Questions

Q1.

The genomes of some species of cichlid fish have been sequenced and analysed.

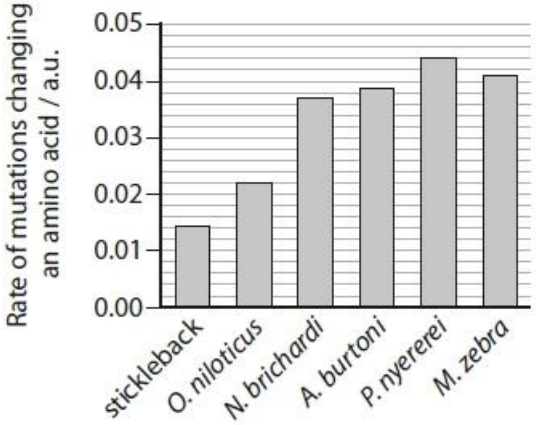
The data collected included:

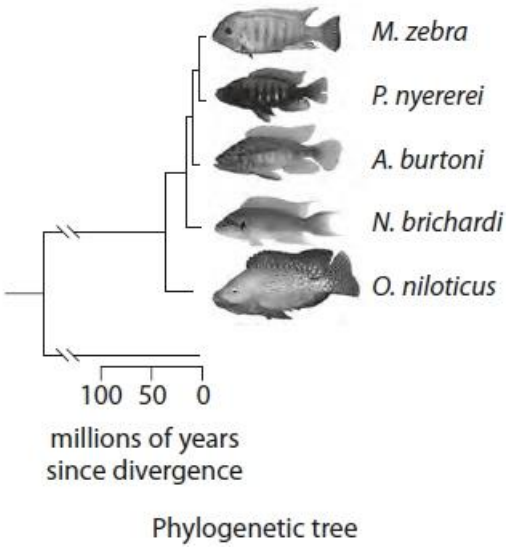
- the rate at which genes have been duplicated to produce additional copies of genes on a chromosome
- the frequency of mutations in transcription factor binding sites
- the rate of mutations that result in a change of an amino acid in a protein.

This information was used to produce a phylogenetic tree.

A comparison was made with a stickleback, which is a slowly evolving fish.

Speed of evolution	Fish	Rate of gene duplication / a.u.	Number of mutations in transcription factor binding sites (compared to *O. niloticus*)
Rapidly evolving cichlid fish	*O. niloticus*	45	0
	N. brichardi	45	214
	A. burtoni	55	140
	P. nyererei	45	129
	M. zebra	60	142
Slowly evolving fish	stickleback	10	0





Phylogenetic tree

Analyse all the data provided to discuss how several species of cichlid fish have evolved over a short period of time.

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(Total for question = 9 marks)

Q2.

Climate change has been linked to the release of carbon dioxide from some power stations.

Some power stations burn wood chips instead of fossil fuels to produce electricity.

The photograph shows wood chips at a power station.

It is thought that burning wood chips is more beneficial to the environment because in the long term it does not add carbon dioxide to the atmosphere.

Explain why burning wood chips does not increase carbon dioxide to the atmosphere in the long term.

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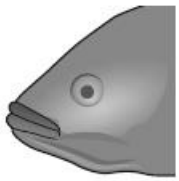
(Total for question = 4 marks)

Q3.

More than 2000 different species of cichlid fish have been identified in lakes and rivers in Africa.

The different species of cichlid fish have evolved from a common ancestor over a short period of time.

The table shows some of the different species of cichlid fish found in lakes and rivers in Africa.

Species	Information	Mouth shape
Oreochromis niloticus	Lives in rivers across northern Africa. Herbivore feeding on plankton and plants. Lays eggs in gravel.	
Neolamprologus brichardi	Lives in shallow but steep rocky habitat in Lake Tanganyika. Carnivore feeding on small crustaceans and invertebrates. Lays eggs between rocks.	
Astatotilapia burtoni	Lives in muddy rivers flowing into Lake Tanganyika. Omnivore feeding on small fish, insect larvae, algae and plant debris. Lays eggs in gravel.	
Pundamilia nyererei	Lives in shallow water in Lake Victoria. Omnivore feeding on insect larvae and zooplankton. Lays eggs between rocks.	
Maylandia zebra	Lives in deep, clear waters of Lake Malawi. Herbivore feeding on plant material. Lays eggs in gravel.	

Describe how different species of cichlid fish have evolved in lakes and rivers in Africa.

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(Total for question = 5 marks)

Q4.

Scientists have studied behavioural, anatomical and genetic variation in elephants.

The table shows some information about two populations of African elephants.

Population	Location	Feeding behaviour	Anatomical differences
Forest elephant	tropical forest of central and West Africa	feeds on leaves and fruits of high-growing plants such as shrubs and trees	• lower jaw longer and narrower • tusks straighter and downward facing • overall a much smaller size
Savannah elephant	African savannah	feeds on grass and leaves of low-growing shrubs	• lower jaw shorter and wider • tusks more curved and upward facing • overall a larger size

The photographs show elephants from the two populations.

Forest elephant

Savannah elephant

DNA samples were collected from these two populations of elephants.

Scientists have concluded that the forest elephant and the savannah elephant are two different species.

* (i) Analyse the data and the information provided to comment on the validity of this conclusion.

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(ii) Explain how two species of African elephant could evolve from a common ancestor.

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(Total for question = 9 marks)

Q5.

Tropical rainforests play a role in maintaining biodiversity and in storing carbon.

Explain how reforestation of tropical rainforests can be used to minimise climate change.

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(Total for question = 3 marks)

Q6.

Trypsin is an enzyme found in many groups of living organisms.

Trypsin specifically acts on a polypeptide to form amino acids.

Trypsin molecules from vertebrates, but not other animals, have a calcium ion binding site.

Explain how this calcium ion binding site could have evolved in vertebrates.

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(Total for question = 3 marks)

Q7.

During the civil war in Mozambique, from 1977 to 1992, 90% of the African elephants were killed for the ivory in their tusks.

Since 1992, the elephant population in Mozambique has increased.

The photograph shows a group of elephants in Mozambique.

A study of an elephant population in Mozambique was carried out in 2017.

The elephants studied were all born before 1992.

The table shows the number of elephants with and without tusks.

Elephants	Number of elephants
with tusks	98
without tusks	102

In most African elephant populations, 2% to 4% of elephants do not grow tusks.

(i) Explain why the percentage of elephants without tusks in Mozambique will probably increase in the future.

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(ii) Describe how the Hardy-Weinberg equation can be used to provide evidence for changes in the elephant population in Mozambique.

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(Total for question = 5 marks)

Q8.

Forests are important habitats.

Many forests are exploited by humans.

(i) Describe how forests can be managed as a sustainable resource.

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(ii) Explain the impact of cutting down trees on climate change.

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(Total for question = 6 marks)

Q9.

Sloths are mammals found in Central and South America.
The map shows the distribution of two species of sloth.
There are currently two major populations of *C. hoffmanni* in South America.
B. pygmaeus is restricted to an island off the coast of Central America.
Each population occupies different habitats.

Discuss why the number of sloth species may change in the future.

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(Total for question = 6 marks)

Q10.

Some fish live in very cold parts of the sea where ice can form.

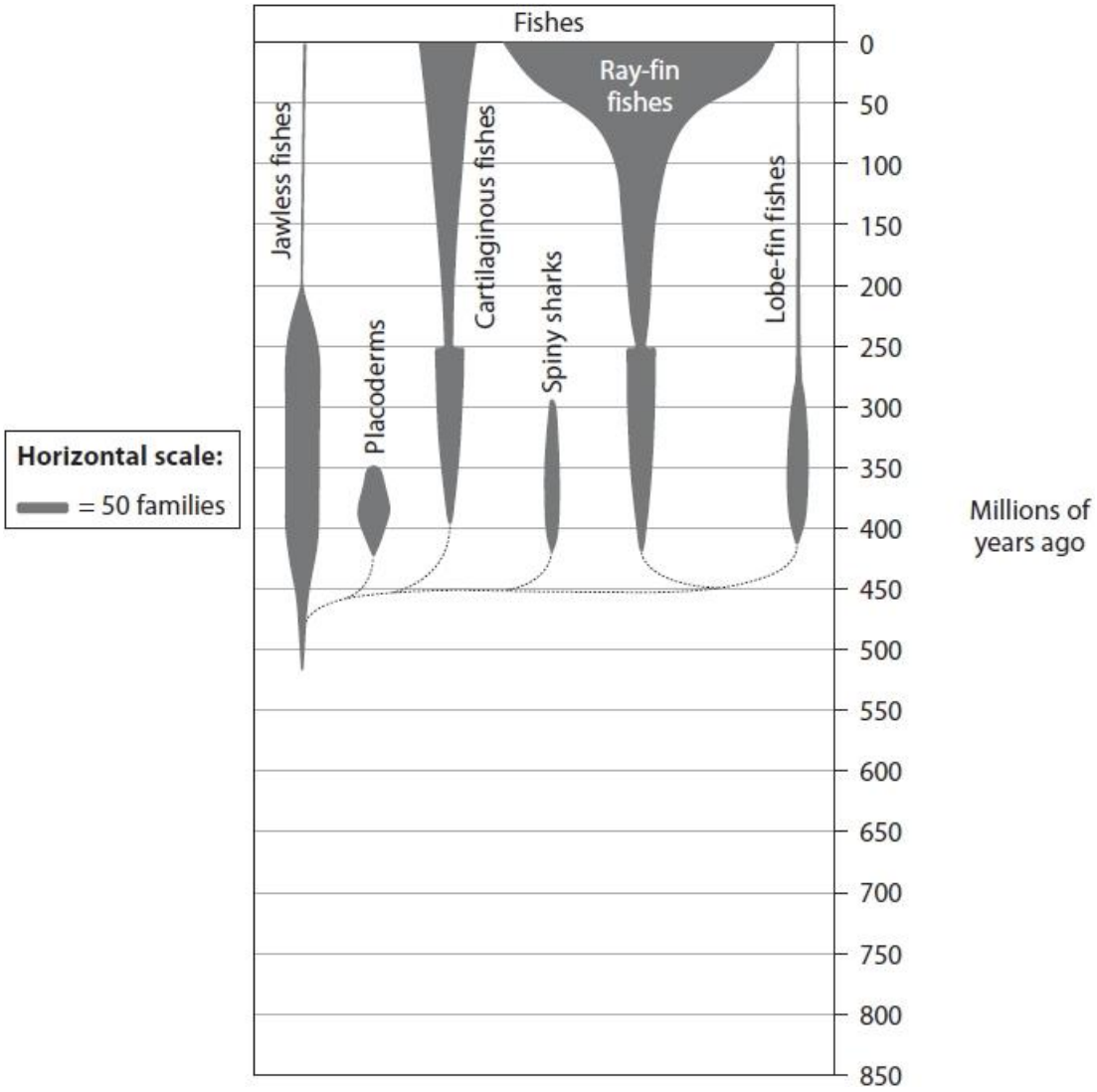
Many of these fish produce anti-freeze proteins, which help to stop ice forming inside the fish.

Sea ice forms only during ice ages.

The table shows Earth's ice ages over the last 1000 million years.

Ice age	Time / millions of years ago
Quaternary	0 to 2.6
Karoo	260 to 360
Andean-Saharan	420 to 460
Cryogenian	630 to 850

The diagram shows how the number of families of fishes has changed over time.



(i) At which time does the diagram show a major loss of biodiversity?

(1)

- ☒ **A** 65 million years ago
- ☒ **B** 252 million years ago
- ☒ **C** 359 million years ago
- ☒ **D** 419 million years ago

(ii) Many different types of anti-freeze protein are produced by ray-fin fishes.

Analyse the data to explain when these ray-fin fish are likely to have evolved the ability to produce anti-freeze proteins.

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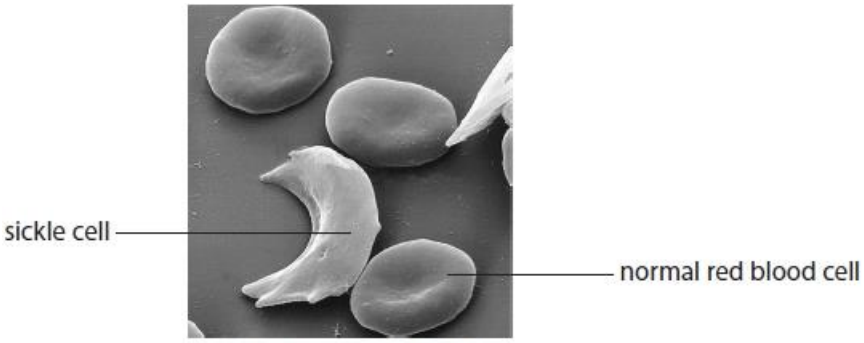
(Total for question = 4 marks)

Q11.

Plasmodium falciparum is a single-celled eukaryotic organism. *P. falciparum* causes the disease malaria when it invades red blood cells.
If untreated, malaria can result in a shorter than normal life span.
The high mortality rate of people with malaria has been claimed to be one of the greatest selection pressures on the human genome in recent history.
Sickle cell anaemia is a genetic condition.
People who are homozygous for the sickle cell allele have red blood cells that become deformed in shape when they are deoxygenated.
The electron micrograph shows these deformed sickle cells alongside normal red blood cells.



(i) The image of the normal red blood cell labelled in the electron micrograph has a diameter of 2 cm.
Which of the following is the actual diameter of this red blood cell?

(1)

- ☒ **A** 0.67 µm
- ☒ **B** 6.7 µm
- ☒ **C** 67 µm
- ☒ **D** 670 µm

(ii) People with a heterozygous genotype for this condition do not develop severe sickle cell anaemia.

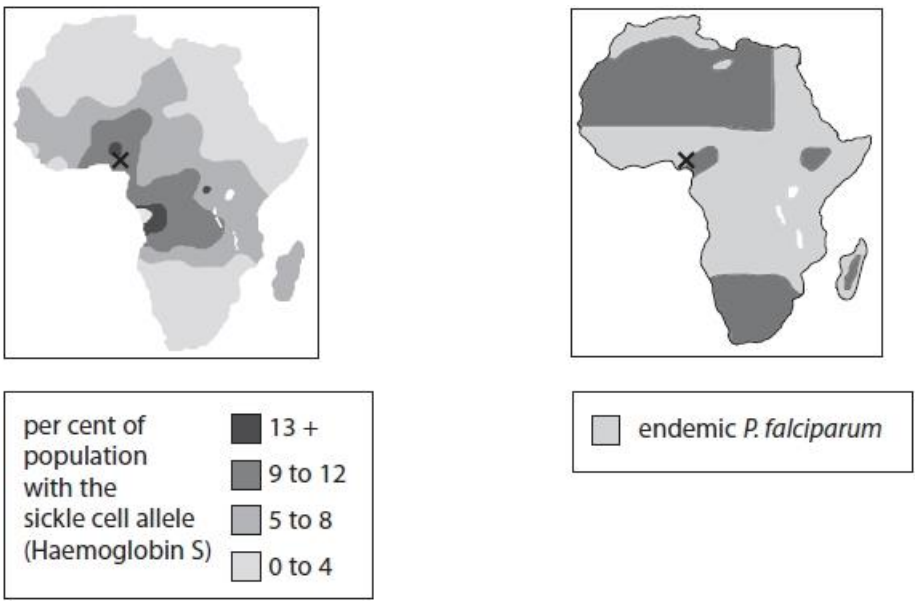
The Yoruba are a group of people who live in West Africa.
In a population of 600 Yoruba individuals, 24 were found to have severe sickle cell anaemia.
Calculate the number of heterozygous individuals in this population.
Use the Hardy Weinberg equation, $p^2 + 2pq + q^2 = 1$.

(3)

Answer .....

* (iii) Individuals who are heterozygous for this condition are resistant to a severe form of malaria, called cerebral malaria, that affects the brain. Individuals who are homozygous for the sickle cell allele are more likely to develop severe sickle cell anaemia.

The maps show the percentage of the population with the allele for sickle cell anaemia and the distribution of *P. falciparum* in Africa. The location of the Yoruba people is indicated with a cross (✕).



Analyse the data to explain how malaria has affected the percentage of individuals in the Yoruba population with the allele for sickle cell anaemia.

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(Total for question = 10 marks)

Mark Scheme

Q1.

Question Number	Indicative content
	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Section of relevant data** • higher rate of mutations than in {slowly evolving fish / sticklebacks} • relatively high rate of mutations that change amino acids compared to slowly evolving fish • low rate of gene duplication in slowly evolving fish / high rate of gene duplication in cichlid fish • higher rate of mutations in regulatory sequences in cichlid fish • variety of habitats available providing different selection pressures **Consequences of data described** • more {amino acid changes / gene duplications} the greater number of alleles in gene pool • altered amino acids result in altered protein function • changes in regulatory sequences allow for different gene expression in tissues etc • duplicated genes can be used for new functions without loss of original function / polygenic phenotypes • variety of habitats provide a number of niches suitable for cichlid fish with different adaptations to exploit **Linkages made to rate of evolution** • example of an altered protein function e.g. enzymes that work at different pH / temperature tolerance • development of new phenotypes • {new enzymes/ different mouth shapes} allow new food types to be exploited • changes in {pigmentation / mouth shape} allow speciation

Edexcel Biology A-level - Natural Selection, Evolution and Speciation

Level	Mark	Descriptor	Additional guidance
Level 0	Marks	No awardable content	
Level 1	1-3	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures. The discussion will contain basic information with some attempt made to link knowledge and understanding to the given context.	At least one relevant piece of data described e.g. higher mutation rate. A consequence described for the data – e.g. linking mutations to protein structure Basic clear conclusion attempted e.g. different proteins are produced
Level 2	4-6	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures. The discussion shows some linkages and lines of scientific reasoning with some structure.	At least two pieces of relevant data referred to. Consequences of at least two pieces of data explained Linkages made to evolution of the fish e.g. changes in phenotype
Level 3	7-9	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures. The discussion shows a well-developed and sustained line of scientific reasoning which is clear and logically structured.	At least three pieces of relevant data referred to Consequences of each piece of data explained Linkages to evolution discussed, e.g. the types of adaptations that may arise due to mutations

Q2.

Question Number	Answer	Additional guidance	Mark
	An explanation that makes reference to the following • carbon dioxide produced by burning wood replaces thatabsorbed by the trees (1) • trees absorb carbon dioxide (from the atmosphere) forphotosynthesis (1) • new trees are grown to replace those that are cut down (1) • therefore no net increase in carbon dioxide (1)	ALLOW converse ALLOW fix carbon ALLOW carbon neutral	**(4)**

Q3.

Question Number	Answer	Additional guidance	Mark
	A description that makes reference to five of the following: • (random) mutations are responsible for variation (1) • different selection pressures (in different habitats) (1) • an example of an adaptation to the habitat that enables the fish to survive (1) • (fish that survive) pass on beneficial alleles to offspring (1) • reduced gene flow between populations (1) • sympatric speciation of fish in same lake / allopatric speciation of fish in different {lakes / rivers} (1)	IGNORE mutations as a response to selection pressures ALLOW a description of different selection pressures e.g. different water quality / food availability or substrate for egg laying e.g. anatomical – mouth shape and food eaten, behavioural – egg laying habit ALLOW 'advantageous' or 'favourable' for 'beneficial' IGNORE genes ALLOW change in allele frequencies ALLOW geographical isolation due to being in different {lakes / rivers}	**(5)**

Q4.

Question Number	Answer
* (i)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. • feeding behaviours • anatomy • genetic differences • no information on whether they can interbreed to produce fertile offspring • different locations do not indicate that they are different species • no information on number of elephants used for DNA analysis • GBA alleles K and L are exclusive to one type of elephant / genetic isolation

Level	Mark	Descriptor	
Level 0	Marks	No awardable content	
Level 1	1-2	An answer may be attempted but with limited interpretation or analysis of the scientific information with a focus on mainly just one piece of scientific information. The answer will contain basic information with some attempt made to link knowledge and understanding to the given context.	Makes reference to one of behavioural, phenotypic, anatomical or genetic differences
Level 2	3-4	An answer will be given with occasional evidence of analysis, interpretation and/or evaluation of more than one pieces of scientific information. The answer shows some linkages and lines of scientific reasoning with some structure.	Makes reference to more than one of behavioural, phenotypic, anatomical or genetic differences Also includes an interpretation of allele data **or** considers reasons why may not be different species
Level 3	5-6	An answer is made which is supported throughout by sustained application of relevant evidence of analysis, interpretation and/or evaluation of all pieces of scientific information. The answer shows a well-developed and sustained line of scientific reasoning which is clear and logically structured.	Also includes an interpretation of allele data **and** considers reasons why may not be different species

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to three of the following: • two populations are geographically isolated from each other (1) • therefore reduced gene flow between the two populations (1) • which leads to allopatric speciation (1) • different selection pressures leading to natural selection (1)	ALLOW description of populations separated by a geographical feature ALLOW description of natural selection in context of selection pressures	3

Q5.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to three of the following • {new / young / growing} trees • resulting in net uptake of carbon dioxide / more carbon dioxide taken in by photosynthesis than released by respiration • therefore reducing carbon dioxide in the atmosphere • which slows the rate of global warming	ALLOW plant more trees ALLOW trees acting as a carbon sink/store ALLOW reduces greenhouse effect	(3)

Q6.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to three of the following: • variation in the trypsin gene • (some variations / mutations) result in production of a calcium (ion) binding site • a calcium (ion) binding site confers a (selective) advantage • (vertebrates) survive, reproduce and pass on this (trypsin) allele / the frequency of this (trypsin) allele increases	ALLOW (random) mutations in the trypsin gene ALLOW makes the enzyme more effective	**(3)**

Q7.

Question Number	Answer	Additional guidance	Mark
(i)	An explanation that makes reference to three of the following • many of the elephants with tusks were killed (for their ivory) / large percentage of population do nothave tusks (1) • elephants without tusks were more likely to surviveand breed (1) • therefore passing on alleles for not having tusks (1) • increasing the frequency of homozygousrecessives in the population (1)	ALLOW converse	**(3)**

Question Number	Answer	Additional guidance	Mark
(ii)	A description that makes reference to the following • calculate the {allele frequencies/ number of dominant and recessive alleles} (in the populationin Mozambique) (1) • (regular) sampling over a period of time (1)		(2)

Q8.

Question number	Answer	Additional guidance	Mark
(i)	A description that makes reference to two of the following: • replacing trees that have been cut down (1) • {remove / cut down} older trees (1) • replace with {seedlings / young / rapidly growing} trees (1)	ALLOW coppicing IGNORE allow trees to fully grow	Choose an item. (2)

Question number	Answer	Additional guidance	Mark
(ii)	An explanation that makes reference to four the following: • less photosynthesis (1) • less carbon dioxide will be fixed / more CO_2 remains in the atmosphere (1) • because CO_2 is a greenhouse gas (1) • more (heat) energy trapped in the atmosphere (1) • more energy in the atmosphere increases (atmospheric) temperature (1)	Less can be implied from MP2 ALLOW more of the products of photosynthesisaccumulate as new biomass than are released due to respiration IGNORE less carbon dioxide will be used IGNORE unqualified reference to greenhouseeffect ALLOW increasing surface temperature of earth	Choose an item. (4)

Q9.

Question Number	Indicative content
	Answers will be credited according to candidate's knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Species number may increase due to: • Fragmentation of habitat / geographical isolation • Different selection pressures on populations of *C. hoffmanni* • Different allele frequencies within separate populations • Evolution leading to formation of new species Species number may decrease due to: • *B. pygmaeus* is currently critically endangered • Only one population • Therefore could be vulnerable to inbreeding depression • At risk of natural disaster, disease, predation etc • Therefore may become extinct

Level	Marks		Additional Guidance
0	0	No awardable content	
1	1-2	An explanation may be attempted but with limited interpretation or analysis of the scientific information with a focus on mainly just one piece of scientific information. The explanation will contain basic information with some attempt made to link knowledge and understanding to the given context.	Geographical isolation. *B. pygmaeus* is currently critically endangered. *C. hoffmanni* becoming more than one species or *B. pygmaeus* becoming extinct
2	3-4	An explanation will be given with occasional evidence of analysis, interpretation and/or evaluation of both pieces of scientific information. The explanation shows some linkages and lines of scientific reasoning with some structure.	*C. hoffmanni* Different habitats with different selection pressures leading to natural selection. Or *B. pygmaeus* has only one population / endemic to one island
3	5-6	An explanation is made which is supported throughout by sustained application of relevant evidence of analysis, interpretation and/or evaluation of both pieces of scientific information. The explanation shows a well-developed and sustained line of scientific reasoning which is clear and logically structured.	(Must consider both species) *C. hoffmanni* populations accumulate different allele frequencies and develop into different species. *B. pygmaeus* more vulnerable to becoming extinct with reasons.

Q10.

Question Number	Answer	Mark
(i)	**B** 252 million years ago	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to three of the following: • (sea) ice is a selection pressure for AFPs / AFPs are advantageous (only) when there is (sea) ice (1) • so AFPs are likely to have { appeared / increased in frequency } during an ice age (1) • the only ice ages since the existence of the ray-fin fish are the Quaternary and Karoo (1) • therefore ray-fin fish producing AFPs are likely to have evolved { in the last 2.6 million years / between 260 and 360 million years ago } (1)	ALLOW AFPs allow fish to survive the ice age ALLOW during the Karoo / Quaternary (ice age)	(3)

Q11.

Question Number	Answer	Mark
(i)	**The only correct answer is B - 6.7 µm** ***A*** *is not correct because did not use calculation 20 000 µm ÷ 3000* ***C*** *is not correct because did not use calculation 20 000 µm ÷ 3000* ***D*** *is not correct because did not use calculation 20 000 µm ÷ 3000*	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct value for p and q • correct proportion of heterozygotes (2pq) • correct number of heterozygotes	<u>Example of calculation</u> ALLOW 0.2 and 0.8 either way round 2pq = 2 x (0.8 x 0.2) = 0.32 number of heterozygotes = 2pq x 600 = 192 Correct answer with no working scores full marks	(3)

Question Number	Answer
* (iii)	Answers will be credited according to candidate's knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. • sickle cell anaemia is more frequent in those areas where malaria is also found (as shown on the maps) • highest proportions of populations with allele for sickle cell anaemia are in areas where there is malaria • the Yoruba people live in an area where *P.falciparum* is found • malaria can be fatal and acts as a selection pressure • individuals heterozygous for sickle cell anaemia more likely to survive malaria • these individuals pass on alleles for sickle cell anaemia to their offspring • over time the number of individuals in the population with alleles for sickle cell anaemia has increased

Level	Marks	Descriptor	Additional guidance
0		No awardable content	
1	1-2	An explanation may be attempted but with limited interpretation or analysis of the scientific information with a focus on mainly just **one** piece of scientific information. The explanation will contain basic information with some attempt made to link knowledge and understanding to the given context.	e.g. 9-12% Yoruba have sickle cell allele / Malaria and Sickle cell anaemia are found in the same place OR Heterozygotes resistant to malaria
2	3-4	An explanation will be given with occasional evidence of analysis, interpretation and/or evaluation of **more than one** piece of scientific information. The explanation shows some linkages and lines of scientific reasoning with some structure.	Two from level 1 Malaria is a selection pressure
3	5-6	An explanation is made which is supported throughout by sustained application of relevant evidence of analysis, interpretation and/or evaluation of **all pieces** of scientific information. The explanation shows a well-developed and sustained line of scientific reasoning which is clear and logically structured.	Individuals with sickle cell allele survive malaria and pass on allele to offspring. Over time frequency of sickle cell allele increases in Yoruba population