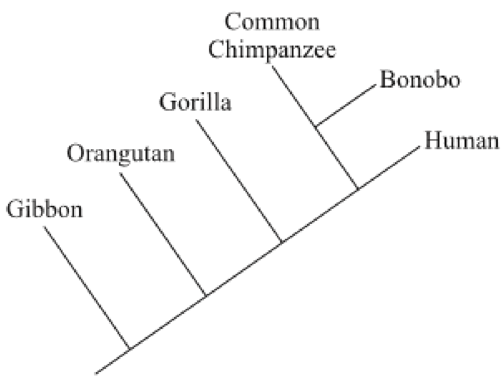
HL Paper 3

c. Outline how variations in specific molecules can lead to phylogeny. [3]

d. Outline the value of classifying organisms. [2]

The diagram below is a cladogram.



a. State a function of each of the following parts of the human brain. [2]

(i) Cerebellum

(ii) Hypothalamus

b (i) Identify the **two** most closely related organisms. [1]

b (ii) Identify the species to which the Bonobo is most distantly related. [1]

c. Describe **one** type of barrier that may exist between gene pools. [3]

b. Define analogous characteristics using **one** example to illustrate your answer. [1]

c. Outline **two** pieces of evidence that support the endosymbiotic theory for the origin of eukaryotes. [2]

d. List **two** anatomical features that define humans as primates. [2]

a. Distinguish between innate and learned behaviour. [1]

c. Distinguish between analogous and homologous structures. [2]

Analogous structures	**Homologous structures**

Discuss the relationship between cladograms and the classification of living organisms.

State **two** characteristics that permit the classification of microbes into domains.

Explain cladistics as a method of classifying organisms.

Explain the biochemical evidence for the common ancestry of living organisms.

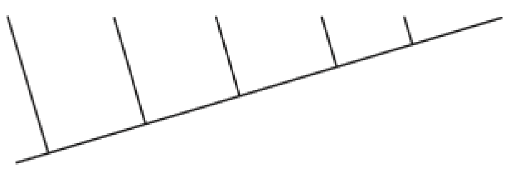
Discuss the use of cladograms in phylogenetic studies.

Explain the biochemical evidence for the common ancestry of organisms on Earth.

a. The table shows certain characteristics present (+) or absent (–) in six organisms. [3]

	Segmented	Jaws	Hair	Placenta	Multicellular	Limbs
Amoeba	–	–	–	–	–	–
Cat	+	+	+	+	+	+
Earthworm	+	–	–	–	+	–
Kangaroo	+	+	+	–	+	+
Lizard	+	+	–	–	+	+
Sponge	–	–	–	–	+	–

Using the data, label the cladogram with the names of the organisms.



c. A species is often defined as a group of similar individuals that interbreed in nature and produce fertile offspring. Discuss some problems with the use of this definition. [2]

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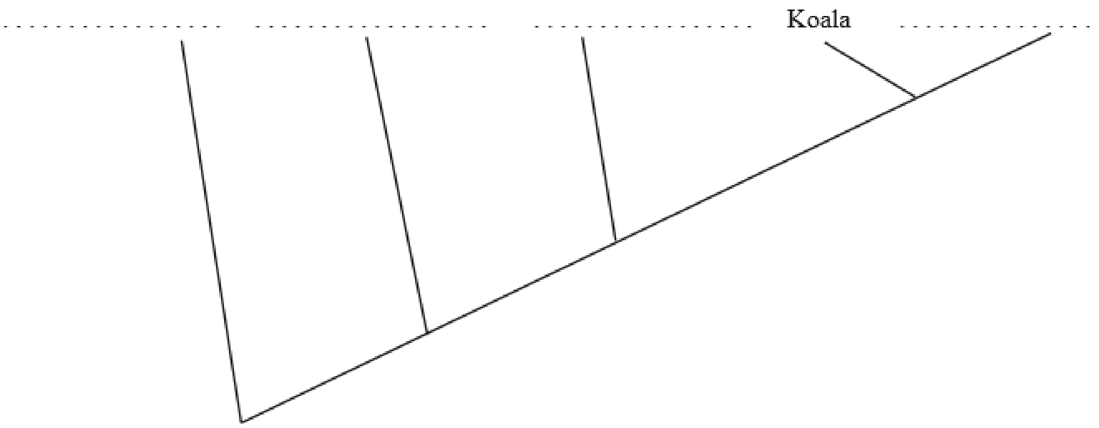
a. Define the term *clade*. [1]

b. Distinguish between analogous and homologous structures, giving an example of each. [2]

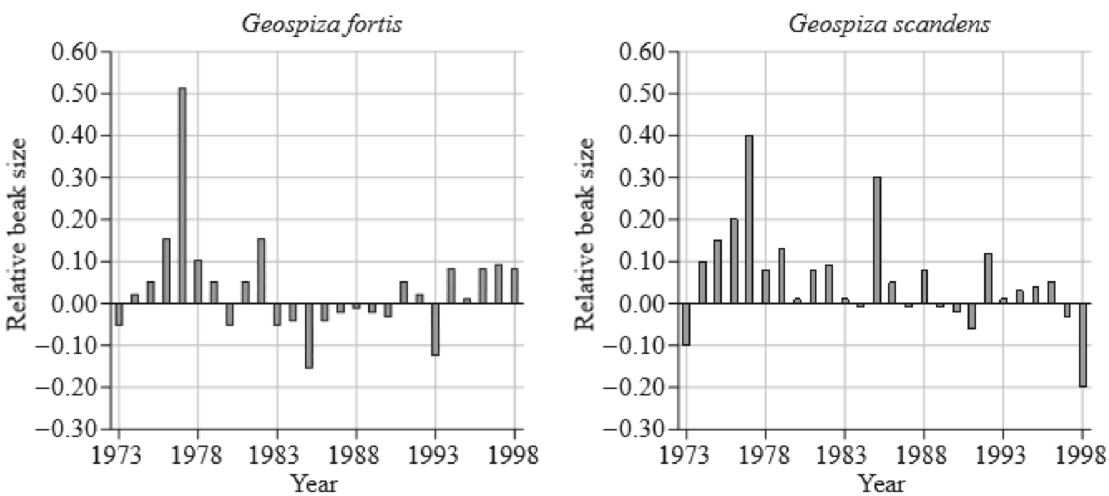
c. The table below lists five animals along with four morphological characteristics. A plus sign (+) indicates that the animal has this characteristic while a minus sign (–) indicates that the characteristic is absent. [2]

Animal	Jaws	Limbs	Hair	Placenta
Salamander	+	+	–	–
Mouse	+	+	+	+
Jellyfish	–	–	–	–
Koala	+	+	+	–
Salmon	+	–	–	–

Based on the features above, a student constructed a cladogram. State the names of the organisms missing in the following cladogram.



A study of two populations of Darwin's finches, medium ground finch (*Geospiza fortis*) and cactus finch (*Geospiza scandens*), was undertaken between 1973 and 1998 on the Galápagos Islands. The graphs below show the mean beak size in each year from 1973 to 1998 compared with the long-term mean size.



Peter R Grant and Rosemary B Grant, "Unpredictable Evolution in a 30-Year Study of Darwin's Finches", *Science*, Vol. 296 no. 5568, pp. 707--711, 26 April 2002. Reprinted with permission from AAAS.

a. State the year in which *G. fortis* had the greatest change in relative beak size. [1]

b. Compare the trends in relative beak size of *G. fortis* and *G. scandens*. [3]

c. Outline possible reasons for the trends in relative beak size in finches. [2]

Antibiotics are sometimes given orally to poultry to prevent disease that may lead to reduced growth. Antibiotic resistance of bacteria from turkeys and chickens bred for meat and from egg laying hens was measured.

Excrement was collected and *Escherichia coli* bacteria were isolated. These bacteria were tested for resistance to a range of antibiotics and the results are shown below.

Number of antibiotics to which *E. coli* are resistant	Turkeys $n = 43$	Chickens $n = 45$	Egg laying hens $n = 20$
0	7	9	13
1	8	5	3
2	7	7	0
3	2	7	3
4	5	7	1
≥5	14	10	0

[Antibiotic resistance of faecal _Escherichia coli_ in poultry, poultry farmers and poultry slaughterers. A. E. van den Bogaard, N. London, C. Driessen, E. E. Stobberingh. _Journal of Antimicrobial Chemotherapy_, 47, June 1, 763--771. 2001, Oxford University Press.]

a. Calculate the percentage risk of bacteria becoming resistant to more than five kinds of antibiotics in turkeys and egg laying hens. [1]

Turkeys:

Egg laying hens:

b. Compare the incidence of drug resistance in bacteria from chickens and egg laying hens. [2]

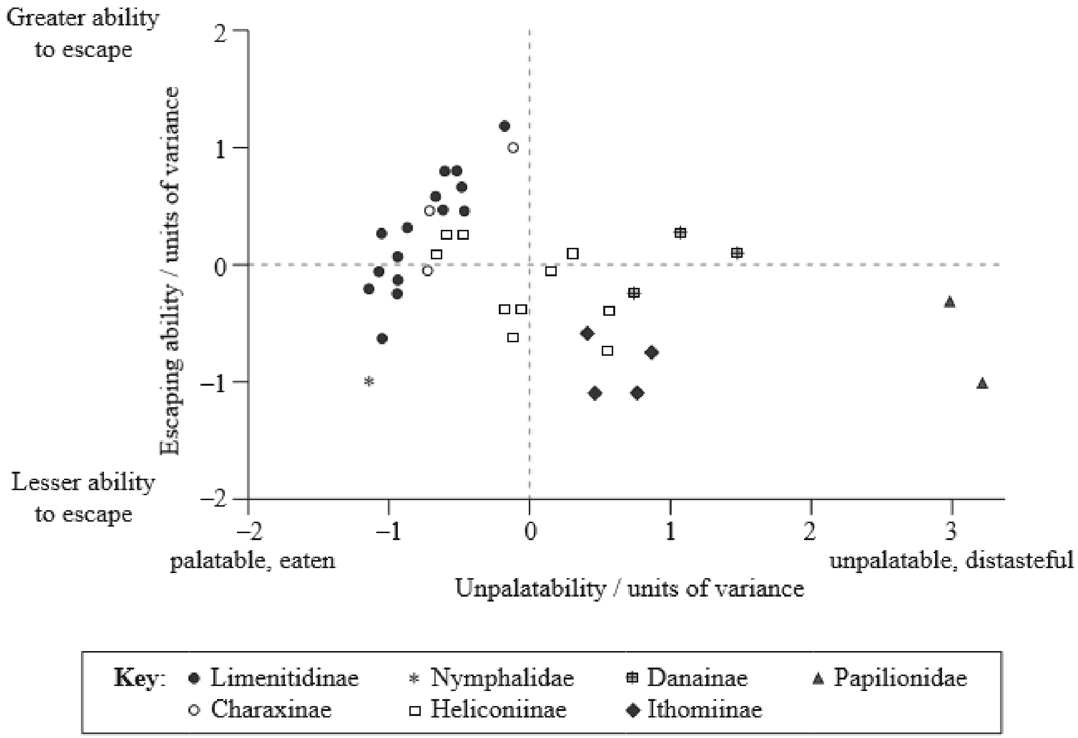
c. Discuss the hypothesis that giving antibiotics increases antibiotic resistance in poultry bacteria. [2]

d. Suggest how antibiotic-resistant bacteria are passed from animals to humans. [1]

e. Outline the mechanism of the action of antibiotics. [2]

e. Outline the mechanism of the action of antibiotics. [2]

Butterflies have evolved different methods of defence against bird attacks. The relative escaping ability and unpalatability (distastefulness) of different tropical butterfly families and subfamilies was investigated in the presence of wild kingbirds, *Tyrannus melancholicus*, a natural predator of butterflies. Each symbol on the graph represents a different species within a (sub)family.



[‘Palatability and escaping ability in Neotropical butterflies: tests with wild kingbirds (Tyrannus melancholicus, Tyrannidae).’ *Biological Journal of the Linnean Society*, **59**, pp. 351–365, Carlos E.G. Pinheiro. ©1996 Linnean Society. Reproduced with permission of Blackwell Publishing Ltd.]

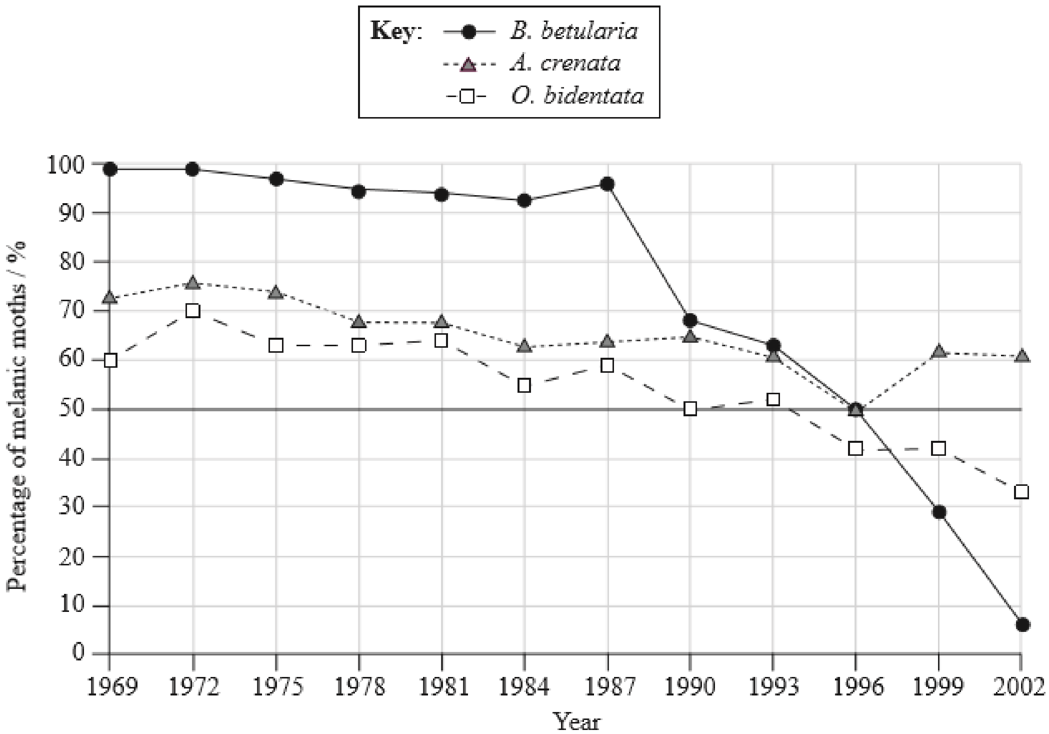
a. State which butterfly (sub)family contains the species with the greatest escaping ability. [1]

b. Suggest one feature of butterfly wings that might help a butterfly to escape from a predator. [1]

c (i) Explain how the ability of a butterfly to escape from predators could increase by natural selection. [3]

c (ii) The graph shows that distasteful butterflies tend to have a lower ability to escape from predators than palatable butterflies. Suggest reasons for this trend. [2]

A study of the changing frequencies of the melanic (dark) and non-melanic (light) forms of three moth species *Biston betularia*, *Odontoptera bidentata* and *Apamea crenata* was carried out in the north of England. Moths were captured using mercury vapour light traps throughout the flying season. All three of the moth species fly at night and rest in the day, when they would be vulnerable to predation by birds, if visible. *B. betularia* rests on tree branches and there is evidence that the change from melanic to non-melanic forms was associated with black soot disappearing from these branches as air pollution was reduced and pale coloured lichens started to grow. *O. bidentata* rests under the leaves of trees or in cracks in tree bark. *A. crenata* rests in long grasses. The graph shows the percentage of melanic moths caught between 1969 and 2002.



a. Identify the year with the highest frequency of the melanic form of *O. bidentata*. [1]

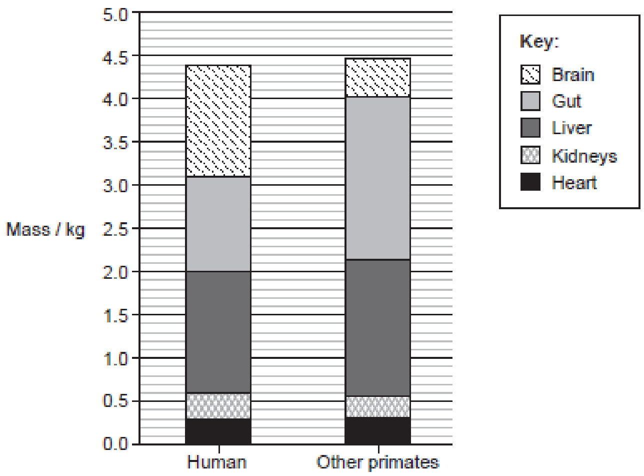
b. Estimate the percentage of **non-melanic** forms of *A. crenata* in 1978. [1]

c (i) Compare the trends for the three moth species during the study. [3]

c (ii) Suggest reasons for the differences in trends. [2]

Researchers investigating human evolution recorded energy use for the brain, gastrointestinal tract (gut), liver, kidneys and heart as a percentage of total energy used in the human body. They found that these organs use around 70 % of the body's energy although they account for only about 7 % of body mass. They also compared the mass of each of these organs in humans with other modern primates, each with a body mass of 65 kg as shown in the bar chart.

Human organs	Brain	Gut	Liver	Kidneys	Heart
Energy use as percentage of total for body / %	16	15	19	8	11



[Source: adapted from L C Aiello, (1997), *Brazilian Journal of Genetics*, **20**, Issue 1]

a. Calculate the percentage of the total body mass made up by the human brain. [1]

b. Compare the mass of human organs with the mass of other primate organs. [2]

c. Using information from the table and the graph, identify the human organ which uses the greatest amount of energy per kilogram of body tissue. [1]

d. Explain the differences between the organ size of humans and other primates in terms of trends in human evolution and their causes. [4]

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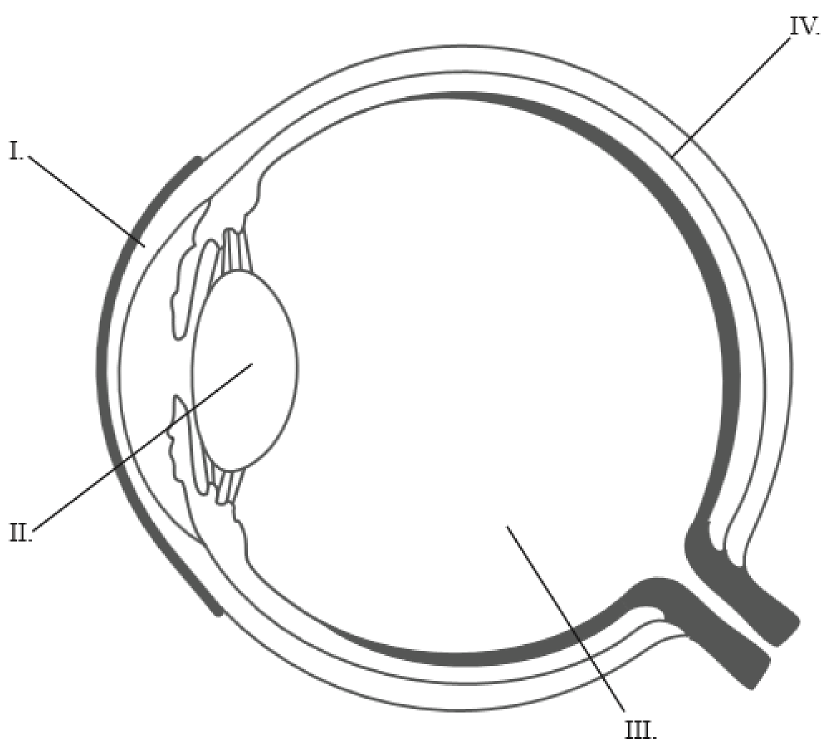
a. The diagram below represents the human eye. State the names of structures I, II, III and IV. [2]



I. ....

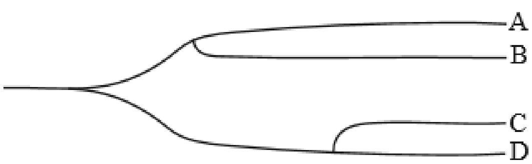
II. ....

III. ....

IV. ....

b. Outline the evidence provided by DNA for the common ancestry of living organisms. [2]

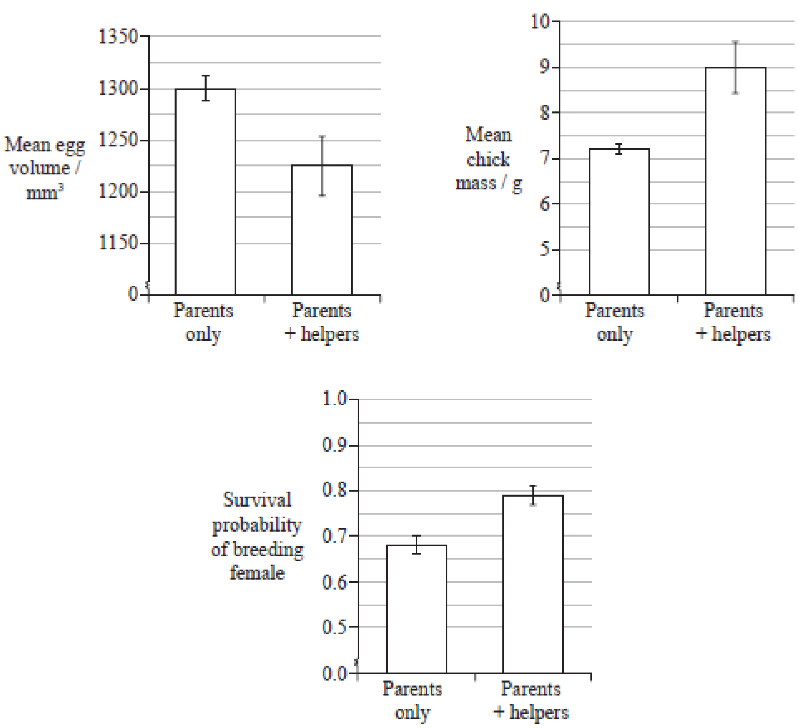
c. The cladogram below shows the classification of species A to D. Deduce how similar species A is to species B, C and D. [2]



d. Suggest **two** reasons for using cladograms for the classification of organisms. [2]

Cooperative breeding in birds occurs when more than two birds of the same species help to rear the young from one nest. For the Australian superb fairy-wren (*Malurus cyaneus*), mature non-breeding birds help to protect and rear the young, although they are not parents of any of them.

The bar charts below show the effect of the presence of helpers on mean egg volume, mean mass of six-day-old chicks and the probability of survival of the breeding females until the next breeding season.



[Source: From A F Russell, et. al., (2007), *Science*, 317, pages 941-944. Reprinted with permission from AAAS.]

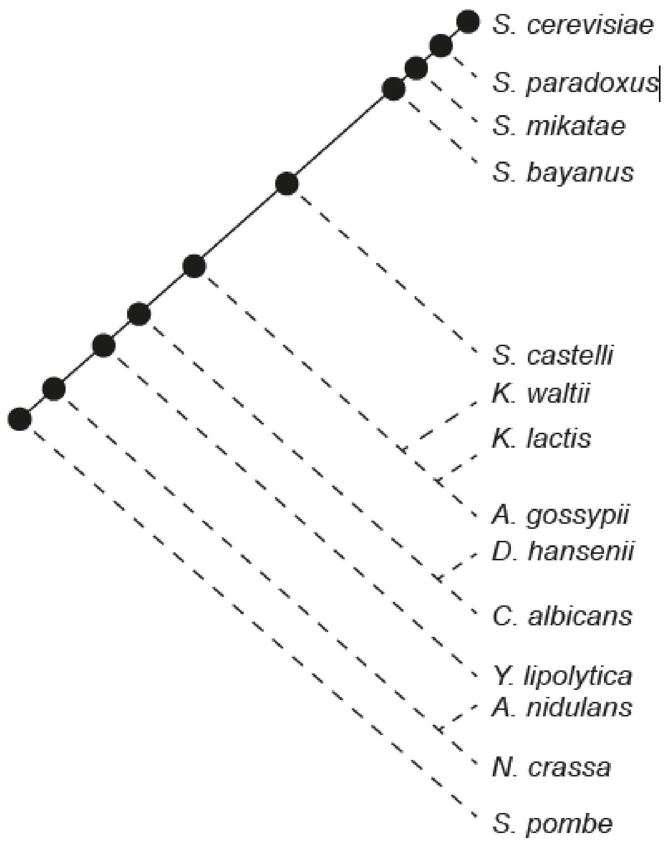
a(i).State the effect of the presence of the helpers on mean chick mass. [1]

b. Calculate the percentage decrease in mean egg volume found in the presence of helpers as compared to the parents only. Show your working. [2]

c. With reference to the data, suggest why the activity of the helper affects the probability of survival of the breeding female until the next breeding season. [2]

d. Cooperative breeding is an altruistic behaviour. Outline the evolution of altruistic behaviour. [2]

The cladogram is based on a comparison of open reading frames in DNA taken from fungi. It is an example of how open reading frames can be used in phylogenetic studies.



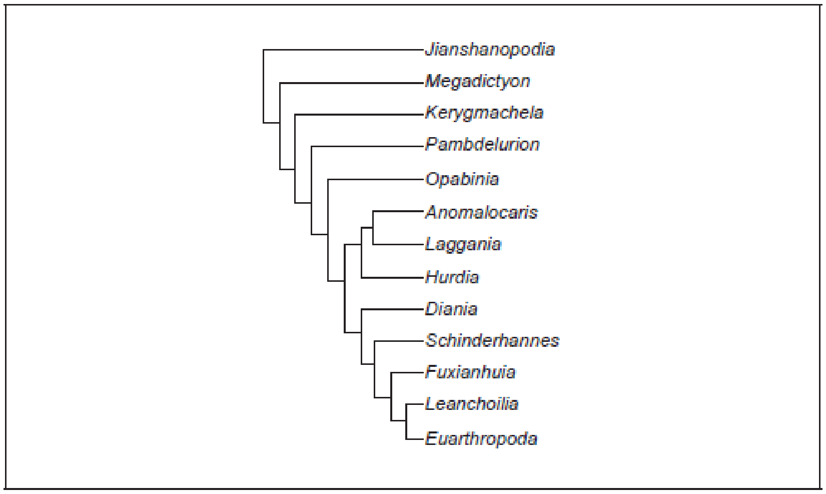
[Source: Reprinted by permission from Macmillan Publishers Ltd: *Nature*, Vol. 487, Anne-Ruxandra Carvunis *et al*. Proto-genes and de novo gene birth, pp. 370–374, copyright (2012), http://www.nature.com/]

a. Outline how open reading frames are identified in DNA. [2]

b. Explain what the branching off points represent in the cladogram of these fungi. [1]

c. There are several methods of introducing DNA into a cell in the laboratory. Outline the introduction of recombinant DNA in plant cell protoplasts. [2]

The diagram shows part of a cladogram for invertebrate species from the Cambrian age.

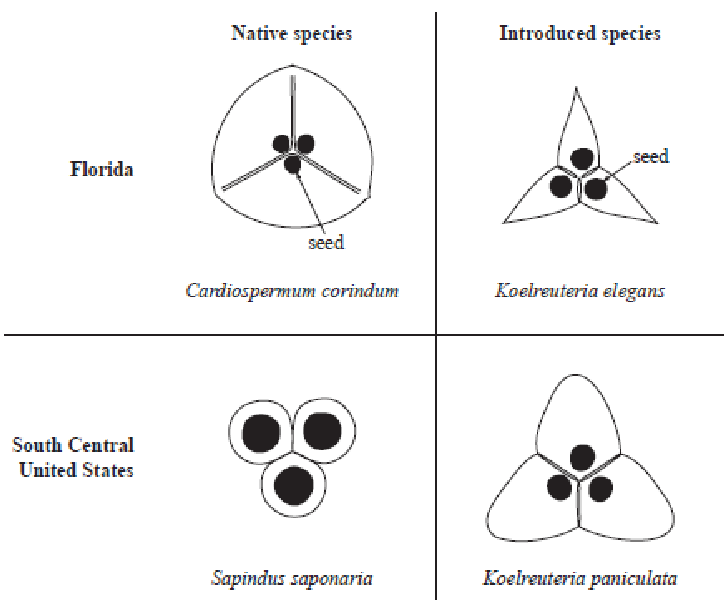


b(i).On the cladogram, label with the letter C the point that shows the most recent common ancestor of *Pambdelurion* and *Fuxianhuia*. [1]

b(ii).Identify which **two** species evolved most recently. [1]

The soapberry bug (*Jadera haematoloma*) feeds on the seeds of plants from the soapberry family (Sapindaceae). It does this by penetrating the fruit containing the seeds with mouthparts called the proboscis.

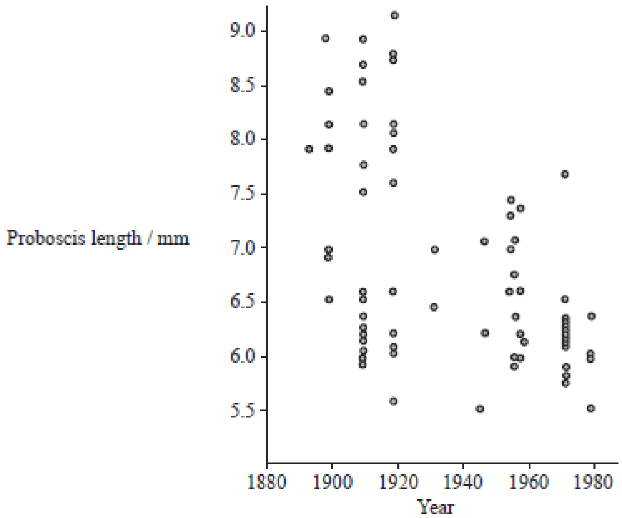
The diagrams below show sections through the fruits taken from four members of the Sapindaceae family.



[Source: Adapted from S P Carroll and C Boyd, "Host race radiation in the soapberry bug: Natural history, with the history", *Evolution*, Vol 46, pages 1052-1069. © John Wiley & Sons]

In Florida, *Cardiospermum corindum* is native to the area while *Koelreuteria elegans* is a species that was introduced in the 1890s and is now common in Florida. In the South Central United States, *Sapindus saponaria* is native while *Koelreuteria paniculata* is an introduced species which has become more common over the past 70 years.

The graph below shows proboscis lengths of samples of adult female soapberry bugs in Florida between 1880 and 1980.



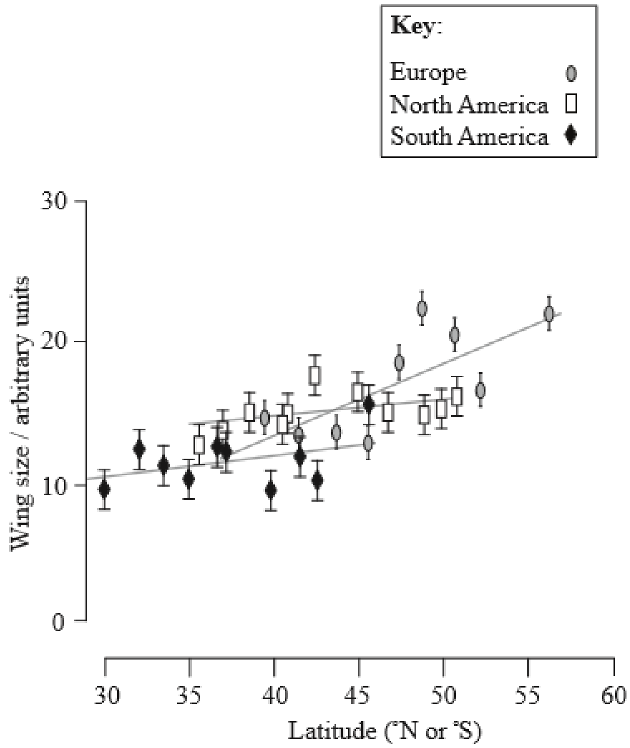
[Source: Adapted from S P Carroll and C Boyd, "Host race radiation in the soapberry bug: Natural history, with the history", *Evolution*, Vol 46, pages 1052-1069. © John Wiley & Sons]

a(i).Outline the trends in proboscis length in soapberry bugs shown in the graph. [2]

b. Suggest, giving a reason, the expected trend in the proboscis length of the soapberry bug in the South Central United States over the past 70 years. [2]

Drosophila subobscura (shown in photograph below) is a species of fruit fly native to Europe. The sample on the left is from Spain, latitude 39°, and the one on the right is from Denmark, latitude 56°. The species was introduced into both South America and North America approximately 20 years ago. The graph below shows the wing size in arbitrary units of *D. subobscura* at different latitudes in the three locations.

[Source: R B Huey, *et al.*, (2005), *Species Invasions; Insights into Ecology, Evolution and Biogeography*, pages 139–164]



[Source: G W Gilchrest, *et al.*, (2004), *Evolution*, **58**, pages 768–780]

[Source: M Vellend, *et al.*, (2007), *Trends in Ecology and Evolution*, **22** (9), pages 481–488]

a. Identify the relationship between wing size and latitude shown by *D. subobscura* in Europe. [1]

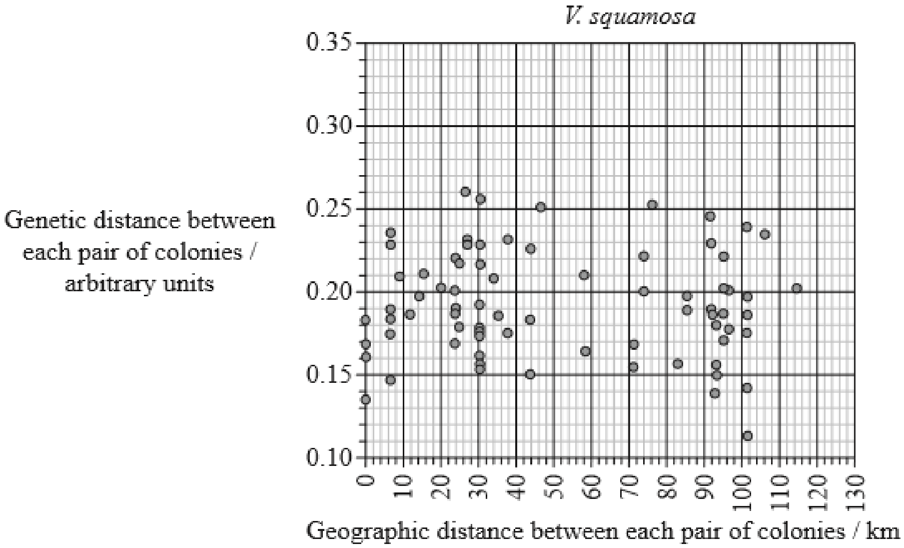
b (i) Compare the data for wing size of *D. subobscura* in North and South America with wing size in Europe. [2]

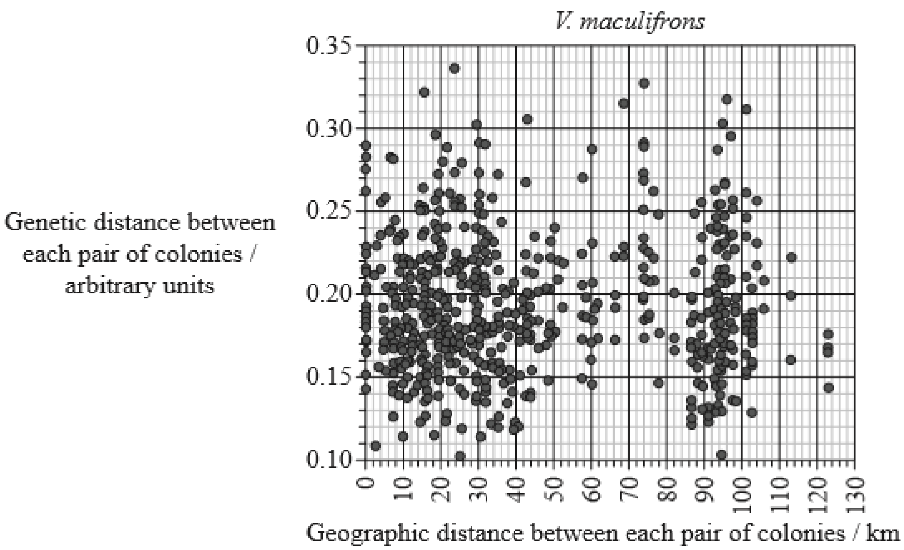
b (ii) Suggest **one** reason for the differences. [1]

c. Predict, with a reason, what might happen to *D. subobscura* in the future as a result of its introduction to new areas. [2]

A study was undertaken of the evolution of two species of wasps, one the parasite of the other. The parasite queen, *Vespula squamosa*, kills the host queen, *Vespula maculifrons*, and takes over her role in the colony. Data was compiled for 13 colonies of *V. squamosa* and 37 colonies of *V. maculifrons* to analyse the genetic structure of the two species.

Each point on the graphs represents the genetic distance and geographic distance between a pair of colonies. The genetic distance indicates the number of differences in specific DNA markers between a pair of colonies. The results are shown below.





Source: "Genetic structure and breeding system in a social wasp and its social parasite" by Hoffman EA, Kovacs JL, Goodisman MAD, *BMC Evolutionary Biology* (2008) 8:239. © 2008 Hoffman et al; licensee BioMed Central Ltd

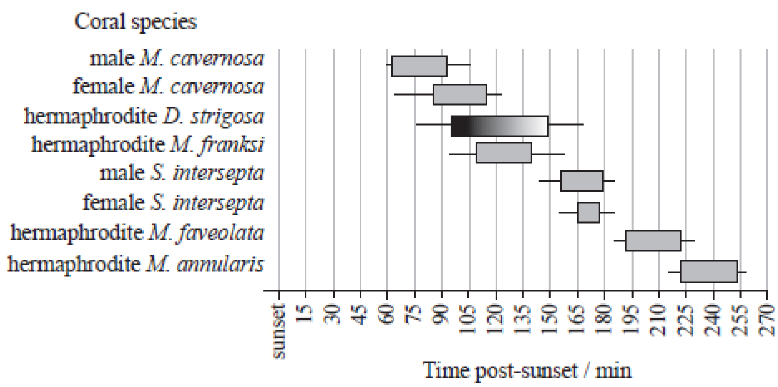
a (i) Determine the greatest genetic distance between any pair of colonies of *V. squamosa.* [1]

a (ii) Identify the greatest geographic distance between any pair of colonies of *V. maculifrons*. [1]

b. Describe the relationship between the geographic distance and genetic distance in the two species. [1]

c. Compare the two species in terms of genetic distance between the pairs of colonies. [2]

Corals can be male, female or hermaphrodite (both male and female) and the release of their gametes is called spawning. Data was collected to study the spawning behaviour in the Gulf of Mexico of three genera of coral: *Montastraea*, *Stephanocoenia* and *Diploria*. The spawning behaviour is expressed in minutes post-sunset. Peak spawning windows are shown as grey bars and the range as black bars.



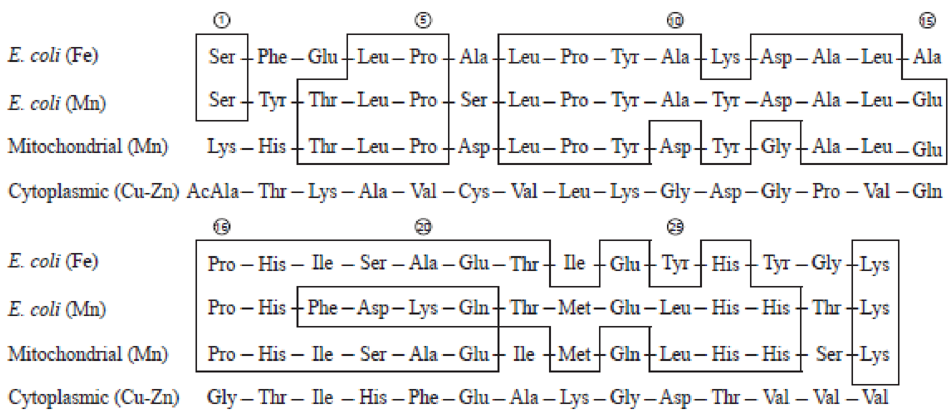
[Adapted from P. D. Vize, J. A. Embesi, M. Nickell, D. P. Brown and D. K. Hagman (2005) "Tight temporal consistency of coral mass spawning at the Flower Garden Banks, Gulf of Mexico, from 1997–2003." _Gulf of Mexico Science_, 1, pp. 107–114.

Superoxide dismutase is an enzyme used by cells to protect themselves against oxidative damage. These enzymes can have different metals as part of their structure.

A study to compare two dismutases from *Escherichia coli* bacteria and two dismutases from eukaryotic cells was undertaken. The following enzymes were used:

- *E. coli* dismutase with iron (Fe)
- *E. coli* dismutase with manganese (Mn)
- eukaryotic mitochondrial dismutase with manganese (Mn)
- eukaryotic cytoplasmic dismutase with copper-zinc (Cu-Zn).

The following shows part of the amino acid sequences of these enzymes. Boxes enclose identical amino acids in the sequence of the two *E. coli* and mitochondrial dismutases.



[H. M. Steinman and R. L. Hill (1973) "Sequence homologies among bacterial and mitochondrial superoxide dismutases". PNAS journal (USA), 70 (12), pp. 3725—3729. Used with the permission of the authors.]

a. State the range of the time of spawning for the male *M. cavernosa*. [1]

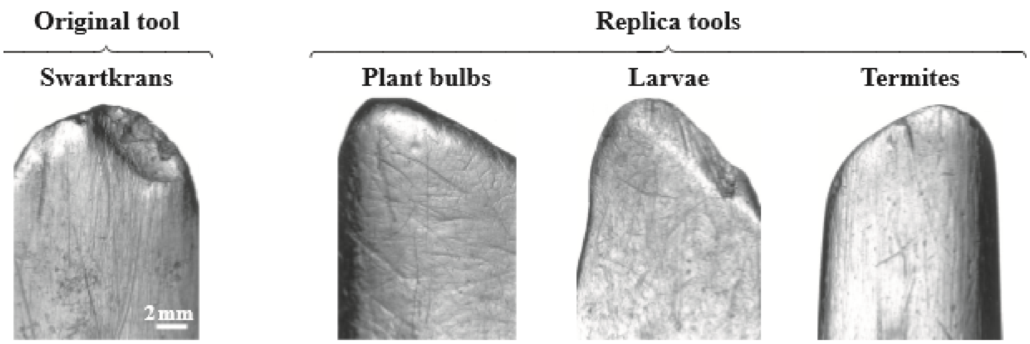
a. State how many amino acids are in the same position in the *E. coli* (Fe), *E. coli* (Mn) and the mitochondrial dismutase sequences shown. [1]

b. State the amino acids which are present in the same position in at **least one** bacterial dismutase and in **both** eukaryotic dismutases. [1]

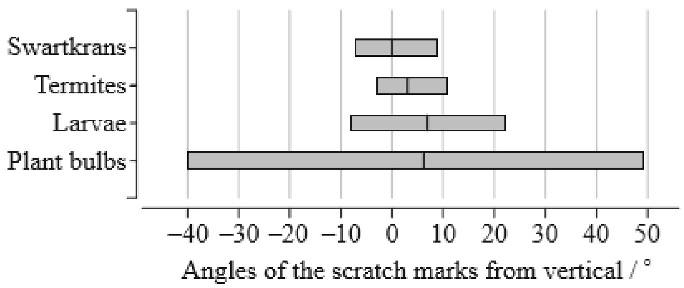
c. Compare the *E. coli* (Mn) and the mitochondrial dismutases. [2]

e. The sequences of the two bacterial dismutases and the mitochondrial dismutase show a high degree of homology. Discuss how this supports the endosymbiotic theory for the origin of mitochondria. [2]

Bone tools found in the Swartkrans site in South Africa were thought to be used by *Australopithecus robustus* when digging for food. Using replica tools, researchers dug around plants for bulbs, dug in soil for larvae and dug in termite mounds for termites. They compared the scratch marks found on the replica tools with those on the original Swartkrans tool to predict the food eaten by *A. robustus*.



The graphs below show the ranges of angles from the vertical position of the scratch marks and the ranges of widths of the scratch marks on each tool. The solid line on each bar represents the mean value for the range.



[Source: Lucinda R. Backwell and Francesco d'Errico, "Evidence of termite foraging by Swartkrans early hominids", *PNAS* 98 (4), 1358–63. Copyright 2001, National Academy of Sciences, USA.]

a. State the greatest angle from the vertical of the scratch marks on the tool used on termite mounds. [1]

b. Calculate the difference in the angle between the mean values for the Swartkrans tool and the tool used to dig for plant bulbs. [1]

c. Compare the width of scratch marks on the tool used to dig for larvae with the Swartkrans tool. [2]

d. Using evidence from the photographs and the graphs, suggest what the researchers' main conclusion was. [2]

e. *A. robustus* was thought to have coexisted with *Homo habilis*, both becoming extinct at the same time. State approximately how many years ago *A. robustus* became extinct. [1]