University of Toronto
National Biology Competition

2009 Examination

Thursday, April 30, 2009

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. What aspect of their structure makes carbohydrates well suited for storing energy?

   a. Because simple carbohydrates are always polymers, they can form long, compact chains of atoms, which store energy more efficiently than monomers.
   b. The high number of carbon-hydrogen bonds release a large amount of energy when oxidized.
   c. Carbohydrate molecules are often attached to a functional group of ATP.
   d. Van der Waals forces that hold carbohydrates together release a large amount of energy when broken.
   e. The long chains of fatty acids attached to carbohydrates are saturated, thus every carbon atom has high-energy bonds with at least two hydrogen atoms.

2. Plants diversified dramatically after they colonized land. Which of the following is an adaptation of plants for life on land?

   a. Alternation of generations (haplodiplontic life cycle)
   b. Vascular tissue
   c. Fleshy fruits
   d. Large gametophytes
   e. Radially symmetric flowers

3. Which of the following taxonomic classifications for the poisonous mushroom *Amanita muscaria* is **CORRECT**?

   a. species: *muscaria*; genus: *Amanita*; kingdom: Plantae; domain: Eukarya
   b. species: *Amanita*; genus: *muscaria*; kingdom: Fungi; domain: Eukarya
   c. species: *muscaria*; genus: *Amanita*; kingdom: Plantae; domain: Archaea
   d. species: *muscaria*; genus: *Amanita*; kingdom: Fungi; domain: Eukarya
   e. species: *Amanita*; genus: *muscaria*; kingdom: Fungi; domain: Archaea

4. In a court case contesting the teaching of evolution in high school, the plaintiff claims that the lack of intermediate evolutionary forms in the fossil record calls into question the scientific validity of evolutionary theory. Which of the following constitutes the strongest rebuttal to the plaintiff's claim?
   a. It is not necessary to find intermediate evolutionary forms in the fossil record because evolutionary theory can be considered valid based on genetic data alone.
   b. Because the fossil record is so incomplete, we would not expect to find any intermediate evolutionary forms.
   c. Because evolution mostly occurs in sudden and rapid leaps of dramatic change, there have been very few intermediate evolutionary forms.
   d. The theory of irreducible complexity argues against the existence of intermediate forms, as they would most likely be poorly adapted to their immediate environment.
   e. The fossil record actually provides many examples of transitional evolutionary forms, including recently discovered fossilized remains of an extinct fish with leg-like limbs.

5. Which statement about lysosomes and peroxisomes is **FALSE**?

   a. Both contain digestive enzymes.
   b. Both are vesicle-like in structure.
   c. Both are formed by the Golgi apparatus.
   d. Both are bound by a single phospholipid bilayer membrane.
   e. Both are able to internally break down macromolecules.

© 2009 University of Toronto

6. Which statement regarding cellular respiration and photosynthesis is **FALSE**?

   a. Glycolysis begins with a hexose sugar; the immediate result of the Calvin cycle is a pentose sugar.
   b. Animals use a chemiosmotic proton pump located exclusively in their mitochondrial membranes to make ATP; plants use a chemiosmotic proton pump located exclusively in their chloroplast thylakoid membranes.
   c. Both mitochondria and chloroplasts are thought to have had endosymbiotic origins.
   d. C4 plants can maintain glucose output by avoiding photorespiration.
   e. In plants, energy storage from photosynthesis is greater than the energy released by cellular respiration.

7. Haemophilia is caused by an X-linked recessive allele. A couple about to have a baby is concerned that they may be carriers of the allele. Though neither of them are haemophiliacs, the man's father and the woman's mother are both haemophiliacs. The couple knows the fetus is male. What is the probability that their baby boy will have haemophilia?

   a. 0
   b. 0.25
   c. 0.50
   d. 0.75
   e. 1.0

8. An anticodon nucleotide sequence of five successive tRNA's involved in protein synthesis was analysed, yielding the following content:

A	G	C	T	U
40%	27%	13%	0%	20%

   What was the corresponding anti-sense strand of original DNA?

	A	G	C	T	U
a.	20%	13%	27%	40%	0%
b.	40%	27%	13%	20%	0%
c.	60%	27%	13%	0%	0%
d.	20%	13%	27%	0%	40%
e.	40%	27%	13%	0%	20%

9. Which of the following statements about the phospholipid bilayer that makes up the cell membrane are **CORRECT**?

   i. It is a fluid layer of completely hydrophobic (nonpolar) molecules.
   ii. Phospholipid molecules move constantly along the plane of the membrane.
   iii. Proteins embedded in the membrane can act as hydrophilic channels for molecules entering or exiting the cell.
   iv. Molecules can only enter or exit the cell through transmembrane proteins.

   a. i, ii, iii, and iv
   b. i, iii, and iv
   c. i and ii
   d. ii and iii
   e. iv only

© 2009 University of Toronto

10. In the development of a mammalian embryo, the zygote quickly divides into multiple cells, forming a spherical blastocyst. What happens in the next developmental stage?

    a. The blastocoel forms, a process called gastrulation.
    b. The blastocyst expands, doubling its volume through additional cellular division.
    c. The neural groove begins to take shape above the notochord, a process called neurulation.
    d. The dorsal-ventral axis is formed and organogenesis begins.
    e. The embryonic cells reorganize into the three primary germ layers.

11. Jack sold his cow for some bean seeds. He put the dry seeds in some damp soil and noticed they didn't grow. A friend told him he should soak them in water in order to 'wash out' a certain plant growth hormone that was in high concentration within the seed coat. The hormone was which of the following?

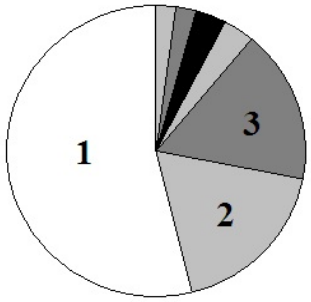
    a. Ethylene
    b. Gibberellin
    c. Abscisic acid
    d. Cytokinin
    e. Auxin

12. Important in cellular respiration, the citric acid (Krebs) cycle also acts as a hub for several 'side' metabolic pathways. Which common food additive could become a participant in the cycle via such a pathway?

    a. Glycogen
    b. Maltose
    c. Citric acid
    d. Methyl cellulose
    e. Monosodium glutamate

13. The chart at the right illustrates a recent global estimate of the relative number of described species of major groups of living organisms.
    Group 1 = insects, and 3 = other invertebrates.
    Which group is represented by the group labelled "2"?

    a. Bacteria
    b. Protozoa
    c. Plants
    d. Fungi
    e. Vertebrates



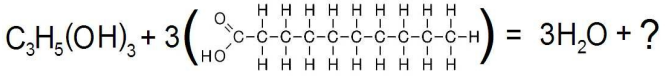
14. Which statement about cytokinesis in plant cells is **CORRECT**?

    a. Division begins with the formation of a cell plate, a line of fused vesicles within which the cell walls of the daughter cells form.
    b. The kinetochores are pulled apart by kinetochore microtubules.
    c. Daughter nuclei do not separate until cytokinesis has occurred.
    d. It begins with the appearance of a cleavage furrow, formed by a band of actin, which separates the daughter cells.
    e. The circular chromosome must first replicate before binary fission can begin.

© 2009 University of Toronto

15. The reaction below illustrates an important anabolic process occurring in the human body. What product other than water is the net result?

    a. A protein
    b. An amino acid
    c. RuBP
    d. A sugar
    e. A fat



16. The geographic distribution of animals or plants in a population is:

    a. most often uniform, providing each individual with the maximum availability of space and resources.
    b. most often clumped, with individuals gathered around resources such as food or mates.
    c. determined by the amount of daylight as compared to hours of darkness.
    d. random in most species.
    e. spatially uniform only when competition for food resources is low.

17. In the mammalian circulatory system, what path does deoxygenated blood take when travelling toward the heart?

    a. It enters the right atrium of the heart via the superior and inferior vena cavae.
    b. It passes through the capillaries to the arterial system, then enters the right ventricle of the heart.
    c. It travels to the lungs, via the pulmonary vein, then enters the left ventricle of the heart via the inferior vena cava.
    d. It enters the left atrium of the heart via the aorta and is then pumped into the right atrium.
    e. It enters the right ventricle of the heart via the superior vena cava.

18. What is the origin of Down syndrome?

    a. An excess of DNA ligase, causing abnormal DNA replication.
    b. A tandem duplication of DNA during meiotic cell division.
    c. A point mutation in the gene encoding a histone.
    d. A frameshift mutation during fetal development.
    e. Nondisjunction of parental chromosomes during meiosis.

19. Multiple sclerosis is an autoimmune disorder in which the body's immune system attacks and destroys the myelin of its own nervous system. What implications does this damage have for the nervous system?

    a. The cell bodies of nerve cells can no longer reach action potential because the receptors that take up sodium have been damaged.
    b. Degraded myelin molecules block receptor proteins in the postsynaptic membrane.
    c. Lack of myelin decreases production of acetylcholine (a neurotransmitter), disrupting muscular coordination.
    d. Axons conduct nervous impulses less effectively because their insulating sheaths have been damaged.
    e. Because the corpus callosum is made of myelin, the right and left sides of the brain are no longer able to communicate.

© 2009 University of Toronto

20. At the onset of normal exhalation in mammals, which statement is **CORRECT**?
    a. The thoracic cavity increases in size.
    b. The intercostal muscles contract.
    c. The pressure in the lungs increases.
    d. The diaphragm moves down.
    e. The rib cage moves up and out.

21. Energy enters an ecosystem via photosynthesis and moves up through the ecosystem's trophic levels. All of this energy will be:
    a. used as fuel by the top predators in the ecosystem.
    b. converted into glucose by the primary producers.
    c. translated into the net primary productivity (NPP) of the ecosystem.
    d. converted into heat, a type of energy unusable by life on Earth.
    e. converted into ATP, the molecule that provides energy for all organisms.

22. A population of laboratory rats in Hardy-Weinberg equilibrium displays a polymorphism for coat colour controlled by two alleles at a single locus. The *B* allele codes for black coat colour and is completely dominant. There are 200 rats in the population: 32 are white and 168 are black. How many of the black rats are heterozygous (*Bb*) at the coat-colour locus?
    a. 160
    b. 96
    c. 72
    d. 48
    e. 32

23. If the concentration of CO_2 suddenly increases in the air surrounding a plant, how is the plant most likely to respond?
    a. Some of the stomata will close because fewer open stomata are needed to take up CO_2.
    b. Water loss will cause the plant to wilt, stimulating it to draw more water up from its roots.
    c. The plant will begin to photosynthesize less because of an excess of CO_2.
    d. The plant will increase its rate of transpiration to aid gas exchange with the atmosphere.
    e. The plant will increase its rate of O_2 uptake to balance out the increase in CO_2.

24. Which reproductive hormones in the list below are **NOT** produced in the ovaries or testes of adult humans?
    i. Testosterone
    ii. Follicle-stimulating hormone
    iii. Estrogen
    iv. Progesterone

    a. i only
    b. ii only
    c. iii only
    d. iii and iv only
    e. i, ii and iii only

© 2009 University of Toronto

25. A DNA restriction enzyme 'recognizes' the sequence TGAGA and cleaves a 5' to 3' strand between the two GAs. Single stranded DNA samples from a 20 bp locus from a crime scene and from four bank robber suspects are cleaved with the enzyme, and the fragments are run on an electrophoresis gel. The crime scene fragment is known to be: 5' CACTGAGACCAGTTGAGAGC 3'. Which suspect DNA profile below would produce a pattern on the gel most similar to the pattern at the crime scene?

    a. 5' GTCTGAGACTTCTGAGAATG 3'
    b. 5' AGTTTGAGAGTAGTGAGATG 3'
    c. 5' TCCATGAGACTTTTGAGATG 3'
    d. 5' ACTCGAAGTGTGAGATGAGA 3'
    e. 5' CGGTGAATGAGATTGAGAGT 3'

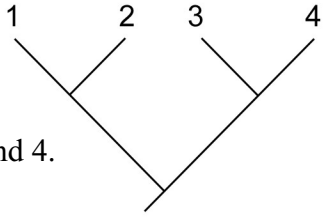
26. Which method of transport across a cell membrane does **NOT** directly involve a protein?

    a. Receptor-assisted endocytosis
    b. Active transport
    c. Facilitated diffusion
    d. Phagocytosis
    e. The sodium-potassium pump

27. The human thyroid gland is controlled by a negative feedback mechanism. The hypothalamus secretes thyrotropin-releasing hormone (TRH). TRH stimulates the anterior pituitary to secrete thyroid-stimulating hormone (TSH). TSH induces the thyroid gland to secrete thyroxine. What is the next step in the control system?

    a. Thyroxine will inhibit the secretion of TRH.
    b. Thyroxine will cause the body's basal metabolic rate and body temperature to drop.
    c. The hypothalamus will secrete a thyroid-inhibiting hormone that slows down production of thyroxine.
    d. Thyroxine will stimulate the increased production of TSH.
    e. The thyroid gland will respond to the rising level of thyroxine and slow down its production.

28. The phylogenetic tree below is a hypothesis of the evolutionary relationships between four species. Which statement is **CORRECT**?



    a. Species 1 evolved first.
    b. Species 3 and 4 are more highly evolved than species 1 and 2.
    c. Species 4 evolved last.
    d. Species 2 and 3 are more closely related to each other than are species 1 and 4.
    e. All four species share a common ancestor.

29. A cell in the G1 phase has two homologous pairs of chromosomes. It undergoes a mitotic division, followed by meiosis. At the end of meiosis 2, what is the sum of all the products of these divisions in all cells?

    a. 16 chromosomes, 16 chromatids, 8 cells, 4 times as many alleles.
    b. 8 chromosomes, 16 chromatids, 8 cells, 2 times as many alleles.
    c. 8 chromosomes, 16 chromatids, 16 cells, 4 times as many alleles.
    d. 8 chromosomes, 16 chromatids, 4 cells, 4 times as many alleles.
    e. 16 chromosomes, 16 chromatids, 4 cells, 4 times as many alleles.

© 2009 University of Toronto

30. What affect does aging (senescence) have on telomerase activity?
    a. Aging cells gradually lose their ability to edit introns from transcribed mRNA sequences, leading to failures in protein synthesis.
    b. Chromosomes gradually decrease in length because normal DNA synthesis cannot complete replication at the end of the lagging strand.
    c. The cell's ability to repair mistakes made during DNA replication decreases, allowing the number of base substitutions in the genome to increase.
    d. DNA replication in the 3' to 5' direction is unaffected, but replication in the 5' to 3' direction slows down, decreasing the rate at which dying cells can be replaced.
    e. DNA can no longer completely uncoil, making replication and gene expression less efficient.

31. An alien visits Earth and is found to have the same 'genetic code' as humans. However, the alien has many more 'stop' codons which replace codons that are redundant in the human genetic code. If nucleotide substitution errors occur at the same rate for aliens and humans, the aliens would have many more of which kind of mutations?

    a. Missense mutations only
    b. Silent mutations only
    c. Nonsense mutations only
    d. Antisense mutations only
    e. Silent and missense mutations

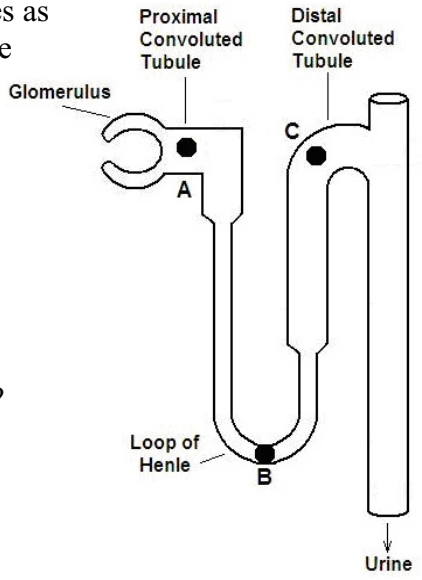
32. Endothermic vertebrates face challenges in regulating their internal temperature. Which statement about endotherms is **FALSE**?

    a. Because small endotherms have a large surface-to-volume ratio, they lose heat relatively more quickly in a cold environment than large endotherms.
    b. Most endotherms have low metabolic rates and need very little energy in order to maintain their stable body temperature.
    c. Sweating and panting are mechanisms that some endotherms use to evaporatively cool their bodies under hot conditions.
    d. In cold conditions, endotherms must sometimes use thermogenesis to maintain body temperature, for example, breaking down stores of fat to generate heat.
    e. Because heat transfer in endotherms is managed through blood flow, an effective way to alter heat exchange with the environment is to dilate or constrict the blood vessels.

33. Which factors regulate the output of the light-independent Calvin cycle (also known as the "dark reaction") in plants?
    i. Concentration of CO_2 in the leaf
    ii. Concentration of O_2 in the leaf
    iii. Amount of photorespiration
    iv. Temperature
    a. i only
    b. i and ii only
    c. i and iii only
    d. i and iv only
    e. i, ii, iii, and iv

© 2009 University of Toronto

34. The solute concentration of fluid in the mammalian nephron changes as the filtrate passes along the tubule. Which statement about the solute concentrations A, B, and C (as shown in the figure at right) is **CORRECT**?



a. A > B and B > C
b. A < B and B < C
c. A > B and B = C
d. A < B and B > C
e. A > B and B < C

35. Which of the following is the best example of sympatric speciation?

a. Darwin's finches
b. Peppered moth
c. Convergent evolution
d. Polyploidy in plants
e. Mimicry

36. Which statement about evolution is **CORRECT**?

a. Analogous structures may be used to infer evolutionary relationships between organisms.
b. The existence of vestigial structures, which are structures found in organisms but not used, is consistent with evolutionary theory.
c. As it is a theory, evolution has not yet been subject to a vast amount of experimental verification.
d. The development of complex structures (e.g., the eye) by accident is consistent with evolution by natural selection.
e. Natural selection can provide a population with new source of alleles.

37. Electron transport down an electrochemical gradient (chemiosmosis) is critical to which of the following cellular processes?

i. Aerobic respiration
ii. Photomorphogenesis
iii. Oxidation-reduction
iv. Photosynthesis
v. Glycolysis

a. iii and v
b. ii, iii, and iv
c. i and iv
d. i, iii, and v
e. i, ii, iii, and iv

38. Which functional group is common to starch, ATP, DNA, and proteins?

a. Carboxyl
b. Ketone
c. Hydroxyl
d. Carbonyl
e. Phosphate

© 2009 University of Toronto

39. Which statement regarding demographic changes for the global human population during the last 6,000 years is most likely to be **CORRECT**?

    a. The value of the carrying capacity, *K*, has changed during the last 6,000 years.
    b. The overall population trend for the past 6,000 years has been exponential.
    c. Since about 1800, the overall global population has reached its carrying capacity.
    d. Dramatic, regular population oscillations have occurred during most of this time.
    e. Prior to 1800, the intrinsic rate of natural increase (*r*) was much greater than 1.

40. What would be the effect of a substance blocking the action of the enzyme cholinesterase at a neural synapse?

    a. The receptor channels in the post-synaptic membrane would not open.
    b. Acetylcholine would be broken down too quickly for neural excitation to occur.
    c. The postsynaptic neuron would repolarize more quickly.
    d. Acetylcholine would not be released from synaptic vesicles in the pre-synaptic neuron.
    e. Acetylcholine would build up and not allow recovery in the post-synaptic neuron.

41. What is most likely to happen when a human red blood cell is suspended in a hypertonic solution?

    a. Nothing, as red blood cells are normally suspended in a hypertonic solution.
    b. Water will diffuse out of the cell, causing it to shrivel up.
    c. Aquaporins will pump water into the cell in an effort to create an isotonic environment within the cell.
    d. Due to high osmotic pressure, water will diffuse into the cell, causing it to burst.
    e. Water will diffuse out of the cell, but the rigid cell wall will help the cell to maintain its shape.

42. Which of the following describes the defining difference between eukaryotic cells and prokaryotic cells (that is, the difference that gives each their name)?

    a. Eukaryotic cells have cilia, while prokaryotic cells have pilli.
    b. Eukaryotic cell walls consist of carbohydrates, while prokaryotic cell walls consist of carbohydrates and peptides.
    c. Eukaryotic cells have membrane-enclosed genetic material, while prokaryotic cells do not.
    d. Eukaryotic cells are autotrophic or heterotrophic, while prokaryotic cells are only heterotrophic.
    e. Eukaryotic genomes are organized into multiple linear chromosomes, while prokaryotic genomes are contained in a single circular chromosome.

43. How does a ribosome interact with the cell's genetic material during translation?

    a. It enters the cell's nucleus in order to directly translate the cell's DNA sequence into a sequence of amino acids.
    b. A molecule of mRNA brings amino acids to the ribosome, which the ribosome then assembles into tRNA.
    c. A ribosome translates the amino acid sequence of a tRNA molecule into mRNA, which then assembles the protein.
    d. A ribosome translates the sequence of an mRNA molecule into a sequence of amino acids, which are retrieved by tRNA molecules.
    e. A molecule of mRNA inside the nucleus sends tRNA molecules into the cytoplasm to direct a ribosome to assemble the protein.

© 2009 University of Toronto

44. Males of a species of lizard that lives on an island are red, females are brown. Recently, introduced rats have been noted to eat the males that are brightest in colour, rathen that dull red males. After many generations, male lizards look brown. This is an example of which process?

    a. Natural selection
    b. Divergent evolution
    c. Disruptive selection
    d. Sexual selection
    e. Exaptation

45. The cryptic shape, cryptic colouration, and cryptic behaviour of a leaf-eating insect are most likely to be evidence of which kind of biological relationship?

    a. Mutualism
    b. Interspecific competition
    c. Commensalism
    d. Predation
    e. Intraspecific competition

46. In cellular respiration _____is oxidized and _____ is reduced. (Fill in the blanks)

	Oxidized	**Reduced**
a.	$FADH_2$	NADH
b.	glucose	$FADH_2$
c.	NADH	$FADH_2$
d.	$FADH_2$	glucose
e.	glucose	FAD

47. What happens to a chlorine atom when it gains a single electron from a sodium atom?

    a. It will share the added electron with the sodium atom, forming a covalent bond.
    b. It will continue to gain extra electrons from other sodium atoms.
    c. It becomes a cation because it has a charge of +1.
    d. It will form an ionic bond with the positively charged sodium atom.
    e. It will quickly lose the added electron to another chlorine atom.

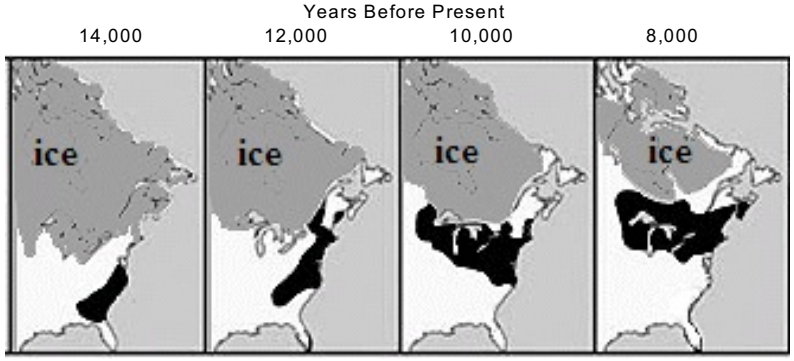
48. In the 1980s, molecular biologists at Harvard University developed and patented OncoMouse®, a mouse carrying an oncogene within its genome. What quality of this mouse makes it useful for biological experimentation?

    a. Oncogenes interfere with the cell's ability to repair mistakes made in DNA replication, so the mouse would have a higher than average number of genetic defects.
    b. Oncogenes promote DNA methylation, which is critical to precise control of gene expression.
    c. Oncogenes interfere with the cell's control over rates of mitosis and cell division, so the mouse would be more likely to develop cancer.
    d. Oncogenes trigger meiosis, so the mouse would produce more gametes and be more fertile.
    e. Oncogenes are tumour-supressing genes, so the mouse's cells would be better able to curb the development of cancerous cells.

© 2009 University of Toronto

49. During the Late Pleistocene in North America, pine trees (dark shading in the figure below) colonized southern Ontario. This is an example of which biological process?

    a. Adaptation to environment
    b. Translocation
    c. Succession
    d. Directional selection
    e. Competition



50. You have a summer job in a lab breeding fruit flies. You are given your first mating pair of flies, both of which have grey bodies and normal wings. You are asked to start a population of flies that share these characteristics with their parents. But upon mating the two flies, you end up with a large amount of variation, as described in the table below. Which statement best explains the outcome of your cross?

Traits	**Number of fly offspring**
Grey body, normal wings	45
Black body, shrivelled wings	5
Grey body, shrivelled wings	15
Black body, normal wings	15

    a. The alleles for body colour and wing shape assort independently.
    b. Crossing over failed to occur during meiosis, generating an unexpected ratio of traits.
    c. Grey body and normal wings are incompletely dominant traits.
    d. The body colour and wing shape traits are polygenic.
    e. The alleles for body colour and wing shape did not segregate during meiosis.

End of exam.

• Thank you for participating in the 2009 National Biology Competition!

• Competition results, including scholarship information, certificates, and cash prizes, will be received by your school in late May.

• Honour rolls of the top students and schools, the names of the students eligible for a competition scholarship, and the exam questions with answers will be posted on the competition's website during the week of May 25th: biocomp.utoronto.ca.

© 2009 University of Toronto