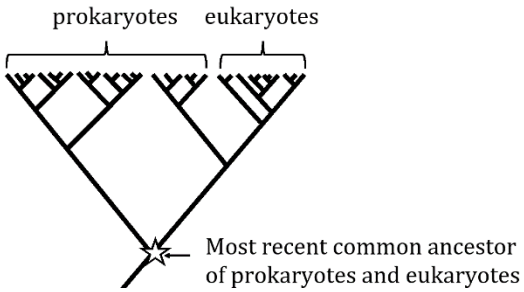
University of Toronto
National Biology Competition
2024 Examination

Thursday, April 18, 2024
Time: 75 minutes
Number of questions: 50

Should you guess the answers to questions about which you are not certain?
Since your score on the exam is based on the number of questions you answered correctly minus one-third of the number you answered incorrectly, it is improbable that guessing will improve your score (it is more likely to lower your score). No points are deducted or awarded for unanswered questions. However, if you are not sure of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices, then your chance of getting the right answer is improved, and it may be advantageous to answer such a question.

1. What was a characteristic of the most recent common ancestor of all prokaryotes and eukaryotes?
   a. It had a semi-permeable nuclear membrane.
   b. It could engulf live prey via phagocytosis.
   c. It moved via amoeboid locomotion.
   d. It lacked transporter proteins in its cell membrane.
   e. It could synthesize its proteins and mRNAs simultaneously.



2. You are surveying the diversity of small aquatic organisms in pond water samples from a remote mountaintop in Brazil. You isolate a particular microorganism and observe it while it grows for several generations. Based on the characteristics on the right, what type of organism is this most likely to be?
   a. A simple, microscopic animal
   b. A motile, microscopic plant
   c. A motile fungus
   d. A complex, colonial bacterium
   e. A colonial protist

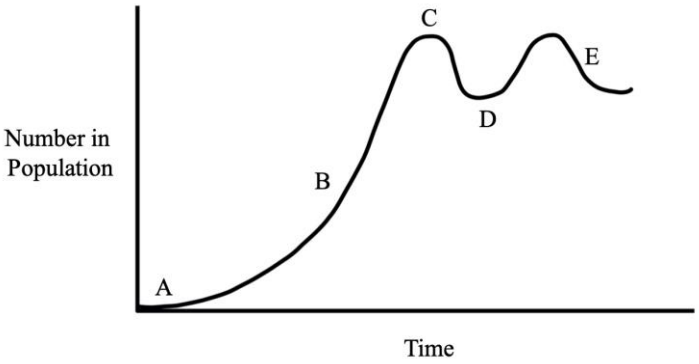
The organism has the following characteristics:
- It swims via flagella.
- It can follow a light source.
- It has chloroplasts.
- It has a cell wall.
- It is composed of multiple cells and cells show specialization/division of labour.
- It requires oxygen to live.

3. Which of the following, **on its own**, would be a taxon?
   a. A group of baby macaroni penguins swimming in view of their parents
   b. A femur from an extinct *Triceratops* skeleton
   c. A new species of mushroom, *Spongiforma squarepantsii*
   d. A single *E. coli* bacterium in a colony on a petri dish
   e. A community of warthogs, meerkats, and wildebeest

4. Which type of organism requires the most energy from the sun (both directly and indirectly) in order to survive?
   a. Primary producer
   b. Secondary producer
   c. Primary consumer
   d. Secondary consumer
   e. Apex predator

5. The Brown-headed Cowbird is a species that lays its eggs in other birds' nests. These foreign offspring are often then raised by the makers of that nest. What term best describes the relationship between the Cowbird offspring and the makers of the nest?
   a. Competition
   b. Predation
   c. Symbiosis
   d. Mutualism
   e. Parasitism

6. Within a given habitat, a population size may increase or decrease depending on factors like food availability or predation. Which point on the figure BEST represents the maximum population growth rate?
   a. A
   b. B
   c. C
   d. D
   e. E



7. A pet wholesaler illegally captures 100 Gila monsters from a large population in their native desert habitat in Arizona and sells them in Dubai. People buy the Gila monsters as pets, but soon realize that they are bad pets. They are slow, venomous, sleep a lot, and require expensive live food that is hard to find in local stores. Gila monsters live for 20-30 years, so people start to release them into the wild because they don't want to care for them long-term. The released Gila monsters are able to survive because they have no natural predators. After 10 years, how would the **allelic diversity** of the released Gila monsters in Dubai compare to the source population?
   a. It would be higher than the diversity in the source population because the released individuals would have evolved new, beneficial alleles as they adapted to their new habitat.
   b. It would be higher than the diversity in the source population because the released individuals were able to exploit the new habitat better than local species, produce many offspring, and diversify rapidly.
   c. It would be higher than the diversity in the source population because the released individuals have limited geographic range, so they will mate more often and many new alleles will emerge through recombination.
   d. It would be lower than the diversity in the source population because the released individuals were only a sample of the allelic diversity of the source population.
   e. It would be lower than the diversity in the original population because the released individuals that survived in the first place must have undergone adaptation already, so only the alleles of the well-adapted individuals were maintained.

8. What observation directly contributed to Charles Darwin and Alfred Russell Wallace's development of the Theory of Evolution?
   a. Organisms only maintain traits that are beneficial and lose traits that they don't use.
   b. Aristotle's theory that all living things emerged from a single ancestral organism.
   c. Gregor Mendel's pea plant breeding experiments demonstrating that genes, encoded by an organism's DNA, determined the traits of that organism.
   d. The theory that in human populations, the ability of individuals to survive varies depending on factors such as the availability of resources, war, and disease.
   e. Body plans are more complex in more highly evolved organisms and are simpler in more primitive ones.

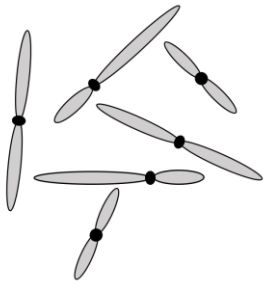
9. You and a friend spend an afternoon in a suburban forest trying to estimate the size of its Northwestern Salamander population. Which technique would be most efficient to estimate the population size?
   a. Search for and count all individuals
   b. Mark and recapture
   c. Set baited traps
   d. Spot salamanders from a fixed location, then extrapolate across the forest
   e. Collect data from quadrats and extrapolate across the forest

10. What statement is accurate regarding the process of speciation?
   a. Speciation can explain how all organisms alive today are ultimately related to a single ancestral species.
   b. During speciation, older species are driven to extinction because they are outcompeted by the newer species that are stronger competitors for resources.
   c. A new species cannot evolve in the same geographical location as an existing, closely related species because it will be outcompeted by the existing, well-adapted species.
   d. All speciation events are the direct result of the process of natural selection.
   e. Speciation occurs to promote the evolution of new traits that enhance the survival of a species.

11. During his journey through the Galápagos Islands, Charles Darwin collected many specimens of songbirds known as finches. Darwin made careful observations of the specimens, and noticed that finch beak shapes varied from island to island. He hypothesized that the evolution of diverse beak shapes enabled different groups of finches to specialize in consuming different types of food sources. For example, broad, strong beaks were more effective for cracking large seeds, while thin, sharply pointed beaks were better suited for skewering insect prey. In order for diverse beak shapes to have emerged through the process of natural selection, which would necessarily be true?
   a. Finches could migrate easily between islands in the Galápagos and mate with one another.
   b. Finches could not easily migrate between islands in the Galápagos to mate with one another.
   c. Specializing on different types of food sources differentially affected the rates of survival and reproduction of the different finch species on different islands.
   d. Finches with broad beaks were unable to consume insects and finches with thin, pointy beaks could not consume seeds.
   e. The common ancestor of the Galápagos finches initially had access to both large seeds and insects in its native habitat.

12. What observation is considered evidence for the Theory of Evolution?
   a. All organisms share DNA sequence similarity.
   b. Complex organisms arise from simpler ones, and not the other way around.
   c. Mutations give rise to traits that lead individuals to be eliminated from the population.
   d. Stronger organisms outcompete weaker ones, so organisms get stronger over time.
   e. Species always adapt to survive changing environmental conditions.

13. The image on the right shows the complete genome for a eukaryotic organism, which has been extracted from the nucleus. What is the nature of this organisms genome?

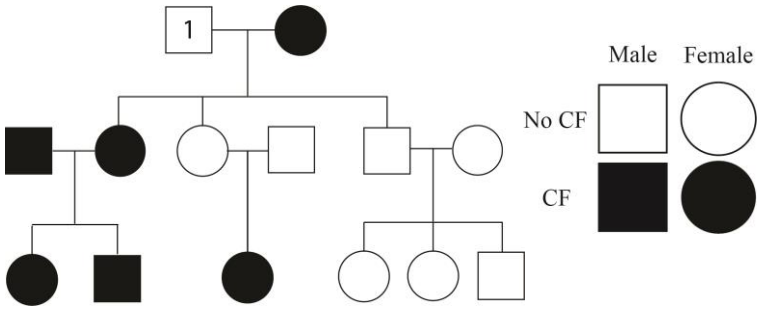


    a. Haploid
    b. Diploid
    c. Triploid
    d. Tetraploid
    e. Hexaploid

14. A school of Sockeye salmon swimming along the coast of Vancouver Island faces an existential threat. Which of the following represents a density-independent factor?
    a. A virus that is lethal to Sockeye prey
    b. An abnormally warm current that is low in dissolved oxygen
    c. A new species of Salmon that eats the same food as the Sockeye
    d. An invasive fish species that exclusively eats Sockeye
    e. A virus that is lethal to Sockeye

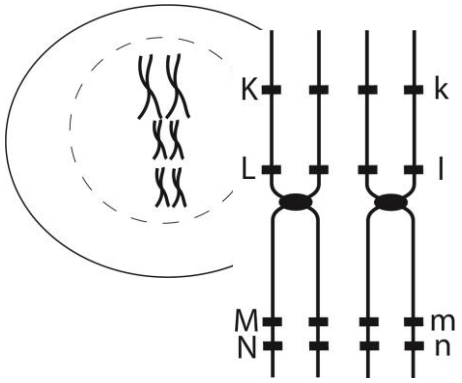
15. A true-breeding white flower with round petals is crossed with a true-breeding yellow flower with pointed petals. In the first generation, all the progeny have yellow flowers with round petals. If the plants in the first generation self-fertilize, approximately how many plants in the next generation do you expect to have yellow flowers and round petals if the genes segregate independently?
    a. 90%
    b. 75%
    c. 55%
    d. 20%
    e. 5%

16. A geneticist created the pedigree chart below for a family with members with cystic fibrosis (CF). Based on the pedigree, what is the nature of the disease and the genotype of individual 1?



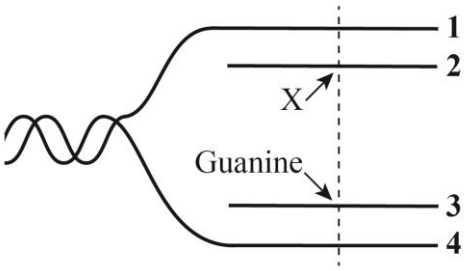
    a. Autosomal, Heterozygous
    b. X-linked, Dominant
    c. Autosomal, Homozygous Recessive
    d. Autosomal, Homozygous Dominant
    e. X-linked, Recessive

17. This diagram shows a pair of homologous chromosomes with the location of four genes (K/k, L/l, M/m, and N/n) marked by black bars. Which is the LEAST likely meiotic product?
    a. K – L – M – N
    b. k – l – M – N
    c. K – l – m – n
    d. k – l – M – n
    e. k – L – m – N



18. A farmer starts growing potatoes in a new field, and notices that the plants are smaller than normal, and the leaves are more yellow. When he tests the soil, he finds that the new field has a very different pH than his other fields. How could this explain what is happening to the potatoes grown in his new field?
    a. The plants cannot absorb nutrients from the soil as well
    b. The plants cannot absorb water from the soil as well
    c. The soil cannot retain water as well
    d. There is less organic matter in the soil
    e. The plants are getting too much water

19. This diagram shows DNA replication. If a guanine nucleotide is located on strand 3 at the dashed line, what nucleotide should be present in the same position on strand 2 (position X)?
    a. Uracil
    b. Thymine
    c. Guanine
    d. Cytosine
    e. Adenine



20. A bacterial operon "*can*" contains three genes, *CanX*, *CanY* and *CanZ*, that encode proteins that work together to break down the sugar Canadose. When Canadose is present in the media, the bacteria breaks it down to use as an energy source. The "*can"* promoter is regulated by a transcriptional repressor protein called Maple. Which of the following could explain how the "*can"* operon works?

	Canadose in the Media	Maple Binding to Operator	Operon Transcription
a.	Present	Maple Binds	Transcription Occurs
b.	Present	Maple Does Not Bind	Transcription Occurs
c.	Present	Maple Does Not Bind	No Transcription
d.	Absent	Maple Binds	Transcription Occurs
e.	Absent	Maple Does Not Bind	No Transcription

21. If the genome of species A is 5 times larger than species B, what can you conclude?
    a. Species A has 5 times as many chromosomes in a cell compared to species B
    b. Species A has 5 times as many cells in one organism compared to species B
    c. Species A has 5 times as many genes in its DNA compared to species B
    d. Species A has 5 times as many DNA base pairs in a cell compared to species B
    e. Species A has 5 times as many DNA strands in a cell compared to species B

22. A researcher uses the restriction enzyme BamHI to digest either a plasmid or the product of a PCR reaction. The BamHI recognition sequence appears 4 times in both the plasmid and the PCR product. How many pieces of DNA will be produced in each case?

	Plasmid	PCR Product
a.	3 pieces	4 pieces
b.	4 pieces	5 pieces
c.	4 pieces	4 pieces
d.	5 pieces	4 pieces
e.	5 pieces	5 pieces

23. Why is the pressure of water in plant cells (turgor pressure) important?
    a. To transport water from roots to leaves
    b. To allow for transpiration
    c. To maintain solute concentrations within cells
    d. To maintain growth and rigidity
    e. To maintain solute concentrations outside of cells

24. Pulmonary fibrosis is a condition that damages lung tissue by thickening the walls of alveoli. How does this disease disrupt adequate gas exchange in the lungs?
    a. The distance between the alveolar air and blood in the capillaries increases, thus reducing diffusion
    b. Thickening the alveolar walls decreases the amount of blood that is available in the lungs for gas exchange
    c. The thickened alveoli require more surfactant than the lungs are able to produce to remain inflated
    d. Fibrotic alveoli cannot allow the passage of immune cells to patrol for pathogens
    e. Thickening the alveolar walls requires considerable energy, immediately depleting much of the oxygen that enters the blood

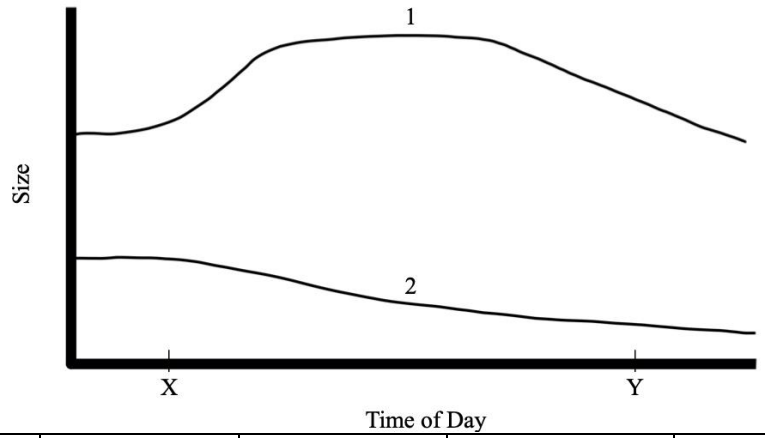
25. Which plant hormone can change the direction that plants grow?
    a. Auxin
    b. Jasmonic acid
    c. Salicylic acid
    d. Abscisic acid
    e. Ethylene

26. Which of the following statements about the excretory system in a healthy person is most accurate?
    a. Blood entering the kidney has a higher osmolarity than urine
    b. Filtrate first entering the nephron has the same concentration of glucose as blood in the renal artery
    c. Fluid in the collecting duct contains less total glucose than the urine
    d. Urine has a higher glucose concentration than salt concentration
    e. Filtrate entering the nephron has more protein than does blood in the renal artery

27. Which of the following has the highest affinity for oxygen?
    a. Adult hemoglobin leaving the lungs
    b. Adult hemoglobin at oxygen-deprived tissue
    c. Fetal hemoglobin leaving the placenta
    d. Fetal hemoglobin leaving a newborn's lungs
    e. Fetal hemoglobin at oxygen-deprived tissue

28. What might a person with exacerbated ulcerative colitis experience?
    a. Large open sores on the undersides of their feet
    b. Discrete patches of red, itchy skin
    c. Shortness of breath, heart palpitations, and night sweats
    d. Extreme abdominal pain, digestive trouble, and diarrhea
    e. Development of bald patches on their scalp

29. Organs in the gastrointestinal tract change throughout the day in response to stimuli like food ingestion and hormones in the blood. Which labels best apply to the figure below?



	Gall Bladder	Stomach	X	Y
a.	Line 1	Line 2	Breakfast time	Dinner time
b.	Line 2	Line 1	Dinner time	Breakfast time
c.	Line 1	Line 2	Bed time	Dinner time
d.	Line 2	Line 1	Dinner time	Bed time
e.	Line 1	Line 2	Bed time	Breakfast time

30. How would the large, highly vascularized ears of the desert hare help it survive in a hot climate?
    a. The large surface area of the ears serves as storage for the blood so it can be rerouted to muscles when evading predators
    b. The large surface area allows for dissipation of the heat, cooling the hare
    c. The large surface area to volume ratio of the hare's ears decreases the dissipation of heat
    d. The ears are thin and therefore are not as metabolically active, preserving energy in the hot temperatures.
    e. They don't help it survive, but rather reproduce since ear size in hares is under sexual-selection pressure only

31. Why might someone with a goiter (enlarged thyroid gland) see its growth slow once they start taking thyroid hormone replacement therapy?
    a. Their hypothalamic-pituitary-thyroid axis receives negative feedback
    b. The goiter receives negative feedback
    c. The thyroid hormone directly inhibits TSH
    d. The thyroid hormone causes the rest of the body's tissue to start growing
    e. The thyroid stops producing thyroid hormone because it is being taken exogenously

32. Which of the following actions would produce the slowest-acting systemic effects?
    a. Activating a neuromuscular junction through an unmyelinated axon
    b. Causing the release of insulin through a myelinated axon
    c. Luteinizing hormone causing the ovaries to release estrogen
    d. Epinephrine binding its receptor on the heart
    e. Estrogen inhibiting the release of GnRH at the hypothalamus

33. In patients with respiratory distress, their bloodstream often accumulates an excess of carbon dioxide. What is one way their body can help counteract these dangerously high levels of CO_2?
    a. Storing HCO_3^- inside tissues that have a low metabolic rate
    b. Increasing the amount of CO_2 that can dissolve directly into plasma
    c. Decrease blood flow in the lungs to maximize the amount of CO_2 released
    d. Releasing HCO_3^- through the feces
    e. Releasing HCO_3^- through the excretory system

34. What is an essential characteristic of enzymes?
    a. Enzymes must increase the rate of a chemical reaction by lowering the free energy of the reaction.
    b. Enzymes must polymerize chains of monomers of macromolecules such as sugars, amino acids, and lipids.
    c. Enzymes must compete with the products of the reactions that they catalyze to bind substrates.
    d. Enzymes must bind substrates according to specific interactions between the substrates and the amino acids in the enzyme's active site.
    e. Enzymes must convert energy stored in complex molecules into simpler more usable forms, such as ATP.

35. Which of the following cellular processes produces oxygen?
    a. Glycolysis
    b. Citric acid cycle
    c. Oxidative Phosphorylation
    d. Calvin Cycle/Dark Reactions
    e. Photophosphorylation/Light Reactions

36. Capsaicin is the chemical compound that gives chili pepper their spicy flavour. Structurally, it has a long hydrocarbon chain which makes much of the molecule non-polar. To generate the sensation of spiciness in our mouth, capsaicin binds to the TRPV1 receptor. In order for capsaicin to bind to the TRPV1 receptor, the binding pocket will need to have which type of amino acids in it?
    a. Polar
    b. Non-polar
    c. Basic
    d. Acidic
    e. Charged

37. What is the overall purpose of photosynthesis?
    a. To absorb the light of the sun
    b. To generate an electrochemical gradient
    c. To produce oxygen for the cell to use in respiration
    d. To capture energy and store it in ATP for the cell to use
    e. To capture energy and store it in polysaccharides for the cell to use

38. If the inner membrane of a mitochondrion were to be damaged in such a way that ions could pass across it, what would be the most directly affected?
    a. Water would not be formed from oxygen
    b. NADH would not be oxidized
    c. ATP would not be synthesized
    d. The electrons would not flow through the electron transport chain
    e. The citric acid cycle would not run

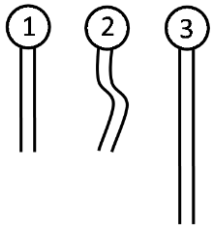
39. The potassium-chloride co-transporter (KCC2) is an important membrane-bound transport protein in neuronal cells of the brain. It is used to keep the concentration of chloride ions low inside the cell. KCC2 can only transport chloride out of the cell when a potassium ion is also bound. Potassium is transported from an area of high concentration (inside the neuronal cell) to an area of low concentration (the extracellular space). The movement of chloride ions described here is an example of what kind of transport?
    a. Passive diffusion
    b. Active transport
    c. Facilitated diffusion
    d. Simple diffusion
    e. Passive co-transport

40. What processes is most likely to consume ATP?
    a. Individual phospholipids forming a micelle in an aqueous solution
    b. Transporting waste CO_2 across cell membranes in your alveoli from capillaries
    c. Transporting water into the cytoplasm of a red blood cell sitting in a hypotonic solution
    d. Enzymes binding to their substrates and undergoing a conformational change
    e. Transporting glucose into an intestinal cell that contains more glucose than the intestinal lumen

41. A mutation occurs in a gene that encodes a protein involved in the synthesis of phospholipids in a cell. What organelles would most likely remain functional in that cell?
    a. Chloroplasts
    b. Vesicles
    c. Nuclei
    d. Ribosomes
    e. Smooth Endoplasmic Reticulum

42. This diagram shows three types of phospholipids, where straight lines indicate saturated fatty acid tails, and wavy tails indicate unsaturated fatty acid tails. Which of the following ranks the lipids according to the fluidity of the membrane they would form?

	Most Fluid		Least Fluid
a.	Lipid 2	Lipid 3	Lipid 1
b.	Lipid 2	Lipid 1	Lipid 3
c.	Lipid 1	Lipid 2	Lipid 3
d.	Lipid 1	Lipid 3	Lipid 2
e.	Lipid 3	Lipid 1	Lipid 2

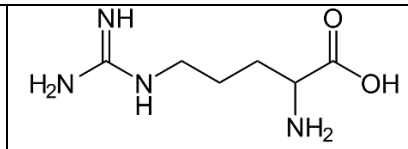
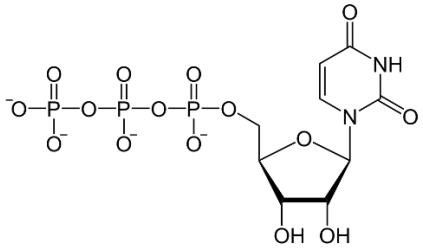
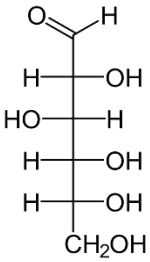


43. One of the main symptoms of cystic fibrosis (CF) is the buildup of thick dry mucus in the lungs. CF can be caused by a mutation in a chloride transporter channel that transports chloride outside the cytoplasm of lung cells. What would happen in the lung cell in someone with CF?
    a. Chloride ions build up in the cell and drive water into the cell
    b. Chloride ions build up in the cell and drive water out of the cell
    c. Water can no longer pass through the cell membrane
    d. Chloride ions build up outside the cell driving water out of the cell
    e. Chloride ions build up outside the cell driving water into the cell.

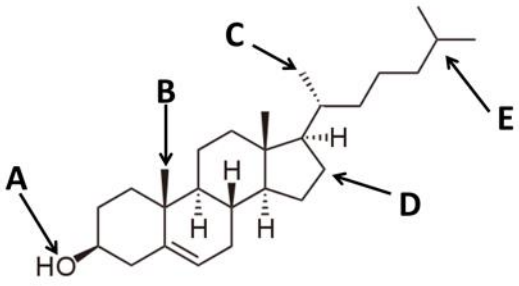
44. What is a shared characteristics of lipids and amino acids?
    a. Energy input is required for both of these macromolecules to fold into higher order structures.
    b. They have identical backbones, but variable side chains.
    c. During polymerization, monomers are linked to form long strands along their chemical backbones.
    d. Both of their chemical structures can include charged, non-polar, and polar regions.
    e. They are both synthesized by ribosomes.

45. Which of the following correctly pairs a type of macromolecule with one of its functions?
    a. nucleic acids – protect cell membranes from degradation
    b. lipids – help chains of amino acids fold into proteins
    c. proteins – store information
    d. carbohydrates – give cells structure
    e. ions – transport vesicles in the cell

46. Which of the following correctly pairs the monomer diagramed below with its respective polymer?

			
a.	Nucleic Acid	Polysaccharide	Protein
b.	Nucleic Acid	Protein	Polysaccharide
c.	Protein	Nucleic Acid	Polysaccharide
d.	Protein	Polysaccharide	Nucleic Acid
e.	Polysaccharide	Nucleic Acid	Protein

47. Below is an image of a molecule of cholesterol. Which of the arrows is pointing to a <u>polar region</u> of the molecule?



48. The 2019 Nobel Prize in medicine was awarded for the discovery of an oxygen-sensing protein called Hypoxia-Inducible Factor (HIF). HIF is made of 2 polypeptide subunits, which come together when the protein complex is activated. Activated HIF is a good example of a protein with what kind of structure?
    a. Primary
    b. Secondary
    c. Tertiary
    d. Quaternary
    e. Quinary

49. The drug tetrahydrocannabinol (THC) binds to the same receptors in the brain as the naturally produced neurotransmitter anandamide. If a synapse contains THC, what would occur?
    a. The axon terminal would not release anandamide
    b. The axon terminal would release anandamide all the time
    c. The axon terminal would not produce an action potential
    d. The anandamide receptors would not be activated
    e. The anandamide receptors would be activated all the time

50. The novel coronavirus of 2019-2020 is an RNA virus that may have spread to humans from an animal. Mutation in which of the following viral proteins is most likely to have been critically important to allow infection of humans?
    a. RNA polymerase
    b. Structural proteins surrounding virus genome
    c. DNA polymerase
    d. Surface proteins
    e. Ribosomes

THE END