UNIVERSITY ENTRANCE EXAMINATION 2019

NUS National University of Singapore

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 $C_6H_{12}O_6$. What would be the molecular formula for a molecule made by linking three glucose molecules together by dehydration reactions?

   A. $C_{18}H_{30}O_{16}$
   B. $C_{18}H_{32}O_{16}$
   C. $C_{18}H_{34}O_{16}$
   D. $C_{18}H_{36}O_{16}$

2. If the DNA content of a diploid cell in the G2 phase of the cell cycle is x, then the DNA content of the cell at the metaphase of meiosis II would be _____.

   A. 0.25*x*
   B. 0.5*x*
   C. *x*
   D. 2*x*
   E. 4*x*

3. Which of the following statements is TURE about DNA agarose gel electrophoresis?

   I. DNA is red colour under UV.
   II. DNA fragments are separated by sizes.
   III. Longer DNA fragments migrate slower than shorter fragments.
   IV. All DNA fragments migrate to the positive end of the electrical field.

   A. II and III
   B. I, II and III
   C. II, III and IV
   D. I, II, III and IV

4. Which of the statements regarding bacterial genetics is/are TRUE?

   I. Its chromosome is highly folded around histone proteins.
   II. Its chromosome consists of a circular double stranded DNA.
   III. Transcription occurs in nucleus and translation occurs in cytoplasm.

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

5. A DNA probe with sequence TCAGGCTTCAG would bind most strongly to which of the following DNA fragments?

   A. UGUCCGUUGUC
   B. AGTCCGAAGTC
   C. GACTTCGGACT
   D. TCAGGCTTCAG

6. The polymerase chain reaction (PCR) allows scientists to do all of the following EXCEPT for:

   A. making gene copies quite rapidly
   B. detecting a pathogen in very low copies
   C. making millions of copies of a particular gene
   D. knowing the sequence of the bases within a gene as it is being copied

7. Proteins manufactured in the endoplasmic reticulum may be chemically altered and sorted in the _____.

   A. cytosol
   B. nucleus
   C. Golgi complex
   D. mitochondrion

8. A plant cell was grown in a test tube containing radioactive nucleotides, the parts from which DNA is built. Later examination of the cell showed the radioactivity to be concentrated in the_____.

   A. lysosome
   B. chloroplast
   C. smooth ER
   D. central vacuole

9. We inhale oxygen and exhale carbon dioxide. At the cellular level, where is the carbon dioxide released during carbohydrate metabolism?

   A. the cytosol
   B. mitochondrion
   C. Golgi complex
   D. endoplasmic reticulum

10. What is the net ATP production from two molecules of glucose via glycolysis?

    A. 4 molecules of ATP
    B. 6 molecules of ATP
    C. 8 molecules of ATP
    D. 10 molecules of ATP

11. Which of the following is NOT required for the DNA replication via PCR?

    A. dNTPs
    B. ddNTPs
    C. DNA primer
    D. Taq DNA polymerase

12. Working in the botanic garden, a biologist isolated DNA from two unknown flower plants, P and Q. He discovered that the adenine content of P was 35% and the cytosine content of Q was 20%. Which of the following is WRONG?

    A. the amount of guanine in P is 15%
    B. the amount of thymine in P is 35%
    C. the amount of guanine in Q is 30%
    D. the amount of thymine in Q is 30%

13. Which of the following mutations is most likely to cause a mild change of protein sequence?

    A. A base substitution at the start codon
    B. deletion of one bases after the start codon
    C. deletion of two bases after the start codon
    D. deletion of three bases after the start codon.

14. The genotype of one person differs usually from his siblings. Which of the following does NOT contribute to this variation?

    A. Crossing over in meiosis
    B. Independent assortment
    C. Chromosome compaction
    D. Random fertilization of gametes

15. 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. Sulfhydryl group
    B. Phosphate group
    C. 5-carbon sugar
    D. Nitrogenous base

16. Which of the following enzymes is NOT necessary for making a recombinant plasmid?

    A. DNA ligase
    B. DNA helicase
    C. DNA polymerase
    D. restriction enzymes

17. During vigorous exercise bouts such as sprinting, our muscle cells may accumulate lactate, this is to _____.

    A. make ADP
    B. block glycolysis
    C. regenerate NAD
    D. stimulate muscle contraction

18. Investigators try to make a DNA fingerprint from a sample collected at a crime scene. Why are primers used in this technique?

    A. Primers make the DNA visible.
    B. Primers cut out the DNA immediately surrounding STRs.
    C. Primers prepare the DNA by making it unwind and unzip, separating the double strands.
    D. Primers bind exclusively to the DNA immediately surrounding STRs, so DNA polymerase knows where to start copying.

19. Which of the following statements is TRUE?

I. Insulin is produced by the liver.
II. Insulin promotes the process of glycogen synthesis.
III. Mature form of insulin consists of two polypeptide chains.
IV. Insulin is secreted in primarily in response to elevated blood concentrations of glucose

A. I and IV
B. II and III
C. I, II and IV
D. II III and IV

20. Which of the following processes requires help from viruses for gene transfer between bacteria?

A. Conjugation
B. Transduction
C. Transposition
D. Transformation

21. Which of the following options is a form of gene mutation?

A. Transcription
B. Insertion
C. Replication
D. Ligation

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. Topoisomerase
C. DNA ligase
D. Primase

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 about gene mutation is/are FALSE?

A. It can change a dominant allele to a recessive one.
B. It can occur in both somatic and sex cells.
C. It can be brought about by exposure to ionizing radiation.
D. A and B 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 is the most likely contributory gamete to a zygote with the rare genotype **XYY** in men?

A. An egg containing an X and a Y chromosome.
B. A sperm produced by non-disjunction at meiosis **I**.
C. A sperm produced by non-disjunction at meiosis **II**.
D. An egg produced by non-disjunction at meiosis **II**.

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 occurs in the light reaction of photosynthesis?

A. Ribulose 1,5-bisphosphate (RuBP) is carboxylated.
B. Hexose phosphates are hydrolysed.
C. Reduced NADP is oxidised.
D. ADP is phosphorylated.

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 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 GTP to GDP.
D. None of the above is CORRECT.

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 molecule is common to both glycolysis and the Calvin cycle?

A. Triose phosphate.
B. Hexose phosphate.
C. Pentose phosphate.
D. NADP.

33. In the Krebs' cycle, which step produces reduced FAD (*i.e.* $FADH_2$)?

A. Citric acid $\rightarrow$ isocitric acid
B. Succinic acid $\rightarrow$ fumaric acid
C. Malic acid $\rightarrow$ oxaloacetic acid
D. Fumaric acid $\rightarrow$ malic acid

34. A double-stranded DNA is composed of 900 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. 149
B. 150
C. 299
D. 300

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. Which of the following statements is/are FALSE?

    A. Genomic libraries are made from genomic DNA of an organism.
    B. Genomic libraries must contain intron sequences.
    C. cDNA libraries are made from total RNA of an organism.
    D. B and C only.

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 is NOT required for a PCR reaction?

    A. DNA polymerase
    B. Template DNA
    C. dNTPs
    D. ddNTPs

39. Which of the following technologies is well suited for mass-production of therapeutic and other useful proteins?

    A. Transgenic technology
    B. Gene targeting
    C. Genome editing
    D. Recombinant DNA technology

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. 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

42. 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.

43. 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.

44. 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

45. 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.

46. 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.

47. 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.

48. 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.

49. 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

50. 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.

51. 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.

52. 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

53. Which of the following factors cannot lead to cancer?

    A. Exposure to carcinogenous chemicals.
    B. Radiation.
    C. Apoptosis.
    D. Chance mutations.

54. 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.

55. 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

56. 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.

57. Which of the following statements is 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.

58. 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.

59. 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.

60. 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.

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