

BIOLOGY

Duration : 2 hours

Please read the following instructions carefully.

1. This paper is made up of 60 Multiple-Choice questions and comprises fifteen printed pages.
2. Answer **all** questions and indicate your answers directly in the answer sheet provided. Marks will not be deducted for wrong answers.
3. Do not take any paper, including the question paper or unused answer sheets, out of the examination hall.

1. The following is the taxonomic classification of modern humans:

Animalia
 Chordata
 Mammalia
 Primates
 Hominidae
 Homo
 Homo sapiens

Which class do modern humans belong to?

- A. Chordata
B. Animalia
C. Primates
D. Mammalia
2. Two isolated islands are inhabited by the same squirrel species. Both islands host exactly the same type of habitat. Island A is 100,000 sq km large, Island B is 10 sq km large, so the squirrel population on Island A is ~10,000 times larger than the population on Island B. Suppose you leave these two populations alone and then revisit after 500 years of stable climate, when both populations still survive. Which population would have undergone the greatest amount of physical change, if any?
- A. The population on Island A, because there are more individuals, creating opportunities for more mutations to happen.
B. The population on Island A, because there is more space into which the population can diversify.
C. The population on Island B, because its smaller population size makes it susceptible to higher levels of genetic drift.
D. Both populations would have undergone extreme levels of physical change because 500 years are a relatively long time for island populations.
3. Hypothetical situation: In 2016, Jack Tan described a new species of bee as *Xylocopa singaporensis*. John Ng disagreed with him and published a manuscript showing that the name *singaporensis* refers to a population that was previously already described as *Xylocopa malayana*. Which of the following applies?
- A. The new name *singaporensis* must replace the old name *malayana*.
B. The old name *malayana* has priority, so the new name *singaporensis* has no more nomenclatural standing and must not be used again.
C. The old name *malayana* has priority, so the new name *singaporensis* becomes its junior synonym. However, *singaporensis* is still available in the future in case someone finds differences within this species complex that are worth naming.
D. The old name *malayana* has priority, so the new name *singaporensis* becomes its junior synonym. However, both names can still be used side by side interchangeably.

4. Which of the following statements are considered homologous structures or behavioural traits?
- i. The wings of a blackbird and the wings of a ladybird
 - ii. The hind limb bone of a snake and the tailbone of a human
 - iii. The cytochrome-b gene sequence of a mouse and the cytochrome-b gene sequence of a human
 - iv. The forelimb of a mouse and the arm of a chimpanzee
 - v. The wings of an eagle and the wings of a bat
- A. I and III only
B. II and IV only
C. IV and V only
D. III, IV and V only
5. New Zealand is sometimes referred to as a little subcontinent of its own because it hasn't been connected to any other landmass for many tens of millions of years. It used to have a rich terrestrial vertebrate fauna before modern humans arrived and drove most species to extinction. Which statement is incorrect?
- A. New Zealand's native terrestrial vertebrate fauna was dominated by birds, as they would have had the easiest time colonizing the landmass via the air.
B. Naïve to the threat posed by humans, many of New Zealand's vertebrate species would have been especially easy to drive to extinction if their persecution benefitted humans in some way.
C. Long isolated from other landmasses, New Zealand had no native mammalian and lizard species.
D. Its geographic isolation notwithstanding, New Zealand would have been affected by the same global climatic fluctuations, such as glaciations, that have affected all other regions of the world.
6. Borneo and Madagascar are two (sub-) tropical islands of roughly the same size – in terms of orders of magnitude. Madagascar has been isolated for many tens of millions of years and has never been connected to adjacent Africa, whereas Borneo is part of the Sundaic continental shelf and has repeatedly been connected to the Southeast Asian mainland for extended periods of time, including as recently as 18,000 years ago. Which statement is incorrect?
- A. Borneo has a higher species diversity because it is often connected to the mainland.
B. Borneo has more endemic species because it is often connected to the mainland.
C. There is no way to predict which island has more species diversity on the basis of their connectivity to the mainland .
D. There is no way to predict which island has more endemism on the basis of their connectivity to the mainland.

7. Two nuclear gene regions, Gene A and Gene B, were sequenced from many closely-related species of beetles and the nucleotide sequences were compared. It was found that Gene A yielded pronounced differences among species whereas there were hardly any differences in Gene B. Which of the following statements is an incorrect explanation of this pattern?
- A. Gene A may have a faster evolutionary rate than Gene B.
 - B. Gene B may be under heavy purifying selection across the whole genus.
 - C. Gene B may be under heavier genetic drift.
 - D. Gene A may have experienced genus-wide positive selection affecting each species differently.
8. Which of the following statements is TRUE when describing genome characteristics for eukaryotes?
- A. Humans have the largest genomes of all animals.
 - B. Whales have the largest genomes of all living animals.
 - C. The larger a genome, the more genes are contained it.
 - D. The larger a genome, the more repetitive elements can be found in it.
9. Biologists have 10 identical environmental plots of a 10 hectare size. Into each of these caged, vegetated outdoor plots, they introduce a certain number of mice, ranging from 100, 200, 300, 400, 500, 600, 700, 800, 900 to 1000, and leave the plots without external interference for several weeks. No matter how many mice they introduce, when they revisit the plots after 10 weeks, they always find that there are approximately 100 mice that have survived and continue to co-exist. Which of the following terms has nothing to do with the results of this experiment?
- A. intraspecific competition
 - B. competitive exclusion
 - C. ecological carrying capacity
 - D. limited resources
10. Which of the following is correct?
- A. As diploid organisms, humans carry one copy of a chromosome from our mother, and one copy of a chromosome from our father.
 - B. All DNA in humans is diploid.
 - C. All the DNA in an individual's genome is subject to the same evolutionary rate
 - D. Some DNA in humans is subject to a different genetic code than other DNA in humans.

11. Haplodiploidy is a sex-determination system in bees and many other insects in which males develop from unfertilized eggs and are haploid, and females develop from fertilized eggs and are diploid. Which of the following is true?
- A. Males only carry the maternal copy of each locus.
 - B. In earth-historic periods of instability, the population will survive without the contribution of males for many thousands of years.
 - C. Any given locus in the genome will have a greater population size in males than in females.
 - D. Females arise from parthenogenesis.
12. A songbird species has been living on the Asian mainland for hundreds of thousands of years without changing much in appearance and behaviour. Then a small number of individuals accidentally disperse onto a small, distant island where they establish a new population. This new population undergoes great changes in appearance and behavior in only a few hundred years. Which one of the following terms is NOT associated with this scenario?
- A. Founder effect
 - B. Genetic bottleneck
 - C. Positive selection
 - D. Genetic drift
13. Which of the following factors cannot lead to cancer?
- A. Exposure to carcinogenous chemicals.
 - B. Radiation.
 - C. Apoptosis.
 - D. Chance mutations.
14. All non-African humans are thought to date back to an emigration even 'out of Africa' around 60,000 – 80,000 years ago during which *Homo sapiens* invaded Eurasia and most other land masses. Many human communities around the hot, equatorial regions of our planet inside and outside of Africa share a dark skin pigmentation. Which of the following is NOT a correct explanation of this pattern of shared pigmentation traits?
- A. Humans in equatorial regions are subject to strong purifying selection against lighter skin colours because of high sunlight incidence and skin cancer risk.
 - B. Dark-skinned human communities have retained an ancestral human trait, whereas light-skinned populations have acquired a novel trait.
 - C. All dark-skinned populations of modern humans are closely related to each other, accounting for their shared patterns of pigmentation.
 - D. Populations of modern humans in cold countries with little sunlight incidence in the winter have been under heavy selective pressure to reduce pigmentation in order to maximize Vitamin D uptake. This pressure never applied to populations of humans that live in hotter parts of the planet.

15. Which of the following statements does not describe a mechanism that helps species maintain their integrity from other species?
- A. Different beetle species may look almost the same but only differ in penis shape, preventing the males of one species to mate with females of another.
 - B. Haldane's Rule states that if in the hybrids between two species, only one sex is inviable or sterile, that sex is more likely to be the heterogametic sex.
 - C. Differences in the sex chromosomes between two species may lead to hybrid incompatibilities.
 - D. Hybrid vigour is the tendency of a cross-bred individual to show qualities superior to those of both parents
16. Two genera of mouse species both go back to an origin about 12 million years ago. Genus A has diversified into 50 species, whereas Genus B has diversified into 5 species. Which of the following statements does NOT provide a good explanation of this pattern?
- A. Genus A has a greater speciation potential than Genus B.
 - B. Genus B has undergone greater morphological change.
 - C. Genus B has a higher incidence of extinction than Genus A.
 - D. Genus A inhabits a large landmass allowing it to undergo an extensive radiation whereas Genus B has been isolated on a smaller landmass.
17. What's an example for balancing selection?
- A. The emergence of greyish coloration in a white, birch-inhabiting butterfly as a response to air pollution and the change in color of birch tree bark from white to sooty-grey.
 - B. The persistence of sickle cell anemia in African populations of humans because of a heterozygote advantage in the presence of malaria.
 - C. The eradication of the plague because of selective sweeps that have killed off anyone who is not immune.
 - D. Morphological stability in a large population over hundreds of thousands of years.
18. Which of the following statements is FALSE?
- A. Long-term climatic fluctuations such as ice ages can increase species diversity by fragmenting habitats, leading to allopatric speciation.
 - B. Long-term climatic fluctuations such as ice ages can decrease species diversity by increasing the number of extinction events.
 - C. Even without human interference, one species can drive another species to extinction.
 - D. Most large animal species driven to extinction by humans disappeared over the last 50 years.

19. Many families of mammals and birds show a cosmopolitan distribution, i.e., they occur on most major continents. What is the best explanation for such a pattern?
- A. All these continents used to be merged as part of the supercontinent Pangaea.
 - B. Overwater dispersal.
 - C. Human introduction events.
 - D. They independently evolved on each landmass.
20. Which of the following statements is a valid concern regarding genetically modified chickens?
- A. Genetically modified disease-resistant chickens may rapidly become useless once novel disease vectors hit the population .
 - B. Genetically modified disease-resistant chickens cannot adapt to the environment as well as wild-type chickens can.
 - C. Genetically modified disease-resistant chickens are more likely to evolve dangerous new mutations.
 - D. Genetically modified disease-resistant chickens, once they escape into the wild, can pose a threat to native non-chicken wildlife in a way that wild-type chickens cannot.
21. Which of the following options is a form of gene mutation?
- A. Transcription
 - B. Insertion
 - C. Replication
 - D. Ligation
22. Allele Z is located at the human X chromosome. A disease is caused by the presence of two copies of the allele Z (assuming there is no duplication event of the gene). What is the most likely mode of genetic inheritance for the disease?
- A. Autosomal, recessive
 - B. Autosomal, dominant
 - C. Sex-linked, recessive
 - D. Sex-linked, dominant
23. A kind of inherited disease is known to be a sex-linked recessive condition. A family has a daughter who is diagnosed with the disease. Which of the following statements is FALSE?
- A. The father must have this disease.
 - B. The mother may not have this disease.
 - C. The second daughter of the family may not have this disease.
 - D. The son of the family must have this disease.

24. Which of the following statements is/are NOT true about mutation?
- A. Deletion of one nucleotide is likely to have a more profound effect than the deletion of three nucleotides.
 - B. A nonsense mutation produces a completely incorrect sequence of amino acids from the point of mutation to the end of the protein.
 - C. Mutation on the first base of a codon is likely to have a more profound effect than a mutation on the third base of the same codon.
 - D. B and C only.
25. Which of the following mutations CANNOT be caused by insertion or deletion of a single nucleotide?
- A. Frameshift
 - B. Duplication
 - C. Silent
 - D. B and C only.
26. Which of the following statements about variations in phenotypes is TRUE?
- A. Continuous variation is caused by many genes.
 - B. Continuous variation is not affected by the environment.
 - C. Discontinuous variation is always caused by one gene.
 - D. Discontinuous variation can never be affected by the environment.
27. Which of the following statements is FALSE?
- A. Linked genes are genes that are found on the same chromosome.
 - B. ABO blood group is a typical example of multiple alleles.
 - C. Epistasis is a term to describe the influence of the environment on the expression of a gene.
 - D. In a monohybrid cross experiment, if both parents are heterozygous for a Mendelian trait, then their F1 offspring will show a dominant to recessive phenotypic ratio of 3:1.
28. Which of the following processes does NOT produce ATP?
- A. Oxidative phosphorylation
 - B. Glycolysis
 - C. Krebs's cycle
 - D. Calvin cycle

29. Which of the following statements is FALSE?
- A. Insulin is secreted in response to high blood sugar concentrations.
 - B. Insulin is produced by the pancreas.
 - C. Insulin is synthesized as proinsulin, and converted to insulin before secretion into the blood stream.
 - D. Insulin suppresses glycogenesis.
30. Which of the following is the correct sequence in cell signaling?
- A. Cyclic AMP → G-protein coupled receptor → Protein Kinase A → hormones
 - B. Hormones → Protein Kinase A → cyclic AMP → G-protein coupled receptor
 - C. Protein Kinase A → hormones → G-protein coupled receptor → cyclic AMP
 - D. Hormones → G-protein coupled receptor → cyclic AMP → Protein Kinase A
31. Which of the following statements is FALSE?
- A. There are three types of neurons.
 - B. The axon transmits a signal away from the cell body.
 - C. During neural signal transmission across a synapse, there is an influx of Ca^{2+} into the axon.
 - D. During neural signal transmission across a synapse, there is an influx of Na^+ into the axon.
32. Which of the following are involved in the Calvin cycle?
- A. Hydrolysis of ATP and the reduction of NADP^+ .
 - B. Synthesis of ATP and the reduction of NADP^+ .
 - C. Synthesis of ATP and the oxidation of NADPH.
 - D. Hydrolysis of ATP and the oxidation of NADPH.
33. In the Krebs's cycle, which step produces reduced FAD (*i.e.* FADH_2)?
- A. Citric acid → isocitric acid
 - B. Succinic acid → fumaric acid
 - C. Malic acid → oxaloacetic acid
 - D. Fumaric acid → malic acid
34. Which of the following enzymes is necessary for making a recombinant plasmid in the test tube?
- A. DNA polymerase
 - B. Reverse transcriptase
 - C. Helicase
 - D. Restriction endoneucleases

35. A bacterial clone hosts a recombinant DNA plasmid with the DNA fragment carrying Gene A inserted into the *lacZ* gene region also contained in the plasmid. The bacteria are plated on medium containing the antibiotic tetracycline and the compound X-gal. What would you expect to observe if the plasmid only contains an ampicillin-resistance gene but not a tetracycline-resistance gene?
- A. Only white colonies will be observed.
 - B. Both blue and white colonies will be observed.
 - C. Only blue colonies will be observed.
 - D. No colonies will be observed.
36. In theory, what is the minimum number of PCR cycles required in order to amplify more than 200 copies from one double-stranded DNA molecule at the beginning?
- A. 5 cycles
 - B. 6 cycles
 - C. 7 cycles
 - D. 8 cycles
37. Which of the following statements is/are TRUE about DNA gel electrophoresis?
- A. All DNA fragments migrate to the positive end of the electrical field.
 - B. DNA fragments are separated by different charges.
 - C. Longer DNA fragments migrate faster than shorter fragments.
 - D. A and C only.
38. Which of the following statements CORRECTLY describe(s) the events in a PCR reaction?
- A. The order of the reaction cycle is strand denaturation, product extension, and primer annealing.
 - B. It follows an exponential increase in the number of molecules generated.
 - C. It works best when the primer and target sequences are in their highest degree of complementarity.
 - D. B and C only.
39. Which of the following cases would NOT be possible to resolve using RFLP?
- A. Parental identification where all individuals including possible parents and children are present.
 - B. Identifying individuals with genetic diseases.
 - C. A crime scene where some skin cells were found under the nails of the victim and may belong to a suspect.
 - D. B and C only.

40. Which statement is NOT true about the spirit and programs of the Human Genome Project (HGP)?

- A. Educate the public on social, ethical, and legal issues concerning the implications of the HGP.
- B. Facilitate genetic testing for improved diagnosis of diseases.
- C. Emphasize the use of bioinformatics and biocomputing to mine genome databases.
- D. Allow patenting of genes to obtain further funding for sequencing research.

41. Which of the following statements is/are FALSE?

- I. Chloroplasts contain DNA and RNA.
- II. Ribosomes contain RNA but not DNA.
- III. Mitochondria contain DNA but not RNA.

- A. I only.
- B. III only.
- C. I and III only.
- D. II and III only.

42. Which description of cellular structures is correctly matched to its function?

	Description of cellular structures	Function
A	A stack of elongated, curved sacs and each sac is surrounded by a single membrane.	Lipid synthesis
B	An organelle containing hydrolytic enzymes and is bounded by single membrane.	Autophagy
C	A network of tubes and sacs where the tubes and sacs are surrounded by a single membrane.	Aerobic Respiration
D	An organelle bounded by two membranes where the inner membrane is highly folded.	Packaging of proteins

43. Which of the following food test results do you expect to see for a solution that contains sucrose and protein only?

- I. Adding of Potassium Iodide - Brown
- II. Benedict's test - Brick red precipitate
- III. Biuret Test - Purple

- A. I only.
- B. II and III only.
- C. I and III only.
- D. I, II and III.

44. Which of the following statement is TRUE about triglycerides?
- A. Triglycerides are low energy food reserve.
 - B. Triglycerides contain polar groups.
 - C. Triglycerides do not contain double bonds.
 - D. Triglycerides are found in animals and plants.
45. Which of the following statements is/are TRUE about enzymes?
- I. All enzymes catalyse the breakdown of larger molecules to smaller molecules.
 - II. All enzymes reduce the energy to start a reaction.
 - III. All enzymes bring reacting molecules into precise orientation for a reaction to occur.
- A. I and II only.
 - B. I and III only.
 - C. II and III only.
 - D. I, II and III.
46. The enzyme beta-galactosidase converts lactose to galactose and glucose. It has been determined that adding 5 mL of 1 % beta-galactosidase to 5 mL of milk produces Y amount of glucose in 5 minutes with substrate limiting the reaction. Which of the following statement is FALSE?
- I. If a non-competitive inhibitor is added to the above reaction mixture, Y amount of glucose cannot be produced in more than 5 minutes.
 - II. If 5 mL of 1 % beta-galactosidase is added into 10 mL of milk, then Y amount of glucose will be produced in less than 5 minutes.
 - III. If 5 mL of 2% beta-galactosidase is added into the 5 mL of milk, then more than Y amount of glucose will be produced in 5 minutes.
- A. I only.
 - B. III only.
 - C. I and II only.
 - D. II and III only.
47. The diploid number of chromosomes in a fly species is six. Assuming the absence of mutation or crossing over, how many genetically unique gametes might be formed in one individual?
- A. 3
 - B. 6
 - C. 9
 - D. 18

48. The amount of DNA in a nucleus of a mammalian gamete cell at the end of interphase is 10 pg. What is the amount of DNA in a nucleus of gamete cell at telophase II?
- A. 2.5 pg
 - B. 5 pg
 - C. 10 pg
 - D. 20 pg
49. Cytosine comprised 32% of the nitrogenous bases in the DNA of cells from a bacterial clone. What was the percentage of thymine in the DNA?
- A. 16%
 - B. 18%
 - C. 28%
 - D. 36%
50. Which of the following statements is/are FALSE?
- I. Deoxyribonucleotides are added to the 3' end of the leading strand but added to the 5' end of the lagging strand.
 - II. The sequence in the lagging strand is complementary to the lagging strand.
 - III. The lagging strand has more RNA primers than the leading strand.
- A. I only.
 - B. III only.
 - C. I and II only.
 - D. I and III only
51. Which of the following if mutated will not affect the transcription of a gene?
- I. Enhancer
 - II. Start codon
 - III. Intron-exon boundary
- A. I only.
 - B. I and II only.
 - C. II and III only.
 - D. I, II and III.

52. Which of the statements regarding bacterial genetics is/are FALSE?
- I. Transcription and translation occurs simultaneously.
 - II. Its chromosome consists of a single stranded circular DNA.
 - III. Its chromosome is highly folded around histone proteins.
- A. I only.
 - B. III only.
 - C. I and III only.
 - D. II and III only.
53. What does the binding of the allolactose molecule to the *lac* repressor ensure?
- A. Lactose metabolizing enzymes are not produced when glucose levels are high.
 - B. Lactose-metabolising enzymes are not produced lactose is absent.
 - C. Lactose-metabolising enzymes are produced when glucose levels are high.
 - D. Lactose-metabolising enzymes are produced when lactose levels are high.
54. Which of the following describes a feature of telomeres?
- A. Telomeres are found in bacterial chromosomes.
 - B. Telomeres can be extended by telomerase.
 - C. Telomeres consist of chains of adenine nucleotides.
 - D. Telomeres prevent the shortening of chromosomes during DNA replication.
55. Which of the following processes involved virus to transfer and recombine genetic material in bacterial cells?
- A. Transposition
 - B. Conjugation
 - C. Transduction
 - D. Transformation
56. Which of the following statements is/are TRUE?
- I. A virus can be classified based on whether their genetic material is a single stranded or double stranded nucleic acids.
 - II. Capsid proteins and viral envelope are encoded by the viral genome.
 - III. Reverse transcriptase has both RNA and DNA polymerase activities.
- A. I only.
 - B. I and II only.
 - C. I and III only.
 - D. II and III only.

57. In the DNA strand that complements mRNA, an adenine was replaced by thymine in a 5'-GAC-3' triplet codon forming a 5'-GTC-3' triplet codon. This resulted in aspartic acid being incorrectly incorporated instead of a valine. What is the anticodon of the transfer RNA molecule carrying this aspartic acid?
- 5'-CAG-3'
 - 5'-GAC-3'
 - 5'-CUG-3'
 - 5'-GUC-3'
58. Which of the following statements are FALSE?
- Men with XYY genotype are conceived from a sperm produced by non-disjunction of meiosis II.
 - Down syndrome is caused by gene mutation on chromosome 21.
 - The disease phenylketonuria (PKU) is due to the production of a non-functional enzyme as a result of duplication of the gene.
- I and II only.
 - I and III only.
 - II and III only.
 - I, II and III.

Question 59 and 60 are based on the figure and information below.

The figure below shows the genomic structure of a human gene that contains two introns while the remaining are exons as represented by the boxes. The numbers in the boxes represent the number of nucleotide base-pairing (bp) found in each region. The DNA base-pairing sequences indicate the corresponding start codon and stop codon at the beginning and end of the boxed region, respectively.

54 bp	ATG (start) TAC 423 bp	Intron 566 bp	202 bp	Intron 634 bp	113 bp	(stop) TAA 522 bp ATT
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59. What is the estimated length (in nucleotides) of the mature mRNA transcript of this gene after splicing but before polyadenylation?
- 1260
 - 1314
 - 2460
 - 2514
60. How many amino acids are present in the protein encoded by this gene?
- 420
 - 419
 - 820
 - 838

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