UNIVERSITY ENTRANCE EXAMINATION
2019

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 molecular formula for glucose is C₆H₁₂O₆. What would be the molecular formula for a molecule made by linking three glucose molecules together by dehydration reactions?
   A. C₁₈H₃₆O₁₈
   B. C₁₈H₃₄O₁₆
   C. C₁₈H₃₂O₁₆
   D. C₁₈H₃₀O₁₅

2. For this pair of items, choose the option that best describes their relationship.
   Item (A): The number of purines in the DNA strand 5'-ATGAGCAGATA-3'
   Item (B): The number of pyrimidines in the DNA strand 5'-AAGAGGAGCAA-3'
   A. Item (A) is less than item (B).
   B. Item (A) is greater than item (B).
   C. Item (A) is exactly or very approximately equal to item (B).
   D. The DNA strand of Item (A) is complementary to the strand of item (B).

3. Cyanide binds with at least one molecule involved in producing ATP. If a cell is exposed to cyanide, most of the cyanide would be found within the
   A. lysosomes
   B. mitochondria
   C. peroxisomes
   D. endoplasmic reticulum

4. The oxygen consumed during cellular respiration is involved directly in which process or event?
   A. glycolysis
   B. the citric acid cycle
   C. the phosphorylation of ADP to form ATP
   D. accepting electrons at the end of the electron transport chain

5. Working on the Singapore River, a biologist isolated DNA from two unknown organisms, P and Q. He discovered that the adenine content of P was 15% and the cytosine content of Q was 42%. This means that
   A. the amount of guanine in P is 15%
   B. the amount of adenine in Q is 42%
   C. the amount of thymine in Q is 21%
   D. the amount of guanine and cytosine combined in P is 70%
6. It became apparent to Watson and Crick after completion of their model that the DNA molecule could carry a vast amount of hereditary information in which of the following?

A. sequence of bases  
B. phosphate-sugar backbones  
C. complementary pairing of bases  
D. side groups of nitrogenous bases

7. Which of the following is not directly involved in the process of gene translation?

A. tRNA  
B. mRNA  
C. ribosomes  
D. RNA polymerase

8. Suppose you are provided with an actively growing and dividing E. coli bacterium to which radioactive thymine has been added, what would happen if a cell replicates once in the presence of this radioactive base?

A. DNA in both daughter cells would be radioactive.  
B. Neither of the two daughter cells would be radioactive.  
C. Radioactive thymine would pair with nonradioactive guanine.  
D. One of the daughter cells, but not the other, would have radioactive DNA.

9. What is the relationship among DNA, a gene, and a chromosome?

A. A DNA is a gene, which makes up of chromosome.  
B. A chromosome contains hundreds of genes which are composed of DNA.  
C. A gene contains hundreds of chromosomes which are composed of protein.  
D. A gene is composed of DNA, but there is no relationship to a chromosome.

10. All cells metabolize glucose for energy. If two glucose molecules go into an anaerobic pathway in our muscle cells, what are the net ATP and NADH production?

A. Two ATP and two NADH  
B. Two ATP and zero NADH  
C. Four ATP and zero NADH  
D. Four ATP and two NADH
11. Which of the following mutations is most likely to cause a catastrophic effect on the function of the encoded protein?

A. A base substitution right after the start codon  
B. Deletion of one base near the 3’ end of start codon  
C. Deletion of one base near the 3’ end of the coding sequence  
D. Deletion of three bases right after the start codon.

12. During which phase of meiosis do chromosomes undergo crossover?

A. Prophase I  
B. Prophase II  
C. Metaphase I  
D. Metaphase II

13. The genotype of a human zygote differs from the genotypes of both parents. Which of the following does NOT contribute to this variation?

A. Mutation of genes  
B. Independent assortment  
C. Presence of dominant genes  
D. Random combination of gametes

14. The amount of DNA in a nucleus of a mammalian skin cell is 10 pg at the end of interphase. What is the approximate amount of DNA in its sperm cell?

A. 1.25 pg  
B. 2.5 pg  
C. 5 pg  
D. 10 pg

15. Imagine that you are looking at a eukaryotic cell under a microscope. You see that the nucleus is not present and that chromosomes are condensed and lined up in two rows in the center of the cell. What is the possible stage of division you might be observing in this cell?

A. Metaphase of mitosis  
B. Metaphase of meiosis I  
C. Metaphase of meiosis II  
D. Metaphase of mitosis or meiosis I
16. A cell has mitochondria, smooth and rough endoplasmic reticulum, and other parts. Based on this information, it could NOT be______.

A. a bacterium  
B. a cell from a pine tree  
C. a grasshopper cell  
D. a yeast (fungus) cell

17. *Drosophila melanogaster* has four pairs of chromosomes in its diploid cells. Sperm from this species are formed by a meiotic process in which homologous chromosome pairs segregate but do not undergo crossing over. How many genetically different kinds of sperms could be produced by a *D. melanogaster* male?

A. 4  
B. 8  
C. 16  
D. 64

18. A molecular genetics lab is given a tooth from the skull of an ancient man and is asked to prepare a sample of a small portion of the Y chromosome from the DNA that is, hopefully preserved in the central tissue of the tooth. Which technique would the scientists use to produce millions of copies of this specific segment of DNA?

A. DNA sequencing  
B. recombinant DNA  
C. gel electrophoresis  
D. polymerase chain reaction (PCR)

19. A group of students purified genomic DNA from their buccal cells, and proceeded to analyze the DNA compositions. Which of following is NOT expected to be present in their results?

A. Uracil  
B. Adenine  
C. Cytosine  
D. Thymine

20. The synthesis of new DNA strands in both a living cell (*in vivo*) and a PCR tube (*in vitro*) follows a process of semiconservative replication. Which of the following statements is correct about these two replication processes?

A. Both processes need ligase  
B. Both processes need helicase  
C. Both processes need DNA primers  
D. Both processes need DNA polymerase
21. Which of the following options is NOT a form of gene mutation?
A. Inversion  
B. Insertion  
C. Replication  
D. Duplication

22. Which of the following replication enzymes, if mutated, may cause DNA polymerase to be unable to add nucleotides at the origin of replication, hence no daughter strands of DNA can be synthesized?
A. Helicase  
B. Primase  
C. DNA ligase  
D. Topoisomerase

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 about gene mutation is/are FALSE?
A. It can occur in both somatic and sex cells.  
B. It can change a dominant allele to a recessive one.  
C. It can be brought about by exposure to ionizing radiation.  
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 is the most likely contributory gamete to a zygote with the rare genotype XYY in men?
A. An egg produced by non-disjunction in meiosis.  
B. An egg containing an X and a Y chromosome.  
C. A sperm produced by non-disjunction at meiosis I.  
D. A sperm produced by non-disjunction at meiosis II.
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 occurs in the light reaction of photosynthesis?
   A. ADP is phosphorylated.
   B. Hexose phosphates are hydrolysed.
   C. Reduced NADP is oxidised.
   D. Ribulose 1,5-bisphosphate (RuBP) is carboxylated.

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 CORRECT regarding the action of G-protein?
   A. Intracellular signalling molecule activates G-protein, resulting in a change in its surface configuration.
   B. G-protein coupled receptor is inactivated when the activated G-protein binds to a membrane protein.
   C. G-protein acts as GTPase enzyme and hydrolyses GDP to GTP.
   D. G-protein activation results in multiple cellular responses.

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 molecule is common to both glycolysis and the Calvin cycle?
   A. Hexose phosphate.
   B. NADP.
   C. Pentose phosphate.
   D. Triose phosphate.
33. In the Krebs’ 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. A double-stranded DNA is composed of 600 nucleotides. It contains the coding sequence of a full-length protein including the start and the stop codons. What is the longest possible peptide chain that can be derived from this DNA via transcription and translation?

A. 200  
B. 199  
C. 100  
D. 99

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. Which of the following statements is FALSE?

A. Genomic libraries are made from genomic DNA of an organism.  
B. Genomic libraries may not contain intron sequences.  
C. cDNA libraries are made from total RNA of an organism.  
D. cDNA libraries do not contain intron sequences.

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. Which of the following is NOT required for a PCR reaction?

A. DNA polymerase  
B. NTPs  
C. dNTPs  
D. Template DNA.
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. The following is the taxonomic classification of the chicken:

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Animalia
  Chordata
    Aves
      Galliformes
        Phasianidae
          Gallus
            Gallus gallus
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Which order does the chicken belong to?

A. *Gallus*
B. Aves
C. Phasianidae
D. Galliformes

42. 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.
43. 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 at least as many species as 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.

44. 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

45. 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.

46. 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. Allogenetic changes favouring heterozygotes.
B. Natural selection favouring heterozygotes.
C. Underdominance of the recessive allele.
D. High mutation rate of the recessive allele.
47. 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.

48. 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.

49. 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

50. 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.

51. 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.
52. 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.

53. 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.

54. 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.

55. 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.
56. 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.

57. 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.

58. 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.

59. 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.
60. 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.

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