INSIGHT

Trial Exam Paper

2010

BIOLOGY

Written examination 2

Solutions book

This book presents:

- correct solutions
- explanatory notes
- mark allocations

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SECTION A - MULTIPLE CHOICE QUESTIONS

Question 1

The peony rose *Paeonia lactiflora* has a diploid number of 20.

At the end of mitosis, a cell of *Paeonia lactiflora* has 20 chromosomes. How many chromatids would be present in the G_2 phase of its next cell cycle?

A. It depends on whether it is undergoing mitosis or meiosis.

B. 10

C. 20

D. **40**

Answer is D

Explanatory notes

- A is incorrect – regardless of whether the cell undergoes mitosis or meiosis, the number of chromatids present in the G_2 phase of its next cell cycle would be the same.
- B is incorrect – there would be 40 chromatids present in the G_2 phase of its next cell cycle. There could only be 10 chromatids present in a cell with a diploid number of 10 during at prophase II or metaphase II of meiosis.
- C is incorrect – there would be 40 chromatids present in the G_2 phase of its next cell cycle. There could be 20 chromatids present in a cell of *Paeonia lactiflora* at the end of meiosis I.
- D is correct – there would be 40 chromatids present in the G_2 phase of its next cell cycle.

Question 2

Pairs of homologous chromosomes

A. synapse during the S phase of cell cycle.

B. are found in gametes.

C. **have genes for the same traits at the same loci.**

D. have identical DNA sequences in their genes.

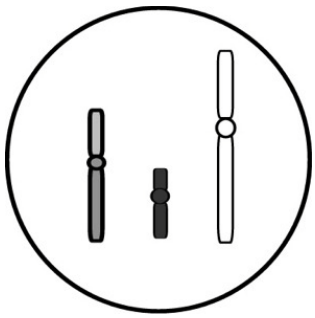
Answer is C

Explanatory notes

- A is incorrect – pairs of homologous chromosomes synapse during prophase I, not during S phase.
- B is incorrect – gametes do not contain homologous chromosomes, as the homologues have separated from each other in meiosis I during anaphase I.
- C is correct – homologous chromosomes have the same length, the same centromere position and the same genes for the same traits located at corresponding loci.
- D is incorrect – a single gene can have multiple forms (alleles), each of which can have a different nucleotide (or DNA) sequence.

Question 3

Sexual reproduction contributes to an increase in variation within a species due to the contribution of genetic material (found in gametes) from both parents. Gametes arise though the process of nuclear division known as meiosis. The diagram shows a cell during a phase of meiosis.



The cell could be from an organism with a

A. haploid number of 6 during telophase I.

B. **haploid number of 3 during telophase II.**

C. diploid number of 6 during telophase I.

D. diploid number of 3 during telophase II.

Answer is B

Explanatory notes

- A is incorrect – the cell has no double-stranded chromosomes and is therefore in meiosis II. It cannot be a cell with a haploid number of 6 during telophase I.
- B is correct – the cell has no double-stranded chromosomes and is therefore in meiosis II. It shows 3 single-stranded chromosomes and therefore is a cell with a haploid number of 3 during telophase II.
- C is incorrect – the cell has no double-stranded chromosomes and is therefore in meiosis II. It cannot be a cell with a diploid number of 6 during telophase I.
- D is incorrect – the cell has no double-stranded chromosomes and is therefore in meiosis II. Its haploid number is 3. At the end of telophase II a cell would be haploid, not diploid.

Question 4

Mendel's law of segregation states that

A. the laws of probability determine gamete formation.

B. **allele pairs separate in gamete formation.**

C. there is a 50% probability that a gamete will get a dominant allele.

D. gene pairs segregate independently of other genes in gamete formation.

Answer is B

Explanatory notes

Mendel's Law of Segregation states that genes have alternative forms (alleles). In a diploid organism, the two alleles of a gene segregate (i.e. separate) during gamete formation with each sperm or egg carrying only one allele of each pair.

- A is incorrect – whilst probability plays a role in gamete formation, this is not the best answer available.
- B is correct – allele pairs are separated in gamete formation.
- C is incorrect – the probability of a gamete receiving a dominant allele is determined by the genotype of the diploid organism; if it is homozygous recessive, Pr (dominant allele) = 0.
- D is incorrect – gene pairs will only segregate independently of other gene pairs if they are not linked.

Question 5

Eye colour in humans can range from dark brown to light blue and is controlled by multiple genes.

Eye colour is an example of

A. multiple alleles.

B. codominance.

C. **polygenic inheritance.**

D. discontinuous variation.

Answer is C

Explanatory notes

- A is incorrect – multiple alleles show discontinuous variation in their phenotypes. Eye colour is a trait with continuous variation, therefore eye colour in humans is not an example of multiple alleles.
- B is incorrect – codominance refers to inheritance patterns that occur when both alleles in a heterozygous organism contribute to the phenotype. This is not an example of codominance because there are multiple genes involved. In addition, codominance is characterised by discontinuous variation, while eye colour is a trait that shows continuous variation.
- C is correct – eye colour is a trait that shows continuous variation, due to the fact that it is influenced by more than one gene. Eye colour in humans is therefore an example of polygenic inheritance.
- D is incorrect – human eye colour shows continuous variation not discontinuous variation.

Question 6

In the diagram shown below, there are

A. **four chromatids and four molecules of DNA.**

B. four chromosomes and two molecules of DNA.

C. two double-stranded chromatids and two molecules of DNA.

D. two double-stranded chromosomes and two molecules of DNA.

Answer is A

Explanatory notes

- A is correct – each chromatid is considered to be a molecule of DNA. There are four chromatids and therefore four molecules of DNA present in the diagram.
- B is incorrect – there are two double-stranded chromosomes (not four) and four molecules of DNA (not two).
- C is incorrect – there are two double-stranded chromosomes (not chromatids) and four molecules of DNA (not two).
- D is incorrect – there are two double-stranded chromosomes and four molecules of DNA (not two).

Question 7

Gene M has two alleles, M and m. Gene R has two alleles, R and r. Gene M and R are linked. An organism has the genotype $\frac{MR}{mr}$. Which of the following genotypes is **not** possible amongst the offspring of a test cross involving this organism?

A. $\frac{MR}{mr}$

B. $\frac{Mr}{mr}$

C. $\frac{mR}{mr}$

D. $\frac{Mr}{Mr}$

Answer is D

Explanatory notes

A test cross would involve a cross between $\frac{MR}{mr}$, MR and $\frac{mr}{mr}$. The possible gametes and the outcome of the cross would include:

	MR	Mr	mR	Mr
mr	$\frac{MR}{mr}$	$\frac{Mr}{mr}$	$\frac{mR}{mr}$	$\frac{mr}{mr}$

- A is incorrect – $\frac{MR}{mr}$ is a possible genotypic outcome of the test cross.
- B is incorrect – $\frac{Mr}{mr}$ is a possible genotypic outcome of the test cross.
- C is incorrect – $\frac{mR}{mr}$ is a possible genotypic outcome of the test cross.
- D is correct – $\frac{Mr}{Mr}$ is NOT a possible genotypic outcome of the test cross.

Question 8

A woman with type B blood has two children, one with type A blood and one with type O blood. Her partner has type O blood. What can be concluded from this information?

A. Neither the woman nor the man could be the biological parent of the child with type A blood.

B. The man could not be the biological father of either child.

C. **The man could be the biological father of the child with type O blood, but not the child with type A blood.**

D. The man must be the biological father of the child with type O blood and could be the biological father of the child with type A blood.

Answer is C

Explanatory notes

- A is incorrect – if the woman was heterozygous for blood type (I^Bi) she could be the biological mother of the child with type A blood, if the genotype of the biological father was I^AI^A or I^Ai.
- B is incorrect – the man could be the biological father of the child with blood type O if his genotype was ii and the woman's genotype was I^Bi.
- C is correct – if the man's genotype was ii and the woman's genotype was I^Bi, he could be the biological father of the child with blood type O but not the child with type A blood.
- D is incorrect – if the man's genotype was ii and the woman's genotype was I^Bi, he could be the biological father of the child with blood type O (as could another male with the same genotype), but he could not be the biological father of the child with type A blood.

The following information relates to Questions 9 and 10.

In humans, androgenic alopecia (AGA), also known as male and female pattern baldness, occurs over many years and usually begins in males after puberty and in females any time after the age of twenty. The condition is controlled by a gene on the X chromosome.

Question 9

A man and woman both aged in their mid thirties and with no sign of hair loss are considering having a child. Both of their fathers have androgenic alopecia. The probability that their first child will develop AGA later in life is

A. 0

B. $\frac{1}{4}$

C. $\frac{1}{3}$

D. $\frac{1}{2}$

Answer is B

Explanatory notes

- A is incorrect – the woman will have received the recessive allele for the condition from her father, therefore even though her partner does not have the condition, there is a $\frac{1}{4}$ chance that they could have a child who will develop the condition.
- B is correct – there is a $\frac{1}{4}$ chance that they could have a child who will develop the condition.
- C is incorrect – the woman will have received the recessive allele for the condition from her father, therefore even though her partner does not have the condition, there is a $\frac{1}{4}$ chance that they could have a child who will develop the condition.
- D is incorrect – the woman will have received the recessive allele for the condition from her father, therefore even though her partner does not have the condition, there is a $\frac{1}{4}$ chance that they could have a child who will develop the condition.

Question 10

If the couple have three children, what is the probability that they will have two children who will develop AGA and one child who will not?

A. 1

B. $\frac{3}{4}$

C. $\frac{3}{64}$

D. $\frac{5}{12}$

Answer is C

Explanatory notes

The probability of each 'event' is independent, therefore it is necessary to multiply the Pr(AGA) × Pr(AGA) × Pr(no AGA). This is $\frac{1}{4} \times \frac{1}{4} \times \frac{3}{4} = \frac{3}{64}$

- A is incorrect – given the genotypes of the man and the woman, it cannot be guaranteed that they will have two children who will develop AGA and one who will not.
- B is incorrect – given the genotypes of the man and the woman, the chance that they will have two children who will develop AGA and one who will not is $\frac{3}{64}$, not $\frac{3}{4}$.
- C is correct – given the genotypes of the man and the woman, the chance that they will have two children who will develop AGA and one who will not, is $\frac{3}{64}$.
- D is incorrect – given the genotypes of the man and the woman, the chance that they will have two children who will develop AGA and one who will not, is $\frac{3}{64}$, not $\frac{5}{12}$.

Question 11

The 5’ ⟶ 3’ nucleotide sequence on a complementary (noncoding) DNA strand is TAA.

5’ ⟶ 3’

TAA

The corresponding codon on mRNA and anticodon on tRNA would be

	mRNA	**tRNA**
A	AUU	UAA
B	**UAA**	**AUU**
C	AUU	TAA
D	TAA	AUU

Answer is B

Explanatory notes

Coding strand of DNA is ATT, therefore complementary mRNA sequence will be UAA and tRNA anticodon will be AUU

- A is incorrect – coding strand of DNA is ATT, complementary mRNA sequence will be UAA (not AUU), tRNA anticodon will be AUU (not UAA).
- B is correct – coding strand of DNA is ATT, complementary mRNA sequence will be UAA, tRNA anticodon will be AUU.
- C is incorrect – coding strand of DNA is ATT, complementary mRNA sequence will be UAA (not AUU), tRNA anticodon will be AUU (not TAA).
- D is incorrect – coding strand of DNA is ATT, complementary mRNA sequence will be UAA (not TAA), tRNA anticodon will be AUU (not AUU).

Question 12

RNA polymerase

A. **begins transcription at a promoter sequence, moves along the template strand of DNA, elongating an RNA molecule in a 5’ ⟶ 3’ direction.**

B. begins transcription at a promoter sequence, moves along the template strand of DNA, elongating an RNA molecule in a 3’ ⟶ 5’ direction.

C. is the enzyme that forms hydrogen bonds between nucleotides on the DNA nontemplate strand and their complementary RNA nucleotides.

D. is the enzyme that unwinds the parental double helix at the replication forks during DNA replication.

Answer is A

Explanatory notes

- A is correct – RNA polymerase begins transcription at a promoter sequence, moves along the template strand of DNA and elongates an RNA molecule in a 5' ⟶ 3' direction.
- B is incorrect – RNA polymerase begins transcription at a promoter sequence, moves along the template strand of DNA and elongates an RNA molecule in a 5' ⟶ 3', not in a 3' ⟶ 5' direction.
- C is incorrect – RNA nucleotides do not bind to the nontemplate strand of DNA in the process of DNA transcription.
- D is incorrect – the enzyme that unwinds the parental double helix at the replication forks during DNA replication is helicase, not RNA polymerase.

The following information relates to Questions 13 to 15.

Forensic police attended the scene of a crime and collected samples of blood from the scene of the crime, the victim and two suspects. The samples were then subjected to a procedure known as Southern blotting in which the DNA found in the blood was treated with a restriction enzyme.

Question 13

The role of a restriction enzyme in DNA technology is to

A. act as a vector for the transfer of recombinant DNA.

B. reseal 'sticky ends' after base pairing of complementary bases.

C. dissociate DNA into single strands to enable hybridisation with complementary sequences**.**

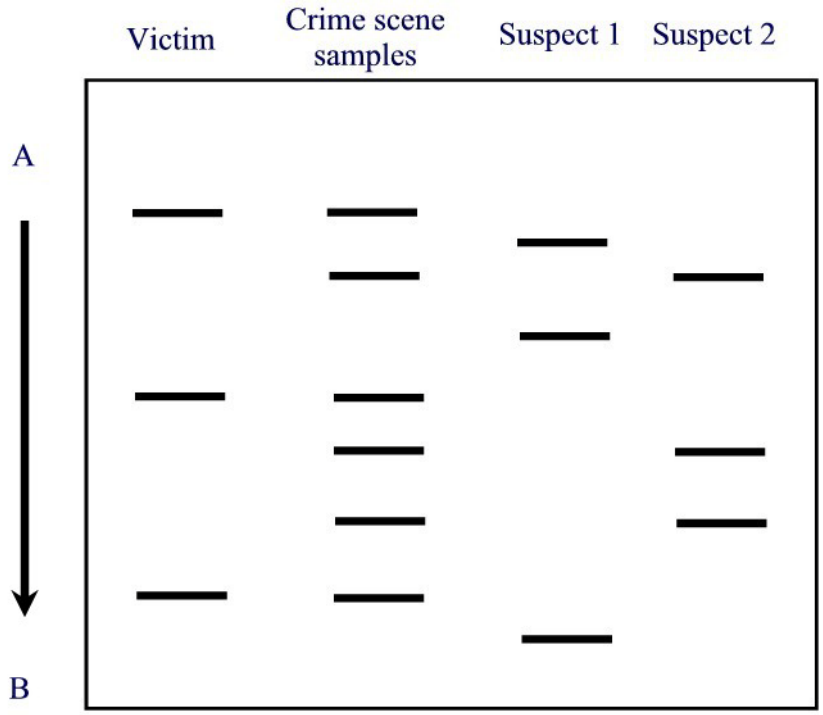
D. cut DNA at a specific nucleotide sequence.

Answer is D

Explanatory notes

- A is incorrect – the role of a restriction enzyme is to recognise and cut DNA at a specific nucleotide sequence, not to act as a vector for the transfer of rDNA.
- B is incorrect – the role of a restriction enzyme is to recognise and cut DNA at a specific nucleotide sequence, not to reseal 'sticky ends' after base pairing of complementary bases.
- C is incorrect – the role of a restriction enzyme is to recognise and cut DNA at a specific nucleotide sequence, not to dissociate DNA into single strands for hybridisation.
- D is correct – the role of a restriction enzyme is to recognise and cut DNA at a specific nucleotide sequence.

An autoradiograph was produced from the blood samples. The diagram below shows the banding pattern displayed on the autoradiograph.



Question 14

The bands in the autoradiograph are most likely to represent

A. DNA molecules that have moved in the direction of A to B due to the positive charge of their phosphate groups.

B. **DNA molecules that have moved in the direction of A to B due to the negative charge of their phosphate groups.**

C. DNA molecules that have moved in the direction of B to A due to the positive charge of their phosphate groups.

D. DNA molecules that have moved in the direction of B to A due to the negative charge of their phosphate groups.

Answer is B

Explanatory notes

- A is incorrect – phosphate groups do not have a positive charge.
- B is correct – bands in an autoradiograph represent DNA molecules that have moved towards a positive (B) terminal due to the negative charge of the phosphate group.
- C is incorrect – phosphate groups do not have a positive charge.
- D is incorrect – bands in an autoradiograph represent DNA molecules that have moved towards a positive terminal due to the negative charge of the phosphate group. They will not move from a positive (B) to a negative (A) terminal.

Question 15

As a result of the blood analysis, it is most likely that

A. neither Suspect 1 nor Suspect 2 will be charged with the crime.

B. both Suspect 1 and Suspect 2 will be charged with the crime.

C. Suspect 1 will be charged with the crime.

D. **Suspect 2 will be charged with the crime.**

Answer is D

Explanatory notes

- A is incorrect – according to the autoradiograph, there is a correlation in the banding pattern of the DNA molecules found at the crime scene and from Suspect 2. It is therefore likely that Suspect 2 will be charged with the crime.
- B is incorrect – according to the autoradiograph, there is no correlation in the banding pattern of the DNA molecules found at the crime scene and from Suspect 1. It is therefore unlikely that Suspect 1 will be charged with the crime.
- C is incorrect – according to the autoradiograph, there is no correlation in the banding pattern of the DNA molecules found at the crime scene and from Suspect 1. It is therefore unlikely that Suspect 1 will be charged with the crime.
- D is correct – according to the autoradiograph, there is a correlation in the banding pattern of the DNA molecules found at the crime scene and from Suspect 2. It is therefore likely that Suspect 2 will be charged with the crime.

The following information relates to Questions 16 and 17.

In 1859, Charles Darwin and Alfred Wallace made the claim that all the species present on Earth descended from a common ancestral species, and that the mechanism for evolution is natural selection.

Question 16

The claim that all the species present on Earth descended from a common ancestor is best supported with evidence from

A. comparative anatomy.

B. comparative embryology.

C. **molecular biology.**

D. the fossil record.

Answer is C

Explanatory notes

- A is incorrect – whilst comparative anatomy does provide some support for the existence of recent common ancestry, the degree of similarity in nucleotide or amino acid sequences is considered to be the strongest evidence for determining phylogenetic relationships.
- B is incorrect – whilst comparative embryology does provide some support for the existence of recent common ancestry, the degree of similarity in nucleotide or amino acid sequences is considered to be the strongest evidence for determining phylogenetic relationships.
- C is correct – the degree of similarity in nucleotide or amino acid sequences is considered to be the strongest evidence for determining phylogenetic relationships.
- D is incorrect – whilst the fossil record does provide some support for the existence of recent common ancestry, the degree of similarity in nucleotide or amino acid sequences is considered to be the strongest evidence for determining phylogenetic relationships.

Question 17

The best description of natural selection is

A. the overproduction of offspring in environments with limited natural resources.

B. **the reproductive success of the members of a population best adapted to the environment.**

C. the struggle for existence.

D. the survival of the fittest.

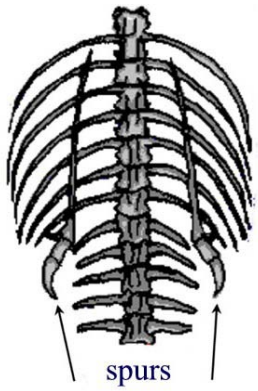
Answer is B

Explanatory notes

- A is incorrect – natural selection is best defined as the reproductive success of the members of a population best adapted to the environment, not the overproduction of offspring in environments with limited natural resources.
- B is correct – natural selection is best defined as the reproductive success of the members of a population best adapted to the environment.
- C is incorrect – natural selection is best defined as the reproductive success of the members of a population best adapted to the environment, not the struggle for existence.
- D is incorrect – natural selection is best defined as the reproductive success of the members of a population best adapted to the environment, not the survival of the fittest.

Question 18

In September 2009 a woman claimed to have discovered a snake with a single clawed foot in her home in southwest China. Whilst the specific case is thought to be the result of a mutation, it is known that the skeletons of some snakes, including boas and pythons, show the remnants of pelvic and leg bones.



(Copyright by Jamie Love: www.synapses.co.uk/evolve)

The pelvic and leg bones appear externally on the snakes as bumps or spurs. Males use their spurs to stimulate females during mating. These remnants

A. provide evidence for the inheritance of acquired characteristics.

B. confirm that lizards evolved from snakes.

C. are homologous structures.

D. **are vestigial structures.**

Answer is D

Explanatory notes

- A is incorrect – there is no evidence that acquired characteristics can be inherited.
- B is incorrect – snakes and lizards evolved from a common ancestor with four legs. Lizards did not evolve from snakes.
- C is incorrect – for a structure to be considered homologous, it will be homologous with structures in another organism. However, there is no other organism presented for comparison.
- D is correct – vestigial structures are of limited, if any, importance to an organism. They were, however, of significant importance to ancestors of the organism.

The following information relates to Questions 19 and 20.

Ellis-van Creveld syndrome is a rare autosomal recessive genetic disorder that results in skeletal malformations such as polydactyly, congenital heart defects and prenatal tooth eruption. The condition is much more prevalent in the Amish people of Pennsylvania than in the general population. The Amish are religious isolates and do not usually marry out of their community. It is known that two members of the original community both had the recessive allele for Ellis-van Creveld syndrome.

Question 19

Ellis-van Creveld syndrome is considered to be an example of genetic drift. Genetic drift is most likely to be observed in a population that

A. has low numbers.

B. experiences changing environmental conditions.

C. has a high migration rate.

D. has a low mutation rate.

Answer is A

Explanatory notes

- A is correct – genetic drift is a process in which chance events cause unpredictable changes in allele frequencies across generations. The influence of genetic drift is thus most noticeable in populations of small size.
- B is incorrect – changing environmental conditions will not necessarily lead to genetic drift unless the population has low numbers to begin with.
- C is incorrect – high migration rate can change allele frequencies in a population, but this is an example of gene flow, not genetic drift.
- D is incorrect – low mutation rates in a population will not necessarily lead to genetic drift unless the population has low numbers to begin with.
-

Question 20

The form of genetic drift observed in the Amish community is also known as

A. sympatric speciation.

B. allopatric speciation.

C. a population bottleneck.

D. a founder effect.

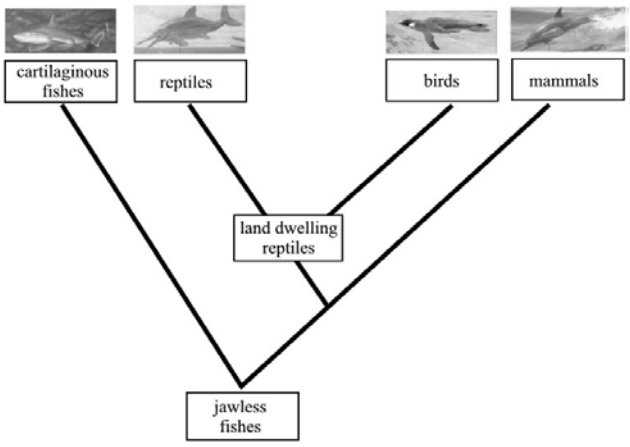
Answer is D

Explanatory notes

- A is incorrect – sympatric speciation is the formation of a new species within populations that live in the same geographic area; no new species has evolved in the example in Question 20.
- B is incorrect – allopatric speciation is the formation of new species in populations that are isolated from each other; no new species has evolved in the example in Question 20.
- C is incorrect – a population bottleneck occurs when a sudden change in the environment significantly reduces the size of the population, this has not occurred in the example in Question 20.
- D is correct – a founder effect occurs when a small group of individuals becomes isolated from a larger population and establishes a new population in which the gene pool differs from the original population. This is the case in the example in Question 20.

The following information relates to Questions 21 and 22.

The phylogenetic tree shown below illustrates the evolutionary lineage of four groups of vertebrates. Life in an aquatic environment has produced a common streamlined body shape. When compared with Darwin's Galapagos finches, which have a known recent common ancestry, sharks (cartilaginous fish), ichthyosaurs (reptiles), penguins (birds) and dolphins (mammals) do not share a recent common ancestor.



The pattern of evolution described in the diagram is an example of

Question 21

A. parallel evolution.

B. **convergent evolution.**

C. divergent evolution.

D. co-evolution.

Answer is B

Explanatory notes

- A is incorrect – parallel evolution occurs when species that are not closely related (i.e. not part of a monophyletic group) respond to similar selection pressures by evolving similar structures.
- B is correct – convergent evolution occurs when distantly related species respond to similar selection pressures by evolving similar structures that perform similar functions.
- C is incorrect – divergent evolution occurs when closely related species respond to different selection pressures and become increasingly different as time progresses.
- D is incorrect – co-evolution occurs when two different species with a mutually beneficial ecological interaction evolve features that favour their mutually beneficial interaction, there is no mutually beneficial interaction in this example.

Question 22

Whilst the four vertebrate groups do not share a recent common ancestor, they all show variations of the pentadactyl limb which enables propulsion through water. This is most similar to the development of

A. the eye for detecting light, in mammals and the octopus.

B. wings for flight, in bees and birds.

C. legs for walking, in spiders and horses.

D. wings for flight in bats and birds.

Answer is D

Explanatory notes

It cannot be assumed that if organisms display homologous structures that they have developed as a result of common ancestry. The four vertebrate groups are distantly, not recently, related. Their body shape is an example of convergent evolution; however, the common pentadactyl limb has persevered since the distant ancestor and is an example of a homologous structure.

- A is incorrect – the eye of the mammal and octopus are not examples of homologous structures: they are analogous.
- B is incorrect – wings for flight in bees and birds are not examples of homologous structures: they are analogous.
- C is incorrect – legs for walking in spiders and horses are not examples of homologous structures: they are analogous.
- D is correct – wings for flight in bats and birds are examples of homologous structures: they have evolved as a result of distant common ancestry.

Question 23

Current data support the view that *Homo sapiens* appeared in Africa around 195 000 years ago. There are many characteristics that distinguish hominins from other primates. The distinguishing characteristic believed to have emerged first is

A. larger brain.

B. **bipedalism.**

C. reduction in jaw bones and musculature.

D. manufacture and use of tools.

Answer is B

Explanatory notes

- A is incorrect – larger brain size has been shown to have occurred after the emergence of bipedalism within the Habilines (*Homo habilis*).
- B is correct – bipedalism is the characteristic believed to have emerged to distinguish hominins from other primates (Australopithecines).
- C is incorrect – reduction in jaw bones and musculature occurred after the emergence of bipedalism.
- D is incorrect – manufacture and use of tools occurred after the emergence of hominins from other primates (Habilines).

Question 24

Fossils are the preserved remains, impressions or traces of once-living organisms. Which of the following is NOT a requirement for successful fossilisation?

A. rapid burial and entombing with sediment.

B. anaerobic conditions.

C. **soil or environment with low pH.**

D. hard parts and unchanging temperature conditions.

Answer is C

Explanatory notes

- A is incorrect – rapid burial and entombing with sediment is required for successful fossilisation.
- B is incorrect – anaerobic conditions are required for successful fossilisation.
- C is correct – low pH is associated with high acidity. Acid is detrimental to the process of fossilisation as it corrodes the materials for preservation.
- D is incorrect – hard parts and unchanging temperature conditions are required for successful fossilisation.

Question 25

Recent comparisons of mitochondrial DNA have provided strong support to the theory that *Canis lupus*, the grey wolf, is the ancestor of domestic dogs. There are over 400 different breeds of dog which have come about as a result of artificial selection. Which one of the following statements about artificial selection is CORRECT?

Artificial selection is

A. a form of directional selection.

B. **capable of maintaining phenotypes in a population that would be selected against under natural conditions.**

C. dependent on the existence of some genetic variability within a chosen population.

D. a continuation of a natural evolutionary process.

Answer is B.

Explanatory notes

- A is incorrect – directional selection is a form of natural selection in which individuals at one end of a phenotypic range have better survival or reproductive outcomes than other individuals of the species. It is not a form of artificial selection.
- B is correct – the process of artificial selection can maintain phenotypes in a population that would be selected against under natural conditions.
- C is incorrect – artificial selection is not dependent on the existence of some genetic variability within a chosen population.
- D is incorrect – artificial selection is not a continuation of a natural evolutionary process. In fact it is a disruption of the natural evolutionary process.

END OF SECTION A

SECTION B – Short-answer questions

Question 1

In the Bengal tiger (*Panthera tigris tigris*), normal coat colour is orange-brown or dark yellow with dark brown, grey or black stripes (Y). A recessive allele (y) can produce cubs with creamy white coats, pink noses and blue crossed eyes. The recessive allele is not found in any other tiger species, nor is it sex-linked.

1a. How many recessive alleles would be present in the somatic cells of Bengal tigers heterozygous for the condition?

1 mark

Solution

One

Explanatory notes

Bengal tigers that are heterozygous for coat colour have the genotype Yy. Somatic cells are diploid and there are two alleles for this monogenic trait. There will be one allele for dominant coat colour and normal eyes (Y) and one allele for white coat and crossed eyes (y).

1b. What is the term used to describe the position occupied by an allele on a chromosome?

1 mark

Solution

Locus

Explanatory notes

There are many genes found on a chromosome. The position of a gene (or an allele) on a chromosome is referred to as a locus.

1c. If two normal tigers that are heterozygous for this condition mate, what is the expected phenotypic ratio of their offspring? Show your working.

3 marks

Solution

$$Yy \times Yy$$

$$YY : Yy : Yy : yy$$

$$1\ YY : 2\ Yy : 1\ yy$$

3 normal tigers/cub : 1 white, cross eyed tiger/cub

Mark allocation

- 1 mark – parental genotypes
- 1 mark – correct working for the mating cross
- 1 mark – correct ratios for offspring

Explanatory notes

Students are required to complete a standard monohybrid cross for 2 heterozygous individuals with an autosomal condition. Genotypes of both individuals should be clearly demonstrated. The working can be shown as above or as a Punnet square and the final answer should be given in the form of a ratio.

In the wild, the likelihood of producing a white, crossed-eyed Bengal tiger is 1 in every 10,000, an approximation based on documented observations of white cubs in their natural habitat. There are very few adult white tigers in the wild. When bred in captivity, mortality rates of cubs are in excess of 80%. The recessive allele that produces white, cross eyed tigers is also linked with other, often fatal characteristics including immune deficiency, scoliosis (curvature) of the spine, cleft palates and early death.

1d. **i.** What is the name of the event that has produced the recessive allele in the Bengal tiger?

1 mark

Solution

Deleterious mutation.

1d. **ii.** Other than congenital abnormalities, suggest another explanation for the extremely low numbers of adult white tigers in the wild.

1 mark

Solution

White tigers would be obvious to their predators (i.e. crocodiles) and thus be more likely to be killed.

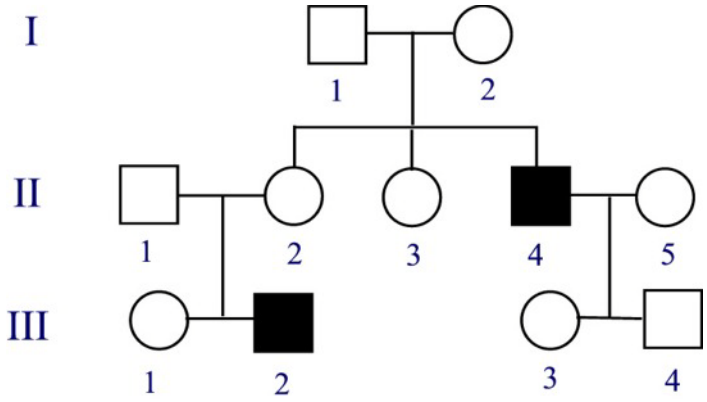
Explanatory notes

Bengal tigers live in a range of different forest types all with good cover and dense vegetation in which they are ideally camouflaged due to their orange-brown coat. A white coat would stand out very clearly in a forest environment, thus placing the tiger at a significant disadvantage in terms of its chances of survival.

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

Question 2

Becker muscular dystrophy (BMD) is an inherited disorder in humans that usually affects only males. The condition is characterised by slow progressive muscle weakness of the legs and pelvis. The pattern of symptom development is similar to that of Duchenne muscular dystrophy (DMD), however the mean age of onset is 12 years. The pedigree shows an inheritance pattern for Becker muscular dystrophy within a family over three generations. The individuals in generation III are all under the age of 10 years.



2a. What is represented by the shading?

1 mark

Solution

An individual affected by the condition under consideration.

Explanatory notes

In all pedigrees, shading of the symbols for male and female is always indicative of an affected individual.

On the basis of the information provided in the pedigree it has been suggested that BMD is inherited as an X-linked recessive condition.

2b. Use the information from the pedigree to demonstrate how the suggestion can be supported.

2 marks

Solution

Recessive trait because trait is passed on from two unaffected parents (I – 1 & I – 2; II – 1 & II – 2) to an affected child (II – 4; III – 2). X-linked because only sons are affected and no daughters.

Explanatory notes

Characteristics associated with X-linked recessive inheritance include:

- All sons of affected mothers show the trait
- An affected daughter must have an affected father
- All offspring from a mating between two individuals with the trait, will exhibit the trait
- More males than females are affected

2c. Assign allelic symbols for BMD.

1 mark

Solution

X^B – unaffected by BMD; X^b – has BMD

Explanatory notes

As BMD is a sex-linked condition, it is necessary to indicate which sex chromosome is involved (the X) and superscripted dominant or recessive alleles are represented using the standard of upper- and lowercase letters (dominant and recessive respectively).

2d. State the genotypes of individual III – 3.

1 mark

Solution

III – 3 : X^BX^b or X^bX^b

Explanatory notes

Individual III–3 is a female. Her father has BMD and will have passed on his affected X chromosome to her. She does not show symptoms of BMD at this stage of her life (she is under 10 years). Her mother is asymptomatic with a possible genotype of X^BX^B or X^BX^b. She could have contributed either an X^B or an X^b to her daughter.

Duchenne muscular dystrophy (DMD) is a condition closely related to BMD; both occur as a result of a mutation in the gene that codes for the production of dystrophin, which is a protein made up of 3700 amino acids. In DMD, abnormal dystrophin, a smaller protein made up of 2500 amino acids, is produced leading to the degradation of muscle fibres. Abnormal dystrophin is known to be missing an exon.

2e. **i.** What is an exon?

1 mark

Solution

An exon is the section of a gene that is transcribed and translated during protein production.

2e. **ii.** Explain how the absence of an exon could lead to the production of the abnormal dystrophin protein.

1 mark

Solution

The absence of an exon results in fewer nucleotides being translated and consequently there will be less amino acids in the protein.

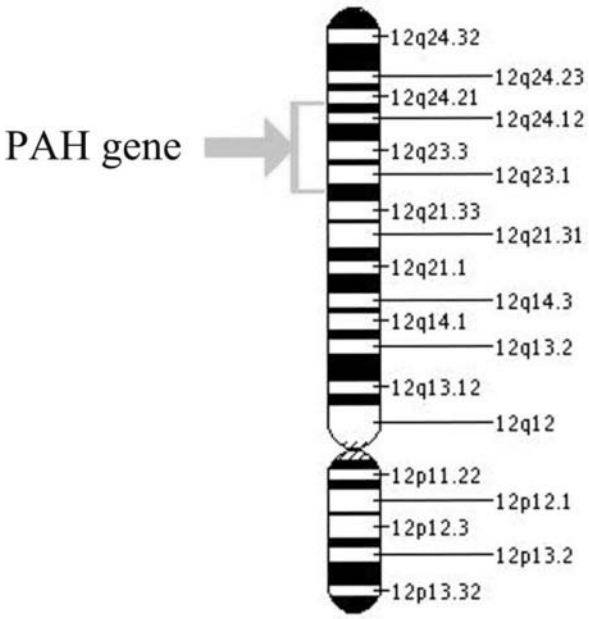
Explanatory notes

An exon is a part section of a gene that codes for a sequence of amino acids within a protein. The absence of an exon results in fewer nucleotides being translated, and consequently there will be less amino acids in the protein. This leads to the production of abnormal dystrophin.

Total 1+2+1+1+1+1= 7 marks

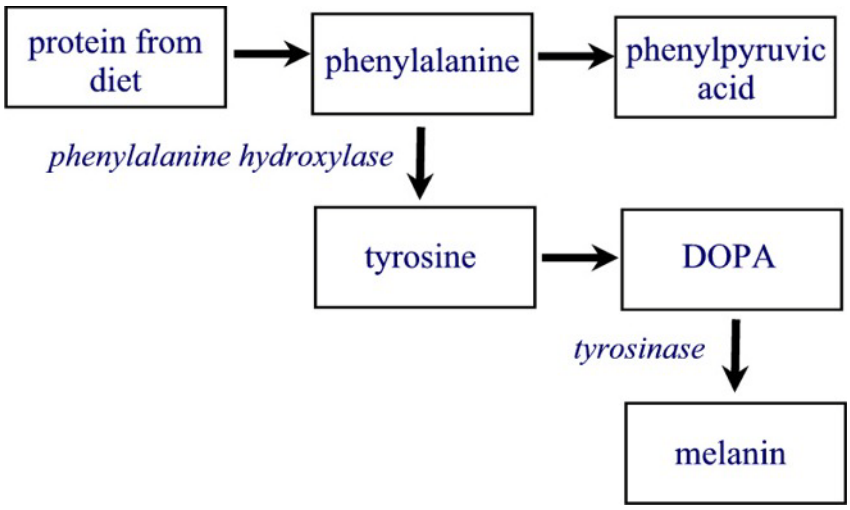
Question 3

Phenylketonuria (PKU) is an autosomal recessive disorder characterised by a deficiency in the enzyme phenylalanine hydroxylase (PAH). PAH is produced by the PAH gene which is located on chromosome 12 (base pairs 101 756 233 to 101 835 510) and is essential in the conversion of the amino acid phenylalanine to tyrosine.



(source: U.S. National Library of Medicine)

The abnormal form of PAH shows a very low level of enzyme activity. If it is produced, phenylalanine is converted to phenylpyruvic acid (also known as phenylpyruvate) which can build up to toxic levels in the body. Nerve cells in the brain are sensitive to phenylalanine levels and excessive amounts impair the development of the nervous system, resulting in severe brain damage. Phenylalanine is an essential amino acid which is obtained through food.



There are more than 500 known mutations in the PAH gene. Most mutations involve a change in a single amino acid in phenylalanine hydroxylase. One of the most common PAH mutations amongst European Caucasians involves a change at codon 408 where CGG is replaced by TGG.

3a. What is the name given to this type of mutation?

1 mark

Solution

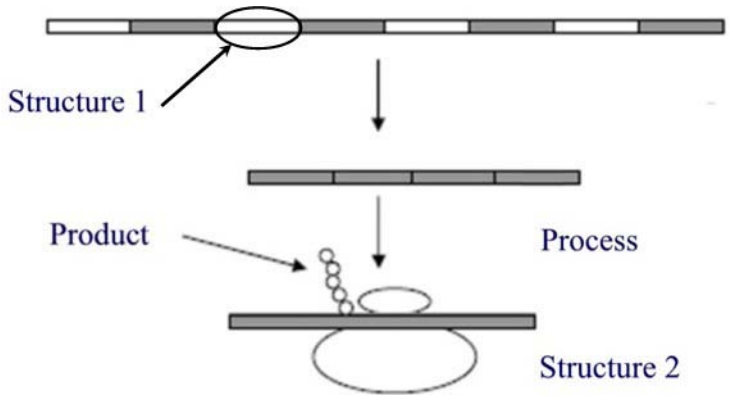
Missense OR point OR substitution

Explanatory notes

Point mutations are the most common form of mutation, and involve chemical changes in a single base pair of a gene. There are several different types of point mutations including substitutions (which produce missense and nonsense) and insertions or deletions (which produce frameshift mutations).

3b. The diagram shows the stages that occur from the gene to the product. Identify the process, the product and each structure.

2 marks



Solution

Process: translation

Product: polypeptide chain OR amino acid chain

Structure 1: intron

Structure 2: ribosome

Mark allocation

- 2 marks – 4 correct
- 1 mark – 3 or 2 correct
- 0 marks – 1 or none correct

Explanatory notes

The process of protein production occurs in several stages. In the nucleus of eukaryotes, RNA is transcribed from a DNA template. The RNA transcript is then spliced (introns removed) and modified to produce mRNA (exons only) which moves to the cytoplasm and attaches to a ribosome, where it is read codon by codon. A succession of tRNA molecules, each of which has a matching complementary anticodon to the codons in the mRNA, each carrying a specific and corresponding amino acid to the codon, moves to the ribosome and passes through one codon at a time. As the tRNA anticodon pairs with the mRNA codon, its amino acid forms a peptide bond with the growing polypeptide which precedes it. The tRNA molecule detaches from the mRNA codon and moves away. The polypeptide chain continues to grow and when complete is released from the ribosome.

The holly-leafed grevillea, *Grevillea infecunda*, is a rare and endangered species of endemic plant found in a small area around Anglesea in Victoria. Even though it flowers regularly every year, it has low fertility, producing no seeds. Instead, it reproduces asexually through root suckering.

The genetic variation between individual plants and between populations was tested by conservation biologists. A few leaves were sampled from every plant in the known populations and DNA was extracted from those leaves. The DNA was cut into fragments and then amplified using PCR.

3c. i. What do the letters PCR represent?

1 mark

Solution

Polymerase chain reaction

3c. ii. What are the four ingredients required for PCR?

2 marks

Solution

Ingredient 1: a sample DNA

Ingredient 2: nucleotides A, C, G, T

Ingredient 3: DNA polymerase

Ingredient 4: single-stranded DNA primers

Mark allocation

- 2 marks – 4 correct
- 1 mark – 3 or 2 correct
- 0 marks – 1 or none correct

3c. **iii.** The process of PCR can be summarised in 3 steps. Identify and briefly outline the 3 steps.

3 marks

Solution

Step 1: Denaturation

Description: Double-stranded DNA is heated briefly to cause the strands to dissociate/separate

Step 2: Annealing

Description: Separated DNA is cooled to allow primers to form hydrogen bonds with the ends of the target sequence

Step 3: Extension

Description: DNA polymerase adds nucleotides to the 3' end of each primer

Explanatory notes

Polymerase chain reaction (PCR) is a process used to amplify a specific target sequence of DNA *in vitro*. The 3 step process produces an exponentially growing population of identical DNA molecules. The process involves heating/denaturing DNA (to separate the strands), cooling (to allow bonding of primers) and extension of the primers (using nucleotides).

Mark allocation

- 1 mark for each step and correct explanation

Total 1+2+1+2+3= 9 marks

Question 4

Within any organism there are many genes which can be classified by function. The genes that appear to be evolving the most rapidly are those that code for transcription factors. Transcription factors are responsible for the control of gene expression. A particular transcription factor which has shown evidence of rapid change in the human lineage is FOXP2, which is thought to be one of the principal genes associated with vocalisation in vertebrates, as well as the development process in mammals for a number of organ systems and exists at high levels in foetal brain tissue. The FOXP2 gene which is located on chromosome 7 is expressed in the brains of songbirds when they are learning their songs and in humans. Severe speech and language impairment is observed if a mutation occurs in the gene.

4a. **i.** What is the name given to a gene, such as FOXP2, that controls other genes?

1 mark

Solution

Regulator gene

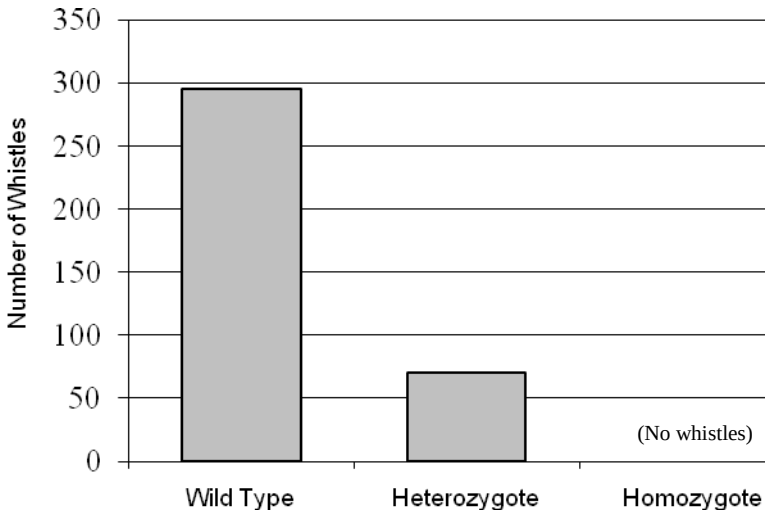
4a. **ii.** Briefly explain how FOXP2 would regulate the genes for vocalisation in vertebrates.

1 mark

Solution

A regulator gene such as FOXP2 would produce DNA binding proteins which bind to nuclear DNA near other target genes and in doing so, switch genes on or off.

In a study designed to test the function of FOXP2, mice, organisms in which genes can be easily 'knocked out', were used as representatives of vocalising vertebrates. Mice use ultrasonic squeaks to communicate stress. Genetic engineering techniques were used to produce mice in which one or both copies of the FOXP2 genes were disrupted. An outline of the two experiments in the study is shown in the table below.

	WILD TYPE two normal copies of FOXP2	HETEROZYGOTE one copy of FOXP2 disrupted	HOMOZYGOTE both copies of FOXP2 disrupted
Experiment 1 Thin sections of brain visualised under UV fluorescence microscope	Brain cells well organised	Brain cells mildly disorganised	Brain cells severely disorganised
Experiment 2 Newborn pups separated from their mothers. Number of ultrasonic whistles made by pups recorded.			

The mice used in this study are referred to as 'knock out' mice.

4b. Explain the meaning of the term 'knock out'.

1 mark

Solution

A 'knock out' mouse is one that has been genetically engineered to produce one or more specific genes that have been switched off.

Explanatory notes

There are many genes that have been sequenced but whose function is unknown. Inferences can be made about the function of genes if they are inactivated, and observations are made of any changes from their normal condition or behaviour. If a specific gene (or genes) of an organism can be switched off, the relevant observations can be made.

4c. i. Using the diagram, describe the results of Experiment 2.

2 marks

Solution

When there is no disruption to FOXP2, mouse pups produced ~295 ultrasonic whistles when they were removed from their mothers. Pups with a disruption to one copy of FOXP2 were able to produce ~70 whistles and pups with both copies of FOXP2 disrupted produced no whistles.

Mark allocation

- 1 mark – comparisons made between three groups
- 1 mark – use of correct numerical data from the figure to support description

4c. ii. What conclusion can be drawn from the results of Experiment 2?

1 mark

Solution

That FOXP2 plays a significant role in the production of ultrasonic vocalisation as a response to stress in mice.

OR

A copy of the normal FOXP2 allele is required for a pup to make whistle noises in response to stress.

Explanatory notes

When there are disruptions to the FOXP2 gene, the effects are reflected in the production of whistles in the knock out mouse pups. The effect of disrupting two genes is far more pronounced than the effect of disrupting one gene. When comparison is made between the number of whistles produced by mice that have two normal copies of the FOXP2 gene and mice with one or both genes disrupted, there is also a clear distinction between the two groups. This supports the idea that the FOXP2 gene plays a significant role in the production of ultrasonic vocalisation as a response to stress in mice.

FOXP2 is one of the 5% most conserved proteins in mammals, and two amino acid substitutions have remained fixed in the human lineage since the divergence from the chimpanzee common ancestor. The amino acid substitutions occur at positions 911 and 977 in exon 7 and change threonine to aspartic acid and arginine to serine. Analysis and comparison of the mitochondrial DNA of Neanderthals and modern humans has revealed that they carry a FOXP2 gene that is identical to that of present-day humans.

4d. Identify **two** difficulties likely to be experienced by paleoanthropologists in the analysis and comparison of the mitochondrial DNA during their study of the FOXP2 gene.

2 marks

Solution

Two of:

Low quantities of endogenous DNA

OR

Breakdown or chemical change to DNA over time

OR

Contamination of modern human DNA with Neanderthal DNA

Whilst academic speculation continues over whether Neanderthals and humans interbred, there has been no definite evidence to support the theory that gene flow is the mechanism by which identical changes to the FOXP2 gene appeared in modern humans and late Neanderthals.

4e. In the absence of gene flow, what is the most likely explanation for the occurrence of identical FOXP2 genes in Neanderthals and modern humans?

1 mark

Solution

These changes evolved in the common ancestor to Neanderthals and modern humans and were passed on.

Total 1+1+1+2+1+2+1= 9 marks

Question 5

Developments in DNA technology have been of enormous benefit to the pharmaceutical industry. Advances in genetic research have enabled the production of drugs for the treatment of medical conditions. Protein based pharmaceutical products can be produced in large volumes using cells or multicellular organisms.

5a. What is an example of a manufactured pharmaceutical product used in the treatment of human disease?

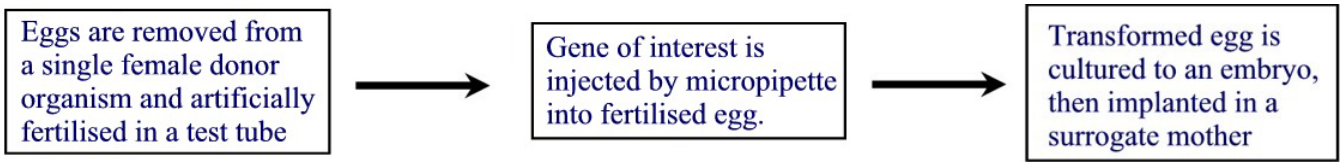
1 mark

Solution

Human growth hormone (HGH) OR human insulin/insulin OR any other appropriate answer.

When animals are used to produce large quantities of protein, they are referred to as transgenic or 'pharm' animals.

The diagram outlines the steps involved in creating a transgenic animal.



5b. What is the name given to the 'gene of interest' which is introduced to the egg from the donor organism?

1 mark

Solution

A transgene

Explanatory notes

The 'gene of interest' is known as a transgene. It is a sequence of DNA that has come from an organism that is not the egg donor, nor the surrogate mother.

5c. How many 'parents' are associated with a transgenic animal? Circle the correct answer and justify your choice.

2 marks

Solution

Three: There are three 'parents' associated with a transgenic animal: the female who donated the eggs, the male who donated the sperm for the artificial fertilisation and the DNA associated with the transgene.

The gene that codes for the production of the human blood protein antithrombin can be inserted into the genome of goats, sheep and cows and is expressed in the milk. The protein is extracted by purifying the milk. Other animals used in transgenic production of protein include pigs, chickens and rabbits. In some circumstances, the human proteins produced by transgenic animals may differ in some ways from the naturally produced human proteins and are rigorously tested before commercial release.

5d. Identify a problem that could occur with transgenic protein products.

1 mark

Solution

Transgenic proteins could contain contaminants from the 'pharm' animal.

OR

Transgenic proteins could cause an allergic reaction.

OR

Transgenic proteins could activate retroviral or pathogenic agents that can be passed onto recipients.

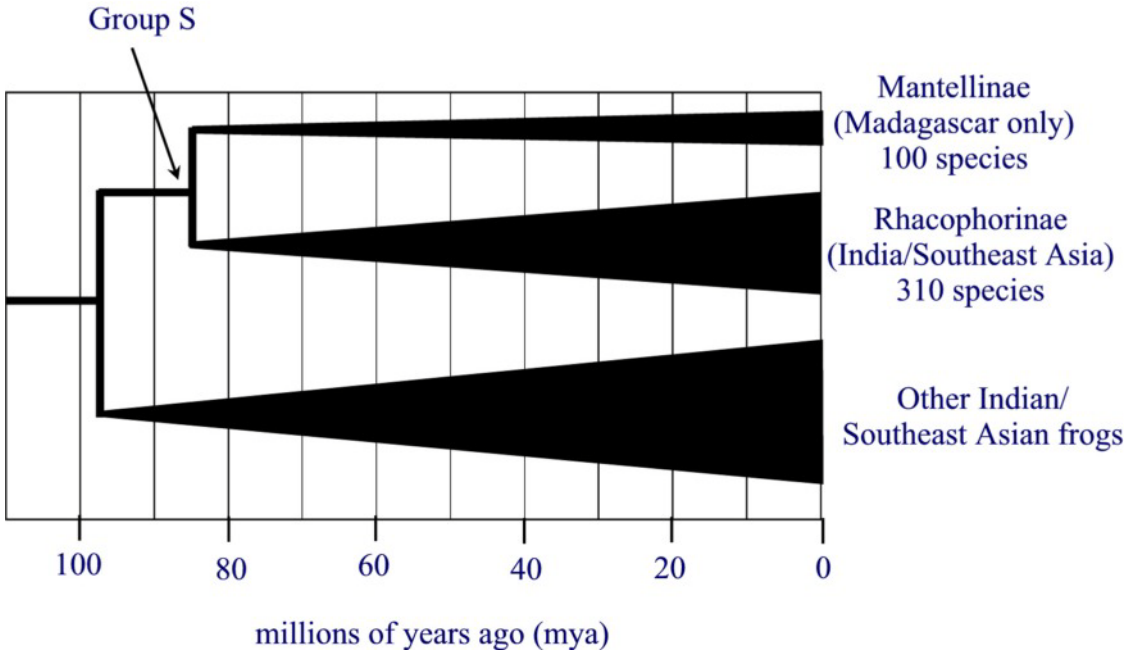
Explanatory notes

Transgenic proteins may exert unexpected effects in users due to the fact that they may differ from the naturally produced protein. With some proteins there is the risk of activating retroviral or pathogenic agents, and human drug products derived from animals could potentially pass on such pathogens to recipients. In addition, there is concern that some new transgenic proteins could induce allergic reactions in people.

Total 1+1+2+1= 5 marks

Question 6

Madagascar is an island that broke away from India around 88 million years ago when it began to move north toward Asia. Presently, in Madagascar the 100 frog species are grouped into the subfamily Mantellinae, whilst in India and Southeast Asia, the 310 frog species are grouped into the subfamily Rhacophorinae.



6a. What criteria would have been used to determine the existence of the 100 species of Malagasy frog?

2 marks

Solution

Different groups of frogs would have been observed to see if they had the ability to naturally produce viable and fertile offspring. If they could not do so, they would have been classified as separate species.

Explanatory notes

If two organisms are capable of naturally producing viable and fertile offspring together, they are considered to be the same species. If they cannot, they are different species to each other.

Mark allocation

- 1 mark – naturally produce viable and fertile offspring
- 1 mark – if they cannot they are different species

6b. From the diagram, what is the relationship between Group S and the subfamilies Mantellinae and Rhacophorinae?

1 mark

Solution

Group S is the common ancestor to these two subfamilies.

Explanatory notes

A common ancestor is the most recent species from which organisms in a group have diverged (into two or more new species) and are directly descended.

6c. Identify the type of speciation that has occurred within each of the frog subfamilies.

1 mark

Solution

Allopatric speciation

Explanatory notes

Allopatric speciation occurs when a population is divided into geographically isolated subpopulations resulting in the interruption of gene flow.

6d. Explain how speciation amongst Malagasy frogs is likely to have occurred.

3 marks

Solution

Malagasy frogs became geographically isolated from each other, leading to restricted gene flow. Different selection pressures act on the phenotypic variations within the isolated groups. Some individuals have phenotypes better suited to the environment leading to a change in allele frequencies, producing subspecies. Genetic differences accumulate in isolated species, gene flow no longer exists, individuals can no longer interbreed to produce viable fertile offspring, speciation has occurred.

Explanatory notes

When Madagascar separated from India, the Malagasy frogs became geographically isolated from each other (due to physical barriers) which led to restricted gene flow. Genetic variation for particular traits existed within the isolated groups, and each group may have been subjected to different selection pressures. Some (but not all) individuals had phenotypes better suited to the environment, resulting in a change in allele frequencies for particular genes which produced subspecies. Isolated subspecies continue to accumulate differences in their genes (including changes in behaviour), gene flow has stopped, individuals can no longer interbreed to produce viable fertile offspring, speciation has occurred.

Mark allocation

- 1 mark – geographical isolation leads to restricted gene flow
- 1 mark – different selection pressures act on existing genetic variation, changing allele frequencies, resulting in subspecies
- 1 mark – accumulation of genetic differences leads to reproductive isolation and speciation

Total 2+1+1+3= 7 marks

Question 7

In 2003, the partial skeleton of an 18 000 year old fossil was discovered at the Liang Bua limestone cave site on the Indonesian island of Flores and was given the name *Homo floresiensis*. The single near-complete skeleton, known as LB1, was fully bipedal, demonstrated a reduced tooth size, a receding forehead and no chin. On the basis of tooth wear, it was aged at about 30 years. The brain size of the adult female was 380cc which is significantly smaller than that of *Australopithecus afarensis* (400–500cc). Stone tools were found throughout the cave site.

7a. What absolute dating technique could have been used to date the fossil found at Liang Bua?

1 mark

Solution

Carbon-14 dating OR uranium-235 dating

Explanatory notes

Fossils can be dated using relative or absolute dating techniques. Given that the age of the fossil was placed at 18 000 years old, the most appropriate method of absolute dating would be carbon-14 or uranium-235. Other significant methods (e.g. potassium-argon or rubidium-87) are useful for older fossil remains.

7b. Suggest **two** forms of evidence that could have been used to place *Homo floresiensis* (the 'Hobbit') into the genus *Homo*.

2 marks

Solution

Two of:

Reduced tooth size (relative to ancestors)

Fully bipedal

Crafting and use of tools

Explanatory Notes

From the information provided it would be reasonable to use reduced tooth size, demonstration of bipedalism and crafting and use of tools as support for placing the 'Hobbit' in *Homo.* Small brain size, lack of a chin and receding forehead exclude the 'Hobbit' from being placed in the genus *Homo*, as they are characteristics associated with ancestors of the genus *Homo*.

Mark allocation

- 1 mark for each form of evidence

More fossilised skeletal fragments have been found since 2003, and the species is now represented by around six to nine individuals. Continued research by Peter Brown, the paleoanthropologist who first described *H. Floresiensis*, has led to the theory that the 'Hobbit's' lineage left Africa some time before the evolution of the genus *Homo*. Brown's most recent theory challenges the 'regional continuity' hypothesis.

7c. Suggest how paleoanthropologists might, if conditions for fossilisation were appropriate, determine the existence of six to nine individuals using only fragments.

1 mark

Solution

By extracting DNA from the fossilised bones.

Explanatory notes

If organisms are buried in volcanic ash, preserved in amber, frozen in polar ice or preserved in arid environments, fragments of their DNA can be found in the remains due to the lack of oxygen and water present during preservation.

7d. Why is Brown's theory a challenge to the 'regional continuity' hypothesis?

2 marks

Solution

The 'regional continuity' hypothesis purports that early humans (*Homo erectus*) left Africa around 1 million years ago, migrating to other world regions where they evolved independently in many regions of the world. Brown's hypothesis lends support to the 'Out of Africa' (or 'Eve') model.

Explanatory notes

The 'regional continuity' hypothesis purports that early humans (*Homo erectus*) left Africa around 1 million years ago, migrating to other world regions, where gene flow was maintained, thus steering modern humans (*Homo sapiens*) in the same evolutionary direction. Brown's hypothesis lends support to the 'Out of Africa' (or 'Eve') model, which suggests that 'Eve's' descendants completely replaced the earlier human populations they encountered on their migration away from Africa, without interbreeding with them.

Total 1+2+1+2= 6 marks

END OF SOLUTIONS BOOK