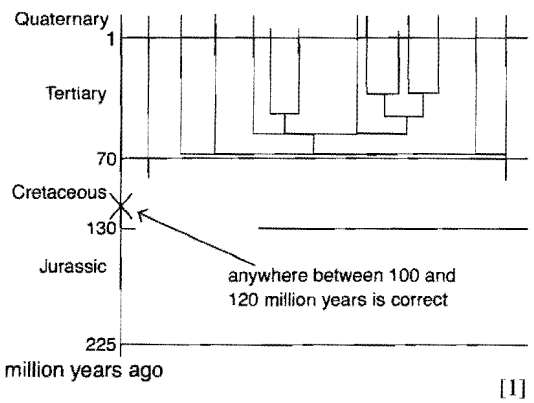
b. That the degree of similarity was related to time since separation [1].

c. No [1]. The chemical composition (including amino acids) of most fossils is not likely to be able to be analysed [1]. (During the fossilisation process, most chemicals change, and in some cases become different elements.)

Question 2.13

a. Divergent evolution occurs when change from a common ancestor increases as time passes due to different habitats and hence different selection pressures [1]. For example, a ringtailed possum lives in trees and is an agile climber and leaper whereas a kangaroo grazes on the plains and does not have the agility of a ringtailed possum [1].

b.



[1]

c. convergent evolution [1]
Marsupials of Australia and placental mammals of America emerged from a common ancestor about 120 million years ago when Gondwana existed. Despite their temporal (over 100 million years) geographical separation, both have remarkable similarities in body-shape, diet and locomotion, due to similar selection pressures in similar habitats [1].

Question 2.14

a. Evolution is the progressive change over many generations in which one species develops into another [1].

b. Divergent (since the original species diverges or develops into three new species) [1].

c.

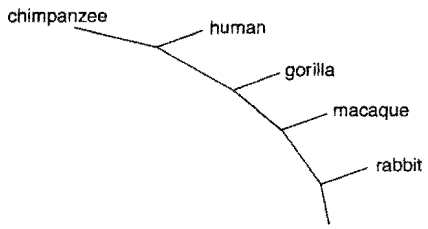
Feature	Convergent evolution	Divergent evolution	Parallel evolution
More species are present at the end of a period of time than at the beginning.		✓	✓
The species present at the end of a period of time occupy similar habitats.	✓		✓
Different environmental pressures cause this to happen.		✓	
All new species originated from the same gene pool.		✓	✓
Reproductive isolation is involved.	✓	✓	✓

1 mark per line [5]

Question 2.15

a. Any two of
- Hominins are bipedal whilst *Pongidae* are quadrupedal;
- Hominins have a larger brain size than *Pongidae*;
- *Pongidae* have an opposable toe whilst hominins do not. [2]

b.



[2]

c. between 93% and 98% [1]

Question 2.16

a. Any two of
- sediment;
- reduced oxygen;
- lack of decomposers/scavengers;
- Or any other reasonable answer. [2]

b. **i.** bipedal stance and gait [1]

ii. Any two of
- parabolic jaw;
- large cerebral cortex;
- reduced canines;
- reduced hair;
- OR any other reasonable answer. [2]

iii. It is possible to determine upright stance and gait from a skull. The position of the foramen magnum, where the spine enters the skull is important. If it is central it indicates that the head sits upright upon the backbone and indicates that an upright stance is possible [1]. A posterior foramen magnum indicates upright stance is not possible [1].

c. divergent [1]

Question 2.17

a. *H. habilis* → *H. erectus* → Neanderthal *H. sapiens* → modern *H. sapiens* [1]

b. *Australopithecus africanus* [1]
It could not have been *A. robustus* because it was present 200 000 years after *Homo habilis* appeared [1]

c. long skull, prominent brows [1]