

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 the chicken:

Animalia
 Chordata
 Aves
 Galliformes
 Phasianidae
 Gallus
 Gallus gallus

Which order does the chicken belong to?

- A. *Gallus*
B. Aves
C. Phasianidae
D. Galliformes
2. When a continental butterfly species colonises an island and founds a new population that eventually evolves into a separate species, the most likely scenario entails _____.
A. an immediate population-genetic break between the island and mainland populations, with no future possibility of gene flow even when new mainland individuals arrive soon after first colonisation.
B. a broad-front colonization movement onto the island, with new continental individuals continually moving in to keep all suitable ecological space on the island occupied.
C. a founder event characterized by a strong bottleneck, followed by steady population expansion and only limited gene flow with the original continental population.
D. a high probability for a sudden loss of flight capability, increasing chances for local extinction.
3. Which one of the following statements is FALSE?
A. Once scientists place an organism in a specific genus, this designation can be changed if new information points to this assignment being incorrect.
B. In Linnaean classification, a Family encompasses more species than any one Genus contained within that same Family.
C. Systematics refers to the science of characterizing the ecosystems that particular species are adapted to.
D. Homology refers to similar characteristics in different species due to their descent from a common evolutionary ancestor.

4. Which of the following statements are considered homologous structures?
- i. The wings of a sunbird and the wings of a ladybird
 - ii. The front limb bone of a lizard and the tailbone of a giraffe
 - iii. Horse's front leg and bat's foot
 - iv. The forelimb of a rat and the arm of a gibbon
 - v. The wings of a hornbill 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. Jaguars and lions are closely related sister species, both belonging to the genus *Panthera*. They separated only around 1-2 million years ago. Lions live in Africa and small parts of Asia, whereas jaguars occur in South and Central America. We know from phylogenetic studies that *Panthera* cats have an Old World (=African/Asian) origin. What could account for the present-day distribution of jaguars in America?
- A. America and Asia used to be connected through the Bering Strait, so the jaguar's ancestors could have invaded through North America.
 - B. Humans have been actively transporting large *Panthera* cats between the two continents.
 - C. *Panthera* cats can swim freely between Asia and South America.
 - D. *Panthera* cats could have floated from Asia to South America on flotsam.
6. Common among Africans, sickle cell anemia is a genetic disorder caused by a recessive allele. A person with the homozygous genotype has a reduced life expectancy and suffers from various long-term ailments. However, people possessing only one allele for sickle cell anemia will not experience the ill effects of the disease, and yet be less susceptible to certain forms of malaria. What could account for the high incidence of the recessive allele in the African population?
- A. Allopatric changes favouring heterozygotes.
 - B. Natural selection favouring heterozygotes.
 - C. Underdominance of the recessive allele.
 - D. High mutation rate of the recessive allele.

7. A gene was sequenced from many closely-related species of beetles and the nucleotide sequences were compared. It was found that certain alternate sections of the gene were almost identical among species, whereas the intervening regions were quite different. Which of the following statements best explains this pattern?
- A. The intervening regions are exons, i.e., functional sections of the gene that code for amino acids. This explains why they are so different among species.
 - B. The intervening regions are introns, i.e. non-coding parts of the gene. This explains why they are so different among species.
 - C. The intervening regions exhibit more differences among species for stochastic reasons unrelated to their coding versus non-coding status.
 - D. There must have been a sequencing error. All parts of a gene should generally display a similar pattern of differentiation among species.
8. Which of the following statements is TRUE?
- A. The approximate genome size of mammals is often around 100-500 billion base pairs.
 - B. The approximate genome size of mammals is often around 1-5 billion base pairs.
 - C. The approximate genome size of mammals is often around 10-50 million base pairs.
 - D. The approximate genome size of mammals is often around 100,000 – 500,000 base pairs.
9. A biologist released two species of mouse in a large fenced experimental plot. Species *A* has a grey fur and longer legs. Species *B* has a black fur and shorter legs. After a few months, observations showed that species *B* overcame species *A*, causing species *A* to die out. This is an example of _____.
- A. intraspecific competition
 - B. competitive exclusion
 - C. parasitism
 - D. mutualism
10. Two loci are located on the same chromosome at approximately ~1000bp from each other. Which statement is correct?
- A. The two loci are unlikely to be in great linkage disequilibrium.
 - B. The two loci will frequently be passed down to an individual from the same ancestor.
 - C. Recombination is likely to increase linkage between these two loci.
 - D. These are different loci, hence they have an independent evolutionary trajectory.
11. Regarding nuclear and mitochondrial DNA, which statement is NOT TRUE?
- A. The size of our nuclear genome is roughly 5 orders of magnitude larger than the size of our mitochondrial genome.
 - B. In any human individual, the population size of a mitochondrial locus is smaller than that of a nuclear locus.
 - C. Both the mitochondrial and the nuclear genome are dominated by non-coding DNA.
 - D. Both animals and plants have mitochondrial DNA.

12. Which evolutionary force has the power to drive an allele to extinction in a large population?
- A. Genetic drift
 - B. Purifying selection
 - C. Sexual selection
 - D. Environmental adaptation.
13. Regarding mutations, which statement is incorrect? In the evolutionary trajectory of a population, we...
- A. ...expect there to be more synonymous than non-synonymous mutations.
 - B. ...expect there to be more transitions than transversions.
 - C. ...expect there to be more mutations at first than at second codon positions.
 - D. ...expect there to be pronounced differences in mutation rate in different parts of the genome.
14. Cancers can occur at any age, but the risk of developing cancer increases with age. Which of the following statements is the most likely explanation for this pattern?
- A. Older individuals are more likely to have accumulated random mutations that increase cancer risk during their life time.
 - B. Older individuals are more likely to have longer telomeres.
 - C. Older individuals are more likely to have more proto-oncogenes.
 - D. Older individuals are more likely to have more tumour suppressor genes.
15. Certain human populations are characterized by a relatively large number of people that are not affected by lactose intolerance. Which sentence best describes the biological process that has led to this situation?
- A. People who are not lactose intolerant mostly belong to cultures in which dairy products are rare. Hence, their ancestors were not often exposed to the allergenic compounds of dairy products, leading to a better compatibility of modern populations with dairy products.
 - B. People who are not lactose intolerant mostly belong to cultures that have a rich history of using dairy products in their cuisine. By ingesting dairy products, their ancestors would have trained their bodies against the allergenic effects of dairy compounds over many generations, removing any intolerances in present-day generations.
 - C. People who are not lactose intolerant mostly belong to cultures that have a rich history of using dairy products in their cuisine. By ingesting dairy products, their ancestors would have been frequently exposed to allergenic compounds, allowing those individuals with alleles to overcome their intolerance to have a higher reproductive fitness than other individuals over many generations.
 - D. People who are not lactose intolerant mostly belong to cultures that have a rich history of using dairy products in their cuisine. By ingesting dairy products, they would have exposed their genomes to the effects of natural selection, increasing their mutation rate to evolve new genes that help overcome lactose intolerance.

16. Which of the following statements does NOT describe the normal functioning of stem cells in a living organism?
- A. Mesenchymal stem cells differentiating into fat cells, connective tissue, muscle or bone.
 - B. Haematopoietic stem cells in the bone marrow or cord blood differentiating into red blood cells, white blood cells and platelets.
 - C. Embryonic stem cells giving rise to all derivatives of the ectoderm, endoderm and mesoderm.
 - D. Skeletal muscle giving rise to smooth muscle.
17. Which of the following statements regarding gene therapy as a cure for genetic disorders is TRUE?
- A. Somatic gene therapy can now correct multiple genes in a single patient effectively.
 - B. Somatic gene therapy does not lead to a permanent cure because somatic cells cannot pass the manipulated gene on to the offspring.
 - C. Somatic gene therapy can utilise viruses as vectors but germ line therapy cannot.
 - D. An effective method of transferring a normal gene into the nucleus is by injecting DNA directly into the bloodstream.
18. Which of the following statements is a risk that prevents gene therapy from becoming an effective treatment for genetic diseases?
- A. The introduced gene may decrease the mutation rate of the patient's genome.
 - B. The introduced gene may replicate relentlessly prior to incorporation in the patient's cells.
 - C. The immune system may mount a reactive attack against the viral vector used to introduce the gene into the patient's genome.
 - D. There is no known method to transfer DNA into the patient's cell.
19. Which one is an inappropriate characterization of the difference between modern methods for generating genetically modified (GM) strains of wheat and past approaches of selective breeding of wheat strains?
- A. Both selective breeding and the creation of GM wheat are a human-mediated intervention in the evolutionary pathway of wheat populations.
 - B. In selective breeding (as opposed to GM approaches), you don't need to know the underlying genetic machinery of a gene you're targeting.
 - C. In traditional selective breeding, new strains never pose a risk to the environment, whereas GM strains may or may not pose a risk.
 - D. In selective breeding, we can attempt to modify traits of the plant that are already in existence in nature. In GM strains, we can introduce new traits that were never part of wheat's natural suite of traits.

20. Which of the following statements is NOT a valid concern regarding genetically modified crops?
- A. Crops producing anti-pest toxins may rapidly become useless once pests evolve resistance.
 - B. Genetically modified crops cannot adapt to the environment as well as the wild-type plant.
 - C. Non-target organisms in the vicinity of crops producing anti-pest toxins may be adversely affected.
 - D. Protein products from transgenic crops could cause allergic reactions in humans.
21. Which of the following options is NOT a form of gene mutation?
- A. Inversion
 - B. Insertion
 - C. Replication
 - D. Duplication
22. Allele Z is located on human chromosome number 16. A disease is caused by the presence of at least one copy of the allele Z. 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 dominant-inherited disease is known to be sex-linked. A family has a daughter who is diagnosed with the disease. Which of the following statements is TRUE?
- A. The father must have this disease.
 - B. The mother must have this disease.
 - C. The second daughter of the family must have this disease.
 - D. The son of the family may not have this disease.
24. Which of the following statements is/are TRUE about DNA mutation?
- A. Deletion of three consecutive nucleotides in general has a more profound effect than insertion of three consecutive nucleotides.
 - B. A missense 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 more profound effect than the third base of the same codon.
 - D. B and C only.

25. Which of the following mutations can be caused by insertion or deletion of a single nucleotide?
- A. Frameshift
 - B. Missense
 - C. Silent
 - D. A and B only.
26. Which of the following statements about variations in phenotypes is TRUE?
- A. Continuous variation is always caused by one gene.
 - B. Continuous variation is usually affected by the environment.
 - C. Discontinuous variation is always caused by many genes.
 - D. Discontinuous variation is not affected by the environment.
27. Which of the following statements is FALSE?
- A. Epistasis is a form of gene interaction where the expression of one gene masks the effects of another.
 - B. Linked genes can be found on different chromosomes.
 - C. ABO blood group is a typical example of multiple alleles.
 - 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. Photophosphorylation
 - B. Glycogenesis
 - C. Glycolysis
 - D. Krebs's cycle
29. Which of the following statements is FALSE?
- A. Glucagon is secreted in response to low blood sugar concentrations.
 - B. Insulin is produced by the spleen.
 - C. Insulin is synthesized as proinsulin, and converted to insulin prior to secretion into the blood stream.
 - D. Insulin promotes glycogenesis.
30. Which of the following is the correct sequence of steps in cell signaling?
- A. Hormones → Protein Kinase A → cyclic AMP → G-protein coupled receptor
 - B. Cyclic AMP → G-protein coupled receptor → Protein Kinase A → hormones
 - 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 only two 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 dendrite.
32. Which of the following are involved in the Calvin cycle?
- A. Hydrolysis of ATP and the reduction of NADP^+ .
 - B. Hydrolysis of ATP and the oxidation of NADPH.
 - C. Synthesis of ATP and the reduction of NADP^+ .
 - D. Synthesis of ATP and the oxidation of NADPH.
33. In the Krebs's cycle, which step produces reduced FAD (*i.e.* FADH_2)?
- A. Malic acid \rightarrow oxaloacetic acid
 - B. Citric acid \rightarrow isocitric acid
 - C. Succinic acid \rightarrow fumaric acid
 - D. Fumaric acid \rightarrow malic acid
34. Which of the following enzymes is/are necessary for making a recombinant plasmid in the test tube?
- A. Restriction endonucleases
 - B. DNA polymerase
 - C. RNA polymerase
 - D. A and B only.
35. A bacterial clone hosts a recombinant DNA plasmid with the DNA fragment carrying Gene A inserted into the *lacZ* gene region 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 does not contain any antibiotic-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 100 copies from one double-stranded DNA molecule at the beginning?
- A. 5 cycles
 - B. 7 cycles
 - C. 9 cycles
 - D. 11 cycles
37. Which of the following statements is FALSE 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. DNA fragments are separated by different sizes.
 - D. Longer DNA fragments migrate slower than shorter fragments.
38. When describing the events in a PCR reaction, which of the following statements is/are FALSE?
- A. The order of the reaction cycle is strand denaturation, product extension, and primer annealing.
 - B. It follows a linear 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. A and B only.
39. Which of the following case(s) would 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. A and B 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. Allow patenting of genes to obtain further funding for sequencing research.
 - C. Facilitate genetic testing for improved diagnosis of diseases.
 - D. Emphasize the use of bioinformatics and biocomputing to mine genome databases.

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

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

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

42. Which structure 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.	Packaging of proteins
B	An organelle containing hydrolytic enzymes and is bounded by single membrane.	Aerobic Respiration
C	A network of tubes and sacs where the tubes and sacs are surrounded by a single membrane.	Autophagy
D	An organelle bounded by two membranes where the inner membrane is highly folded.	Lipid synthesis

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

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

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

44. Which of the following statement is TRUE about triglycerides?

- A. Triglycerides produces water when oxidised by respiration.
- B. Triglycerides contain polar groups.
- C. Triglycerides do not contain double bonds.
- D. Triglycerides are found in animals but not plants.

45. Which of the following statements is/are FALSE about enzymes?
- I. Enzymes increase the rate of a reaction by supplying the energy to start a reaction.
 - II. All enzymes catalyse the breakdown of larger molecules to smaller molecules.
 - III. All enzymes denatured at temperatures above 60°C.
- 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 in excess of substrate. Which of the following statement is TRUE?
- 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 more than Y amount of glucose will be produced in 5 minutes.
 - III. If the 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 III only.
 - D. II and III only.
47. The diploid number of chromosomes in a fly species is eight. Assuming the absence of mutation or crossing over, how many genetically unique gametes might be formed in one individual?
- A. 4
 - B. 8
 - C. 16
 - D. 32
48. The amount of DNA in a nucleus of mammalian gamete cell at the end of interphase is 10 pg. What is the amount of DNA in a nucleus of a gamete cell at anaphase I?
- A. 2.5 pg
 - B. 5 pg
 - C. 10 pg
 - D. 20 pg

49. Cytosine comprised 38% of the nitrogenous bases in the DNA of cells from a bacterial clone. What was the percentage of thymine in the DNA?

- A. 12%
- B. 19%
- C. 24%
- D. 38%

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

- I. Deoxyribonucleotides are added to the 3' end of the leading strand and of the lagging strand.
 - II. The leading strand has more Okazaki fragments than the lagging strand.
 - III. The leading strand has more RNA primers than the lagging strand.
- A. I and II only.
 - B. I and III only.
 - C. II and III only.
 - D. I, II and III.

51. Which of the following if mutated will not affect the transcription of a gene?

- I. Intron-exon boundary
 - II. Start codon
 - III. Stop codon
- 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. Its chromosome consists of a single stranded circular DNA.
 - II. Its chromosome is highly folded around histone proteins.
 - III. Transcription occurs in nucleus and translation occurs in the cytoplasm.
- A. II only.
 - B. I and II only.
 - C. II and III only.
 - D. I, II and III.

53. What does the binding of the catabolite activator protein to its binding site upstream of the operator on the *lac* operon ensure?
- A. Production of lactose metabolizing enzymes are decreased when glucose levels are high.
 - B. Production of lactose-metabolising enzymes are repressed when lactose is absent.
 - C. Production of lactose-metabolising enzymes are increased when glucose levels are low.
 - D. Production of lactose-metabolising enzymes are induced when lactose levels are high.
54. Which of the following statements describe a feature of telomeres?
- A. Telomeres are found at the ends of linear chromosomes.
 - B. Telomeres can be extended by DNA polymerase.
 - C. Telomeres consist of chains of adenine nucleotides.
 - D. Telomeres prevent the shortening of chromosomes during DNA replication.
55. Which of the following processes allow genetic material to be transferred through cell-cell contact between two bacterial cells?
- A. Binary Fission
 - B. Conjugation
 - C. Transduction
 - D. Transformation
56. Which of the following statements is/are FALSE?
- 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 DNA polymerase and RNA polymerase activity.
- A. I only.
 - B. II only.
 - C. III only.
 - D. II and III only.
57. In the DNA strand that complements mRNA, a thymine was replaced by adenine in a 5'-CTT-3' triplet codon forming a 5'-CAT-3' triplet codon. This resulted in valine being incorrectly incorporated instead of glutamic acid. What is the anticodon of the transfer RNA molecule carrying this valine?
- A. 5'-AUC-3'
 - B. 5'-AUG-3'
 - C. 5'-GUA-3'
 - D. 5'-CAU-3'

58. Which of the following statements are FALSE?

- I. Men with XYY genotype are conceived from a sperm produced by a father whose cells lacks chromosome X.
 - II. Down syndrome is caused by gene mutation on chromosome 21.
 - III. The disease phenylketonuria (PKU) is due to the production of a non-functional enzyme as a result of duplication of the gene.
- A. I and II only.
B. I and III only.
C. II and III only.
D. 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.

69 bp	ATG TAC 428 bp	Intron 546 bp	202 bp	Intron 654 bp	118 bp	TAA 542 bp ATT
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59. What is the estimated length (in nucleotides) of the mRNA transcript of this gene after splicing but before polyadenylation?

- A. 1290
- B. 1359
- C. 2490
- D. 2559

60. How many amino acids are present in the protein encoded by this gene?

- A. 430
- B. 429
- C. 853
- D. 830

End of Paper