INSIGHT

Trial Exam Paper

2011

BIOLOGY

Written examination 2

Solutions book

This book presents:

- correct solutions
- explanatory notes
- mark allocations

SECTION A – MULTIPLE-CHOICE QUESTIONS

Question 1

In bilbies (*Macrotis lagotis*), males and females show a different number of diploid chromosomes. The male has a diploid number of 19, whereas the female has a diploid number of 18. The number of autosomes present in a single normal oocyte is

A. 18

B. 19

C. **8**

D. 9

Answer is C.

Explanatory notes

- An oocyte is a female gamete which is haploid–there will be 8 autosomes present.
- A is incorrect – an oocyte is a female gamete which is haploid; there will be 8 autosomes present, not 18.
- B is incorrect – an oocyte is a female gamete which is haploid; there will be 8 autosomes present, not 19.
- C is correct – an oocyte is a female gamete which is haploid; there will be 8 autosomes present.
- D is incorrect – an oocyte is a female gamete which is haploid; there will be 8 autosomes present, not 9.

Question 2

In a human with a normal karyotype, variation can arise from

A. replication of chromosomes during early prophase.

B. **exchange of genetic information during crossing over.**

C. non-disjunction of chromosomes during anaphase.

D. undergoing mitotic division.

Answer is B.

Explanatory notes

- A is incorrect – there is no crossing over during early prophase therefore variation cannot arise from here.
- B is correct – exchange of genetic information during crossing over leads to variation.
- C is incorrect – non-disjunction of chromosomes during anaphase does not lead to variation.
- D is incorrect – variation does not occur as a result of mitosis.

Question 3

On a chromosome, the position occupied by a gene is its _____. Variants of genes, known as _____ can be found at these positions.

A. allele, homologues

B. locus, homologues

C. allele, loci

D. **locus, alleles**

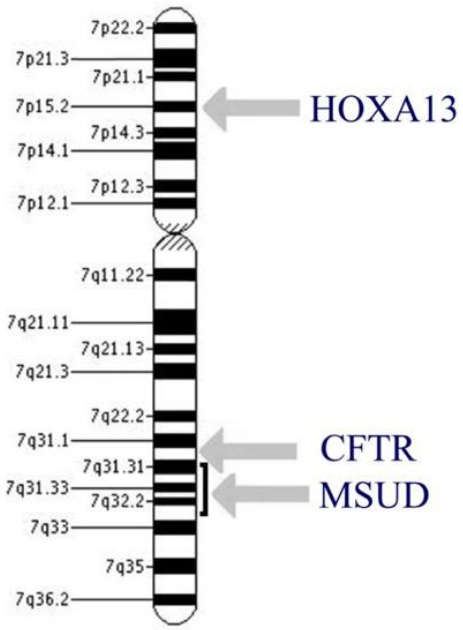
Answer is D.

Explanatory notes

- A is incorrect – the position occupied by a gene is its locus, NOT an allele and the variants of genes are alleles, NOT homologues.
- B is incorrect – the position occupied by a gene is its locus, however the variants of genes are alleles, NOT homologues.
- C is incorrect – the position occupied by a gene is its locus, NOT an allele and the variants of a gene are alleles, NOT homologues.
- D is correct – the position occupied by a gene is its locus, and the variants of genes are alleles.

The following information relates to Questions 4 and 5.

The diagram shows a map of a particular human chromosome showing the cystic fibrosis transmembrane conductance regulator (CFTR) gene. The CFTR gene codes for the production of the CFTR protein, which functions as an ion channel within the cell membrane. The CFTR protein occurs in tissue that produces mucus, sweat, saliva, tears, and digestive enzymes. Two other genes are also shown.



Question 4

According to the system of identification used in chromosome mapping, the CFTR gene is

A. **found on chromosome number 7.**

B. located on the short arm of the chromosome.

C. approximately 31 base pairs in length.

D. positioned in the second region of the long arm of the chromosome.

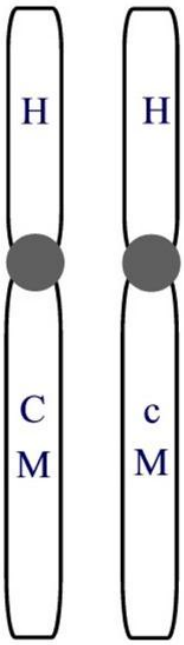
Answer is A.

Explanatory notes

- A is correct – the first number or letter of a gene map position is the chromosome on which it is found.
- B is incorrect – the CFTR gene is found on the longer of the two arms, the q arm.
- C is incorrect – it is not possible to tell from the identification system how many base pairs are found in the CFTR gene.
- D is incorrect – the final number of a gene map position indicates what region of the arm the gene is found, the CFTR gene is positioned in the third region.

Question 5

A pair of homologous chromosomes involved in normal meiosis in the testes carries the alleles for the HOXA13 (H), CFTR (C) and MSUD (M) genes.



Chromosomes found in the sperm produced would be

A.

B.

C.

D.

Answer is D.

Explanatory notes

- A is incorrect – this combination not possible as there is no recessive allele (h) for HOXA13 on the germ-line cell chromosomes.
- B is incorrect – this combination not possible as there is no recessive allele (h) for HOXA13 and no recessive allele (m) for MSUD on the germ-line cell chromosomes.
- C is incorrect – this combination not possible as there is no recessive allele (m) for MSUD on the germ-line cell chromosomes.
- D is correct – it shows a chromosome with parental type arrangement of alleles.

The following information relates to Questions 6 and 7.

A hairless hamster is bred with a normal haired hamster. Twelve pups are born in the litter, seven of the pups are hairless and five pups are normal haired. When a pair of the hairless hamsters are interbred, the litter produced also has twelve pups, four of which are normal haired and eight of which are hairless.

Question 6

The results of the first cross between the hamsters indicate a cross between

A. heterozygote x heterozygote.

B. homozygote x homozygote

C. **heterozygote x homozygote.**

D. hemizygote x homozygote.

Answer is C.

Explanatory notes

- A is incorrect – if the hamsters were both heterozygotes, the ratio of offspring would be 3:1.
- B is incorrect – if the hamsters were both homozygotes, all offspring would show the same phenotype.
- C is correct – 1:1 ratio of the first cross indicates a cross between a heterozygote and a homozygote hamster, supported by the second cross; hairless hamsters cannot have a homozygous genotype because then only hairless hamsters would be produced.
- D is incorrect – there is no evidence to suggest that one of the hamsters is a hemizygote for this trait.

Question 7

The results of the cross between the two hairless hamsters suggests that the

A. heterozygous genotype may be lethal.

B. **homozygous recessive genotype may be lethal.**

C. hairless hamsters have hemizygous genotypes.

D. hairless hamsters have homozygous genotypes.

Answer is B.

Explanatory notes

- A is incorrect – heterozygous genotypes are not lethal as evidenced by the parents in the first cross.
- B is correct – the 1:2 ratio indicates that the homozygous recessive genotypes may be lethal, there are no homozygous recessive embryos or living offspring.
- C is incorrect – there is no evidence to suggest that hairless hamsters are hemizygous.
- D is incorrect – hairless hamsters cannot have homozygous genotypes because they produce offspring with different phenotypes.

Question 8

The phase of meiosis most directly related to Mendel's law of independent assortment is

A. prophase I.

B. **metaphase I.**

C. anaphase II.

D. telophase II.

Answer is B.

Explanatory notes

- A is incorrect – at prophase I, there is no separation of chromosomes and therefore no assortment of chromosomes.
- B is correct – at metaphase I, pairs of alleles segregate independently in the formation of gametes.
- C is incorrect – at anaphase II, pairs of alleles have already separated, the sister chromatids are separating at this stage and they are identical to one another; there is no assortment of chromosomes at this stage.
- D is incorrect – at telophase II, chromatid separation is complete and cytokinesis begins; there is no assortment of chromosomes by this stage.

Question 9

A plasmid has two genes for antibiotic resistance, one for tetracycline and one for ampicillin. It is treated with a restriction enzyme that makes a cut in the middle of the ampicillin gene. DNA fragments containing a human globin gene were cut with the same enzyme. The plasmids and fragments are mixed, treated with ligase and used to transform bacterial cells. Clones that have taken up the recombinant DNA are those that

A. **can grow on plates with tetracycline but not ampicillin.**

B. can grow on plates with both antibiotics.

C. can grow on plates with ampicillin but not tetracycline.

D. cannot grow with any antibiotics.

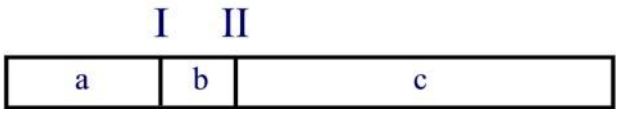
Answer is A.

Explanatory notes

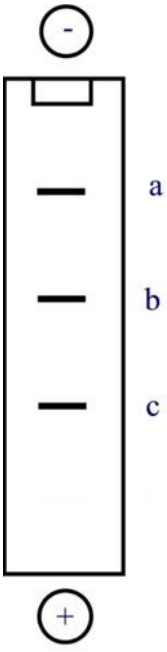
- A is correct – cutting the ampicillin resistance gene renders the clones susceptible to ampicillin but not tetracycline; they can grow in presence of tetracycline but not ampicillin.
- B is incorrect – cutting the ampicillin resistance gene renders the clones susceptible to ampicillin; thus they cannot grow on plates with both antibiotics.
- C is incorrect – cutting the ampicillin resistance gene renders the clones susceptible to ampicillin, thus they cannot grow on plates with ampicillin.
- D is incorrect – cutting the ampicillin resistance gene renders the clones susceptible to ampicillin but not tetracycline; they can grow in presence of tetracycline, an antibiotic.

Question 10

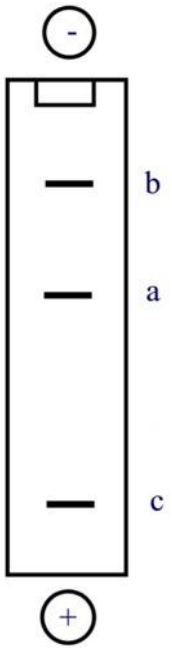
A segment of DNA has been cut with a restriction enzyme to produce the fragments *a*, *b* and *c*. Which of the following electrophoresis gels represents the separation and identity of these fragments?



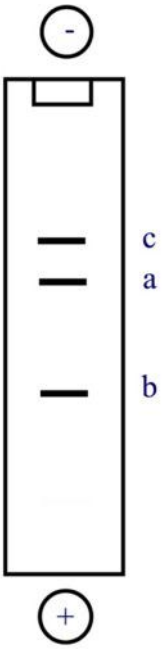
A.



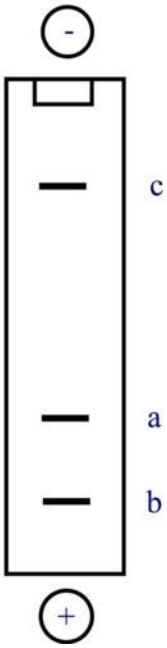
B.



C.



D.



Answer is D.

Explanatory notes

- A is incorrect – in an electrophoresis gel, the shortest fragments travel the fastest, they should be in the order of length: *b* closest to the positive end, *a* second, *c* third, not *c, b, a.*
- B is incorrect – in an electrophoresis gel, the shortest fragments travel the fastest, they should be in the order of length: *b* closest to the positive end, *a* second, *c* third, not *c, a b.*
- C is incorrect –while this order is correct, the distance between the fragments is not correctly represented, there should be a larger distance between *a* and *c*.
- D is correct – this order is correct and the distance between the fragments is correctly represented.

Question 11

Four students were asked to contribute information about chromosomes and plasmids to a class study guide at the end of the semester. Which information should be **excluded** from the study guide?

	plasmid	**prokaryote chromosome**	**eukaryote chromosome**
A.	circular	circular	linear
B.	no histones present	no histones present	histones present
C.	**single stranded**	**single stranded**	**double stranded**
D.	replicated independently of binary fission	replicated through binary fission	replicated during mitosis or meiosis

Answer is C.

Explanatory notes

- Students should remember that all DNA is double-stranded.
- A is incorrect – all statements are correct and should not be excluded from the study guide.
- B is incorrect – all statements are correct and should not be excluded from the study guide.
- C is correct – plasmids and chromosomes from prokaryotes and eukaryotes are all double-stranded; this information is incorrect and should therefore be excluded from the study guide.
- D is incorrect – all statements are correct and should not be excluded from the study guide.

Question 12

DNA helicase is an enzyme that

A. **untwists the double strands of DNA at the replication forks making them available as templates.**

B. enables the copying of DNA from an existing template.

C. breaks, swivels and rejoins DNA strands to relieve strain in the double helix ahead of the replication fork during replication.

D. makes a primer by joining RNA nucleotides whilst using the parental DNA strand as a template.

Answer is A.

Explanatory notes

- A is correct – this is the correct definition of DNA helicase.
- B is incorrect – this is a definition of DNA polymerase, not DNA helicase.
- C is incorrect – this is a definition of DNA toposoimerase, not DNA helicase.
- D is incorrect – this is a definition of primase, not DNA helicase.

Question 13

In DNA, a short tandem repeat (STR) occurs when a pattern of two or more nucleotides is repeated and the sequence of repeats occurs directly adjacently. DNA from STRs is unique to individuals, which means it can be used to match DNA from a crime scene to a single person. It would not be possible to use this method of DNA profiling if the suspect

A. was a dizygotic twin.

B. **was a monozygotic twin.**

C. had no living relatives**.**

D. had only left saliva samples at the scene of the crime.

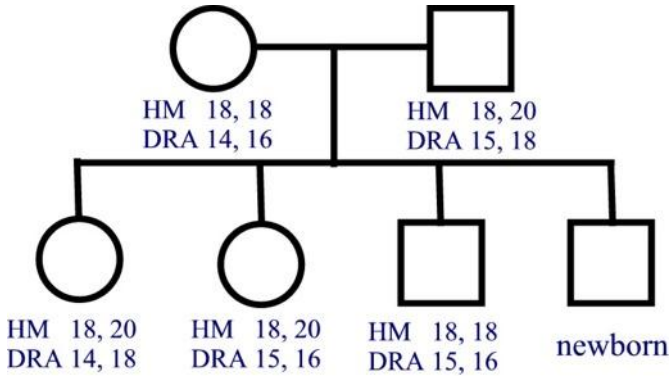
Answer is B.

Explanatory notes

- A is incorrect – dizygotic twins (non-identical) have different DNA and therefore different STRs, it would be possible to use this method of DNA profiling to determine the criminal.
- B is correct – monozygotic twins (identical) have identical DNA therefore it is not possible to distinguish between them as they share the same STRs.
- C is incorrect – DNA profiling is not dependent on comparison of DNA samples with living relatives, it is performed using the sample from the individual in question.
- D is incorrect – If the suspect left saliva that would be adequate to complete DNA profiling as DNA profiling uses blood, saliva or body fluids.

The following information relates to Questions 14 and 15.

In a hospital, the identification wrist bands in a maternity ward were faulty and fell off several newborn infants. The hospital staff rebanded the babies. However, in order to confirm that the identities of the babies were not mixed up, DNA analysis of two minisatellite loci (locus HM and locus DRA) was carried out for each of the families involved. The results for one family are shown in the pedigree below. Assume that no mutation involving these two loci has occurred in the family.



Question 14

The result, which confirms that the newborn belongs to the family above, is

A. HM 20, 20, DRA 14, 18.

B. HM 18, 20; DRA 15, 18.

C. HM 18, 20; DRA 14, 16.

D. **HM 18, 20; DRA 16, 18.**

Answer is D.

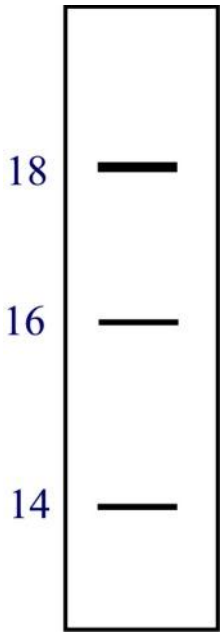
Explanatory notes

- A is incorrect – the baby's alleles must come one from each parent; he has not received an HM allele from each parent.
- B is incorrect – the baby's alleles must come one from each parent; he has not received a DRA allele from each parent.
- C is incorrect – the baby's alleles must come one from each parent; he has not received a DRA allele from each parent.
- D is correct – the baby's alleles must come one from each parent; he has received an HM allele and a DRA allele from each parent.

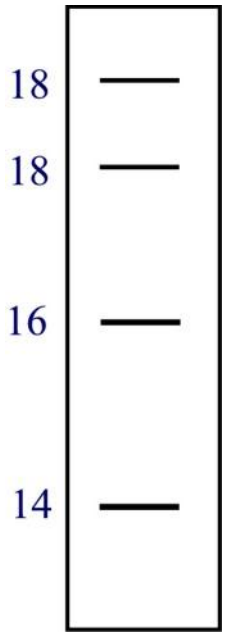
Question 15

Which diagram shows the simplified DNA fingerprint of the mother?

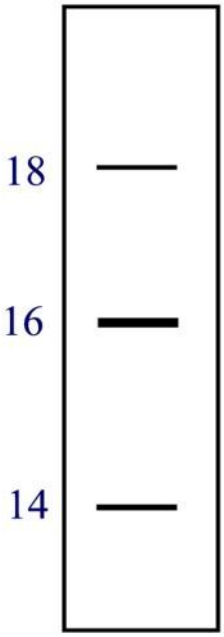
A.



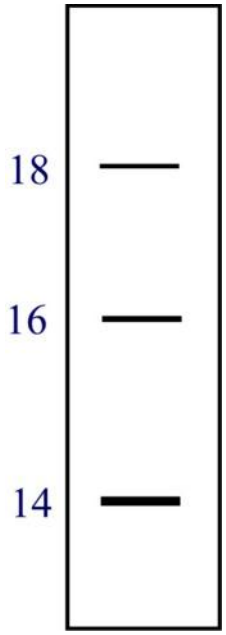
B



C.



D.



Answer is A.

Explanatory notes

- A is correct – the fewer repeats, the smaller the fragment, the further it moves in the gel. Band 18 is thicker to denote two fragments of the same size and therefore the same position in the gel.
- B is incorrect – band 18 should only appear once and appear thicker than band 16 and band 14.
- C is incorrect – band 18 should be the thicker band, band 16 should only appear once and at the same thickness as band 14.
- D is incorrect – band 18 should be the thicker band, band 14 should only appear once and at the same thickness as band 16.

Question 16

On the Hawaiian Archipelago there are 28 morphologically diverse species of a group of sunflowers called silverswords. These species are an example of

A. the founder effect.

B. convergent evolution.

C. **divergent evolution.**

D. the bottleneck effect.

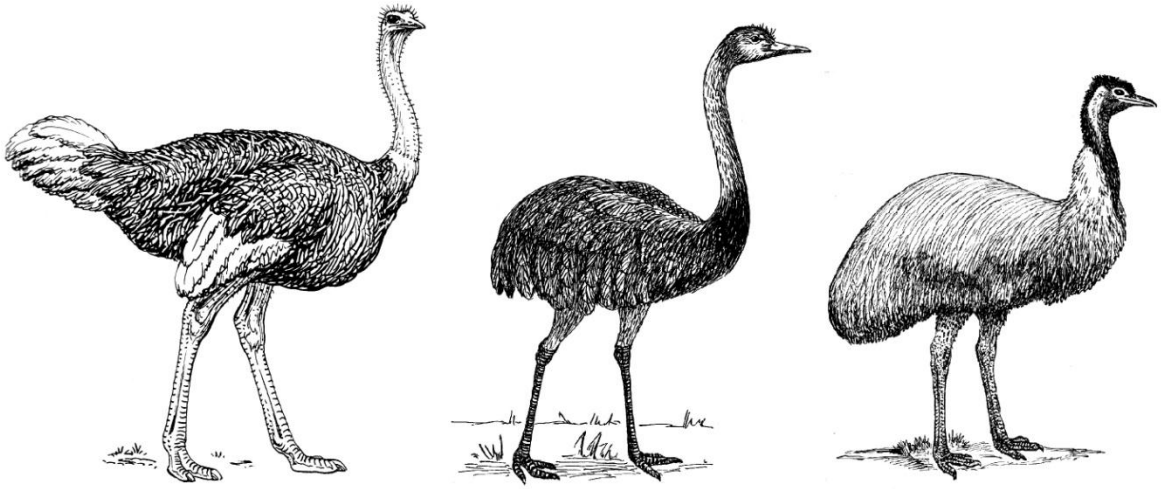
Answer is C.

Explanatory notes

- A is incorrect – the founder effect is seen in populations that have emerged from a small founder group and the effects of small genetic changes is more marked.
- B is incorrect – convergent evolution is the evolution of similar features in independent evolutionary lineages; this is not an example of convergent evolution.
- C is correct – this is an example of divergent evolution, a time of evolutionary change when a group of organisms forms many new species whose adaptations allow them to fill vacant niches in their communities.
- D is incorrect – the bottleneck effect occurs when the size of a population is reduced by a natural disaster or human actions; this is not an example of bottleneck effect.

Question 17

Three ratites, the ostrich, rhea and emu are ecologically similar extant species of bird.



In determining the phylogeny of these three birds, the best data could be obtained from

A. a quantitative analysis of morphological similarities and differences.

B. the fossil record.

C. a comparison of embryological development.

D. **a comparison of DNA sequences.**

Answer is D.

Explanatory notes

- A is incorrect – as a source of data for determining phylogeny, quantitative analysis of morphological similarities and differences is not as accurate as a comparison of DNA sequences.
- B is incorrect – the fossil record is an incomplete and less accurate source of data for determining phylogeny as a comparison of DNA sequences.
- C is incorrect – as a source of data for determining phylogeny, comparison of embryological development is not as accurate as a comparison of DNA sequences.
- D is correct – even though there are problems using DNA sequences in the determination phylogeny, it is the best of the four methods listed in the question.

Question 18

The budgerigar *Melopsittacus undulatus* and the chimpanzee *Pan paniscus* are vertebrates and both have four appendages. This is an example of

A. **a shared ancestral character.**

B. a shared derived character.

C. analogy rather than homology.

D. a character useful for distinguishing birds from mammals.

Answer is A.

Explanatory notes

- A is correct – birds and mammals have a distant common ancestor from which the character has come.
- B is incorrect – a shared derived character is one found among two or more taxa and their most recent common ancestor, whose ancestor in turn does not possess the character, having four appendages is not a derived character.
- C is incorrect – an analogous structure is a trait or an organ that appears similar in two unrelated organisms, birds and mammals have a shared distant but common ancestor.
- D is incorrect – the character of having four appendages is shared, thus it cannot be used to distinguish birds from mammals.

Question 19

In human populations no two individuals are identical, with the exception of identical twins. The principle cause of genetic variation amongst humans is due to

A. genetic drift due to the small size of the population.

B. new mutations that arise in the preceding generation.

C. **the reshuffling of alleles in sexual reproduction.**

D. geographic variation within the population.

Answer is C.

Explanatory notes

- A is incorrect – genetic drift is most noticeable in populations of small size, the human population is not small.
- B is incorrect – while new mutations do occur, they are not the principle cause of genetic variation.
- C is correct – crossing over leads to new combinations of alleles, which causes genetic variation.
- D is incorrect – geographic variation occurs as a result of environment; however, it is not the principle cause of genetic variation in humans.

Question 20

The time course of speciation has been described as punctuated or gradual. According to the punctuated equilibrium model

A. evolutionary change occurs almost unnoticeably and slowly over a long period of time.

B. **evolutionary change occurs rapidly over short periods of time, interspersed with long periods of no change.**

C. speciation is due to a single mutation.

D. transitional forms of species will be found in the fossil record.

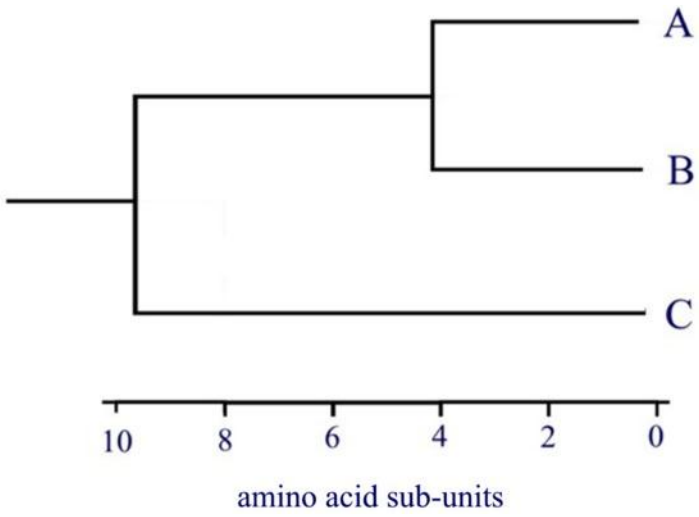
Answer is B.

Explanatory notes

- A is incorrect – this is true of gradualism, not punctuated equilibrium.
- B is correct – punctuated equilibrium states that evolutions occurs in short bursts accompanied by periods of no change before and after.
- C is incorrect – speciation is due to a series of mutations, not just one.
- D is incorrect – this is true of gradualism, not punctuated equilibrium.

The following information relates to Questions 21 and 22.

The molecular clock suggests that the number of differences in the proteins of two species can be indicative of the time that has elapsed since they diverged from their most recent common ancestor. Protein X has been estimated to change at the rate of one amino acid sub-unit every one million years. This protein is compared between three species of organism and the data is represented in the diagram below.



Question 21

According to the diagram, the number of differences in the amino acid sequence between species A and B are

A. 0

B. 2

C. **4**

D. 6

Answer is C.

Explanatory notes

- A is incorrect – Species A and B diverged from each other 4 million years ago, therefore there must be 4 differences in the amino acid sequence (1 per each million years), not 0.
- B is incorrect – Species A and B diverged from each other 4 million years ago, therefore there must be 4 differences in the amino acid sequence (1 per each million years), not 2.
- C is correct – Species A and B diverged from each other 4 million years ago, therefore there must be 4 differences in the amino acid sequence (1 per each million years).
- D is incorrect – Species A and B diverged from each other 4 million years ago, therefore there must be 4 differences in the amino acid sequence (1 per each million years), not 6.

Question 22

While the molecular clock is a powerful tool for inferring evolutionary relationships between species, it does have limitations. Care must be taken when making inferences about species relatedness because

A. different proteins are comprised of different amino acid sub-units.

B. **the rates of change in a specific protein can differ between species.**

C. proteins are subject to mutations.

D. amino acid sub-units are subject to mutations.

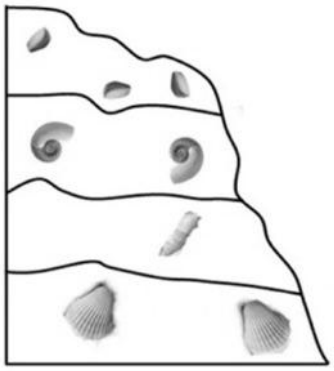
Answer is B.

Explanatory notes

- A is incorrect – the molecular clock is used to measure differences in proteins, that proteins are different does not create a limitation within the tool.
- B is correct – this is a limitation; the rates of change are not constant between species.
- C is incorrect – the molecular clock is used to measure differences in proteins. That proteins undergo mutations and become different does not create a limitation within the tool.
- D is incorrect – the molecular clock is used to measure differences in proteins. That amino acids undergo mutations and become different does not create a limitation within the tool.

The following information relates to Questions 23 and 24.

A profile of rock containing fossils is shown below.



Question 23

What kind of rock is this profile most likely to be made from?

A. metamorphic

B. igneous

C. **sedimentary**

D. basalt

Answer is C.

Explanatory notes

- A is incorrect – rapid burial and entombing with sediment is required for successful fossilisation, not metamorphic.
- B is incorrect – anaerobic conditions are required for successful fossilisation, not igneous.
- C is correct – fossils are found most commonly in sedimentary rock.
- D is incorrect – fossils are found most commonly in sedimentary rock, not basalt.

Question 24

Which of the following statements is true for the diagram?

A. the more recent the layer of rock, the less resemblance there is between the fossils found in it and living organisms.

B. the fossils found in older layers are more specialised than those found in the more recent layers.

C. the number of organisms living today is much greater than the number of extinct species found fossilised.

D. **more primitive fossils are found in the lower layers of the profile.**

Answer is D.

Explanatory notes

- A is incorrect – the more recent the layer of rock, the *greater* the resemblance there is between the fossils found in it and living organisms.
- B is incorrect – the fossils found in older layers are *less* specialised than those found in the more recent layers.
- C is incorrect – the number of organisms living today is much *less* than the number of extinct species found fossilised.
- D is correct – fossils of organisms found in the deepest layers of the rock are older and far less specialised than those above.

Question 25

After bipedal locomotion, which of the following was next to appear as humans diverged from other primates?

A. domestication of wild animals.

B. **making of stone tools.**

C. burial of the dead.

D. established language.

Answer is B.

Explanatory notes

- A is incorrect – domestication of wild animals occurred with the establishment of sedentary lifestyles, much later than bipedal locomotion.
- B is correct – making (and use) of stone tools occurred after bipedal locomotion.
- C is incorrect – burial of the dead, a cultural practice, occurred much later than the emergence of bipedal locomotion.
- D is incorrect – established language development occurred after the emergence of stone tool making.

END OF SECTION A

END OF SECTION A
TURN OVER

SECTION B – SHORT ANSWER QUESTIONS

Question 1

Turner syndrome (TS) is a chromosomal condition that affects approximately 1 in 2000 females and is typically characterised by short stature, lack of secondary sexual characteristics and infertility. TS is an example of monosomy. The following karyotype is from a female baby with the condition.

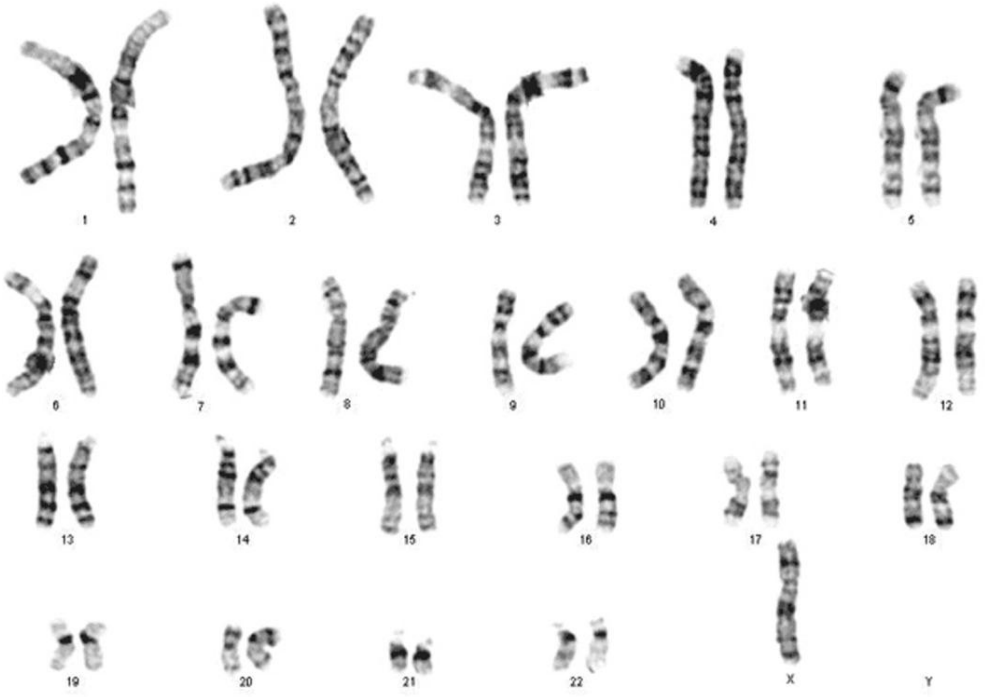


Image source: NSW Health. *The Centre for Genetics Education*.

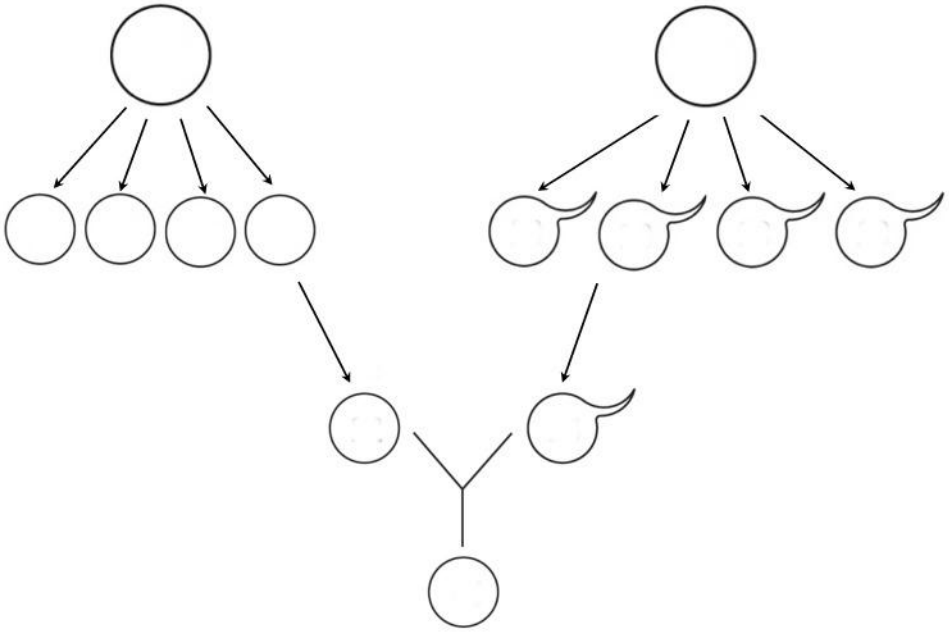
1a. What is the chromosomal abnormality that causes TS?

1 mark

Solution

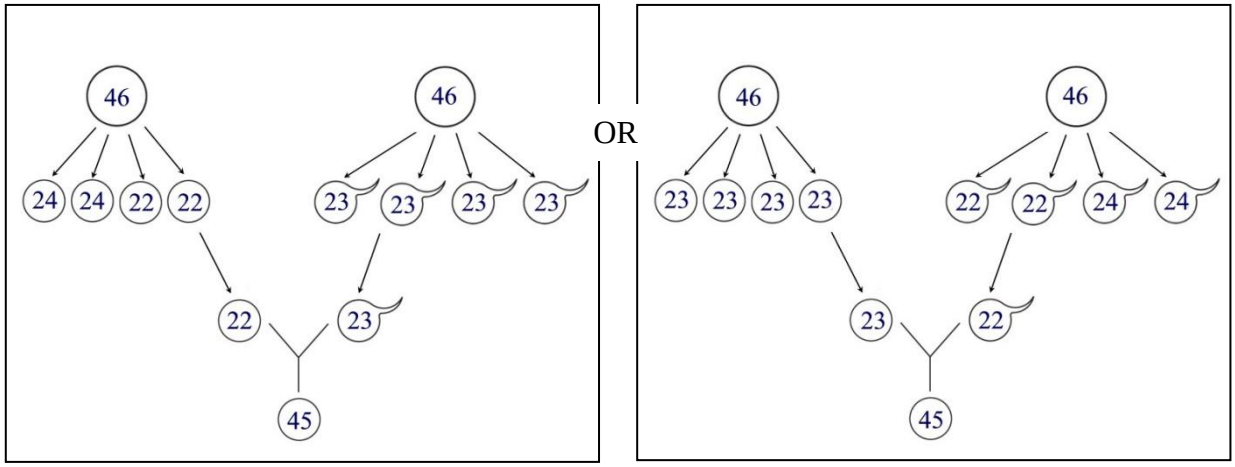
A missing X chromosome

1b. Write in the correct number of chromosomes in each cell in the diagram to show how TS occurs.



3 marks

Solution



Mark allocation

- 1 mark – germline cells 46 chromosomes (diploid)
- 1 mark – gametes showing evidence of non-disjunction (24/22 chromosomes)
- 1 mark – correct number of chromosomes (45) for offspring

1c. What is the name of the process that leads to TS?

1 mark

Solution

Chromosomal non-disjunction OR non-disjunction

1d. At what stage of cell division is the process identified in **1c.** most likely to occur?

1 mark

Solution

Anaphase I OR anaphase II of meiosis.

1e. What is the probability of a woman who has TS passing the condition on to her daughters?

1 mark

Solution

Women with TS are infertile and cannot pass the condition on; there is zero probability of passing the condition on.

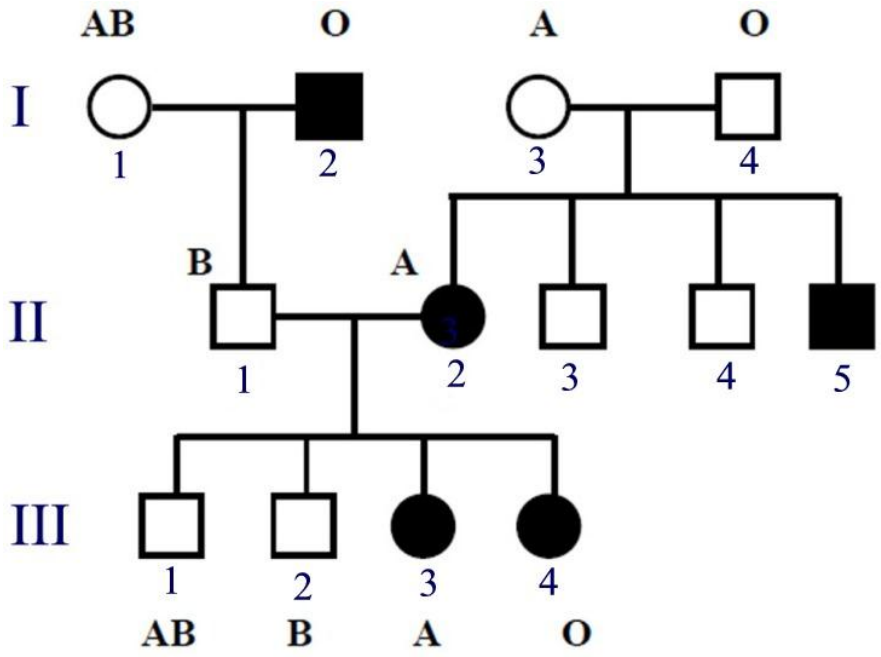
Total 1+3+1+1+1 = 7 marks

Explanatory notes

This question requires students to recognise and identify features within human karyotypes. They should be able to make observations of and draw inferences from karyotypes, in order to draw conclusions about patterns of inheritance. A working knowledge of the stages of meiosis and the processes that can lead to karyotype abnormalities is also essential. Students should be able to process information presented in the question stem and apply it, where necessary, in their response to questions.

Question 2

Alkaptonuria is an inherited condition in which the body fails to produce the enzyme homogentisate oxidase which breaks down the amino acids tyrosine and phenylalanine. As a result, a substance called homogentisic acid (HGA) accumulates in the skin and other body tissues. HGA leaves the body through the urine, which turns brownish-black on exposure to air. The three major features of alkaptonuria are the presence of HGA in the urine, ochronosis (bluish-black pigmentation in connective tissue), which usually occurs in the fourth decade, and arthritis of the spine and larger joints, which often begins in the third decade. The condition is rare and affects from 1 in 250,000 to 1 in 1 million people worldwide. The *HGD* gene controls the production of homogentisate oxidase and is closely linked to the gene which determines the ABO blood groups. A pedigree of a family with alkaptonuria is shown below. Affected individuals are indicated by the shaded symbols. In addition, the blood group of family members is given.



2a. What is the mode of inheritance of this trait?

1 mark

Solution

Autosomal recessive

2bi. Assign appropriate allelic symbols for alkaptonuria.

1 mark

Solution

A – breaks down tyrosine and phenylalanine

a – cannot break down tyrosine and phenylalanine

2bii. With respect to alkaptonuria and blood type, what are the genotypes of the following individuals?

Individual	Genotype
I2	
II1	

1 mark

Solution

Individual	Genotype
I2	a*i*a*i*
II1	AI^{B}ai

1+1 = 2 marks

Mark allocation

- 1 mark – 2 correct
- 0 marks – 1 or none correct

II1 and II2 decide to have a fifth child.

2c. What is the chance that the child will have alkaptonuria? Show your working out including the genotypes of II1 and II2.

3 marks

Solution

Parental genotypes: father Aa x mother aa

	$\frac{1}{2}$ a	$\frac{1}{2}$ a
$\frac{1}{2}$ A	$\frac{1}{4}$Aa	$\frac{1}{4}$Aa
$\frac{1}{2}$ a	$\frac{1}{4}$aa	$\frac{1}{4}$aa

$\frac{1}{2}$ Aa : $\frac{1}{2}$ aa

$\frac{1}{2}$ normal : $\frac{1}{2}$ alkaptonuria

There is a 50% chance that the fifth child will have alkaptonuria.

Mark allocation

- 1 mark – correct parental genotypes
- 1 mark – correct Punnet square with correct working
- 1 mark – correct statement of chance/probability (i.e., 50% or 0.5 chance)

The pedigree shows four blood groups A, B, AB and O.

2d. What is the expression used to describe the inheritance pattern shown by the A and B alleles for blood group?

1 mark

Solution

Co-dominance

Total 1+2+3+1 = 7 marks

Explanatory notes

This question deals with pedigrees and pedigree analysis. Students are required to demonstrate an understanding of and make predictions about modes of inheritance. The question tests the ability to devise appropriate allelic symbols and then to determine genotypes of individuals in a pedigree. Also essential is the ability to use a Punnet square and show workings to predict the likelihood of inheriting a condition. Students should also be able to distinguish relationships between the expression of alleles.

Question 3

In human chromosomes, region 17q21.31 has been studied in detail. It contains the genes for microtubule-associated protein tau (MAPT), corticotrophin releasing hormone receptor 1 (CRHR1) and several other genes.

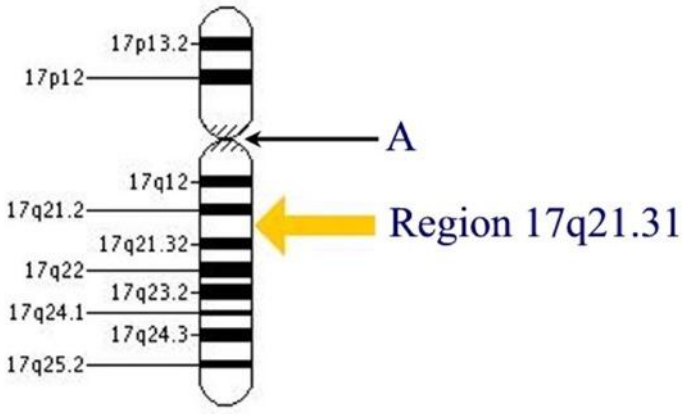


Image source: National Library of Medicine (NLM)

3a. Identify the structure and its function at A.

1 mark

Solution

Structure at A: a centromere

Function: region where chromatids are attached to one another OR

region where chromatids attach to spindle fibres during cell division

In human chromosomes, the region occurs as two haplotypes, H1 (normal orientation) and H2 (inverted orientation). A haplotype is a group of closely located alleles (for different genes) that are found on the same chromosome and usually inherited together. The H2 inverted haplotype is found in 21% of northern Europeans (in 20% of Icelandic people), 6% of Africans and 1% of Asians. Icelandic women with this chromosomal inversion have significantly more children than women without it.

3b. What is a chromosomal inversion?

1 mark

Solution

A chromosome rearrangement in which part of a chromosome is broken off, turned upside down and returned to its original place.

3c. Predict what will happen to the frequency of the H2 inversion in the Icelandic population in future generations.

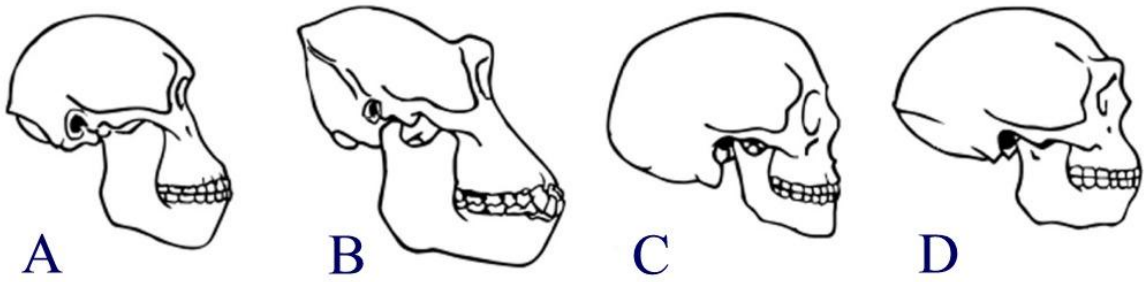
1 mark

Solution

It will persist and spread, given that more offspring are born to women with this inversion, it must be advantageous.

When chromosomal inversions occur, they are associated with increased rates of recombination, which result in highly divergent lineages. The pronounced divergence between the H1 and H2 lineages suggests that the H2 lineage was introduced into the ancestral human gene pool in Africa from species such as *Homo heidelbergensis* or *Homo erectus*. There is even a possibility that their separation potentially pre-dated the genus *Homo*.

The following diagram shows the skulls of four primates. All of the primates are members of the family Hominidae but not all are hominins. Hominins can be distinguished from other primates by their upright and bipedal locomotion. The only living hominins are humans, all other hominins are extinct.



3di. Identify two forms of evidence that enable palaeobiologists to determine if a fossil species walked upright.

2 marks

Solution

Evidence: any two of:

- position of the foramen magnum
- angle between the femur and the tibia
- shape of the pelvis

3dii. Identify the hominin skulls in the diagram and outline two differences that enable you to distinguish them from other hominids.

3 marks

Solution

Hominin skull(s): A, C, D

Differences: any two of:

- hominins have a larger braincase whereas other hominids have a small brain case
- hominins have reduced canines whereas other hominids have prominent/large canines
- hominins have a prominent nose and reduced eye ridges whereas other hominids have a flattened nose and pronounced bony eye ridges

Mark allocation

- 1 mark – correct skulls identified
- 1 mark – Difference 1 – correct and includes comparison to hominids
- 1 mark – Difference 2 – correct and includes comparison to hominids

2+3=5 marks

Total 1+1+1+5 = 8 marks

Explanatory notes

Students are required to demonstrate knowledge of chromosome structure and function, in particular that chromosome rearrangements occur and that they can lead to changes in gene expression and phenotype. The question also directs students to consider and demonstrate their knowledge of human patterns of evolution, in particular, forms of evidence for bipedal locomotion. Students should also be able to identify hominin skulls and outline differences that distinguish them from other hominids.

Question 4

In humans, protein 53, encoded by the *p53* gene, is directly involved in the regulation of the cell cycle. The *p53* is found on chromosome 17 and is located at region 17p13.1. The diagram shows an intron from the *p53* gene.

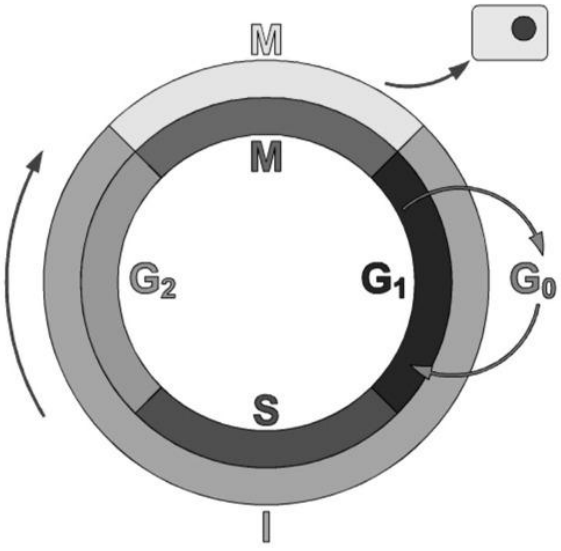
4a. What is the size of the *p53* gene?

1 mark

Solution

20 kilobases (or 20,000 base pairs) long

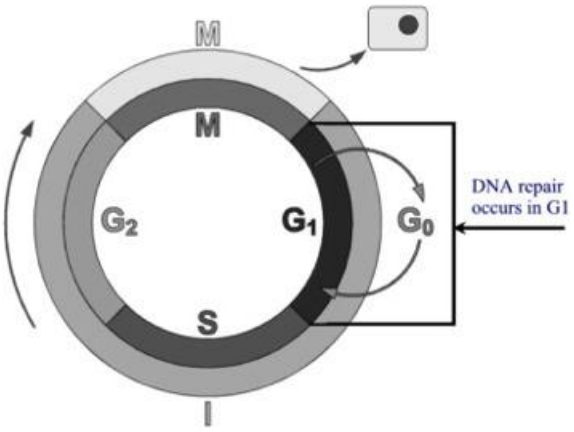
If DNA is damaged, *p53* can activate DNA repair proteins, trigger growth arrest by halting the cell cycle so that damaged DNA can be repaired before the next division cycle, and initiate apoptosis. The diagram shows a representation of the cell cycle.



4b. Use a labelled arrow to indicate where repair to damaged DNA is most likely to occur during the cell cycle.

1 mark

Solution



4c. What is apoptosis and why does it occur?

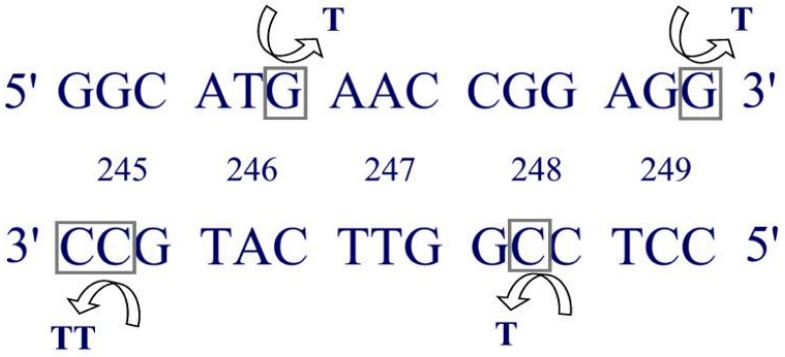
1 mark

Solution

Programmed cell death or controlled suicide AND at least one of:

- occurs when cells are infected OR
- when cells are damaged OR
- when cells have reached the end of their functional life span.

The action of four carcinogens on part of a normal sequence of the *p53* gene is shown below.



4di. What is the name given to these changes?

1 mark

Solution

Point mutation

4dii. Using the information from the normal sequence of *p53*, complete the following table.

original DNA	GGC ATG AAC CGG AGG
mutant DNA	
tRNA	

2 marks

Solution

original DNA	GGC ATG AAC CGG AGG
mutant DNA	*GGC ATT AAC CGG AGT*
tRNA	*GGC AUU AAC CGG AGU*

1+2=3 marks

Total 1+1+1+3 = 6 marks

Explanatory notes

Students are required to demonstrate their knowledge of the gene and its size, specifically to read and interpret information in diagrams. An understanding of the cell cycle and the role of apoptosis in response to damaged cells is essential. Students should also be familiar with and be able to identify specific types of mutation and to determine the changes that occur in nucleotide sequences in DNA and tRNA following a mutation.

Question 5

The three-dimensional structure shown below is produced in the nucleus and then moves to the cytoplasm. It is about 80 nucleotides long and is directly involved in the production of a polypeptide.

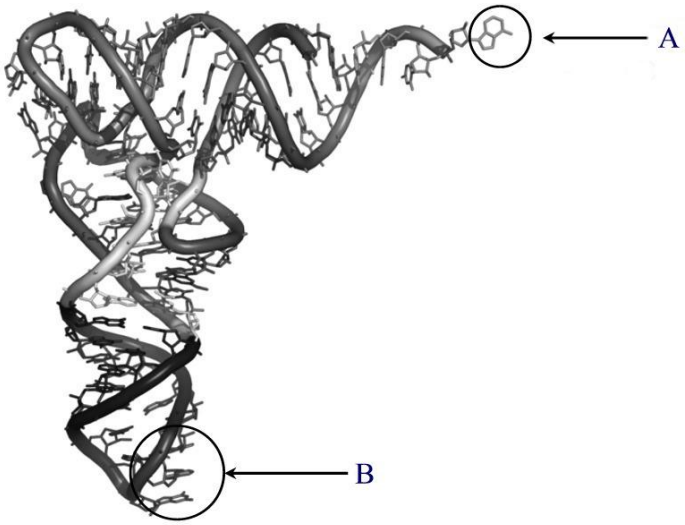


Image source: The Full Wiki. (Structural Biochemistry/Nucleic Acid/RNA/Transfer RNA (tRNA): Wikis)

5a. What is this molecule?

1 mark

Solution

transfer RNA molecule (tRNA molecule)

5b. What is the significance of Site A and Site B?

1 mark

Solution

Site A is an amino attachment site and Site B is the anticodon of the tRNA molecule.

Mark allocation

- 1 mark – both Site A and Site B must be correct

5c. Clearly explain what happens to the molecule shown in the diagram during the formation of a polypeptide.

2 marks

Solution

The tRNA molecule matches up and binds with its specific amino acid in the cytoplasm. At a ribosome the tRNA molecule is held in close proximity with the mRNA, the anticodon on the other end of the tRNA molecule matches up with its specific mRNA codon, while the amino acid forms a peptide bond and joins a growing polypeptide chain.

Mark allocation

- 1 mark – tRNA molecule matches up and binds with its specific amino acid
- 1 mark – at a ribosome the anticodon on the other end of the tRNA molecule matches up with its specific mRNA codon and the amino acid joins a growing polypeptide chain

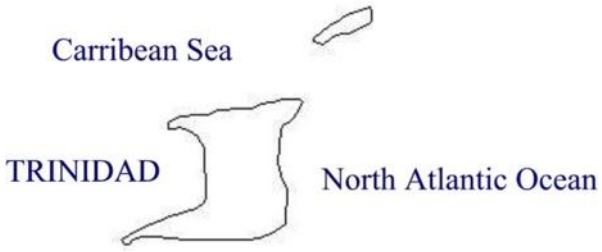
Explanatory notes

A knowledge of gene translation, polypeptide formation and the associated molecules and structures is required in this question. Students should be able to process information provided in the question stem to interpret and identify structures in the diagram. This question in particular extends student exposure to molecular images of tRNA molecules. Specifically, Site A is the acceptor arm of the tRNA molecule (that accepts and binds with the amino acid that it transports to the ribosome) and Site B is the anticodon loop (note the three exposed sites for complementary bonding with the mRNA codon). The ability to explain the process of gene translation in clear and specific detail is essential.

Total 4 marks

Question 6

The guppie, *Poecilia reticulata*, is a small freshwater fish that occurs in Trinidad, an island in the Caribbean.



In wild populations, the patterns on adult male guppies vary significantly from brightly coloured to drab. Female guppies are attracted to brightly coloured males. The guppy has two main predators, the killifish *Rivulus hartii*, which preys on juvenile guppies which have not expressed their adult colouring and the pike-cichlid *Crenicichla alta*, which preys principally on adult guppies.

Colour patterns in the guppy are under the control of many genes which are only expressed in adult males.

6a. What causes the colour pattern phenotype in guppies?

1 mark

Solution

Polygenic inheritance

In wild populations of guppies, males in pools with few predator species tend to be brightly coloured whereas those in pools with many predators are less brightly coloured. When brightly coloured guppies are transferred to pools with many predators, over time the transferred guppy populations become less brightly coloured.

6bi. Identify the process that has occurred in the transferred population of guppies.

1 mark

Solution

Natural selection

6bii. Explain how the process in **part i** produces the differences in colour in the populations of guppies.

3 marks

1+3 = 4 marks

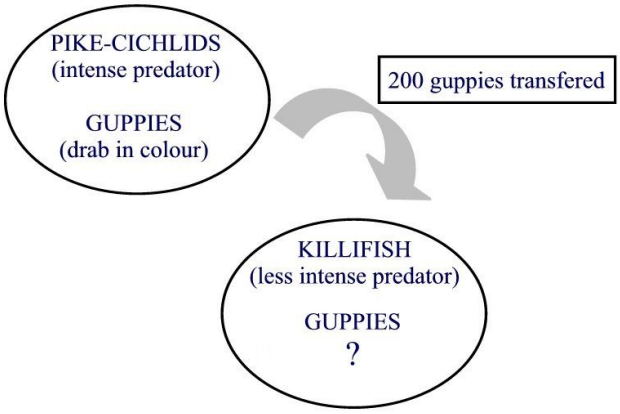
Solution

Variation in male guppy colouration exists in the population. Predation (selection pressure) selects against bright colouration and favours drab colouration, consequently guppies with drab colouration survive to reproductive age, reproduce and pass on their alleles to the next generation.

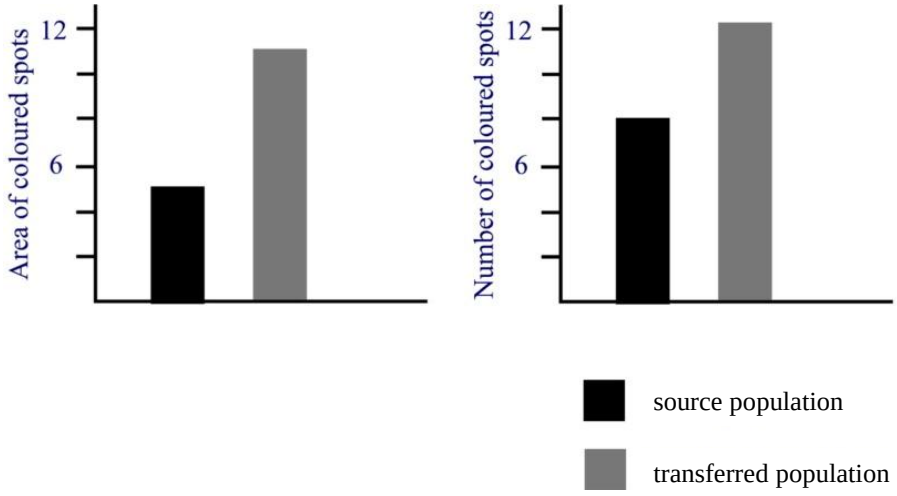
Mark allocation

- 1 mark – variation in male guppy colouration exists
- 1 mark – predation (selection pressure) selects against bright colouration and favours drab colouration
- 1 mark – guppies with drab colouration survive to reproductive age, reproduce and pass their alleles on to the next generation

An experiment was carried out to study the impact of predators on guppies. At the beginning of the two-year experiment, 200 guppies from pools containing only pike-cichlids (intense guppy predators) were transferred to pools containing killifish (less intense guppy predators). The number of brightly coloured spots and the total area of these spots were recorded for the male guppies in all of the 15 generations.



The graphs show the results of the experiment.



6ci. What conclusion could be drawn from the results of this experiment?

1 mark

Solution

The change in predator resulted in brighter colour patterns being favoured in the transferred population of guppies.

6cii. Identify the type of change that has occurred in the transferred population.

1 mark

Solution

Evolution (rapid)

1+1 = 2 marks

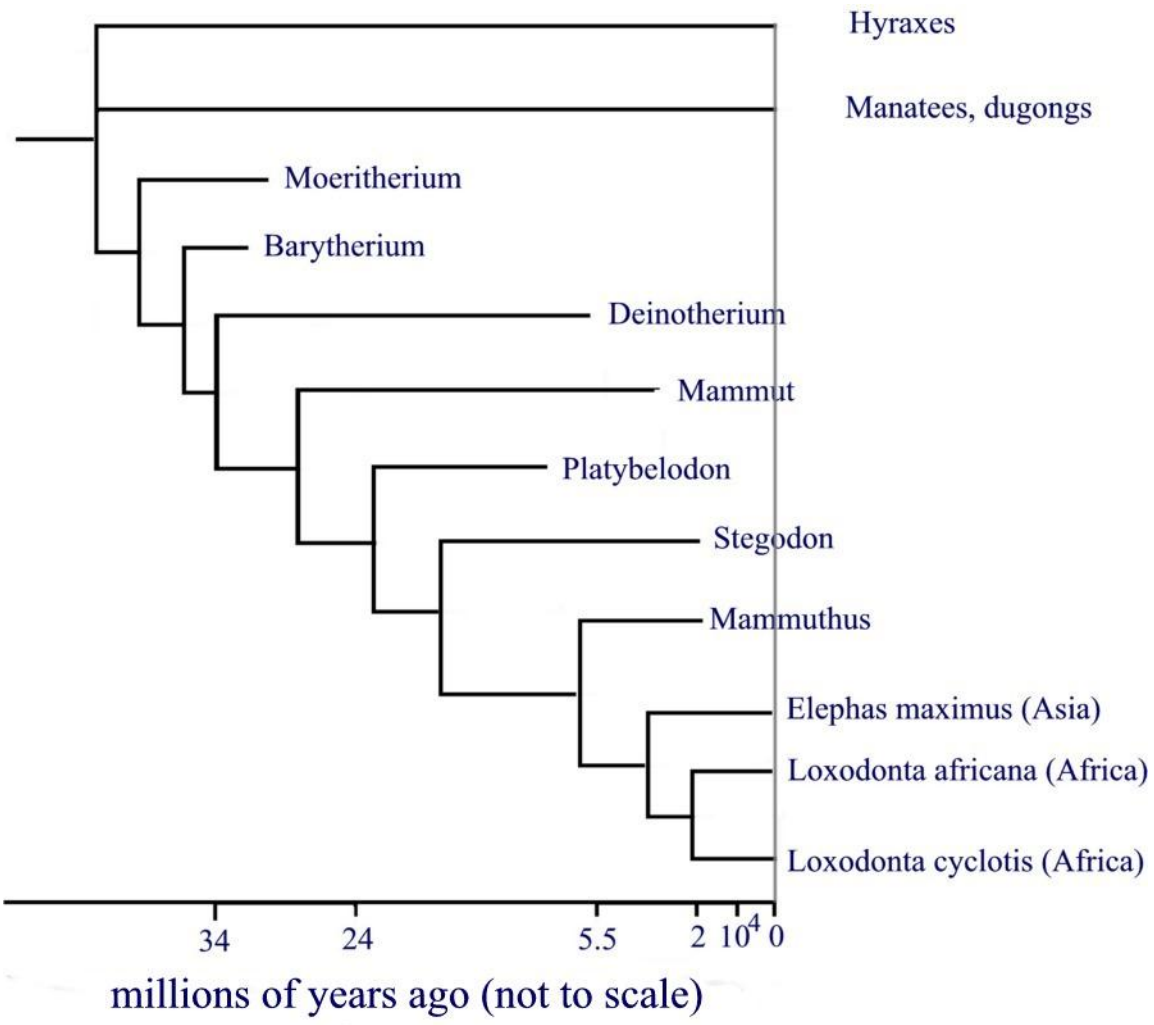
Total 1 + 4 + 2 = 7 marks

Explanatory notes

Students are required to demonstrate a clear understanding of variation in populations and the interaction between natural selection, polygenic inheritance and variation. The ability to read, process and understand experimental design and data is important in the second part of the question. Students are required to be able to draw conclusions from presented data and to be able to identify the forms of change that have been observed.

Question 7

In the past, African elephants found in the African savanna and forests, were classified as a subspecies of the same species. Studies of the mitochondrial DNA from African elephants found evidence of interbreeding between forest and savanna elephants around 500 000 years ago. A phylogenetic tree of elephants and their relatives, developed prior to the 2010 study, is shown below. (Note: the time line is not to scale.)



7ai. Based on the phylogenetic tree shown above, approximately how long ago did the African elephants evolve from their common ancestor?

1 mark

Solution

Around 2–5 million years ago.

7aii. Identify one extant relative of the Asian and African elephants.

1 mark

1+1 = 2 marks

Solution

Hyrax OR manatee OR dugong

The following table shows some comparisons between the African forest elephant and the African savanna elephant.

	African forest elephant (*Loxodonta cyclotis)*	**African savanna elephant** (*Loxodonta africana)*
shoulder height	male 2.4–2.8 m female 1.8–2.4 m	male 4 m female 2.2–2.6 m
weight	male 4 000–6 300 kg female 2 400–3 500 kg	2 700–6 000 kg
family group	nuclear family group size = 2–4	extended family group size = 4–14

7b. Explain whether the African elephants could be classified as separate species on the basis of the information in the table.

2 marks

Solution

No, they cannot be classified as separate species on the basis of the information in the table. Visible morphological, or physical, differences don't necessarily indicate that animals are of separate species. The inability of two fertile individuals from each of the two groups to produce viable, fertile offspring *would* support the classification of African elephants as separate species.

Mark allocation

- 1 mark – no, physical or morphological differences not enough
- 1 mark – inability of two fertile individuals to produce viable, fertile offspring

In 2010, the results of a new study indicated that the African forest elephant, *Loxodonta cyclotis*, and African savanna elephant, *Loxodonta africana*, are as genetically distinct from one another as the Asian elephant and the extinct woolly mammoth. In contrast with earlier research, the study sequenced the nuclear genomes of both types of African elephant, and of the Asian elephant (*Elephas maximus*). They also extracted and sequenced nuclear DNA from the extinct woolly mammoth (*Mammuthus primigenius*) and mastodon (*Mammut americanum*). Comparison of the five genomes found that the forest and savanna elephants diverged into separate species between 2.6 and 5.6 million years ago. This was around the same time as African and Asian elephants separated into separate species.

7c. Give a reason why researchers sequenced the nuclear genomes of the elephants and not just their mitochondrial DNA.

2 marks

Solution

The nuclear genome is much larger than the DNA contained in mitochondria and gives a broader and more accurate genetic picture of elephants' history. Mitochondrial DNA only gives researchers information on maternal ancestry, as this genetic material is inherited solely from the mother.

Mark allocation

- 1 mark – nuclear genome is larger than mitochondrial genome
- 1 mark – mitochondrial DNA only gives information about maternal line, not both maternal and paternal

All female African elephants stay close to their place of birth while all male African elephants roam freely.

7d. What is likely to happen to the African forest elephant gene pool over a long period of time?

1 mark

Total 2+2+2+1 = 7 marks

Solution

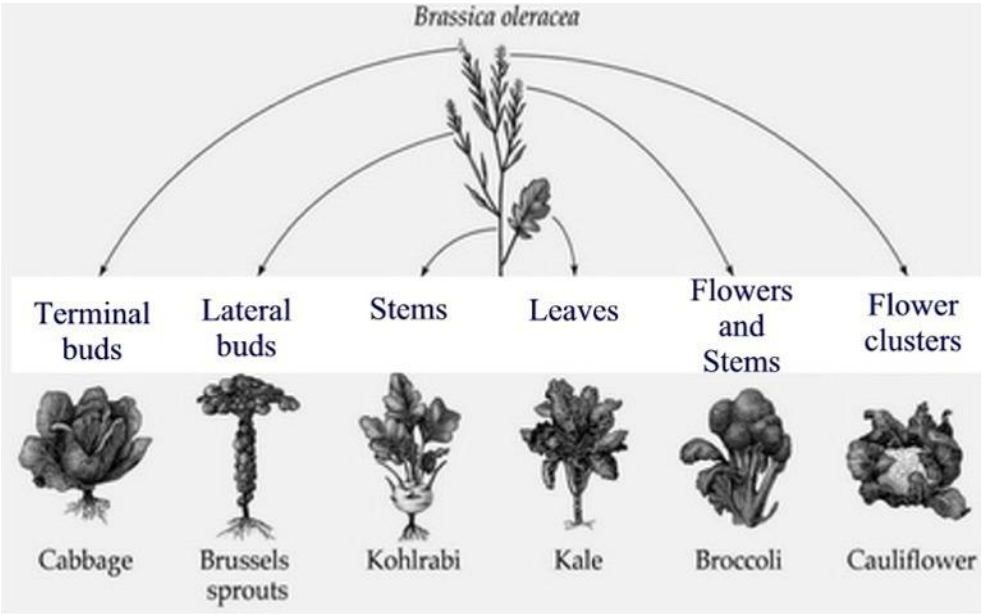
Gene flow from the African savanna elephant gene pool would occur. The forest elephant gene pool would become diluted and displaced, but the forest elephant DNA would be conserved in the mitochondrial DNA, which is passed on through the female line.

Explanatory notes

Students need to demonstrate their knowledge, understanding and ability to read and interpret phylogenetic trees. Familiarity with the definition of a species and the ability to apply it to examples is necessary. An awareness and understanding of the differences between nuclear and mitochondrial DNA and their respective usefulness in developing knowledge of speciation is necessary. Knowledge of gene pools and gene flow over time is also required.

Question 8

The vegetables shown in the diagram are all varieties of the wild cabbage species *Brassica oleracea*. Farmers have cultivated many different crops on the basis of the various attributes of the plant.



8a. Identify and explain the form of selection the farmers have engaged in.

2 marks

Solution

Artificial selection; when people (instead of nature) select which organisms get to reproduce.

Mark allocation

- 1 mark – artificial selection
- 1 mark – people (not nature) select which organisms get to reproduce

Canola seeds are produced by flowering plants in the Brassica family. The seeds are pressed to produce canola oil, which has the lowest level of saturated fatty acids of any vegetable oil. Canola plants usually self-pollinate and pollen from other canola plants is usually outcompeted. However, airborne cross-pollination can occur if crops are found within metres of each other. Canola pollen is quite heavy and cannot remain airborne for more than a few metres. In addition, pollen dries out quickly and loses its ability to pollinate. After the western Victorian floods in January 2011, concerns over genetically modified (GM) seed contamination have been raised. The company holding the patent for GM canola technology stated that GM canola and non-GM canola crops can co-exist.

8b. Should western Victorian farmers with adjoining properties be concerned about contamination between their GM and non-GM crops?

2 marks

Total 2 + 2 = 4 marks

Solution

Yes, the farmers should be concerned because if the properties are adjoining, they are within metres of each other, GM canola pollen can be transferred to non-GM canola flowers, resulting in cross pollination and contamination

Mark allocation

- 1 mark – yes, should be concerned
- 1 mark – if properties are adjoining they are within metres of each other, GM canola pollen can be transferred to non-GM canola flowers

Explanatory notes

Student knowledge of artificial selection as a form of selective breeding is necessary in this question. More specifically, a familiarity with the main issues associated with GM versus non-GM crops in agriculture is required.

END OF SECTION B
END OF SOLUTIONS BOOK