

**University of Toronto  
National Biology Competition**

**2005 Examination**

**Thursday, April 28, 2005**

Time: 75 minutes

Number of questions: 50

General Instructions

Do not open this booklet until you are instructed to do so.

Print your name at the top of this booklet.

Indicate all of your answers to the questions on the separate Response Form. No credit will be given for anything written in this booklet, but you may use the booklet for notes or rough work. No additional time will be given after the exam to transfer your answers to the Response Form.

After you have decided which of the suggested answers is best, **COMPLETELY** fill in the corresponding bubble on the Response Form. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely.

Use your time effectively. Do not spend too much time on questions that are too difficult. Go on to other questions and come back to the difficult ones later if you have time. It is not expected that everyone will be able to answer all questions.

Good luck and have fun!

*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.

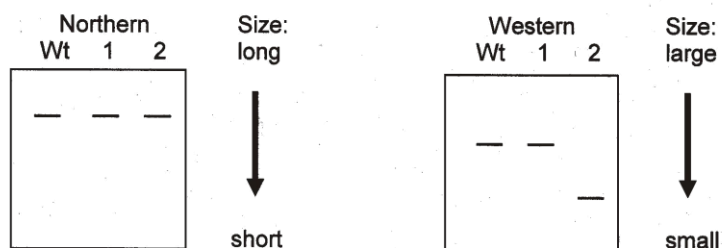
1. A biology teacher gave her students a culture of colourless single-celled organisms to study. The students observed that each cell was about 100  $\mu\text{m}$  in diameter, had a single nucleus, was rectangular in shape, and did not burst when placed in a hypotonic solution. Which statements about these organisms are supported by the observations?
  - i. They were eukaryotic.
  - ii. They were bacteria.
  - iii. They probably had a cell wall outside of the cell membrane.
  - iv. The organisms were cells that normally grew in salt water.
  - v. They were animal cells.
  - a. i and iii
  - b. i, iii, and v
  - c. i and iv
  - d. ii and iii
  - e. ii and iv
  
2. Which statement is **CORRECT**?
  - a. Animal cells have mitochondria and no chloroplasts; plant cells have chloroplasts and no mitochondria.
  - b. Energy is produced in the mitochondrion in the form of ATP and does not involve an electron transport chain; energy produced in the chloroplasts involves a light-activated electron transport chain.
  - c. Oxygen is released by the Calvin cycle during photosynthesis.
  - d. Pyruvate is the end product of the Krebs (citric acid) cycle.
  - e. Chloroplasts and mitochondria both produce ATP through the process of chemiosmosis.
  
3. What occurs when fat is synthesized?
  - a. One fatty acid and one glycerol molecule are hydrolysed.
  - b. Three fatty acid molecules combine with a molecule of glycerol to produce a molecule of fat plus three molecules of water.
  - c. Three fatty acid molecules are hydrolysed by three molecules of water and one molecule of glycerol to produce a fat molecule.
  - d. One fatty acid and one glycerol molecule are condensed.
  - e. All bonds between the carbon atoms in the hydrocarbon chain become single bonds.
  
4. A plant scientist visited his mother and admired her azalea plant that was huge and had healthy dark green leaves. "But it never flowers", his mother complained. What is the most likely reason why the plant did not flower?
  - a. The plant needed more calcium.
  - b. The plant had been given too much potassium.
  - c. The plant does not receive enough light.
  - d. The plant had been supplied with too much nitrogen.
  - e. The plant needed more magnesium.

5. First there was the Human Genome Project. Then scientists around the world began cataloguing all the proteins in the proteome. Now the Canadian-led International Regulome Consortium is taking on the challenge of deciphering the biochemical code that switches the 30,000 genes in the human genome on and off. What type of proteins will they be studying?
- Transcription factors
  - Proteases
  - Redox enzymes
  - Structural proteins
  - Neurotransmitters
6. What do biologists call the region of the chromosome where spindle fibres attach during mitosis and meiosis?
- Centriole
  - Centrosome
  - Centromere
  - Chromomere
  - Chromatid
7. The side chains of amino acids that are embedded in the interior portion of a membrane are best characterized as:
- hydrophobic.
  - acidic.
  - hydrophilic.
  - polar.
  - basic.
8. A person has a condition resulting in unusually large amounts of fat being eliminated in the feces, even though the diet is normal. What is the most likely explanation?
- Insufficient proteases from the pancreas.
  - Excess hydrochloric acid from the stomach.
  - Reduced number of receptors for the hormone gastrin, which acts on the stomach.
  - Lack of lipid transporter proteins in the small intestine.
  - Lack of a functioning gene for hormones acting on the gall bladder.
9. What aspect of DNA allows it to function as a hereditary molecule, faithfully carrying information from generation to generation?
- The simple composition of four nitrogenous bases.
  - The complementary base pairing during semi-conservative replication.
  - The incorporation of thymine instead of uracil.
  - The capacity for methylation of cytosines and adenines.
  - The formation of nucleosomes and higher-order chromatin structures.

10. A population of butterflies has two alleles for wing-spot colour. The red allele is fully dominant to the white allele. In a population of 200 diploid butterflies known to be in Hardy-Weinberg equilibrium there are 18 white-spotted butterflies. What percentage of the population is heterozygous?
- 9%
  - 18%
  - 21%
  - 42%
  - 63%
11. Some species of ants guard plants where aphids feed, preventing other potential predators from attacking the aphids. The aphids excrete a sweet fluid that the guard ants feed on. What term best describes this relationship between the guard ants and aphids?
- Mutualism
  - Parasitism
  - Commensalism
  - Predation
  - Social parasitism
12. A scientist was studying the production of a protein that was released by an animal cell into a culture medium. She found that the protein only appeared in the culture medium after she added a few drops of a hormone to the cell. Before adding the hormone, she labelled the protein inside the cell with a fluorescent dye and looked at the cell under the light microscope: the dye was seen in flattened sheets and tube-like structures throughout the cell, and in stacks of flattened sac-like structures. After adding the hormone, the dye was also seen as small dots clustered against the cell membrane. Which statement most likely explains these observations?
- The hormone stimulates protein synthesis in the cell vacuole; the protein is then passed to the Golgi apparatus, and eventually passes through the cell membrane by passive diffusion.
  - The hormone triggers the synthesis of the protein in the endoplasmic reticulum and it is then secreted outside of the cell via channel proteins in the cell membrane.
  - The protein is made on parts of the cytoskeleton, is passed to the Golgi apparatus, and is secreted through hormone-stimulated exocytosis.
  - The protein is made in the endoplasmic reticulum, is passed to the Golgi apparatus, and is secreted through hormone-stimulated exocytosis.
  - The protein is made in the Golgi apparatus, is passed to the endoplasmic reticulum, and is secreted through hormone-stimulated pinocytosis.
13. A molecule of carbon dioxide leaves a muscle cell in your leg and enters the blood in a capillary bed. On its way to leaving the body via exhaled air which of the following structures will it **NOT** pass through?
- The trachea
  - An alveolus
  - A pulmonary vein
  - A vena cava
  - The right atrium

14. A geneticist crossed *YYRR* (yellow-round) peas with *yyrr* (green-wrinkled) peas and self-pollinated the  $F_1$  to produce  $F_2$  offspring. In the  $F_2$  generation what proportion of the yellow-round individuals were pure-breeding (homozygous for both genes)?
- 1/16
  - 3/16
  - 1/4
  - 1/9
  - 9/16
15. A scientist cultured some single-celled amoebae which he fed with cells of smaller single-celled organisms. If he genetically modified these amoebae so that the hydrogen ion pumps found in the membrane of lysosomes only worked at temperatures below 16°C, what would happen if the temperature was raised to 20°C?
- The lysosomes would burst open.
  - The amoebae would die instantly because of the high level of hydrogen ions in the cytoplasm.
  - The amoebae would swell and burst.
  - The amoebae would starve to death.
  - The lysosomes would disappear.
16. Which of the following traits in an insect is most likely the result of sexual selection?
- Females possessing long ovipositors.
  - Males possessing larger mandibles to defend against predators.
  - Males and females both showing camouflage colouration.
  - Females laying sticky eggs on the undersides of large leaves.
  - Males having larger red patches on their wings than females.
17. Which of the following is the best example of a density-independent effect?
- Inbreeding depression reducing the reproductive success of an endangered species.
  - The spread of avian flu in commercial chicken farms.
  - The population cycles of Lynx (predator) and Hare (prey) in Canada's boreal forest.
  - The population decline in birds of prey due to water pollution.
  - The increase in water clarity in the Great Lakes resulting from the invasion of filter-feeding zebra mussels.
18. Body temperature in humans is normally controlled by homeostatic feedback mechanisms. A fever is a condition where the body temperature is higher than normal, usually during a bacterial or viral infection. Which of the following is the most likely causal mechanism of a fever?
- An increase in basal metabolic rate that produces more heat than the feedback system can cope with.
  - A change in the "set-point" of the negative feedback loop.
  - A decrease in the ability to cool, for example, by shutting down sweating.
  - An increase in the delay between a rise in body temperature and its detection in the brain.
  - An "opening" of the feedback loop, for example, by damage to the temperature-sensitive cells in the brain.

19. Two different mutations were found in a gene. The gene has been cloned and an antibody is available for the protein product of this gene. Northern and Western analyses were performed on each mutant (1 and 2) and the wild-type gene (Wt, no mutation). The results are shown below. What type of mutation has occurred in the two mutants?



- Mutants 1 and 2 both have missense mutations at different positions.
  - Mutant 1 has a missense mutation, while mutant 2 has a silent mutation.
  - Mutant 1 has a missense mutation, while mutant 2 has a nonsense mutation.
  - Mutant 1 has a nonsense mutation, while mutant 2 has a silent mutation.
  - Mutants 1 and 2 both have silent mutations at different positions.
20. In cancer cells, telomerase is often turned on again. How does this contribute to cell immortalization (the ability to grow and divide forever)?
- Telomeres would shorten and disappear.
  - Telomere lengths would be stabilized.
  - Broken chromosomes would have telomeres added to their ends.
  - Mutations in telomeric sequences would be repaired.
  - The rate of DNA replication starting from telomeres would increase.
21. What main nitrogenous waste product would most likely be secreted by a vertebrate whose natural habitat is a desert?
- Ammonia
  - Urea
  - Uric acid
  - Nitric acid
  - Nitrogen
22. Which of the following characteristics best describes the overall reaction resulting from the combustion of propane (which is shown in the equation below)?
- $$\text{C}_3\text{H}_8 (\text{gas}) + 5\text{O}_2 (\text{gas}) \rightarrow 3\text{CO}_2 (\text{gas}) + 4\text{H}_2\text{O} (\text{liquid})$$
- $$\Delta H = -2220 \text{ kJ/mol C}_3\text{H}_8$$
- Exothermic; propane is oxidized.
  - Endothermic; propane is oxidized.
  - Exothermic; propane is reduced.
  - Endothermic; propane is reduced.
  - Hydrogen and oxygen are hydrolysed to form water.

23. Which of the following would most likely reduce the chances of a species going extinct?
- Breeding only occurring in colonies of hundreds of individuals.
  - A highly specialized diet.
  - A low dispersal rate.
  - A small fundamental niche.
  - High genetic variation.
24. A drug that partially blocked receptors for luteinizing hormone (LH) in the hypothalamus would cause:
- decreased levels of GnRH (gonadotropin releasing hormone) in the blood.
  - atrophy of the testes.
  - increased levels of LH in the blood.
  - longer menstrual cycles.
  - impotence.
25. Which of the following is best suited to treatment with gene therapy?
- A dominant mutation (such as in Huntington's disease).
  - A recessive mutation (such as in cystic fibrosis).
  - An extra chromosome (such as in Down syndrome).
  - Gene amplification (such as *neu* in breast cancer).
  - A chromosome translocation (such as in Burkitt's lymphoma).
26. Which of the following is most likely to result in adaptive radiation?
- Stabilizing selection
  - Convergent evolution
  - Niche overlap
  - A diversity of habitats
  - Genetic drift
27. Which statement about structures found within cells is **CORRECT**?
- The chloroplast is surrounded by a single membrane, whereas the mitochondrion is surrounded by a double membrane.
  - Mitochondria and chloroplasts contain DNA and ribosomes.
  - Actin filaments (microfilaments) are found in plant cells on the outside of the cell membrane.
  - Animal cells do not contain centrioles.
  - Peroxisomes contain enzymes that break down long chains of carbohydrates.
28. Which characteristic is **NOT** shared by all chordates at some stage in their life cycle?
- Three primary cell layers
  - Dorsal, hollow nerve cord
  - Pharyngeal gill slits
  - Vertebrae
  - Bilaterally symmetrical body plan

29. A population is in Hardy-Weinberg equilibrium. Which statement about the population is most likely to be **CORRECT**?
- Females in the population choose their mates at random.
  - The force of natural selection acting on the population is greater than the force of genetic drift.
  - The force of natural selection acting on the population is less than the force of gene flow.
  - The mutation rate per generation is greater than  $1 \times 10^{&6}$ .
  - There are fewer than 500 individuals in the population.
30. For a science fair project, a student studied the pH within some animal cells. He found that when he grew the cells in a culture medium with a pH of 6.3, the pH inside the cytoplasm was 6.7. When he lowered the pH of the culture medium to 6.0, the pH inside the cell did not change, but when he added a powder that absorbed sodium ions to the same culture medium, the pH inside the cell decreased to 6.2. Which of the following is the best explanation for these results?
- Sodium ions are essential for living cells, so when sodium is removed from outside of the cell, the cell starts to die, which allows hydrogen ions to leak out of the cell.
  - Sodium removal prevents the action of pumps in the cell membrane that pump extracellular sodium ions into the cell by active transport and, at the same time, allows intracellular hydrogen ions to leave the cell along their concentration gradient.
  - Sodium ion removal prevents the normal flow of sodium into the cell through ion channels; this sodium normally neutralizes the acidity of the cytoplasm.
  - Sodium ions normally are pumped out of the cell to produce a sodium gradient across the cell membrane that can “power” the transport of hydrogen ions out of the cell against their concentration gradient as sodium is allowed to flow back into the cell; the removal of external sodium destroyed the gradient, so flow of hydrogen ions stops.
  - The cell membrane contains ion channels that carry sodium ions out of the cell along their concentration gradient, and sodium-activated hydrogen ion channels that allow hydrogen ions to pass into the cell along their concentration gradient; if sodium is removed, the hydrogen ion channel closes, preventing hydrogen ions from entering the cell.
31. Which of the following would have the greatest impact on decreasing a person’s ecological footprint?
- Consuming food grown at the top of the food chain.
  - Consuming vegetables grown on another continent.
  - Consuming only organically-grown vegetables produced on another continent.
  - Using an electric heater to heat the home instead of natural gas.
  - Walking to school or work rather than driving in a car.
32. A student looked at a slide of stained onion cells and found one where the chromosomes looked X-shaped and were scattered over the nuclear area. The cell was in:
- G1 phase of the cell cycle.
  - prophase.
  - metaphase.
  - anaphase.
  - cytokinesis.



33. A couple are both carriers of the autosomal recessive allele for albinism. They have two children. What is the probability that both children will be phenotypically identical with regard to skin colour?
- 1/4
  - 3/4
  - 1/16
  - 9/16
  - 5/8
34. Methane is a “greenhouse gas” that traps 25 times more heat than CO<sub>2</sub> and is thought to significantly contribute to global warming. Up to 12% of the food energy consumed by a cow is converted in the cow’s gut to methane, and released to the atmosphere when the cow burps or farts (passes gas). Scientists have found that if a cow is fed an antibiotic, the amount of methane released by the cow is reduced. They also found that samples of food from the cow’s stomach produce methane if put in a sealed container without air, but do not produce methane if air is bubbled through the mixture. When they heat the mixture above 100°C, methane production stops. What is the most likely explanation of these observations?
- Methane is produced by the action of the cow’s digestive enzymes, and these enzymes are inhibited by the presence of oxygen.
  - Methane is produced by bacteria in the cow’s gut through an anaerobic process involving enzymes.
  - Methane is produced by a non-biological chemical reaction that is inhibited by the presence of oxygen.
  - Viruses in the cow’s gut contain enzymes that produce methane through an anaerobic process.
  - The antibiotic introduced air into the cow’s gut that destroyed the methane, which is unstable in the presence of oxygen or when heated.
35. Which of the following is **NOT** shared by gymnosperms and angiosperms?
- Seeds
  - Pollen
  - Ovaries
  - Vascular tissue
  - Ovules
36. Bacteria that live in vents on the ocean floor (where hot magma superheats the water) have an extremely high proportion of guanine and cytosine in their DNA. Which statement best explains why this bacterial DNA is very stable in hot temperatures?
- The high guanine and cytosine content means the strands of bacterial DNA are less likely to be anti-parallel.
  - The chemical structure of purines makes them more heat stable.
  - The chemical structure of pyrimidines makes them more heat stable.
  - Guanine and cytosine base-pair with three hydrogen bonds; while the other nucleotides base-pair with two hydrogen bonds.
  - The phosphate bridges that allow adenine and thymine to base-pair are very unstable in hot environments.

37. As a class experiment, students added a chemical to elongated protist cells as they watched them under the microscope. The cells became spherical and organelles within the cells stopped streaming through the cytoplasm. What structure was most likely directly affected by the chemical?
- Cell wall
  - Cytoskeleton
  - Cell membrane
  - Centrosome
  - Vacuole
38. Very young mammals, as well as mature mammals that hibernate (such as grizzly bears), have “brown fat” cells containing very high numbers of mitochondria. These cells contain an “uncoupling protein” that prevents the build-up of a hydrogen ion gradient across the inner mitochondrial membrane. What is the most likely function of these cells?
- To synthesize high levels of fats.
  - To reduce the amount of oxygen consumed.
  - To produce high levels of energy in the form of ATP.
  - To produce heat.
  - To conserve glucose.
39. A soluble red dye is injected into the phloem of a young plant about half-way up the stem. At the same time a yellow dye is injected into the xylem at the same height along the stem. Which statement best explains where the two dyes will be found one day later?
- The tip of the plant (farthest from the soil) will contain only red dye; the tip of the root (deepest into the soil) only yellow dye.
  - The tip of the plant will contain only yellow dye; the tip of the root only red dye.
  - The tip of the plant will contain both red and yellow dye; the tip of the root only red dye.
  - The tip of the plant will contain only red dye; the tip of the root both red and yellow dye.
  - The tip of the plant will contain both red and yellow dye; there will be no dye in the tip of the root.
40. Which of the following is **LEAST** likely to result from the effects of global climate change?
- A lowering of ocean levels will result in the destruction of coral reefs and coastal habitats.
  - An increase in the frequency of severe storms.
  - An increase in drought in parts of North America.
  - Increased flooding.
  - A spread of tropical diseases to temperate areas.
41. Which of the following is **NOT** an advantage for insects that undergo complete metamorphosis in their development (such as butterflies)?
- The larval stage is specialized for feeding and growth.
  - The adult stage is specialized for dispersal and reproduction.
  - Pupae can suspend development and become dormant during periods of environmental stress.
  - Adults can be more mobile, improving the probability of locating a mate.
  - Feeding adults can disperse to new food resources, thus avoiding competition with larvae.

42. A young athlete was interested in bodybuilding and concluded that he would increase his muscle mass if he ate a high protein diet consisting mainly of cheese and well-cooked steaks. He gave five reasons for his decision, but only one was scientifically accurate. Which one of the following is the only correct statement?
- Proteins can be a source of energy.
  - Proteins are converted into muscle tissue more easily than amino acids.
  - Proteins cannot be converted into fats.
  - Proteins are not found in plant products such as peas and nuts.
  - The cooked steaks (derived from cattle muscle) would contain enzymes that help muscle development.
43. A store placed a large basket of fruit containing oranges and unripe bananas by the cash register. There were too many bananas to fit in the basket, so they put the rest in the back room. The next day, the bananas in the basket had ripened, but the ones in the back room had not. What is the most likely explanation?
- The heat in the store had accelerated the ripening process.
  - The oranges released gibberellins into the air, which triggered the bananas to ripen.
  - The cytokinins in the oranges diffused into the bananas where the two fruits touched each other and triggered the bananas to ripen.
  - The auxin in the oranges diffused into the bananas where the two fruits touched each other and triggered the bananas to ripen.
  - The oranges had released ethylene into the air, which triggered the bananas to ripen.
44. Female gametes (ova) are more likely (than male gametes) to have chromosomal abnormalities such as aneuploidies (where one or more chromosomes are either lacking or present in excess). What is the most likely reason for this?
- Oocytes arrest in prophase I during fetal development and remain there until ovulation decades later.
  - Developing oocytes are exposed to more fat soluble carcinogens.
  - Female germ cells are constantly replicating, starting at puberty.
  - Fluctuating hormone levels lead to chromosome nondisjunction in oocytes.
  - Chromosome non-disjunction leads to the formation of polar bodies.
45. Evaporative cooling is a process whereby \_\_\_\_\_ (1) moving \_\_\_\_\_ (2) molecules vaporize, thus \_\_\_\_\_ (3) large amounts of heat. (Fill in the blanks)

	(1)	(2)	(3)
a.	slow	water	adding
b.	fast	water	removing
c.	slow	oxygen	adding
d.	fast	oxygen	removing
e.	slow	carbon dioxide	removing

46. Which statement is **CORRECT**?
- Insects use hemolymph instead of blood to transport oxygen to their tissues.
  - An open (as opposed to closed) circulatory system lacks a heart and major blood vessels.
  - Small terrestrial organisms such as insects tend to lose water more rapidly relative to their body weight than large animals such as reptiles.
  - Insects cannot use muscle contraction to assist in gas exchange, and must rely solely on diffusion.
  - A closed circulatory system is necessary if an animal is to use a respiratory pigment for oxygen transport.
47. As humans diverged from other primates, which of the following most likely appeared first?
- The development of culture
  - Language
  - An erect stance
  - Tool making
  - An enlarged brain
48. Which of the following determines a population's intrinsic rate of increase?
- Amount of available resources
  - A Type 1 survivorship curve
  - A Type 3 survivorship curve
  - Maximum reproductive rate
  - Maximum population size
49. Autoimmune diseases result from a breakdown in the body's ability to:
- produce interferons.
  - produce memory cells.
  - distinguish between harmless and harmful viruses.
  - destroy Major Histocompatibility Complex (MHC) proteins.
  - distinguish "self" from "non-self".
50. Which statement about human vision is **CORRECT**?
- The pigmented cornea gives the human eye its colour.
  - In farsightedness (hyperopia), the retina is positioned too close to the lens.
  - The amount of light entering the eye is regulated by the lens.
  - Rod cells can distinguish colour in daylight.
  - Cone cells are responsible for vision in dim light.

End of exam.