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Supplemental Materials

for

The Use of Group Activities in Introductory Biology Supports Learning Gains and Uniquely Benefits High-Achieving Students

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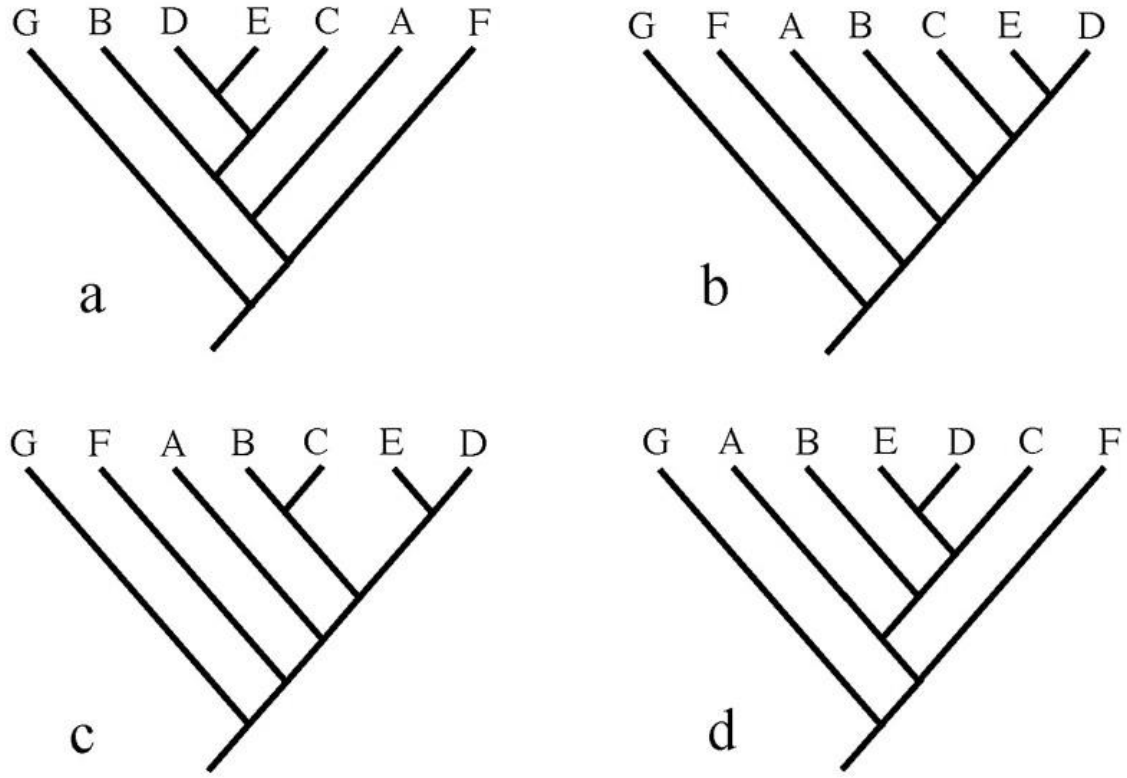
Appendix 2: Principles of Biology III – pre examination.

(Note, the correct answer is bolded)

(1) Which of the four trees below depicts a different pattern of relationships than the others? Explain.
Answer: C



(2) If you were to measure and plot the metabolic rates of a series of mammal species that had very similar body shapes but ranged in size from very small to very large, would you expect that metabolic rate would

a) be nearly indistinguishable among all species measured since all mammals are warm-blooded
b) increase more slowly than body length
c) increase more quickly than body length
d) increase at about the same rate as body length

(3) Constraints imposed by the physics of diffusion

a) largely explain many of the structural features of multicellular organisms
b) account for the success of early eukaryotic organisms

c) explain why molecules can move rapidly from cell to cell even in very large organisms like elephants

d) are relevant to the movement of molecules through the air, but are largely irrelevant within the bodies of organisms

(4) A chemical reaction associated with a large decrease in Gibbs free energy,

a) is unlikely to occur in a living organism since it would not be adaptive

b) requires a small input of energy to occur

c) requires a large input of energy to occur

d) brings the system closer to chemical equilibrium

(5) Electron transport chains

a) **involve sequences of electron carriers, each of which alternates between a reduced and oxidized state**

b) involve sequences of electron carriers, each type of which is always either reduced or oxidized

c) play a major role in glycolysis but not in oxidative phosphorylation

d) play a major role in mitochondria but not in chloroplasts

(6) All of the following are likely explanations for why sexual reproduction is the norm in eukaryotes, with one exception. Which is NOT such an explanation?

a) Genetically variable progeny are more prepared for a variable environment or parasites.

b) Sexual reproduction greatly increases the population growth rate compared to parthenogenesis.

c) Sex allows harmful mutations to be selectively eliminated from the genome.

d) Sex can speed adaptation by bringing together rare beneficial mutations.

(7) For which of the following are the events or stages of animal development in the correct order (earliest to the left, latest to the right)?

a) organ formation blastula gastrulation fertilization cleavage

b) cleavage gastrulation blastula fertilization organ formation

c) fertilization cleavage gastrulation blastula organ formation

d) blastula gastrulation cleavage organ formation fertilization

e) fertilization cleavage blastula gastrulation organ formation

(8) Which of the following traits first appeared in flowering plants, and is not shared with gymnosperms?

a) Seeds

b) Formation of separate mega- and micro-spores

c) Fruits derived from an ovary wall

d) Secondary xylem (wood)

e) Meiosis

(9) Which of the following explains why water tends to cross into the cytoplasm of root cells from the soil and the surrounding cell walls?

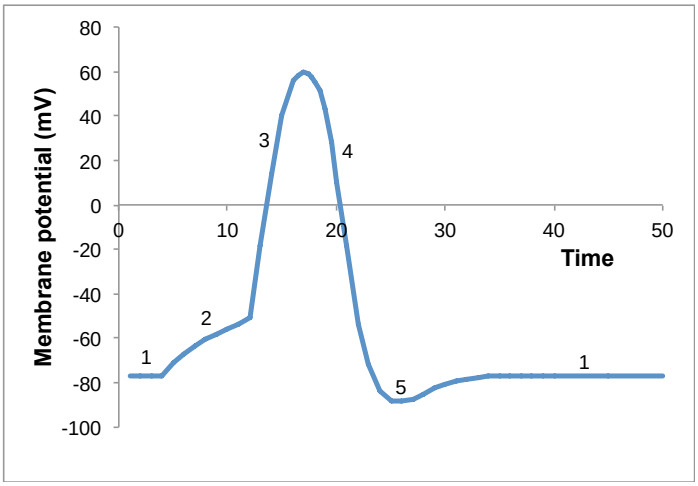
a) There is lower concentration of solutes in the root cells than in the surrounding soil solution.
b) There is a higher concentration of solutes in the root cells than in the surrounding soil solution.
c) There is a proton pump that is acidifying the soil solution, and this proton gradient powers active transport.
d) Water is attracted by oxidative phosphorylation.
e) none of the above

(10) Consider a situation where an equimolar mixture of CO_2 and O_2, each at a partial pressure of 0.5 Atm, is sealed into a chamber with a small beaker of water and held there for several days. With this in mind, is the following statement true or false? "After several days, the concentration of CO_2 and O_2 dissolved in the water will be the exactly same."

a) True
b) False

(11) In an action potential shown here, which point on the curve corresponds to membrane potential that is mostly controlled by the movement of sodium ions?

a) 1
b) 2
c) 3
d) 4
e) 5



(12). The response of a neuron and whether it fires an action potential depends on

a) It receiving excitatory stimulus
b) It receiving inhibitory stimulus
c) It receiving excitatory and inhibitory stimulus but discounting the inhibition
d) It receiving excitatory and inhibitory stimulus but discounting the excitation
e) It receiving excitatory and inhibitory stimulus and integrating them both

(13) In learning and memory, neural synapses can be modified by

a) Changing the type of ion that flows through a channel
b) Changing the neurotransmitter that a gated channel responds to
c) Changing the number of gated channels in the presynaptic neuron
d) Changing the number of gated channels in the postsynaptic neuron
e) Changing the neurotransmitter released by the post synaptic neuron

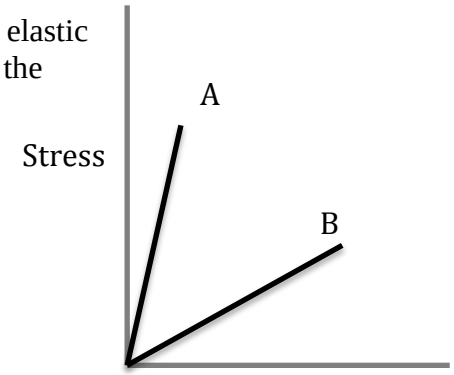
(14) Sensory neurons are specialized and so differ from other types of neurons in many ways. Which of the following is NOT one of those

a) They are located in in organs specialized to gather signals from the environment
b) They maximize the amount of membrane containing receptor proteins
c) They utilize specialized receptor molecules which detect a particular kind of stimulus
d) They produce neural outputs that tell downstream neurons about the signal received

(15) Why would an organism have both ionotropic and metabotropic receptors for sensing signals?

a) Both receptor types are designed for high speed
b) Both receptor types are designed for high sensitivity
c) Ionotropic receptors are designed for speed and metabotropic receptors are designed for sensitivity
d) Ionotropic receptors are designed for sensitivity and metabotropic receptors are designed for speed
e) Ionotropic receptors are designed for speed and sensitivity but metabotropic receptors are poor at both

(16) The stress – strain curve provides information on how stiff or elastic a material is and ends at the point of failure. Two objects are the same overall size but are made of different materials. If the same series of tensile forces are applied to each, which of the following is true?



a) A will change length more than B and has a larger tensile strength
b) A will change length less than B and has a larger tensile strength
c) A will change length more than B and has a smaller tensile strength
d) A will change length less than B and has a smaller tensile strength

(17) What would be the effect on muscle contraction if troponin was defective and could not interact with tropomyosin, preventing the complex from binding to actin?

a) Muscle contraction could no longer occur.
b) Muscles could not relax after contraction.

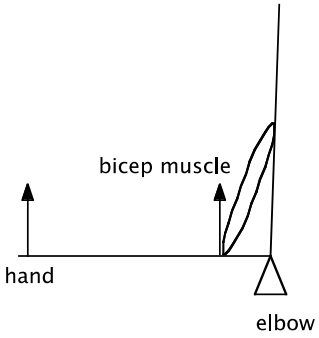
c) Muscle contraction would be weakened but would still occur as long as tropomyosin is functional.
d) ATP could not be hydrolyzed by enzymes in the muscle.

(18) When the branch of a tree is bending under the weight of heavy snow, it is less likely to break if,

a) the wood on the upper side of the branch is strong in compression
b) the branch is hollow
c) the wood on the lower side of the branch is strong in compression
d) the radius of the branch is small
e) the wood on the lower side of the branch is strong in tension

(19) Your elbow is a lever system. When you use your bicep muscle to lift your hand, the muscle must apply a certain force to lift the load of the hand. Which of the following is true?

a) The hand moves less than the muscle and the load lifted is less than the force applied by the muscle.
b) **The hand moves more than the muscle and the load lifted is less than the force applied by the muscle.**
c) The hand moves less than the muscle and the load lifted is more than the force applied by the muscle.
d) The hand moves more than the muscle and the load lifted is more than the force applied by the muscle.



(20) Which means of locomotion requires the least amount of energy?

a) Running with legs in semi-erect position (like a chimpanzee)
b) Running with legs in a sprawling position (like a crocodile)
c) Swimming (like a penguin)
d) Flying (like a sea gull)

Appendix 3: Principles of Biology III - Final Examination.

(BSCI 207)

Instructions:

- Put your name, section, and UID on this first page.
- Read each question carefully
- Place all multiple choice or True/False answers (#1-45) on the Scantron using #2 pencil
- Place essay answer in (and ONLY in) the spaced provided.
- You have 120 minutes for this exam
- Please note you are supposed to have **13** pages. Make sure you have 13 pages. Equations are on the last page.

Questions 1 – 45 (Scantron including 1 extra credit)	_____ of 110 points
Question 46	_____ of 5 points
Question 47	_____ of 10 points
Question 48	_____ of 6 points
Question 49	_____ of 5 points
Question 50	_____ of 8 points
Question 51	_____ of 6 points
Total	**_____ of 150 points**

Please read and sign that you agree to follow the University of Maryland honor pledge:
"I understand my obligation to uphold the University Code of Academic Integrity and pledge I have not received or given any unauthorized assistance on this academic exercise."

Signature _____ Date_____

QUESTIONS 1-45: MULTIPLE CHOICE, 2.5 POINTS PER QUESTION (includes 1 extra credit)

1) All of the following are likely explanations for why sexual reproduction is the norm in eukaryotes, with one exception. Which is NOT such an explanation?
   a) Genetically variable progeny are more prepared for a variable environment or parasites.
   b) Sexual reproduction greatly increases the population growth rate compared to parthenogenesis.
   c) Sex allows harmful mutations to be selectively eliminated from the genome.
   d) Sex can speed adaptation by bringing together rare beneficial mutations.

2) Which of the following best explains why terrestrial fungi are isogamous?
   a) They don't have sex, so they don't need any gametes.
   b) Plasmogamy and karyogamy are separated in time and space.
   c) Their attached gametes grow into each other and there is no embryonic development.
   d) Mycelia have huge surface areas for digestion and absorption of nutrients.
   e) Mushrooms are largely composed of heterokaryotic cells.

3) Which of the following is true about the Hox genes?
   a) Each gene is expressed throughout the organism, but is only necessary in some segments.
   b) They encode secreted signaling proteins related to *Sonic hedgehog*.
   c) They are only found in *Drosophila* and related flies.
   d) Their expression in the embryo is collinear with their order on the chromosome.
   e) They are crucial to distinguish sepals from petals.

4) Which of the following best summarizes the forces bringing water to the top of a tall tree?
   a) osmotic pressure in the roots + transpiration in the leaves
   b) osmotic pressure in leaves + transpiration in the roots
   c) osmotic pressure in the roots and upper branches
   d) proton pumps in companion cells drive water into the root phloem
   e) osmotic pressure in stomatal guard cells + evaporative tension in the bark

5) Which of the following transport mechanisms are shared by root cells importing NO_3^- from soil, phloem companion cells concentrating sugar, AND mammalian intestinal cells importing glucose from the lumen of the gut?
   a) symplastic transport
   b) a cotransporter/symporter that uses an ion gradient generated by a separate ATPase pump
   c) cation exchange in the extracellular environment
   d) a single pump protein that burns ATP and concentrates the solutes
   e) facilitated diffusion

6) At a partial pressure of 100 mm of Hg, oxygen will dissolve into adjacent water to a concentration of roughly 0.1 mM. If you climb a mountain to 6000 meters above sea level, the partial pressure of oxygen in the lungs decreases to 50 mm of Hg. According to Henry's Law, what would the concentration of oxygen in water be at this elevation?
   a) 0 mM
   b) 0.05 mM
   c) 0.1 mM
   d) 0.2 mM
   e) none of the above

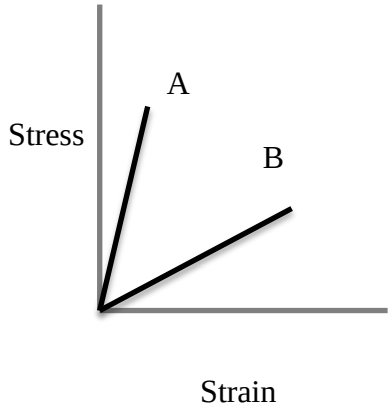
7) Where in the human digestive system does breakdown of starches begin?
   a) the mouth
   b) the stomach
   c) the pancreas
   d) the small intestine
   e) the colon

8) Which of the following experiments most directly demonstrated that a product of the gene *bicoid* was necessary to specify the anterior of a fruit fly (*Drosophila*) embryo?
   a) UV irradiation of the posterior pole of the embryo.
   b) UV irradiation of the anterior pole of the embryo.
   c) removal of *bicoid* function during oogenesis of homozygous mutant mothers.
   d) ectopic transfer of *bicoid* mRNA to the middle of a host embryo
   e) ectopic transfer of *nanos* mRNA to the middle of a host embryo

9) If you were to mark the primary xylem and phloem in an oak seedling with permanent dyes, which of the following would be true about these dye marks ten years later, when the seedling had become a woody tree?
   a) They would be next to each other in the very center of the trunk.
   b) They would both be near the outside of the trunk, on either side of the vascular cambium.
   c) They would both be completely gone, having sloughed off the outside with the cork.
   d) They would be widely separated—one in the very center, one just under the cork.
   e) none of the above

10) Dr. Eric described a simple model that examined how egg size, egg number, and larval mortality interact to predict the fitness of a sessile marine animal. Which of the following scenarios would select for direct developing offspring?
   a) the need for larvae to disperse larger distances than before
   b) reduction in mortality of larvae
   c) increase in the mortality of larvae
   d) increase in the amount of material available for egg production
   e) none of the above

11) The stress – strain curve provides information on how stiff or elastic a material is and ends at the point of failure. Two objects are the same overall size but are made of different materials. Based on the graphs of stress and strain for these materials, which of the following is true?
   a) A will change length more than B and has a larger tensile strength
   b) A will change length less than B and has a larger tensile strength
   c) A will change length more than B and has a smaller tensile strength
   d) A will change length less than B and has a smaller tensile strength
   e) None of the above



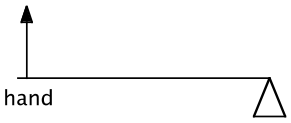
12) When the branch of a tree is bending under the weight of heavy snow, it is less likely to break if
   a) The wood on the upper side of the branch is strong in compression
   b) The branch is hollow
   c) The wood on the lower side of the branch is strong in compression
   d) The radius of the branch is small
   e) The wood on the lower side of the branch is strong in tension

13) Size and shape have great implications for the physiology of organisms. Other things being equal,
   a) a smaller bird will have an easier time staying warm in the winter than a larger bird will because of the smaller bird's smaller surface-to-volume ratio
   b) a smaller bird will have a harder time staying warm in the winter than a larger bird will because of the smaller bird's smaller surface-to-volume ratio
   c) a larger bird will have a harder time staying warm in the winter than a smaller bird will because of the larger bird's smaller surface-to-volume ratio
   d) a smaller bird will have a harder time staying warm in the winter than a larger bird will because of the smaller bird's larger surface-to-volume ratio
   e) a larger bird will have a harder time staying warm in the winter than a smaller bird will because of the larger bird's smaller surface-to-volume ratio

14) Which means of locomotion requires the least amount of energy?
   a) Running with legs in semi-erect position
   b) Running with legs in a sprawling position
   c) Swimming
   d) Flying

15) Your elbow is a lever system (see below). When you use your bicep muscle to lift your hand, the muscle must apply a certain force to lift the load of the hand. Which of the following is true?
   a) The hand moves less than the muscle and the load lifted is less than the force applied by the muscle.
   b) The hand moves more than the muscle and the load lifted is less than the force applied by the muscle.
   c) The hand moves less than the muscle and the load lifted is more than the force applied by the muscle.
   d) The hand moves more than the muscle and the load lifted is more than the force applied by the muscle.
   e) None of the above

16) What is the elbow design best for with regards motion?
   a) Mechanical advantage
   b) Velocity advantage
   c) Both
   d) Neither



17) What causes rigor mortis, when muscles freeze in place after an organism dies?
   a) Exhaustion of Ca^{2+} from the sarcoplasmic reticulum
   b) Lack of ATP in myofibrils
   c) Cessation of action potentials
   d) Lack of acetylcholine from the motor neurons
   e) None of the above

18) A dopaminergic neuron releases dopamine when it generates action potentials. It is post synaptic to an inhibitory neuron that releases GABA and an excitatory neuron that releases glutamate. What factors will determine and ensure that the neuron releases dopamine?
   a) Only how much GABA it detects
   b) Only how much glutamate it detects
   c) The amount of GABA and glutamate detected as long as there is more GABA than glutamate
   d) The amount of GABA and glutamate detected as long as there is more glutamate than GABA

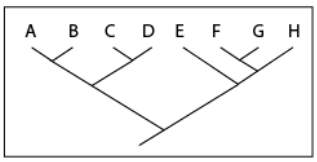
19) At the resting membrane potential
   a) K^+ ions only leave the cell
   b) K^+ ions only enter the cell
   c) K^+ ions move in and out of the cell though more K^+ ions come in than go out
   d) K^+ ions move in and out of the cell though more ions go out than come in
   e) K^+ ions move in and out of the cell equally

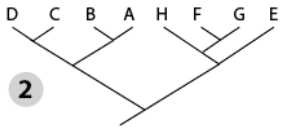
20) Exergonic reactions
   a) are often facilitated by enzymes that lower activation energy
   b) are associated with negative ΔG
   c) are involved in catabolism
   d) are exemplified by the synthesis of ATP from ADP and inorganic phosphate
   e) a, b, and c are all true

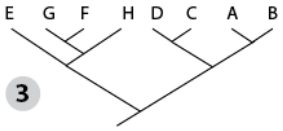
21) A successful living organism
   a) must maintain itself at thermodynamic equilibrium with its surroundings to stay alive
   b) must increase the entropy ("disorder") of its surroundings to stay alive
   c) must use oxygen as the final electron receptor to extract energy from organic or inorganic molecules
   d) must hydrolyze ADP to make ATP to obtain energy
   e) both a and b are true

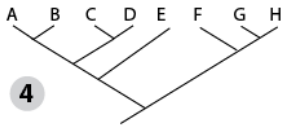
22) Which of the trees at right represents relationships that are identical to the boxed tree below? Be sure to choose the answer that includes all correct trees; there may be more than one correct tree.

a) tree 2 only
b) tree 4 only
c) trees 2 and 3
d) trees 1, 2, and 3
e) trees 1, 2, 3, and 4





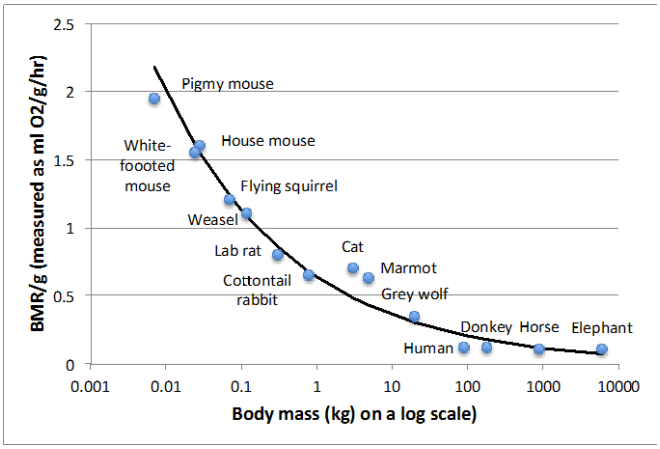




23) In comparing the relationship between two variables, if the scaling coefficient, *b*, has a value of 1, then

a) the two variables have a linear relationship on a linear scale
b) the two variables have a linear relationship on a logarithmic scale
c) the two variables must have an isometric relationship
d) the two variables must have an allometric relationship
e) both a and b are true

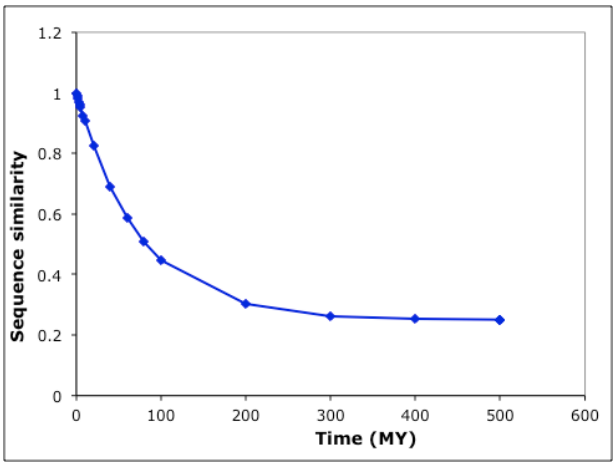
24) Based on the graph below, which one of the following statements is FALSE:



a) A pigmy mouse has a mass-adjusted basal metabolic rate around twice that of a weasel
b) A house mouse has a greater mass than a pigmy mouse on a linear scale
c) Pigmy mouse and flying squirrel are closer in size than are human and donkey
d) Under identical conditions, a donkey has a higher mass-adjusted basal metabolic rate than does an elephant
e) Under identical conditions, a flying squirrel consumes more oxygen in an hour than a horse does

25) As shown in the graph at right, random mutation causes the sequences of a particular segment of DNA to gradually diverge in two descendant populations, with the sequence identity declining through time until it stabilizes around 25% similarity. At around what percent similarity would we expect this plateau to be reached if DNA were composed of 8 different nucleotides instead of 4?

a) 0.125
b) 0.25
c) 0.75
d) 1
e) none of the above



26) Which of the following statements about countercurrent exchange is FALSE:

a) it is not only seen in nature, but is also commonly used by human engineers
b) It involves arranging flow patterns in such a way that a concentration gradient is maintained which, in turn, maintains diffusive transfer
c) It occurs mainly in terrestrial warm-blooded organisms living in cold environments, such as Arctic foxes
d) It can be used by organisms to reduce heat loss to the environment
e) It can be used by organisms to maximize gas exchange

27) Which one of the following statements about simple diffusion of molecules is FALSE:
   a) Diffusion can occur without any input of cellular energy
   b) In diffusion, molecules move only from a region of greater concentration to a region of lesser concentration
   c) In diffusion, molecules move randomly in all directions
   d) Diffusion does not occur in the absence of a concentration gradient
   e) For multicellular organisms, diffusion is generally not useful for moving molecules over long distances within their bodies

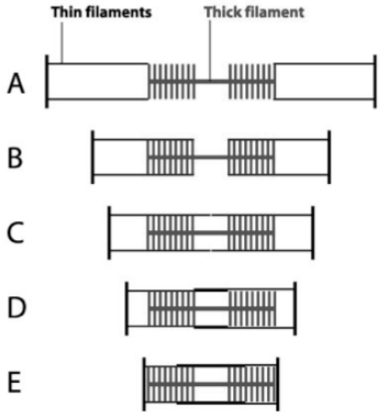
28) Which of the following is a correct pairing of a fiber and a motor protein to accomplish a particular cellular motion
   a) Myosin and tubulin for cytokinesis.
   b) Kinesin and tubulin for vesicle transport.
   c) Kinesin and dynein for extending pseudopodia.
   d) Actin and tubulin for cytoplasmic streaming
   e) None of the above

29) Optogenetics uses light sensitive channels from single celled organisms and expresses them in mammalian neurons. Two different types of channels can be expressed in the same neuron: halorhodopsin and channelrhodopsin. When halorhodopsin absorbs yellow light, H^+ leave the cell. When channelrhodopsin absorbs blue light, Na^+ ions enter the cell. What will happen when first blue light and then a few seconds later yellow light illuminates this neuron?
   a) Nothing will happen because mammalian neurons are not light sensitive.
   b) The cell will depolarize and remain excitatory.
   c) The cell will hyperpolarize and remain inhibitory.
   d) The cell will first depolarize and then hyperpolarize.
   e) The cell will first hyperpolarize and then depolarize.

30) If two muscles are compared where muscle A is twice as long as muscle B, but both have the same diameter, how will the speed and strength of muscle A contracting compare to muscle B?
   a) Muscle A will be half as fast and half as strong as B.
   b) Muscle A will have the same speed and strength as B.
   c) Muscle A will be twice as fast but have the same strength as B.
   d) Muscle A will have the same speed but be twice as strong as B.
   e) Muscle A will be twice as fast and twice as strong as B.

31) Which of the following correctly describes a way that slow-twitch and fast-twitch muscles differ?
   a) Slow twitch muscles have more mitochondria than fast twitch muscles
   b) Slow twitch muscles have fast myosin while fast twitch muscles have slow myosin
   c) Slow twitch muscles have more glycogen than fast twitch muscles
   d) Slow twitch muscles have less myoglobin than fast twitch muscles
   e) Slow twitch muscles tire more quickly than fast twitch muscles

32) The figure at the right shows a line drawing of a sarcomere. In which configuration can the sarcomere contribute the most force to the muscle fiber?
   a) A
   b) C
   c) E
   d) C and E are the most
   e) They are all the same.



33) Which of the following is not a composite
   a) Rabbit collagen
   b) Lobster cuticle
   c) Dog cartilage

d) Wood of oak tree
e) Elephant bone

34) The tibia in a 5 yr old child is approximately 20 cm long and 2 cm diameter, but in a 6 mo old is only 10 cm long and 1 cm diameter. If the same compressive force is applied to the two bones, how does the stress and therefore the strain of the 5 yr old bone compare with the 6 month old bone?

a) The strain of 5 yr old bone is four times as great
b) The strain of 5 yr old bone is twice as great.
c) The strain of 5 yr old bone is the same as 6 mo old bone
d) The strain of 5 yr old bone is one half as much
e) The strain of 5 yr old bone is one quarter as much

35) For these same two bones, what is the absolute length change of the 5 yr old to 6 mo old bone?
a) The length change of 5 yr old bone is four times as great
b) The length change of 5 yr old bone is twice as great.
c) The length change of 5 yr old bone is the same
d) The length change of 5 yr old bone is one half as much
e) The length change of 5 yr old bone is one quarter as much

36) Which of the following animals do not have bone as a major part of their skeleton?
a) Dog
b) Salamander
c) Shark
d) Monitor lizard
e) Tuna fish

37) Why do organisms build skeletons from layered composites?
a) It is difficult to secrete just one compound to make a skeleton
b) They need materials that only withstand tension
c) They need materials that only withstand compression
d) They need materials that resist tension and compression but in only one direction
e) They need materials that resist tension and compression along multiple directions

38) Why might organisms build holes and spaces into the materials that make up their skeletons?
a) It lightens the weight of the skeleton
b) It prevents cracks from propagating
c) It leaves a space for blood cell manufacture
d) All of the above
e) None of the above

39) Many organisms have to struggle to prevent their structures from buckling. Which of the following is THE BEST way to make a plant stem more resistant to buckling?
a) Make the stem twice as long
b) Make the stem half as long
c) Make the stem twice as wide
d) Make the stem twice as long but twice as wide
e) Make the stem half as long but twice as wide

40) If step size is proportional to leg length and step time is proportional to square root (leg length / acceleration due to gravity) which of the following is true?
a) If your legs are four times longer, your step size is four times longer
b) If your legs are four times longer, your step time is 2 times longer
c) If your legs are four times longer, your velocity is 2 times faster
d) If you are walking on the moon (where g is 6x smaller), your step time is more than two times longer
e) All of the above

41) Drag can be used to enable animals to move. But drag can also prevent animals from moving. Which of the following is an adaptation to reduce the type of drag that prevents locomotion.
   a) A sugar glider that has large flaps of skin to glide from tree to tree
   b) A snake that has become wide bodied to glide through the air
   c) A dog that uses its legs to pull water along and dog paddle
   d) A tuna that is tear drop shaped for streamlining
   e) None of the above

42) When animals move rapidly through air or water, they can generate lift. This can occur passively by gliding or actively by flapping. Which of the following statements are true
   a) A high aspect ratio is good for gliding
   b) A high aspect ratio is good for flapping
   c) A high wing loading is good for gliding
   d) Strong wing muscles are necessary for gliding
   e) None of the above

43) A cheetah has many advantages that make it one of the fastest animals on land with burst speeds of up to 70 MPH. Which of the following would not explain its top rate of speed?
   a) The cheetah can swing its legs to give it a long stride
   b) The cheetah can arch its back to give it a long stride
   c) The cheetah has fast twitch muscles that can contract quickly
   d) The cheetah has fast twitch muscles that rapidly produce ATP by burning glycogen
   e) The cheetah's fast twitch muscles produce lactic acid by anaerobic respiration

44) Some evolutionary events were singular, occurring only once to cause that most unlikely event of creating life. Others have happened multiple times. Which of the following is thought to have occurred more than once.
   a) Evolution of the genetic code
   b) Evolution of nucleic acids
   c) Evolution of the nuclear membrane
   d) Evolution of organelles
   e) Evolution of neurons

Extra credit

45) Which group did Dr Karen not play music by this semester?
   a) OK Go
   b) Black Eyed Peas
   c) Jet
   d) Beatles
   e) Sandobal Symphony

End of multiple choice. Write the rest of the answers on this exam sheet

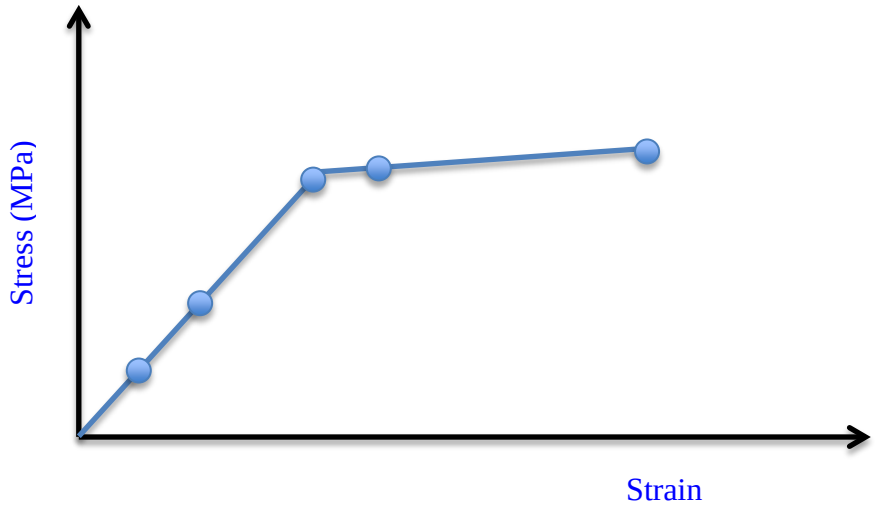
46) (5 pts) We discussed the critical importance of ATP this semester.
   a) How do we know that all organisms rely on ATP?
      All organisms have ATP synthase

   b) List four different ways in which the body uses ATP
      Muscle contractions
      Transport along filaments
      Cotransporters
      Ion pumps
      Protein synthesis / biochemistry
      DNA nucleotide

47) (10 pts) You have been sent to Mars to determine if life ever existed there. You are studying some materials that have been discovered in a subterranean cavern, which are remarkably well preserved. They seem to be organic in nature. You want to know if the material you have found could have been some sort of connective tissue. You measure its strain for different stresses to get the following data:

a) (2 pts) Plot the data and connect the points with a line. Remember to label the axes.

Strain	Stress (MPa)
0.01	0.12
0.02	0.24
0.04	0.48
0.05	0.49
0.10	0.5
breaks	0.51



b) (2 pts) Define stress and explain why it is given in units of Pascals?
Stress is force per unit area. Since force is in Newtons and area is in m^2, force per area is pressure which is measured in pascals.

c) (2 pts) Calculate the elastic modulus of this material based on the data your measured.

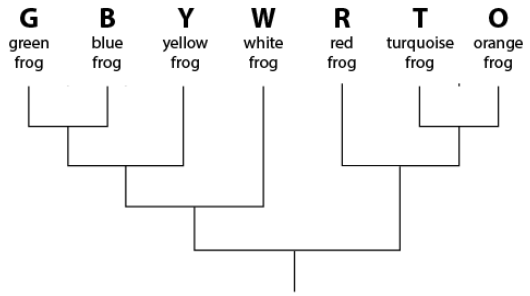
E = slope = change in stress / change in strain = (0.24 – 0.12) / (0.02 – 0.01) = 12.0 MPa

d) (2 pts) You remember some elastic moduli for a few biological materials, including E(elastin) = 1 MPa, E(cartilage)= 20 MPa, E (collagen)=100 MPa and E(bone)=200 MPa. Would you characterize your newly discovered material as stretchy or stiff? Could it be biological if it is carbon based?
It is close to elastin and very stretchy. Yes it could be biological. Why not.

e) (2 pt) If the piece of material is 1 cm long, how long will it be just before it breaks?
It will be 10% longer or 1.1 cm long.

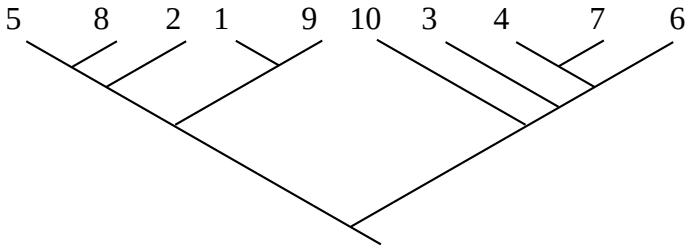
48) A) (3 pts) Draw the branching relationships (cladogram) for Tree B so that the relationships among taxa are identical to those represented in Tree A.

TREE A



TREE B

B) (3 pts) Below on the left are the evolutionary relationships among ten species of frogs found in Costa Rica. A fungus that kills frogs becomes established in Costa Rica and causes the extinction of four of these species: species 5, 1, 4, and 6. Draw on the right the tree representing the relationships among the six remaining species.



49) (5 pts) You have an aquarium that is partially filled with water. You measure the partial pressure of gas A above the water and the concentration of gas A dissolved in the water and find that these values are 0.78 Atm and 4.8 X 10^{-4} mol/L.

a) Based on the table of data, what is the identity of gas A?

K = C / P = 4.8 x 10^{-4} mol/L / 0.78 Atm = 6.15 x 10^{-4} Mol/L Atm

Gas is N_2

b) Based on the table, which of the gases listed is most soluble in water?

CO_2 is the most soluble gas.

Gas	K (Mol/L*Atm
O_2	1.3×10^{-3}
H_2	7.8×10^{-4}
CO_2	3.4×10^{-2}
N_2	6.1×10^{-4}
He	3.7×10^{-4}
Ne	4.5×10^{-4}
Ar	1.4×10^{-3}
CO	9.5×10^{-4}

50) (8 pts) You are studying the biomechanics of the jaws of the skull below*. Assume that muscles 1 and 2 are made of the same kind of muscle fibers and have the same properties and dimensions (same length, same cross sectional area, same rate of contraction).

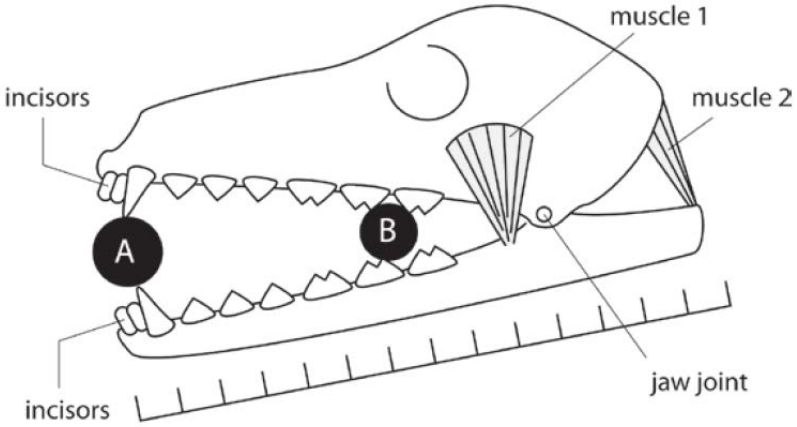


*Image originally appeared in Towards a Constructional Morphology of Cichlid Fishes (Teleostei, Perciformes). Barel, C.D.N., Netherlands Journal of Zoology, 33, 357-424 (1982), DOI:http://dx.doi.org/10.1163/002829683X00183. Reprinted with permission.

A) (2 pts) What happens to the jaw when muscle 1 contracts? What happens when muscle 2 contracts?
Muscle 1 closes the jaw. Muscle 2 opens the jaw.

B) (3 pts) Assume muscle 1 contracts. Which object (A or B) would experience the higher biting force? Use lever mechanics to explain your reasoning.
B has the higher biting force.
The biting force is F_{load} which is $F_L = F_M\, d_M / d_L$. Since F_M and d_m are the same for both biting locations, the only thing that determines F_L is d_L. F_L will be bigger if d_L is smaller. Since the distance to point B is shorter, the biting force is greater there.
Another way to argue this is the mechanical advantage is $F_M / F_L = d_M/d_L$. Again d_L is smaller for B than for A. So mechanical advantage and hence biting force is larger for B.

C) (3 pts) If you were to measure the speed that the mouth opens or closes at the point of the incisors, would the mouth open faster or close faster (assuming each muscle contracts independently). Use lever mechanics to explain your reasoning.
Speed is faster for closing.
The speed is determined from the similar triangles. Here the incisors are the load.
Since $v_L / v_M = x_L / x_M = d_L / d_M$
For jaw motion then
$$v_L = v_M * d_L/d_M$$
The distance d_L is the same for both muscles since the incisors are the same distance from the jaw joint. Also, the muscles contract at the same speed so v_M is the same. Therefore speed will depend only on d_M. Since the closing muscle is closer to the joint, it has the smaller d_M . Therefore the jaw will close faster than it opens.

51) (6 pts) You are working in a clinic in Africa when someone brings in a young woman. She has been having convulsions. They bring some special herbal medicine that she has taken. You immediately recognize it as Digitalis, which you know to inhibit the sodium potassium pump in neurons. You quickly take her blood and send it to the lab. They send you back an analysis which allows you to compare her values to those that are normal:

Ion	P_{ion}	Inside cell	Blood (normal)	Blood (your patient)
K^+	1	140	5.5	10
Na^+	.02	15	150	150
Cl^-	.01	125	9	9

Note Cl is backwards

a) (2 pts) Calculate the resting potential of your patient using the Goldman equation.

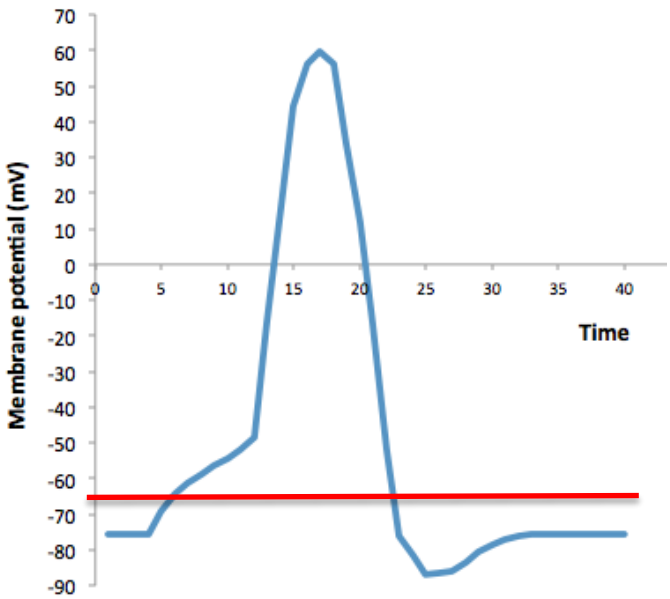
$$E_{membrane} = 62mV\left(\frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}}\right)$$

$$= 62mV\left(\frac{1*10mM + 0.02*150mM + 0.01*125mM}{1*140mM + 0.02*15mM + 0.01*9}\right) = -62mV$$

b) (2 pts) If the resting potential of a healthy person is -75 mV, why does your patient's value make sense based on her blood results?

Since there is more potassium outside the cell, the membrane is less negative because it doesn't have to work as hard to keep K+ in the cell (the concentration gradient is shallower)

c) (1 pt) Draw a line across the graph of the normal action potential to show your patient's resting potential.



d) (1 pt) Why does it make sense that your patient is having convulsions based on this result?

Your patient's resting membrane potential is closer to the threshold value making it easier to generate action potentials and cause convulsions.

Fortunately you can give her some medicine to help her feel better till the Digitalis is out of her system.

Useful formula for thinking about biology

$\Delta G = G_{final} - G_{initial}$

$\Delta G = \Delta H - T\Delta S$

$$J = -D\frac{\Delta C}{\Delta x}$$

$$D = \frac{kT}{6\pi\mu r}$$

$$\frac{dS}{dt} = DA\frac{\Delta C}{\Delta x}$$

$$t = \frac{x^2}{2D}$$

$$I(\lambda) = I_0(\lambda)\exp(-\alpha_\lambda l)$$

$$\frac{F}{A} = E\frac{\Delta L}{L} \qquad \sigma = E\varepsilon$$

$$F_{buckle} = C\frac{\pi r_{\max}^2}{L^2}$$

$F_{muscle}d_{muscle}=F_{load}d_{load}$

$$\frac{v_{load}}{v_{muscle}} = \frac{d_{load}}{d_{muscle}}$$

$$y = ax^b \qquad \log y = \log a + b * \log x$$

Aspect ratio = span / chord

C = K P

Wing loading = M / A

$$E_{ion} = \frac{RT}{zF}\ln\frac{[ion]_{out}}{[ion]_{in}} = 2.303 * \frac{RT}{zF}\log\frac{[ion]_{out}}{[ion]_{in}}$$

$$For\_20^{\circ}C$$

$$E_{ion} = \frac{58mV}{z}\log\frac{[ion]_{out}}{[ion]_{in}}$$

$$For\_37^{\circ}C$$

$$E_{ion} = \frac{62mV}{z}\log\frac{[ion]_{out}}{[ion]_{in}}$$

$$For\_20^{\circ}C$$

$$E_{membrane} = 58mV * \log\left(\frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}}\right)$$

$$For\_37^{\circ}C$$

$$E_{membrane} = 62mV * \log\left(\frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}}\right)$$