The evolution of life

Question Paper

Level	Pre U
Subject	Biology
Exam Board	Cambridge International Examinations
Topic	The origin and evolution of life
Sub Topic	The evolution of life
Booklet	Question Paper

Time Allowed: **59 minutes**

Score: **/49**

Percentage: **/100**

Part - B

Adapted to survive in a harsh habitat

The Shetland Islands lie in the Atlantic 100 km north of mainland Scotland (Fig. 5.1). The Keen of Hamar (Fig. 5.2) is a rocky headland in northern Shetland where there are large areas of stony ground known as debris, which are almost bare of vegetation.

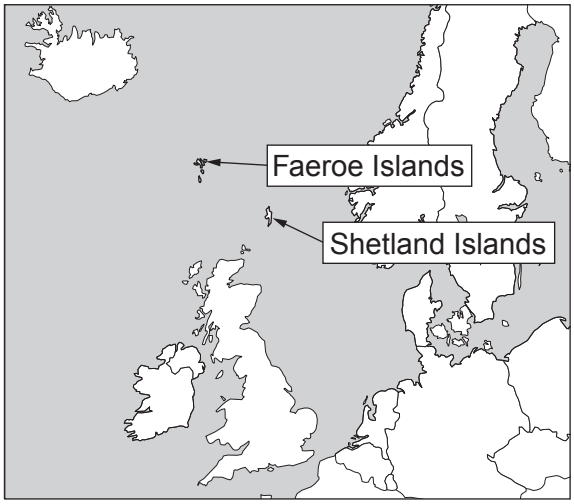

Fig. 5.1

Fig. 5.2

Fig. 5.3

Fig. 5.4

Shetland, the most northerly part of the UK, is only 400 km south of the Arctic Circle but it has an oceanic, rather than an arctic, climate with mild winters (relatively little frost) and cool summers. Most of Shetland is not bare like the Keen but is covered in vegetation, mainly grassland, heather moor and peat bog. The Keen is a Site of Special Scientific Interest (SSSI). The debris, with its shallow, nutrient-deficient, sandy, freely-draining soil may look bare, but quite a number of plant species grow amongst the small stones on the surface. Of particular scientific interest is the Shetland mouse-ear, *Cerastium nigrescens* (Fig. 5.3 and Fig. 5.4), which is almost entirely confined to the Keen debris. This species is believed to have always been restricted to this area, where it evolved in response to local environmental conditions.

The Shetland mouse-ear almost certainly evolved from the Arctic mouse-ear, *Cerastium arcticum*, a species which remains widespread on bare stony soil in the northern parts of Scandinavia, Russia, Siberia and North America. The nearest population of Arctic mouse-ear to the Keen is 200 km to the north-west, in the Faeroe Islands (Fig. 5.1).

At the end of the last Ice Age, the Arctic mouse-ear is thought to have been widespread not only on Shetland, but also further south, growing on stony ground left bare by melting ice. Over the next few thousand years vegetation, such as forest, heath or grassland, spread north to cover most of the land. The Keen debris habitat was one of the exceptions to this and it remained bare despite no longer having an arctic climate. It has probably changed little in 10 000 years.

1 **(a)** There have been times in the past when biologists have regarded *Cerastium nigrescens* and *C. arcticum* as different forms of the same species.

Describe how you would confirm that they are different species.

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(b) **(i)** The herring gull, *Larus argentatus*, and the lesser black-backed gull, *L. fuscus*, both occur on the Shetland Islands. These two species are regarded by some scientists as parts of a 'ring species' complex. These two species of gull do not interbreed on Shetland.

Explain what is meant by a ring species.

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(ii) Some biologists think that the lesser black-backed gull is spreading east to west from Shetland towards Canada.

How might this affect this ring species complex?

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(iii) Suggest why plant species, such as the Shetland mouse-ear, are less likely to be part of a ring species complex than the *Larus* gulls.

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[Total: 9]

Mitochondrial Eve: the mother of us all?

In 1987, Cann, Stoneking and Wilson published the results of research which led them to suggest that all modern humans, of whatever race, are descended from one woman, Mitochondrial Eve, who lived in Africa between 150 000 to 200 000 years ago. This extraordinary claim, which remains controversial, was based on analysis of mitochondrial DNA (mtDNA) of 157 people chosen to represent all existing racial groups. In 2000, Ingman and his co-workers carried out a similar study based on a sample of 53 people of different races using improved techniques and arrived at a similar conclusion.

The investigation was carried out by studying the nucleotide sequence of DNA of the mitochondria of each person. mtDNA consists of a circle of DNA made up of about 37 genes concerned with the production of proteins, including cytochrome c oxidase and NADH dehydrogenase. Features of mtDNA which make it particularly important in this type of study include:

- higher mutation rate than chromosomal DNA,
- little or no genetic recombination,
- humans, male or female, derive all their mitochondria from their mother through the cytoplasm of the ovum.

The figure of between 150 000 and 200 000 years ago is derived by means of a method of calculation known as the Molecular Clock Hypothesis. This is based on the average rate of mutation of DNA over time and the idea that the greater the difference in nucleotide sequence, the longer ago it was that individuals shared a common ancestor. The molecular clock can be calibrated by comparing the differences in nucleotide sequence between similar species whose date of speciation can be calculated independently from fossil evidence.

Mitochondrial Eve was a modern human, *Homo sapiens*, like yourself. When her descendants arrived in Europe over 40 000 years ago they found a population of another human-like animal already present, now known as Neanderthals. By about 30 000 years ago, the Neanderthals had become extinct.

A question which interests many people is ‘were the Neanderthals and *H. sapiens* separate species – or just slightly different races of the same species?’

2 **(a)** The text in question 6 states that the changes in mtDNA were 'relatively neutral in terms of evolution'.

Explain what is meant by this statement.

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(b) mtDNA evidence alone is unlikely to be enough to determine whether Neanderthals and modern humans are of the same or of different species.

Suggest what further information would help to resolve this question.

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(c) Suggest what might have been the circumstances which led to one woman giving rise to the whole modern human race.

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[Total: 9]

3 **(a)** Name **and** outline the theory which accounts for the existence of mitochondria in eukaryotic cells.

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(b) Suggest why it is biologically important that mtDNA includes genes for cytochrome c oxidase and NADH dehydrogenase.

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(c) Suggest how all the mitochondria in a male muscle cell derive from the mitochondria of his mother.

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(d) mtDNA is a group of genes which is transmitted to both male and female offspring.

How may a group of genes be transmitted **only** to male offspring?

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[Total: 10]

4 In 2000, Geisert and his co-workers carried out research on mtDNA. They analysed the nucleotide sequence of the mtDNA of

- 994 modern humans (including a range of racial groups)
- one Neanderthal fossil
- nine chimpanzees.

Once they knew the nucleotide sequences of each of these samples of mtDNA they compared each of these sequences with each of the 994 modern human nucleotide sequences. In this way they were able to make human to human, Neanderthal to human and chimpanzee to human comparisons. The number of differences in the nucleotide sequence for each comparison was then recorded. The differences in mtDNA were quite small – no more than a few nucleotide bases – and relatively neutral in terms of evolution.

The results of these comparisons are shown in Fig. 6.1.

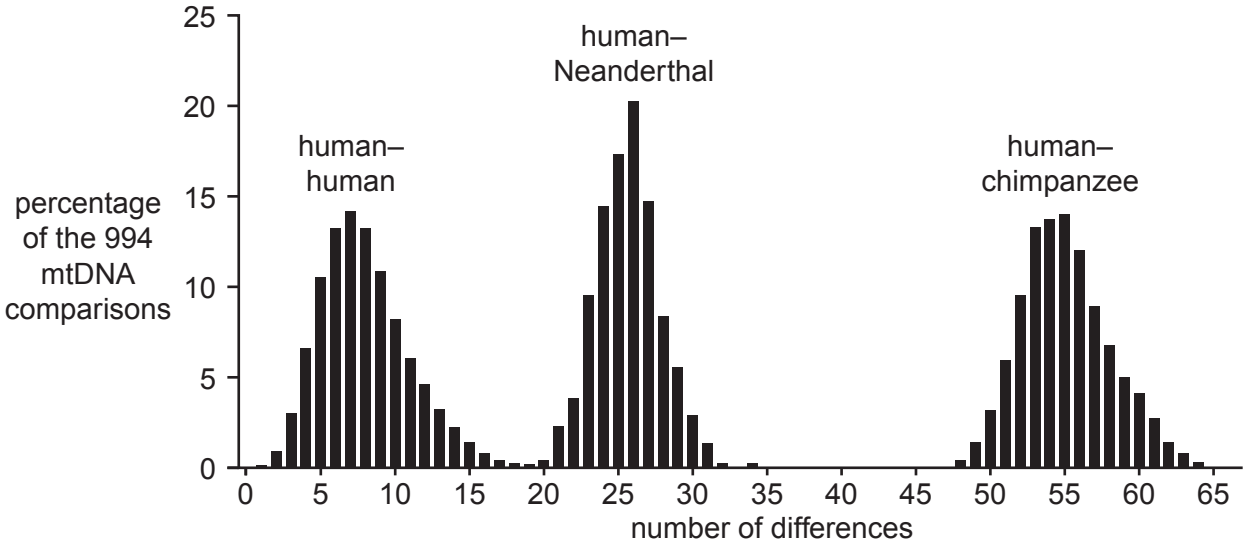

Fig. 6.1

(a) Neanderthal mtDNA is very difficult to obtain. In the case of the specimen referred to in Fig. 6.1, only very small quantities were available.

Suggest how the researchers were able to copy many times the few available Neanderthal mtDNA molecules to provide enough mtDNA to carry out their analyses.

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(b) Suggest why the higher mutation rate and the virtual absence of recombination make mtDNA more useful in tracing ancestry over many generations than the chromosomal DNA of eukaryotic cells.

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(c) Comment on the information given in Fig. 6.1.

You may wish to include potential conclusions, discussion or evaluation in your comments.

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[Total: 11]

5 Carl Linnaeus introduced, in 1735, a system of naming and classifying living organisms just over one hundred years before Darwin and Wallace published their theory of evolution. He wrote:

- 'All the species recognized by Scientists came forth from God's hand, and the number of these is now and always will be exactly the same.'
- 'The species are as numerous as the different forms which exist upon this globe – they produce others similar to themselves but in greater numbers.'
- 'Organisms are divided into two kingdoms of nature: viz. the vegetable and animal kingdoms.'
- 'The species and the genus are always the work of nature; the class and the order are the work of nature and art.'

Compare Linnaeus' views of the nature of a species and their classification with those of modern biologists, and account for any differences.

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