

CORRECTED

Supplemental Material

CBE—Life Sciences Education

Batz et al.

Paper Invitation

Hello,

We (Drs. Olsen and Dastoor) are concerned about your BIO100 exam 1 grade so we have asked your lab TA to give you this letter offering you **FREE** tutoring in the course.

These sessions are 1 hour per week with a trained tutor who did well in BIO100. During these sessions you and a small group of your classmates will review selected exam questions from previous years. These sessions also offer you a chance to prepare for future exams and get to know your classmates

Tutoring Session Times - All sessions in 304 Murray Hall		
Tuesday	Wednesday	Thursday
9:00 AM	9:00 AM	10:00 AM
11:00 AM	10:00 AM	1:00 PM
2:00 PM	1:00 PM	2:00 PM
5:00 PM	4:00 PM	3:00 PM

Interested? Spots are limited and on a first come first serve basis so please sign up ASAP! Tutoring starts the week of September 30th.

Three ways to register:

1. Talk to the tutors sitting in Murray 109.
2. Send an email to [email address here] with your name and the session you want to sign up for
3. Sign up on your own via Synapse by following the directions below

How to sign up for Tutoring Sessions via Synapse

1. Sign into Synapse and select **BIO 100 LEC** from the dropdown list at the top.
2. Click on **groups** in the left sidebar
3. This will display all the MLA tutoring sessions. Each section can have up to 10 students, if a section has less than 10 students then it will say "Available" in the sign up column. Double click on any available section to register.
4. A pop-up window will ask you to confirm that this is the section you want to register for; click "Yes, join"
5. The list of MLA tutoring sessions will now indicate that this is your group
6. You may switch tutoring sessions, to do so simply double click on another section and a pop-up window will ask you to confirm you want to switch. Once the groups have all been established, you will no longer be able to switch.

Email Invitation

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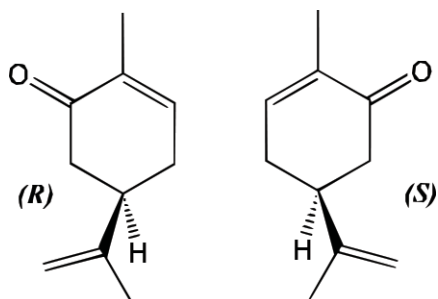
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If you have trouble registering, send an email [email address here] with your name and the tutoring session you'd like and he will register for you.

R-Carvone (shown below) tastes like mint while S-Carvone tastes like caraway.



What relationship do these molecules have to each other?

- They have different molecular formula.
- They are both held together using Van der Waals forces.
- They are geometric isomers and have different properties.
- They are enantiomers and have different physiological properties.
- They are structural isomers of each other.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Polysaccharides, lipids, and proteins are all similar in that they...

a. are monomers synthesized by the process of hydrolysis.

b. are synthesized as a result of peptide bond formation between monomers.

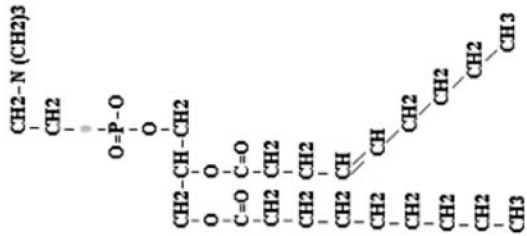
c. are broken down into macromolecules by dehydration reactions.

d. all contain the same monomer building blocks.

e. are synthesized from monomers by dehydration reactions.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The image below is of...



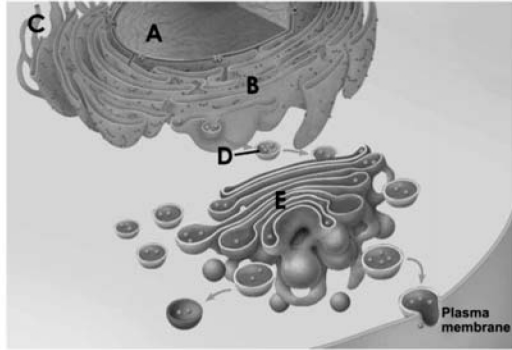
- a polysaccharide.
- a phospholipid.
- a carbohydrate.
- a triglyceride.
- a polypeptide.

(For justification of wrong answers here, draw what the other molecules look like)

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Figure from: Test Bank for Campbell Biology 8th edition, Barstow, W., Paquin, L., Dini, M., Zarnetske, J., Lepri, J., Patterson, C.O. (2008) San Francisco, CA, Benjamin Cummings

The cell structure indicated by B is _____ and its function is _____.



- a. the nucleus; to contain chromosomes
- b. a transport vesicle; to fuse with the smooth endoplasmic reticulum
- c. the rough endoplasmic reticulum; synthesis of secreted proteins
- d. the smooth endoplasmic reticulum; to allow synthesis of lipids
- e. the golgi; to package secreted proteins.

Figure from: Campbell Biology, 9th edition, Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). San Francisco, CA, Benjamin Cummings

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Animal cells package powerful hydrolytic enzymes into specialized structures called _____, which prevent general destruction of cellular components by these enzymes.

- a. lysosomes
- b. chloroplasts
- c. mitochondria
- d. vacuoles
- e. peroxisomes

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

3. Which of the following cell structures is **CORRECTLY** matched with the cell type it can be found in?

- a. Golgi – animal cell
- b. nucleus – bacteria
- c. lysosome – archaea
- d. nucleoid – plant cell
- e. mitochondria – virus cell

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

4. Which of the following conditions would produce a cell with lots of free ribosomes (not associated with the endoplasmic reticulum)?

- a. a cell that is secreting proteins
- b. a cell that is producing cytoplasmic enzymes
- c. a cell that is constructing its cell wall or extracellular matrix
- d. a cell that is hydrolyzing starch molecules
- e. a cell that is enlarging its vacuole

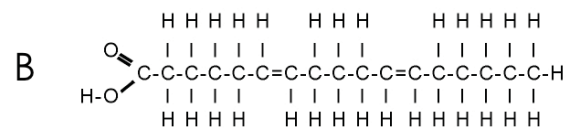
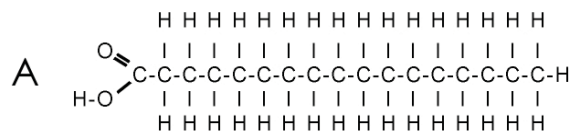
Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Why are lipids and proteins able to move laterally in biological membranes?

- a. The interior of the membrane is filled with liquid water.
- b. Hydrophilic parts of the lipids and proteins associate with the hydrophobic parts of the membrane.
- c. Lipids and proteins are held to each other by very weak covalent bonds.
- d. Cellulose keeps the membrane "loose" so that lipids and proteins can move around.
- e. There are no covalent bonds between the lipids and proteins in the membrane.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

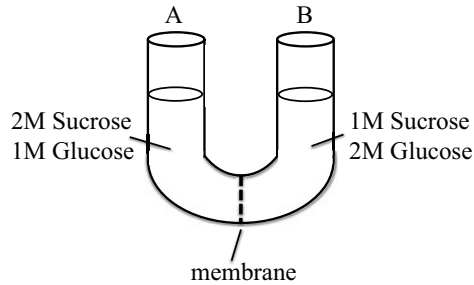
The two molecules (A and B) shown here represent fatty acid chains. Chose the **INCORRECT** statement below.



- a. Molecule B could contribute to the formation of a solid fat at room temperature.
- b. Molecule A could be a component of a triglyceride.
- c. Triglycerides formed with B would be found in plants.
- d. Molecule A is an example of a saturated fatty acid.
- e. Molecule B could covalently attach to a glycerol molecule.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The solutions in the two arms of this U-tube are separated by a membrane that is permeable to water and glucose, but **NOT** to sucrose. Side A is filled with a solution of 2 M sucrose and 1 M glucose. Side B is filled with 1 M sucrose and 2 M glucose. Initially, the liquid levels on both sides are equal. After the system reaches equilibrium, what changes will be observed?



- a. All the sucrose will have been converted into glucose.
- b. The concentration of glucose is higher in side A than in side B.
- c. The water level is higher in side A than in side B.
- d. The concentration of sucrose remains higher on side A.
- e. The water level is higher in side B than in side A

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The movement of potassium ions from the outside (1 M K^+) to the inside (9 M K^+) of an animal cell (such as a neuron) requires...

a. diffusion of potassium ions down a concentration gradient.

b. cells that are big enough to accept the potassium ions.

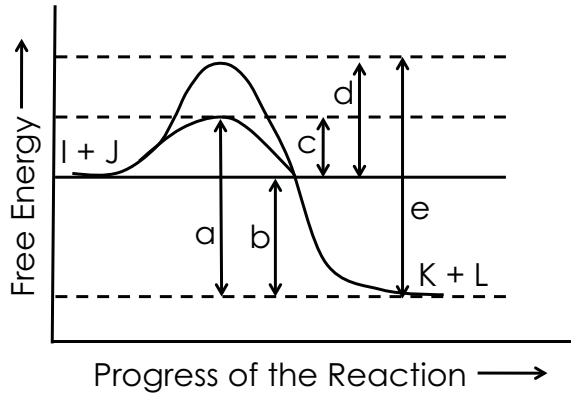
c. an energy source such as ATP.

d. a cotransport protein.

e. an efficient osmosis mechanism so that ions can form and be transported.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Using the image below showing the reaction of $I + J \rightarrow K + L$. Which arrow corresponds to the energy released by the enzyme-catalyzed reaction?



- a. a
- b. b
- c. c
- d. d
- e. e

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The reaction shown below represents...



- a. those of the Calvin cycle.
- b. the overall reaction of photosynthesis.
- c. those of the light reactions.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	

Where would one find the enzymes of the Calvin cycle?

- a. The stroma of the chloroplast
- b. Within the membranes of the thylakoids
- c. The outer membranes of the thylakoids
- d. Within the thylakoid space

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	

Early investigators thought that the oxygen produced through photosynthesis came from carbon dioxide. In fact, it comes from...

- a. water.
- b. glucose.
- c. the air that plants breathe
- d. the hydrolysis of carbohydrates.
- e. oxidation of NADPH.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Assume a thylakoid membrane is punctured so that the interior of the thylakoid is no longer separated from the stroma. This damage will have the most immediate effect on...

- a. the ability to split water.
- b. the absorption of light energy by chlorophyll.
- c. the flow of electrons from photosystem II to photosystem I.
- d. the ability to synthesize ATP.
- e. the reduction of NADP^+ to NADPH .

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

In linear electron flow, ATP and NADPH are produced by _____ and subsequently used by _____.

a. Glycolysis/fermentation

b. Calvin cycle/oxidative phosphorylation

c. Light reactions/substrate level phosphorylation

d. Light reactions/Calvin cycle

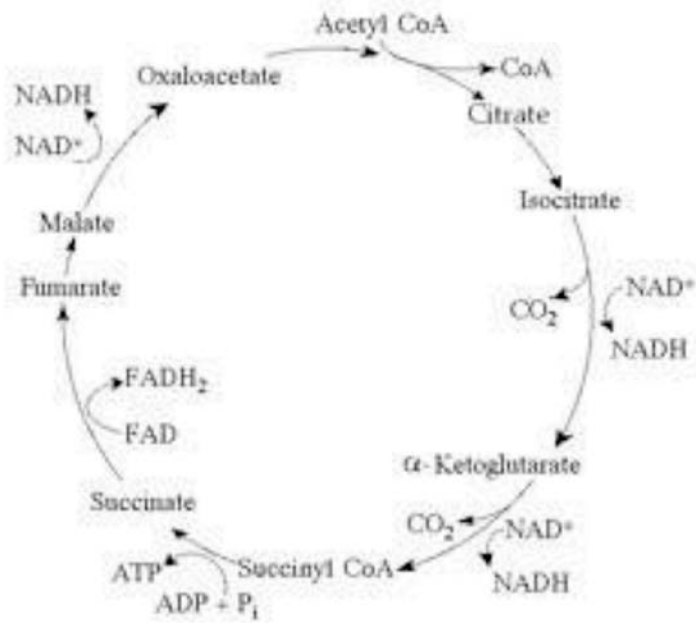
Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	

Which of the following occur exclusively in the cytoplasm of both eukaryotic and prokaryotic cells?

- a. substrate-level and oxidative phosphorylation
- b. oxidation of pyruvate to acetyl CoA and substrate level phosphorylation
- c. the Citric acid cycle and the Calvin cycle
- d. only chemiosmosis
- e. glycolysis and fermentation

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Using this image and starting with one molecule of citrate and ending with oxaloacetate, what is the maximum number of ATP molecules that could be made through **oxidative phosphorylation**?
 (Assume only 1 turn of the cycle)



- a. 1
- b. 2
- c. 11
- d. 12
- e. 14

Show your work:

Justify your answer selection:

Figure from: Test Bank for Campbell Biology 8th edition, Barstow, W., Paquin, L., Dini, M., Zarnetske, J., Lepri, J., Patterson, C.O. (2008) San Francisco, CA, Benjamin Cummings

As electrons travel from Complex I towards Complex IV of the electron transport chain...

a. oxygen, carbon dioxide, and water are moved from the matrix into the intermembrane space of the mitochondrion.

b. a proton (H^+) gradient is created across the inner membrane of the mitochondrion.

c. oxygen is produced.

d. NADH is converted into $FADH_2$.

e. CO_2 molecules are reduced.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

After glycolysis and the Citric Acid (Krebs) Cycle and before the electron transport chain and oxidative phosphorylation, the carbon skeleton of glucose has been broken down to carbon dioxide. Most of the energy from the original glucose, at this point, is in the form of _____.

- a. ATP
- b. CO₂
- c. H₂O
- d. protons
- e. NADH₂

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

These images represent three pairs of homologous chromosomes as they might appear during various stages of either Mitosis **OR** Meiosis.

Which image(s) represents metaphase II?

- a. I
- b. II
- c. III
- d. IV
- e. V

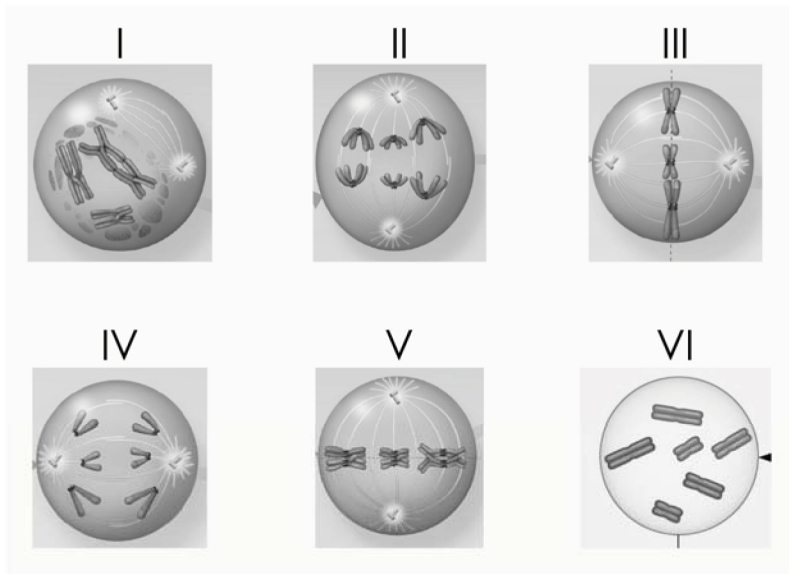


Figure from: Campbell Biology, 9th edition, Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). San Francisco, CA, Benjamin Cummings

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Crossover, the exchange of segments of homologous chromosomes, takes place only during...

- a. DNA replication
- b. Cytokinesis
- c. Anaphase I
- d. Prophase I
- e. Metaphase

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

In which group of organisms or type of cell does the nuclear envelope remain intact during mitosis?

- a. apple tree flower cells
- b. bone marrow
- c. yeasts
- d. bacteria

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	

Independent assortment of chromosomes can occur during...

- a. Mitosis.
- b. Meiosis II only.
- c. Mitosis and Meiosis I.
- d. Meiosis I only.
- e. fertilization.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which of the following occurs in MEIOSIS but NOT in MITOSIS?

- a. sister chromatids separate from each other
- b. attachment of centromeres/kinetochores to spindle fibers
- c. disappearance of the nuclear membrane and condensing of the chromosomes
- d. pairing up of homologous chromosomes
- e. lining up of duplicated chromosomes along the middle of the dividing cell

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

A woman with blood type A+ has a daughter who is type O- and a son who is type B-. Rh positive (+) is a trait that shows simple dominance over Rh negative (-) and is designated by the alleles R and r, respectively. The genes for these two traits are on separate chromosomes.

Which of the following might be the genotype of these children's father?

- a. $I^A I^A r r$
- b. $I^A I^B R r$
- c. $I^A i r r$
- d. $I^B i r r$
- e. $I^B i R R$

Show your work and justify your answer choice.

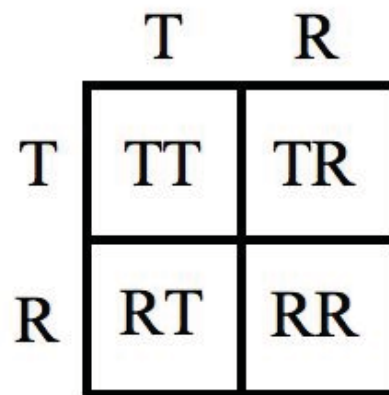
Justification/Explanation	Where did you find this information?
<p>Show your work:</p>	
<p>Justify your answer choice:</p>	

The image below of a Punnett Square predicts the probability of outcomes between the cross of 2 heterozygotes (pink flowers). The alleles T and R show INCOMPLETE dominance for pigmentation in flower petal color (T = red pigment/R = white pigment).

If the two different pure breeding offspring resulting from the cross shown below in the Punnett square were selected and further crossed what would be the offspring?

- All white-colored flowers.
- All pink-colored flowers.
- 1 red-color, 1 white-color, and 2 pink-color flowering plants.
- 2 plants will have red flowers and 2 will have white flowers.
- 3 plants will have red flowers and 1 will have white flowers.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	



Show your work:

Using the Punnett square below, what offspring are predicted from a cross between individual 1 and individual 2?

- a. Dd
- b. DD
- c. dd
- d. 50% DD and 50% Dd
- e. 1 DD, 2 Dd, and 1 dd

	D	d
D	1	2
d	4	3

Justification/Explanation	Where did you find this information?
Show your work:	
Justify your answer choice and explain how the other answer choices could arise from breeding the individuals from the question stem:	

In a cross $AaBbCc \times AaBbCc$, what is the probability of producing the genotype $AABbcc$? Each of these three genes is on a different chromosome.

- a. $1/4$
- b. $1/32$
- c. $1/64$
- d. $4/32$
- e. $4/64$

Show your work and justify your answer choice.

What is the probability of producing offspring with either the $AABbcc$ or $AAbbcc$ genotype?

Justification/Explanation	Where did you find this information?
<p>Show your work:</p>	
<p>Justify your answer choice:</p>	

In four o'clock plants, a single gene determines color phenotype. If true-breeding red flowered and true-breeding white flowered four o'clock plants are crossed, pink-flowered F_1 offspring are produced. If two of these F_1 are crossed, the F_2 contain red, white, and pink four o'clock flowers. This flower color trait must be an example of...

- a. epistasis.
- b. codominance.
- c. incomplete dominance.
- d. pleiotropy.
- e. environmental factors.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The sex of chickens is determined by a ZW chromosome scheme. Males are ZZ and females are ZW. A recessive lethal allele that causes death of the embryo is sometimes present on chicken chromosomes. What would be the sex ratio in the LIVING offspring of a cross between a male that is heterozygous for a lethal allele and a normal female?

- a. 1 male: 2 female
- b. 1 male: 1 female
- c. 4 male: 3 female
- d. 3 male: 1 female
- e. 2 male: 1 female

Justification/Explanation	Where did you find this information?
Show your work:	
Justify your answer choice: What if this gene was on the autosomal (non-sex) chromosomes?:	

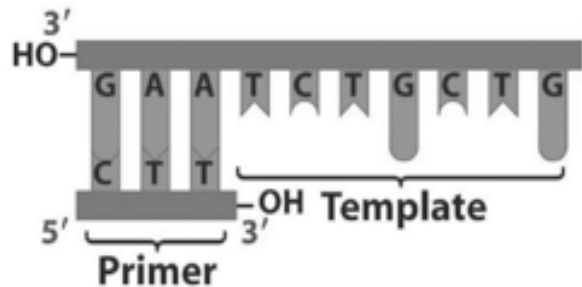
In which way is the leading strand in DNA replication different from the lagging strand?

- a. The leading strand is synthesized in the nucleus, while the lagging strand is synthesized in the cytoplasm.
- b. The leading strand requires an RNA primer while the lagging strand does not.
- c. The leading strand is synthesized continuously in the 5' to 3' direction, while the lagging strand is synthesized in short segments in the 5' to 3' direction.
- d. DNA Polymerase I synthesizes the leading strand while DNA Polymerase III synthesizes the lagging strand.
- e. The leading strand is synthesized completely before synthesis of the lagging strand begins.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

A primer has been made using one strand of DNA as a template as shown below. Which enzyme will use the primer to start making new DNA?

- a. Primase
- b. RNA polymerase
- c. DNA Polymerase III
- d. Topoisomerase
- e. DNA Polymerase I



Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The DNA double helix has a uniform diameter because...

a. cytosine nucleotides pair with adenine nucleotides.

b. the molecular backbone is made of deoxyribose and phosphates.

c. nucleotides bind with amino acids.

d. pyrimidines only pair with purines.

e. all the H-bonds are the same length.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Place the following steps of DNA replication in chronological order.

1. Single-stranded binding proteins attach to DNA strands.

2. Hydrogen bonds between base pairs of antiparallel strands are broken.

3. Primase binds to the site of origin.

4. DNA polymerase polymerizes along the template strand.

5. An RNA primer is created.

a. 1, 2, 3, 4, 5

b. 2, 1, 3, 5, 4

c. 3, 2, 1, 5, 4

d. 1, 2, 3, 5, 4

e. 2, 3, 5, 1, 4

Justification/Explanation	Where did you find this information?
Put these steps in order and describe why they must occur in that order:	

A possible sequence of nucleotides in the mRNA that would code for the polypeptide sequence arg-val-thr-tyr would be...(The table indicates codons with 5' on the left and 3' on the right.)

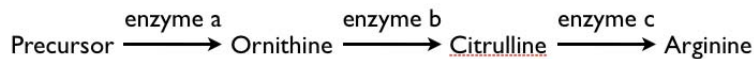
- a. 3' TCA-CCA-TGT-ATG 5'.
- b. 5' AGG-GUU-ACA-UAC 3'.
- c. 5' AUG-CTG-CAG-TAT 3'.
- d. 3' TCC-CCG-ATG-GUU 5'.
- e. 5' UCC-CAA-UGU-AUG 3'.

		Second base							
		U	C	A	G				
U	UUU	Phe	UCU		UAU	Tyr	UGU	Cys	U
	UUC		UCC	Ser	UAC		UGC		C
	UUA	Leu	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Trp	G
C	CUU		CCU		CAU	His	CGU		U
	CUC	Leu	CCC	Pro	CAC		CGC	Arg	C
	CUA		CCA		CAA	Gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU		ACU		AAU	Asn	AGU	Ser	U
	AUC	Ile	ACC	Thr	AAC		AGC		C
	AUA		ACA		AAA	Lys	AGA	Arg	A
	AUG	Met	ACG		AAG		AGG		G
G	GUU		GCU		GAU	Asp	GGU		U
	GUC	Val	GCC	Ala	GAC		GGC	Gly	C
	GUA		GCA		GAA	Glu	GGA		A
	GUG		GCG		GAG		GGG		G

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

According to the table and figure below, representing data similar to the Beadle and Tatum experiment, which enzyme is defective in mutant #2?

- a. DNA polymerase
- b. The enzyme that converts ornithine to citrulline
- c. The enzyme that converts precursor to ornithine
- d. The enzyme that converts citrulline to arginine
- e. The enzyme that converts precursor to enzyme a



Mutant #	Medium + no ornithine no <u>citrulline</u> no arginine	Medium + ornithine no <u>citrulline</u> no arginine	Medium + no ornithine <u>citrulline</u> no arginine	Medium + no ornithine no <u>citrulline</u> arginine
1	no growth	growth	growth	growth
2	no growth	no growth	growth	growth
3	no growth	no growth	no growth	growth

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which of the following mutations, if it occurred in the DNA, is potentially the LEAST damaging to the resulting polypeptide?

a. A base substitution in the first position of one codon in the middle of the gene.

b. A frame shift mutation close to the beginning of the gene.

c. A silent mutation close to the translation stop site.

d. Removal of the start codon.

e. A nonsense mutation close to the 5' end of the mRNA.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Transcription in prokaryotic and eukaryotic cells share all the following, EXCEPT...

- a. RNA Polymerase is required.
- b. a 5'-Cap and a 3'-Poly-A tail are required before translation can start.
- c. transcription starts before translation can begin.
- d. transcription stops at a transcription stop site.
- e. ribonucleotides are monomers used in the synthesis of the mRNA.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The process of TRANSLATION...

- a. adds ribonucleotides, in groups of 3, to make a polypeptide.
- b. converts the genetic information stored in mRNA into a polypeptide.
- c. converts the genetic information stored in DNA into mRNA.
- d. converts each nucleotide into 3 amino acids.
- e. occurs before transcription starts.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which of the following could potentially have the **HIGHEST** Darwinian fitness?

- a. A childless personal trainer who works out at the gym every day.
- b. A childless scientist who devotes herself to science and wins the Nobel Prize.
- c. A woman who has one child and takes very good care of her.
- d. A man who home schools his two children (one male and one female).
- e. A man who fathers 10 children who also all reproduce.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which of these statements is **INCORRECT**?

a. Environmental change plays a role in evolution

b. The smallest entity that can evolve is an individual organism

c. Individuals can adapt in response to new environments or situations

d. Inherited variation in a population is a necessary precondition for natural selection to operate.

e. Natural populations tend to produce more offspring than the environment can support

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Currently the only predator of the Galápagos marine iguana is the Galápagos hawk. Iguana body size is not correlated with the risk of hawk predation, although small iguanas can run faster than large iguanas. If a new predator (e.g., cats) that preferably catches and eats slower iguanas is introduced to the island, iguana body size is likely to _____ in the absence of other factors due to _____ selection.

- a. increase; directional
- b. increase; disruptive
- c. decrease; directional
- d. decrease; stabilizing
- e. stay the same; stabilizing

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which of these conditions **would always** cause populations to evolve by Natural Selection?

Condition 1: The population must vary in traits that are heritable.

Condition 2: Some heritable traits increase reproductive success.

Condition 3: Individuals pass on all traits they acquire during their lifetime.

- a. Condition 1 only
- b. Condition 2 only
- c. Condition 3 only
- d. Conditions 2 and 3
- e. Conditions 1 and 2

Justification/Explanation	Where did you find this information?
Condition 1 -	
Condition 2 -	
Condition 3 -	
Answer Choice:	

A farmer uses a triazine-based herbicide to control pigweed in her field. For the first few years, the triazine works well and almost all the pigweed dies; but after several years, the farmer sees more and more pigweed. Which of these explanations **BEST** describes this observation?

- a. Natural selection caused the triazine to mutate so that it no longer kills pigweed.
- b. Pigweed seeds must be blowing in from a neighbor's farm.
- c. Only triazine-resistant weeds survived and reproduced, so each year more pigweed was triazine-resistant.
- d. Her crops must be absorbing the triazine herbicide, thus allowing the pigweed to grow.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	

Cyanobacteria, a photosynthetic prokaryote, were important to the evolution of life on earth because...

- a. they are probably the first organisms to colonize the oceans.
- b. they are probably the first organisms to release O₂ into the atmosphere.
- c. they are the earliest known fermenting organisms.
- d. they are the closest relatives of early fungi.
- e. they formed symbioses with animal cells to become the first plant cells.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

The Dunkers are a religious group that moved from Germany to Pennsylvania in the mid-1700s. They do not marry with members outside their own immediate community. Today, the Dunkers are genetically unique and differ in gene frequencies, at many loci, from all other populations including those in their original homeland. Which of the following are the **MOST** likely explanations for the genetic uniqueness of this population?

- a. Population bottleneck and Hardy-Weinberg equilibrium
- b. Heterozygote advantage and stabilizing selection
- c. Sexual selection and inbreeding depression
- d. Mutation and natural selection
- e. Founder effect and genetic drift

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

In a Hardy-Weinberg population with 2 alleles, A and a, that are in equilibrium, the frequency of a is 0.4. What proportion of the population is heterozygous for this allele?

- a. 4%
- b. 16%
- c. 32%
- d. 48%
- e. 60%

Show Your Work

Justify your answer choice

Which of the following is **NOT** evidence for common ancestry?

- a. The similarities between bat wings and butterfly wings.
- b. The homology between human arms and cat forelimbs.
- c. All organisms use the same amino acids and nucleotides.
- d. Human embryos have gill slits and tails.
- e. The fossil record showing ancestors of horses having 5 toes.

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which of the following is an example of a **post-zygotic** reproductive barrier between species?

- a. One pine species sheds its pollen 2 months before another pine species.
- b. Two bird species, the Eastern Meadowlark and Western Meadowlark have different songs.
- c. A hybrid between two species of plants produces deformed flowers and no pollen.
- d. Black Sage flowers are pollinated by honeybees and White Sage flowers by wasps.
- e. One species of Garter snake lives mainly on land and another mainly in water.

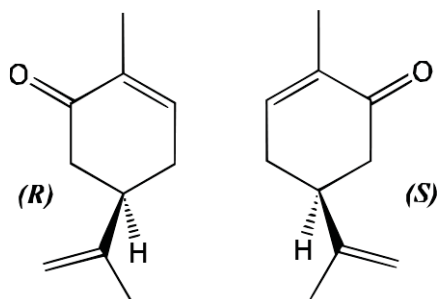
Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

Which term describes the most brightly colored male peacocks mating more frequently than drab colored peacocks?

- a. artificial selection
- b. genetic drift selection
- c. sexual selection
- d. stabilizing selection
- e. disruptive selection

Justification/Explanation	Where did you find this information?
A.	
B.	
C.	
D.	
E.	

R-Carvone (shown below) tastes like mint while S-Carvone tastes like caraway.



What relationship do these molecules have to each other?

- a. They have different molecular formula.
- b. They are both held together using Van der Waals forces.
- c. They are geometric isomers and have different properties.
- d.** They are enantiomers and have different physiological properties.
- e. They are structural isomers of each other.

Justification/Explanation	Where did you find this information?
A. Looking at the two molecules you can see that the two contain the same atoms therefore they must have the same molecular formula.	Diagram
B. Van der Waals forces are interactions between separate molecules; they do not hold together individual molecules. These molecules are held together by covalent bonds.	
C. While they do have different properties, geometric isomers have different arrangements around double bonds. These molecules have identical arrangements around their double bonds. Also, geometric isomers are referred to as cis- or trans- rather than R- or S-	
D. Enantiomers are mirror images of one another, like these two molecules. Also, R- and S- notation indicates enantiomers. By definition, isomers have different physiological properties (the question itself states that they have different tastes).	
E. Structural isomers have different arrangement of functional groups. These two molecules have identically arranged functional groups.	

Polysaccharides, lipids, and proteins are all similar in that they...

a. are monomers synthesized by the process of hydrolysis.

b. are synthesized as a result of peptide bond formation between monomers.

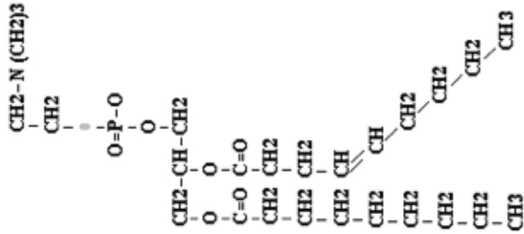
c. are broken down into macromolecules by dehydration reactions.

d. all contain the same monomer building blocks.

e. are synthesized from monomers by dehydration reactions.

Justification/Explanation	Where did you find this information?
A. Hydrolysis does not synthesize macromolecules it breaks them down.	
B. Only proteins are formed as the result of peptide bonds.	
C. Polysaccharides, lipids, and proteins are macromolecules therefore they are not broken down into macromolecules. Also, dehydration reactions do not break down macromolecules.	
D. Polysaccharides are comprised of monosaccharides; proteins are comprised of amino acids; and lipids are comprised of various fatty acids, sterol rings, and glycerols.	
E. Each of these macromolecules is synthesized by linking monomers through dehydration reactions, so this is true.	

The image below is of...



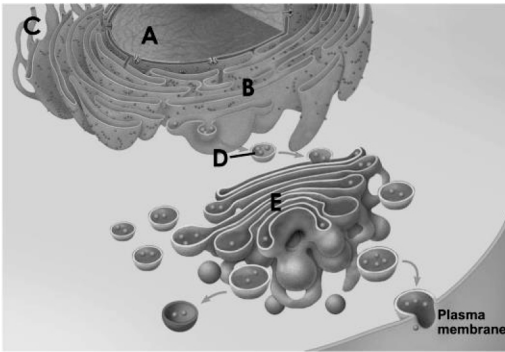
- a. a polysaccharide.
- b.** a phospholipid.
- c. a carbohydrate.
- d. a triglyceride.
- e. a polypeptide.

(For justification of wrong answers here, draw what the other molecules look like)

Figure from: Test Bank for Campbell Biology 8th edition, Barstow, W., Paquin, L., Dini, M., Zarnetske, J., Lepri, J., Patterson, C.O. (2008) San Francisco, CA, Benjamin Cummings

Justification/Explanation	Where did you find this information?
<p>A.</p> <p>Cellulose poly (1,4'-O-β-D-glucopyranoside)</p>	
<p>B.</p>	
<p>C.</p>	
<p>D.</p>	
<p>E.</p> <p>Amino-terminal residue → Carboxyl-terminal residue</p>	

The cell structure indicated by B is _____ and its function is _____.



- a. the nucleus; to contain chromosomes
- b. a transport vesicle; to fuse with the smooth endoplasmic reticulum
- c.** the rough endoplasmic reticulum; synthesis of secreted proteins
- d. the smooth endoplasmic reticulum; to allow synthesis of lipids
- e. the golgi; to package secreted proteins.

Figure from: Campbell Biology, 9th edition, Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). San Francisco, CA, Benjamin Cummings

Justification/Explanation	Where did you find this information?
<p>A. Figure B is not the nucleus (figure A is the nucleus). this is, however, the correct function for the nucleus. These chromosomes contain the genetic information that codes for protein and lipid synthesis which occurs in the cell.</p>	
<p>B. Figure B is not a transport vesicle (figure D is a transport vesicle). this is, however, a somewhat correct description of the role transport vesicles play in the cell. Transport vesicles are small “bubble” like objects that move synthesized proteins and lipids from where they are created to where they need to go. These vesicles originate as an outpocketing of the organelle membrane of either the SER, RER, or Golgi.</p>	
<p>C. Figure B is the rough endoplasmic reticulum. It’s tough to see in the picture, but there are dots on B, denoting that this is, in fact, the RER and not the SER. Denoting the RER and SER is as simple as seeing which one has a large number of externally embedded ribosomes.</p>	
<p>D. Figure B is not the SER (figure C is the SER). This is, however, the correct function for the SER. Because of the lack of ribosomes in the SER, it does not produce many proteins, however it is involved in lipid synthesis and is closely situated to the nucleus and golgi apparati for easy access to genetic information and transport.</p>	
<p>E. Figure B is not the Golgi (figure E is the Golgi). The golgi and the SER look quite similar, however the difference lies in their positioning and what they do. The SER is generally located closer to the nucleus and the Golgi releases transport vesicles that travel throughout the cell.</p>	

Animal cells package powerful hydrolytic enzymes into specialized structures called _____, which prevent general destruction of cellular components by these enzymes.

- a. lysosomes
- b. chloroplasts
- c. mitochondria
- d. vacuoles
- e. peroxisomes

Justification/Explanation	Where did you find this information?
<p>A. The difference between lysosomes and peroxisomes is poorly understood, but the trick is in the name. Peroxisomes MAKE hydrogen peroxide and other compounds to be used to break down certain compounds (fatty acids primarily). Lysosomes use hydrolytic enzymes to break down ('lyse') cellular components. "Lysosomes use hydrolytic enzymes to lyse"</p>	
<p>B. The question stem states that this is an animal cell. Animal cells do not have chloroplasts. Furthermore, chloroplasts are involved in photosynthesis and the creation of sugars from sun energy and carbon dioxide, which is unrelated to the breakdown of toxic substances.</p>	
<p>C. The mitochondria play a major role in the production of cellular energy (ATP). These organelles include a large number of enzymes and other compounds used in cellular respiration but are not involved in the breakdown of toxic substances.</p>	
<p>D. The central vacuole plays a role in water storage, among other functions, but does not play a role in using hydrolytic enzymes to break down substances.</p>	
<p>E. Peroxisomes MAKE hydrogen peroxide and other compounds to be used to break down certain compounds (fatty acids primarily). While this is similar to lysosomes, note that the name of lysosome and peroxisome tells you something about their function.</p>	

Which of the following cell structures is **CORRECTLY** matched with the cell type it can be found in?

- a. Golgi – animal cell
- b. nucleus – bacteria
- c. lysosome – archaea
- d. nucleoid – plant cell
- e. mitochondria – virus cell

Justification/Explanation	Where did you find this information?
A. Animal cells are eukaryotic cells. By definition eukaryotic cells have membrane bound organelles, one of which is the Golgi or Golgi apparatus.	
B. Bacterial cells (domain eubacteria) are by definition prokaryotic. Prokaryotic cells do not have a membrane bound nucleus. Their genetic information is anchored within the cytoplasm but is free in that it is not enclosed in a membrane bound nucleus.	
C. Lysosomes are membrane bound organelles involved in the breakdown of toxic substances. By definition, cells in domain archaea are prokaryotic, and as such they do not have membrane bound organelles.	
D. Nucleoid is a term that refers to a sort of pre-nucleus in some prokaryotic cells, an area of the cytoplasm where most of the genetic material resides. We know that plants (domain eukarya) are eukaryotic cells, and as such house their genetic material in a nucleus.	
E. Viruses are interesting because their structure is composed only of a protein cap and genetic information. They do not have organelles, so they do not have mitochondria.	

4. Which of the following conditions would produce a cell with lots of free ribosomes (not associated with the endoplasmic reticulum)?

a. a cell that is secreting proteins

b. a cell that is producing cytoplasmic enzymes

c. a cell that is constructing its cell wall or extracellular matrix

d. a cell that is hydrolyzing starch molecules

e. a cell that is enlarging its vacuole

Justification/Explanation	Where did you find this information?
<p>A. A cell that is secreting proteins would produce the majority of its proteins in the rough endoplasmic reticulum, which would allow for more rapid transport to the golgi apparatus for packaging and delivery to the outside of the cell.</p>	
<p>B. A cell that produces cytoplasmic enzymes would have a number of free ribosomes in the cytoplasm to minimize the amount of movement of proteins required. Making proteins close to where they are required in the cytoplasm is energetically favorable.</p>	
<p>C. A cell that is constructing its cell wall/extracellular matrix will create the lipids in the smooth endoplasmic reticulum and the membrane proteins in the rough endoplasmic reticulum. Neither activity requires free ribosomes in the cytoplasm to be involved.</p>	
<p>D. Starch is hydrolyzed by extracellular secretions which includes enzymes such as alpha-amylase. Proteins that are destined to be secreted are produced by ribosomes associated with the rough endoplasmic reticulum and immediately are packaged for extracellular transport by the Golgi, as opposed to free floating cytoplasmic ribosomes.</p>	
<p>E. Enlarging a vacuole requires the production of a number of lipids to make up the organelle wall of the vacuole. This is a task that is done in the smooth endoplasmic reticulum and does not require free cytoplasmic ribosomes.</p>	

1. Why are lipids and proteins able to move laterally in biological membranes?

a. The interior of the membrane is filled with liquid water.

b. Hydrophilic parts of the lipids and proteins associate with the hydrophobic parts of the membrane.

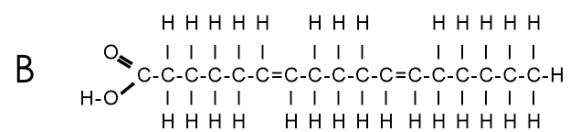
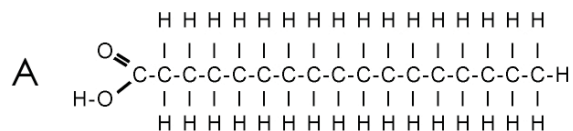
c. Lipids and proteins are held to each other by very weak covalent bonds.

d. Cellulose keeps the membrane "loose" so that lipids and proteins can move around.

e. There are no covalent bonds between the lipids and proteins in the membrane.

Justification/Explanation	Where did you find this information?
A. The interior of the membrane is hydrophobic, this term means "water-fearing" so it wouldn't make any sense that it would be filled with liquid water.	
B. Hydrophobic molecules typically associate with other hydrophobic molecules, not hydrophilic molecules.	
C. Again, bonding between lipids and proteins would hinder lateral movement so this can't be the answer.	
D. Cellulose is a polysaccharide. Polysaccharides do not alter the "looseness" of a membrane. The described action is the function of cholesterol.	
E. The lack of bonds between the lipids and proteins in the membrane allows for lateral movement.	

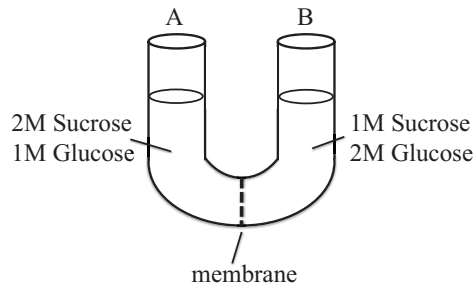
The two molecules (A and B) shown here represent fatty acid chains. Chose the **INCORRECT** statement below.



- a. Molecule B could contribute to the formation of a solid fat at room temperature.
- b. Molecule A could be a component of a triglyceride.
- c. Triglycerides formed with B would be found in plants.
- d. Molecule A is an example of a saturated fatty acid.
- e. Molecule B could covalently attach to a glycerol molecule.

Justification/Explanation	Where did you find this information?
A. Unsaturated fatty acids disrupt the Van der Waals interactions between fats, preventing them from solidifying. Molecule B is an unsaturated fatty acids therefore it would not contribute to the formation of a solid fat at room temperature.	
B. Triglycerides are comprised of three fatty acids and a glycerol, this is a fatty acid so it can be a component of a triglyceride.	
C. Molecule B is an unsaturated fatty acid. As stated in B, fatty acids are a component of triglycerides so this molecule can form a triglyceride. Plant cells typically have more unsaturated fats so the triglyceride containing this fatty acid may commonly be found in plants.	
D. All carbons in the hydrocarbon chain on Molecule A contain exclusively single bonds therefore this fatty acid is saturated.	
E. Triglycerides are formed when three fatty acids covalently bond to a glycerol molecule. Molecule B is a fatty acid therefore it can covalently bond to a glycerol molecule.	

The solutions in the two arms of this U-tube are separated by a membrane that is permeable to water and glucose, but **NOT** to sucrose. Side A is filled with a solution of 2 M sucrose and 1 M glucose. Side B is filled with 1 M sucrose and 2 M glucose. Initially, the liquid levels on both sides are equal. After the system reaches equilibrium, what changes will be observed?



been converted into glucose.

b. The concentration of glucose is higher in side A than in side B.

c. The water level is higher in side A than in side B.

d. The concentration of sucrose remains higher on side A.

e. The water level is higher in side B than in side A

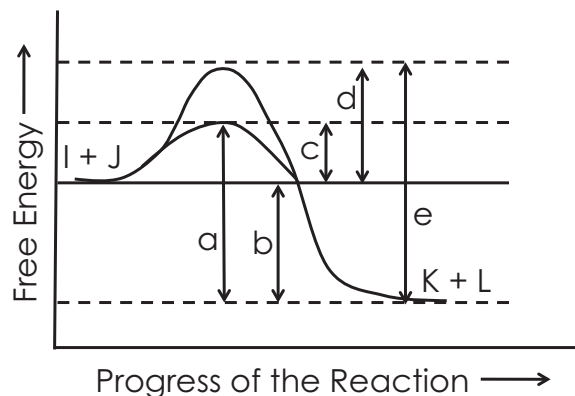
Justification/Explanation	Where did you find this information?
A. The conversion of sucrose into glucose requires an enzyme catalyst that is not present in this setup.	
B. The membrane is permeable to glucose therefore the concentration of glucose will diffuse through the membrane until they have reached equilibrium.	
C. Glucose will pass through the membrane from right to left and reach an equilibrium of 1.5M on either side. Sucrose cannot pass through the membrane so the left side will have a higher solute concentration. This in turn will result in water diffusing from right to left to equalize the solute concentration and a higher water level on side A.	
D. Water will diffuse to Side A lowering the concentration of sucrose until the two sides have equal sucrose concentrations.	
E. Water will diffuse to equalize the sucrose concentrations on either side. As stated in C, this will lower the water level on Side B.	

The movement of potassium ions from the outside (1 M K⁺) to the inside (9 M K⁺) of an animal cell (such as a neuron) requires...

- a. diffusion of potassium ions down a concentration gradient.
- b. cells that are big enough to accept the potassium ions.
- c.** an energy source such as ATP.
- d. a cotransport protein.
- e. an efficient osmosis mechanism so that ions can form and be transported.

Justification/Explanation	Where did you find this information?
A. The transport of K ⁺ ions from a low concentration to a high concentration is movement up the concentration gradient, not down. Diffusion cannot move up a concentration gradient.	
B. Cells are many times larger than K ⁺ ions so the size of the cell is not a limiting factor for ion transport.	
C. Movement of K ⁺ ions up the concentration gradients occurs via the K ⁺ /Na ⁻ pump. This pump is driven by energy from ATP.	
D. Cotransport proteins can move ions up a concentration gradient however they are not used for K ⁺ ions.	
E. Osmosis is a form of passive transport and can not move up a concentration gradient.	

Using the image below showing the reaction of $I + J \rightarrow K + L$. Which arrow corresponds to the energy released by the enzyme-catalyzed reaction?



- a. a
- b. b**
- c. c
- d. d
- e. e

Justification/Explanation	Where did you find this information?
A. This reaction is exothermic; the amount of energy released in an exothermic reaction is defined as the difference in free energy between the reactants and products. Answer A includes the activation energy required to drive the catalyzed reaction.	
B. This reaction is exothermic; the amount of energy released in an exothermic reaction is defined as the difference in free energy between the reactants and products. This difference is indicated by answer B.	
C. Answer choice only represents the activation energy of the catalyzed reaction and does not include the difference between the reactants and products.	
D. Answer choice only represents the activation energy of the uncatalyzed reaction and does not include the difference between the reactants and products.	
E. This reaction is exothermic; the amount of energy released in an exothermic reaction is defined as the difference in free energy between the reactants and products. Answer E includes the activation energy required to drive the uncatalyzed reaction.	

The reaction shown below represents...



a. those of the Calvin cycle.

b. the overall reaction of photosynthesis.

c. those of the light reactions.

Justification/Explanation	Where did you find this information?
A. The Calvin cycle consumes CO ₂ to produce glucose independent of light. It is powered by the ATP and NADPH from the light-dependent reactions	
B. Photosynthesis is a two-part process, beginning with the light reactions and ending with the Calvin cycle. The net reaction consumes light, water, and Carbon Dioxide to form glucose and oxygen.	
C. The light reactions produce energy in the form of ATP and NADPH to power the Calvin cycle.	

Where would one find the enzymes of the Calvin cycle?

- a. The stroma of the chloroplast
- b. Within the membranes of the thylakoids
- c. The outer membranes of the chloroplast
- d. Within the thylakoid space

Justification/Explanation	Where did you find this information?
A. The Calvin Cycle occurs in the stroma of the chloroplast so the enzymes related to this reaction would be housed in the stroma.	
B. The membrane of the thylakoid is most directly involved in the light reactions, not the Calvin Cycle.	
C. The primary function of the outer membrane of the chloroplast is to maintain the environment of the chloroplast relative to the surrounding cell. It is not directly involved in the Calvin Cycle.	
D. The thylakoid space mainly functions as a Hydrogen ion sink creating a gradient which helps drive ATP synthesis in the light reaction.	

Early investigators thought that the oxygen produced through photosynthesis came from carbon dioxide. In fact, it comes from...

- a. water.
- b. glucose.
- c. the air that plants breathe
- d. the hydrolysis of carbohydrates.
- e. oxidation of NADPH.

Justification/Explanation	Where did you find this information?
A. Water is split by Photosystem II where the electrons it releases are excited by light absorbed via pigments. As a result of this splitting, Oxygen is released.	
B. Glucose is a product of photosynthesis so it could not possibly be the source of the Oxygen.	
C. The air that plants breathe is CO ₂ . The question itself points out that Oxygen is not produced from CO ₂ . The oxygen held in CO ₂ is incorporated into glucose and water.	
D. Carbohydrate hydrolysis is not related to photosynthesis. The break down of carbohydrates is part of cellular respiration.	
E. The oxidation of NADPH results in NADP ⁺ + a proton and an electron.	

Assume a thylakoid membrane is punctured so that the interior of the thylakoid is no longer separated from the stroma. This damage will have the most immediate effect on...

- a. the ability to split water.
- b. the absorption of light energy by chlorophyll.
- c. the flow of electrons from photosystem II to photosystem I.
- d.** the ability to synthesize ATP.
- e. the reduction of NADP⁺ to NADPH.

Justification/Explanation	Where did you find this information?
<p>A. Water is split by Photosystem II, this process does not rely on the electrochemical gradient maintained by an intact thylakoid membrane so it would not be immediately impacted.</p>	
<p>B. Chlorophyll and other pigments absorb light independent of the electrochemical gradient maintained by the thylakoid membrane. The pigments are contained within the photosystems and should retain their function despite the puncture.</p>	
<p>C. This flow would be minimally impacted if at all. The embedded photosystem proteins are free moving throughout the 3D thylakoid membrane therefore they would maintain their function as long as they were able to reorient so the puncture did not physically separate them in the membrane.</p>	
<p>D. ATP synthase relies directly on the electrochemical gradient between the thylakoid lumen and the stroma. Puncturing the membrane would <i>immediately</i> destroy this gradient as H⁺ diffuses into the lumen.</p>	
<p>E. The reduction of NADP⁺ to NADPH is at the end of the linear electron flow. If the flow from PSII to PSI is not affected then the reduction to NADPH should be intact.</p>	

In linear electron flow, ATP and NADPH are produced by _____ and subsequently used by _____.

a. Glycolysis/fermentation

b. Calvin cycle/oxidative phosphorylation

c. Light reactions/substrate level phosphorylation

d. Light reactions/Calvin cycle

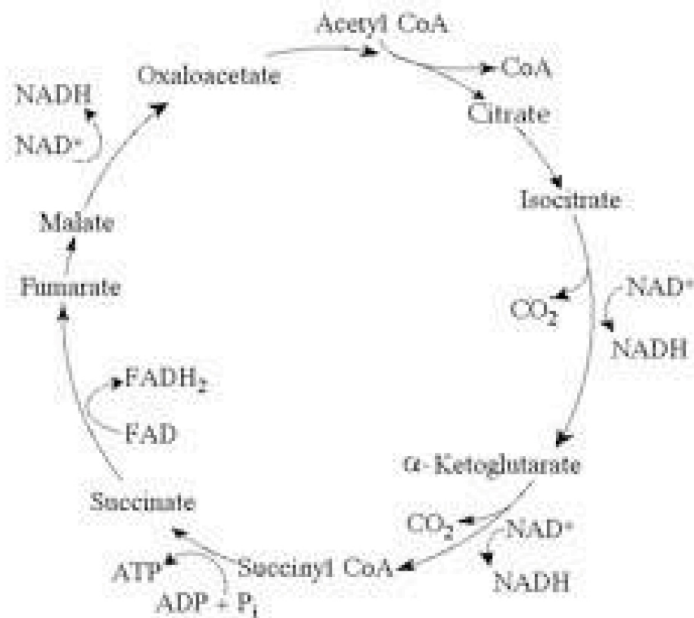
Justification/Explanation	Where did you find this information?
<p>A. Glycolysis produces NADH not NADPH. ATP produced by glycolysis is not used to drive fermentation. Also, the term “linear electron flow” refers to a photosynthetic process.</p>	
<p>B. The Calvin Cycle uses ATP and NADPH; it does not produce them. However, the second half of this statement would be correct – oxidative phosphorylation does consume ATP and NADPH.</p>	
<p>C. Light reactions do produce ATP and NADPH however substrate level phosphorylation also produces ATP rather than consuming it.</p>	
<p>D. The light reaction drives the linear electron flow that creates NADPH and ATP. These energy stores are then used to drive the Calvin cycle and produce glucose.</p>	

Which of the following occur exclusively in the cytoplasm of both eukaryotic and prokaryotic cells?

- a. substrate-level and oxidative phosphorylation
- b. oxidation of pyruvate to acetyl CoA and substrate level phosphorylation
- c. the Citric acid cycle and the Calvin cycle
- d. only chemiosmosis
- e. glycolysis and fermentation**

Justification/Explanation	Where did you find this information?
A. Substrate-level phosphorylation occurs in both the cytoplasm, during glycolysis, as well as in the mitochondria during the Citric Acid Cycle. Furthermore, Oxidative phosphorylation in eukaryotes occurs in the mitochondria, not the cytoplasm.	
B. Acetyl CoA is the precursor molecule to the citric acid cycle. It is generated by via pyruvate oxidation in the mitochondrial matrix.	
C. The citric acid cycle occurs in the mitochondrial matrix and the Calvin cycle occurs in the chloroplast.	
D. Chemiosmosis refers to the movement of Hydrogen ions across the mitochondrial membrane during ATP synthesis so it occurs only in the mitochondria.	
E. Neither glycolysis nor fermentation requires a gradient maintained by a membrane to proceed (contrast with electrochemical gradient in electron transport chain, for example). As a result, they both are able take place exclusively in the cytoplasm.	

Using this image and starting with one molecule of citrate and ending with oxaloacetate, what is the maximum number of ATP molecules that could be made through **oxidative phosphorylation**?
 (Assume only 1 turn of the cycle)



- a. 1
- b. 2
- c. 11**
- d. 12
- e. 14

Show your work:

For each turn of the cycle, three NADH's, one FADH₂, and one ATP are generated. Each NADH can be oxidized to produce 3 ATP molecules through oxidative phosphorylation. Each FADH₂ can be oxidized to produce 2 ATP molecules through oxidative phosphorylation.

$$(3 \text{ ATP} \times 3 \text{ NADH}) + (2 \text{ ATP} \times 1 \text{ FADH}_2) + 1 \text{ ATP} = 12 \text{ ATP Total}$$

However, the ATP generated during the cycle is created via substrate-level phosphorylation rather than oxidative. The question is specifically looking for the number of ATP created by oxidative phosphorylation therefore the answer is 11 ATP.

The reason why NADH is responsible for the creation of 3 ATP whereas FADH₂ is responsible for only 2 ATP is because the electrons carried by each compound enter the electron transport chain at different points and NADH enters earlier (Complex I vs Complex II).

Justify your answer selection:

The ATP generated during the cycle is created via substrate-level phosphorylation rather than oxidative. The question is specifically looking for the number of ATP created by oxidative phosphorylation therefore the answer is 11 ATP.

As electrons travel from Complex I towards Complex IV of the electron transport chain...

a. oxygen, carbon dioxide, and water are moved from the matrix into the intermembrane space of the mitochondrion.

b. a proton (H^+) gradient is created across the inner membrane of the mitochondrion.

c. oxygen is produced.

d. NADH is converted into $FADH_2$.

e. CO_2 molecules are reduced.

Justification/Explanation	Where did you find this information?
A. The movement of electrons through the complexes of the electron transport chain moves hydrogen ions from the mitochondrial matrix to the intermembrane space. Oxygen, CO_2 and water are not shuttled as part of this system.	
B. The electron transport chain uses the energy generated via electron transfer to move hydrogen ions into the mitochondrial intermembrane space against its concentration gradient. The resulting electrochemical gradient is used to generate ATP via ATP synthase.	
C. Oxygen atoms act as the final electron acceptor in this transport chain. It receives electrons exiting the chain at Complex IV where Oxygen bonds to two hydrogen atoms to form water.	
D. NADH never is converted to $FADH_2$. Remember that these two molecules act as electron carriers that alternate between oxidized states (NAD^+ , FAD^+) and reduced states ($NADH$, $FADH_2$) throughout cellular respiration.	
E. During cellular respiration, CO_2 is created as a byproduct of glucose oxidation. Once created, CO_2 is not processed further (it is released as waste).	

After glycolysis and the Citric Acid (Krebs) Cycle and before the electron transport chain and oxidative phosphorylation, the carbon skeleton of glucose has been broken down to carbon dioxide. Most of the energy from the original glucose, at this point, is in the form of _____.

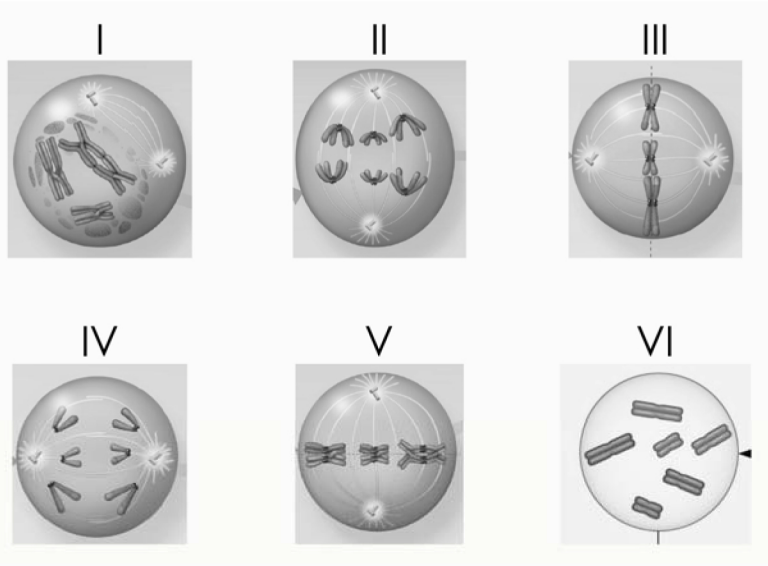
- a. ATP
- b. CO₂
- c. FADH₂
- d. protons
- e. NADH**

Justification/Explanation	Where did you find this information?
A. Both the Citric Acid Cycle and glycolysis have taken place at this point, each producing 2 ATP via substrate-level phosphorylation. Each glucose molecule produces 30-34 ATP molecules -- at this point the majority of the energy is not stored as ATP but rather in the form of high energy electrons carried by electron carriers.	
B. CO ₂ is produced by the breakdown of glucose however it does not function as an energy reservoir. Furthermore, if cellular respiration stored energy in CO ₂ , this energy would be lost because CO ₂ is released as a waste product of the reaction.	
C. The Citric Acid Cycle produces two FADH ₂ molecules per glucose. The electrons carried by each molecule can be used to create 2 ATP through oxidative phosphorylation. 2 ATP x 2 FADH ₂ = 4 ATP, this is still the minority of the 30-34 ATP created by each glucose.	
D. Because the question is asking about energy storage prior to the electron transport chain, hydrogen ions (aka protons) are not integrally involved in energy storage or creation.	
E. The Citric Acid Cycle produces 6 NADH molecules per glucose and glycolysis produces 2. The electrons carried by each molecule can be used to create 3 ATP molecules through oxidative phosphorylation 3 ATP x 8 NADH = 24 ATP, therefore this molecule is the major energy reservoir at this point.	

These images represent three pairs of homologous chromosomes as they might appear during various stages of either Mitosis **OR** Meiosis.

Which image(s) represents metaphase II?

- a. I
- b. II
- c. III**
- d. IV
- e. V



Justification/Explanation	Where did you find this information?
A. In this image, the nuclear envelope has begun to dissipate and the kinetochore microtubules have begun to assemble. This represents late-prophase I or early-prometaphase I.	
B. In this image, homologous chromosomal pairs are being pulled towards the poles by microtubules. This represents Anaphase I.	
C. This image shows sister chromatids lined up on the metaphase plate with patches that have crossed over. This image shows Metaphase II. If this were metaphase in mitosis, there would not be any evidence of crossing over.	
D. This image shows sister chromatids, with evidence of crossing over, being pulled apart towards the poles of the cell. This is anaphase II. Again, the evidence of crossing over distinguishes Anaphase II from Anaphase of mitosis.	
E. Here tetrads are shown lined up on the metaphase plate. This is indicative of Metaphase I.	

Figure from: Campbell Biology, 9th edition, Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). San Francisco, CA, Benjamin Cummings

Crossover, the exchange of segments of homologous chromosomes, takes place only during...

- a. DNA replication
- b. Cytokinesis
- c. Anaphase I
- d. Prophase I**
- e. Metaphase

Justification/Explanation	Where did you find this information?
A. DNA replication occurs during the S phase of the cell cycle. The S phase precedes crossing over that occurs during Meiosis.	
B. The homologous chromosomes are physically distant from one another during cytokinesis and separated by newly forming nuclear envelopes. Crossing over requires contact between the homologous chromosomes therefore it cannot occur during cytokinesis.	
C. Anaphase I separates the homologous chromosomes after crossing over has occurred.	
D. Crossing over requires physical contact between homologous chromosomes; during Prophase I, the homologous chromosomes pair up allowing them to exchange genetic material.	
E. Metaphase (without a I or II) is a mitotic process. In mitosis, Metaphase lines up sister chromatids rather than homologous chromosomes therefore this could not be the answer.	

In which group of organisms or type of cell does the nuclear envelope remain intact during mitosis?

- a. apple tree flower cells
- b. bone marrow
- c. yeasts**
- d. bacteria

Justification/Explanation	Where did you find this information?
A. Plant cells dissipate their nuclear envelopes allowing kinetochores to associate with centromere regions and control chromosomal movement during cell division.	
B. Animal cells dissolve their nuclear envelopes during mitosis to allow centrioles/kinetochores to associate with centromeres and control chromosomal movement during cell division.	
C. Yeast cells undergo an intermediate form of cell division between binary fission and higher eukaryotic mitosis. This intermediate does <i>not</i> require the breakdown of the nuclear envelope.	
D. Bacteria do not have nuclear envelopes and undergo binary fission rather than mitosis.	

Independent assortment of chromosomes can occur during...

- a. Mitosis.
- b. Meiosis II only.
- c. Mitosis and Meiosis I.
- d.** Meiosis I only.
- e. fertilization.

Justification/Explanation	Where did you find this information?
<p>A. Independent assortment refers to the random alignment of homologous chromosomes on the metaphase plate during Metaphase I. During mitotic Metaphase, sister chromatids line up rather than homologous chromosomes.</p>	
<p>B. Homologous chromosomes are separated from one another during Meiosis I, as a result Meiosis II has sister chromatids rather than homologous pairs. Independent assortment occurs with homologous pairs so it cannot occur during Meiosis II.</p>	
<p>C. As stated in A, independent assortment does not occur during mitosis.</p>	
<p>D. Homologous chromosomes line up randomly along the metaphase plate during Metaphase I. This results in 2^N chromosomal possibilities in the gametes (where N = the number of chromosomes in the organism).</p>	
<p>E. Independent assortment randomly partitions maternal and paternal chromosomes into new gametes. In contrast, Fertilization brings together the maternal in the paternal gametes into a 2N zygote – these chromosomes can only be viably organized in one way.</p>	

Which of the following occurs in MEIOSIS but NOT in MITOSIS?

- a. sister chromatids separate from each other
- b. attachment of centromeres/kinetochores to spindle fibers
- c. disappearance of the nuclear membrane and condensing of the chromosomes
- d.** pairing up of homologous chromosomes
- e. lining up of duplicated chromosomes along the middle of the dividing cell

Justification/Explanation	Where did you find this information?
A. Sister chromatids must separate in each process, otherwise the number of sets of chromosomes (N-number) would increase with each replication.	
B. The attachment of centromeres/kinetochores to spindle fibers is an integral process of both mitosis and meiosis. This attachment is responsible for moving the chromosomes to the metaphase plate as well as pulling the chromosomes apart during anaphase.	
C. Both mitosis and meiosis are processes that are responsible for the division of the nucleus to make new cells. In order to do this accurately and efficiently, the nuclear envelope must be dissolved and the chromosomes must condense so that the events in B can occur smoothly.	
D. Homologous chromosomes pair up during Meiosis I and are collectively called tetrads. This is a major difference between Meiosis I and Mitosis. In both processes, the amount of genetic material is similar, but in Mitosis sister chromatids line up instead of homologous pairs of chromosomes.	
E. This describes the events that occur during metaphase. This phase is seen in both Mitosis and Meiosis. Because the question stem does not specify what type of duplicated chromosomes are lining up, both processes could have this step.	

A woman with blood type A+ has a daughter who is type O- and a son who is type B-. Rh positive (+) is a trait that shows simple dominance over Rh negative (-) and is designated by the alleles R and r, respectively.

Which of the following might be the genotype of these children's father?

- a. $I^A I^A r r$
- b. $I^A I^B R r$
- c. $I^A i r r$
- d. $I^B i r r$**
- e. $I^B i R R$

Show your work and justify your answer choice.

Justification/Explanation	Where did you find this information?
<p>Show your work:</p> <p>Mom: $I^A i$ for ABO blood type (has a child who is type O, therefore must have an i allele), $R r$ for Rh blood type (has two children who are Rh negative, so must have an r allele)</p> <p>Daughter: $I^B i$ for ABO blood type (cannot be $I^B I^B$ because the mother does not have an I^B allele (if the mother did she would be AB, not just A)), $r r$ for Rh blood type</p> <p>Son: $i i$ for ABO blood type, $r r$ for Rh blood type</p> <p>Dad: must have an I^B allele because the daughter is type B, must also have an i allele because the son is type O, meaning he is $I^B i$ for ABO blood type. Must have at least one r allele because both of his children are Rh negative. It is possible that the father could be $R r$ or $r r$.</p>	
<p>Justify your answer choice: the father must be either $I^B i R r$ or $I^B i r r$ because of the genotype of the mother and the genotype of his children. Because $I^B i R r$ is not one of the answer choices, we know that d is the correct answer. The other answers are incorrect because a mating between those genotypes and the mother could not result in the children from the question stem.</p>	

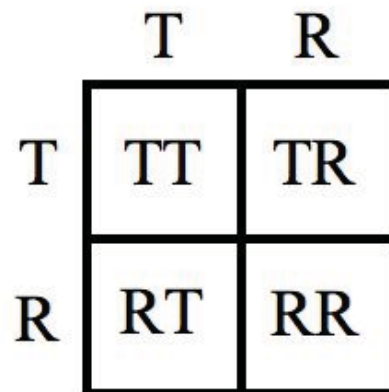
The image below of a Punnett Square predicts the probability of outcomes between the cross of 2 heterozygotes (pink flowers). The alleles T and R show INCOMPLETE dominance for pigmentation in flower petal color (T = red pigment/R = white pigment).

If the two different pure breeding offspring resulting from the cross shown were selected and further crossed, what would be the F2 phenotype(s)?

- a. All white-colored flowers.
- b.** All pink-colored flowers.
- c. 1 red-color, 1 white-color, and 2 pink-color flowering plants.
- d. 2 plants will have red flowers and 2 will have white flowers.
- e. 3 plants will have red flowers and 1 will have white flowers.

Explain what kind of inheritance pattern would cause the incorrect answers.

Justification/Explanation	Where did you find this information?
A. In order to have all white flowers, you would have to mate RR with another RR. Because the question states two DIFFERENT pure breeders must be selected, this is not possible.	
B. The two PURE BREEDING F1 flowers are TT and RR, meaning a cross of the two would result in all TR flowers (pink).	
C. This would be the result if two pink flowers (TR) were crossed, like the Punnett Square in the question stem, but as you can see these are not PURE BREEDING plants.	
D. This result is impossible if we breed a pure breeding red and white plant together.	
E. This ratio would be seen if the T allele was DOMINANT to the R allele.	



Show your work:

TT x RR would result in all TR (pink) flowers.

Using the Punnett square below, what offspring are predicted from a cross between individual 1 and individual 2?

- a. Dd
- b. DD
- c. dd
- d. 50% DD and 50% Dd**
- e. 1 DD, 2 Dd, and 1 dd

	D	d
D	1	2
d	4	3

Justification/Explanation	Where did you find this information?									
<p>Show your work:</p> <p>Individual 1 is DD (homozygous dominant) and Individual 2 is Dd (heterozygous). A cross between the two would produce:</p> <table border="1" data-bbox="837 457 1411 984"> <tr> <td></td> <td>D</td> <td>D</td> </tr> <tr> <td>D</td> <td>DD</td> <td>DD</td> </tr> <tr> <td>d</td> <td>Dd</td> <td>Dd</td> </tr> </table> <p>This cross produces 2 DD and 2Dd individuals by genotype. These individuals would all exhibit the dominant phenotype if this gene follows a dominant/recessive pattern of inheritance.</p>			D	D	D	DD	DD	d	Dd	Dd
	D	D								
D	DD	DD								
d	Dd	Dd								
<p>Justify your answer choice and explain how the other answer choices could arise from breeding the individuals from the question stem: By doing the Punnett Square for the two individuals, we came to this answer. Answer A would be the result of a homozygous dominant and recessive cross. Answer b would be the result of two homozygous dominants crossing. Answer c would be the result of two homozygous recessives crossing, and answer e would be the result of two heterozygotes crossing.</p>										

In a cross $AaBbCc \times AaBbCc$, what is the probability of producing the genotype $AABbcc$?

- a. $1/4$
- b. $1/32$**
- c. $1/64$
- d. $4/32$
- e. $4/64$

Show your work and justify your answer choice.

Justification/Explanation		Where did you find this information?																											
<p>Show your work:</p> <p>This is a trihybrid cross. Completing the full punnet for these three genes would be very time consuming. Instead we can look at the probabilities for each individual genotype occurring and then multiply the probabilities of these independent events to determine the overall probability of the genotype $AABbcc$ occurring.</p> <p>Probability of child having $AABbcc$=</p> <table border="1" style="display: inline-table; margin-right: 20px;"> <tr><td></td><td>A</td><td>a</td></tr> <tr><td>A</td><td>AA</td><td>Aa</td></tr> <tr><td>a</td><td>Aa</td><td>aa</td></tr> </table> <table border="1" style="display: inline-table; margin-right: 20px;"> <tr><td></td><td>B</td><td>b</td></tr> <tr><td>B</td><td>BB</td><td>Bb</td></tr> <tr><td>b</td><td>Bb</td><td>bb</td></tr> </table> <table border="1" style="display: inline-table;"> <tr><td></td><td>C</td><td>c</td></tr> <tr><td>C</td><td>CC</td><td>Cc</td></tr> <tr><td>c</td><td>Cc</td><td>cc</td></tr> </table> <p>Here we see that there is a $\frac{1}{4}$ chance each that these two parents create a homozygous child for the A and C genes, while there is a $\frac{1}{2}$ chance of these two parents create a heterozygote child for the B gene. These conditions must all occur simultaneously therefore we use the product rule:</p> <p>$\frac{1}{4}$ (chance AA) x $\frac{1}{2}$ (chance Bb) x $\frac{1}{4}$ (chance cc) = $1/32$ chance $AABbcc$</p>				A	a	A	AA	Aa	a	Aa	aa		B	b	B	BB	Bb	b	Bb	bb		C	c	C	CC	Cc	c	Cc	cc
	A	a																											
A	AA	Aa																											
a	Aa	aa																											
	B	b																											
B	BB	Bb																											
b	Bb	bb																											
	C	c																											
C	CC	Cc																											
c	Cc	cc																											
<p>Justify your answer choice:</p> <p>By using the multiplication rule, we can see that this genotype would be produced $1/32$ times.</p>																													

If true-breeding red flowered and true-breeding white flowered four o'clock (*Mirabilis jalapa*) plants are crossed, pink-flowered F₁ offspring are produced. If two of these F₁ are crossed, the F₂ contain red, white, and pink four o'clock flowers. This flower color trait must be an example of...

- a. epistasis.
- b. codominance.
- c.** incomplete dominance.
- d. pleiotropy.
- e. environmental factors.

Justification/Explanation	Where did you find this information?
<p>A. Epistasis is when the expression of a particular gene is influenced by the presence of some other gene. If this were the case in this problem, we would have to have more information, and this particular type of epistasis would be extremely rare.</p>	
<p>B. Codominance is when both phenotypes are present at the same time in a heterozygote. An example of this is the ABO blood type system where an AB heterozygote expresses both the A and B phenotypes at the same time. This question describes a “blended” heterozygote phenotype, which is not codominance.</p>	
<p>C. This is the correct answer. Incomplete dominance is when the heterozygote has a “blended” phenotype somewhere in between the phenotypes of the homozygous individuals for that gene. In this case, pink is a blend of red and white.</p>	
<p>D. Pleiotropy is when one gene codes for multiple phenotypes. This question describes a “blended” heterozygote phenotype for one gene, whereas pleiotropy would explain the changing of multiple phenotypes from the altering of one genotype.</p>	
<p>E. While environmental factors certainly can influence the degree to which a particular genotype is expressed, in this case, the presence of a blended phenotype for both heterozygote individuals suggests incomplete dominance rather than environmental factors.</p>	

The sex of chickens is determined by a ZW chromosome scheme. Males are ZZ and females are ZW. A recessive lethal allele that causes death of the embryo is sometimes present on chicken sex chromosomes. What would be the sex ratio in the LIVING offspring of a cross between a male that is heterozygous for a lethal allele and a normal female?

- a. 1 male: 2 female
- b. 1 male: 1 female
- c. 4 male: 3 female
- d. 3 male: 1 female
- e.** 2 male: 1 female

Justification/Explanation		Where did you find this information?									
<p>Show your work: If we call a normal allele Z and a lethal allele Z-, and assume that this gene is passed on via the sex chromosomes:</p> <table border="1" data-bbox="835 396 1432 995"> <thead> <tr> <th></th> <th>Z</th> <th>Z- (male)</th> </tr> </thead> <tbody> <tr> <th>Z</th> <td>ZZ</td> <td>ZZ-</td> </tr> <tr> <th>W</th> <td>ZW</td> <td>Z-W</td> </tr> </tbody> </table> <p>We can see from this cross that one half of the offspring will receive the lethal allele, however the question asks what the sex ratio will be for only the LIVING offspring. We can see that the female Z-W offspring will, in fact, die before being born. As such, the ratio will be 2 living males for each living female.</p>				Z	Z- (male)	Z	ZZ	ZZ-	W	ZW	Z-W
	Z	Z- (male)									
Z	ZZ	ZZ-									
W	ZW	Z-W									
<p>Justify your answer choice: By doing the Punnett square for the given genotypes, we found that one of the females would die, thus the left over ratio is 2 males:1female.</p> <p>What if this gene was on the autosomal (non-sex) chromosomes?: There would be 50% carrier individuals and 50% normal individuals genetically, and all individuals would live, meaning that the sex ratio would be 1:1.</p>											

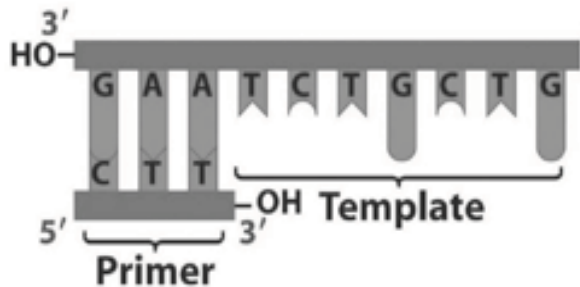
In which way is the leading strand in DNA replication different from the lagging strand?

- a. The leading strand is synthesized in the nucleus, while the lagging strand is synthesized in the cytoplasm.
- b. The leading strand requires an RNA primer while the lagging strand does not.
- c.** The leading strand is synthesized continuously in the 5' to 3' direction, while the lagging strand is synthesized in short segments in the 5' to 3' direction.
- d. DNA Polymerase I synthesizes the leading strand while DNA Polymerase III synthesizes the lagging strand.
- e. The leading strand is synthesized completely before synthesis of the lagging strand begins.

Justification/Explanation	Where did you find this information?
A. All DNA replication is done in the Nucleus. The only time that DNA is in the cytoplasm is during Mitosis and Meiosis when the nuclear envelope dissipates.	
B. Both the leading and lagging strands require an RNA primer. The lagging strand requires MORE THAN ONE RNA primer, however both strands require RNA primers to start replication.	
C. This is correct. Both the leading and lagging strands are synthesized at the same time, in the same direction. However, because of the shape of the replication fork, how it opens up, and the antiparallel structure of DNA, the lagging strand must be synthesized in short segments rather than continuously. "semidiscontinuous".	
D. DNA polymerase I and DNA polymerase III are BOTH involved in the synthesis of new DNA on the lagging AND leading strands. DNA polymerase III is responsible for the elongation of the new DNA strand by adding bases one at a time. DNA polymerase adds bases one at a time, but only replaces the RNA primer. This must be done for both strands.	
E. If this were the case, it would be extremely time consuming. In actuality, when the replication bubble opens up, the leading and lagging strands are both synthesized at the same time in both directions down the chromosome.	

A primer has been made using one strand of DNA as a template as shown below. Which enzyme will use the primer to start making new DNA?

- a. Primase
- b. RNA polymerase
- c. DNA Polymerase III**
- d. Topoisomerase
- e. DNA Polymerase I



Justification/Explanation	Where did you find this information?
A. Primase is the enzyme responsible for actually making the primer. Once the primer is complete, primase is no longer used.	
B. RNA polymerase is an enzyme that is used in making large molecules of RNA, a process called transcription. It has a similar function to primase, DNA polymerase III, and DNA polymerase I, but is used in a different situation.	
C. DNA polymerase III is responsible for the elongation of new DNA molecules. It reads the template strand of DNA and synthesizes new DNA base by base in a 5' to 3' direction. DNA polymerase III needs a 3' end to start working, so the primer provides that.	
D. Topoisomerase is an enzyme that is responsible for the unwinding of DNA so that replication can occur. DNA is tightly wound for storage purposes when DNA is not being replicated or transcribed into RNA. Topoisomerase is not involved in making new DNA directly.	
E. DNA polymerase I DOES make new DNA, BUT it does not USE THE PRIMER to do so. In fact, it replaces the primer, which is made of RNA bases, with DNA bases.	

The DNA double helix has a uniform diameter because...

a. cytosine nucleotides pair with adenine nucleotides.

b. the molecular backbone is made of deoxyribose and phosphates.

c. nucleotides bind with amino acids.

d. pyrimidines only pair with purines.

e. all the H-bonds are the same length.

Justification/Explanation	Where did you find this information?
A. Although adenine and Cytosine are purines and pyrimidines, respectively, they do not pair. In fact, Cytosine and guanine pair, while adenine and thymine pair.	
B. the backbone is made of deoxyribose and phosphates, however that does not determine the uniform diameter of the molecule. Each DNA base has the same sugar/phosphate background, but that is not what determines the diameter.	
C. Nucleotide is a term that refers to the monomer form of DNA. They are composed of a sugar, a phosphate group, and a nitrogenous base. Amino acids are another kind of monomer that combine to form proteins. These monomers do not combine to form DNA and are not responsible for the size of DNA	
D. this is correct. While answer A is an example of a pyrimidine and a purine pairing, it is an incorrect pairing, so that answer is incorrect. This answer is more general, and describes how a pyrimidine (a smaller nitrogenous base) will always pair with a purine (a larger nitrogenous base) to maintain a uniform diameter.	
E. The length of the hydrogen bonds between nitrogenous bases are very similar, however they are not all identical.	

Place the following steps of DNA replication in chronological order.

1. Single-stranded binding proteins attach to DNA strands.

2. Hydrogen bonds between base pairs of antiparallel strands are broken.

3. Primase binds to the site of origin.

4. DNA polymerase polymerizes along the template strand.

5. An RNA primer is created.

a. 1, 2, 3, 4, 5

b. 2, 1, 3, 5, 4

c. 3, 2, 1, 5, 4

d. 1, 2, 3, 5, 4

e. 2, 3, 5, 1, 4

Justification/Explanation	Where did you find this information?
Put these steps in order and describe why they must occur in that order:	

A possible sequence of nucleotides in the mRNA that would code for the polypeptide sequence arg-val-thr-tyr would be...(The table indicates codons with 5' on the left and 3' on the right.)

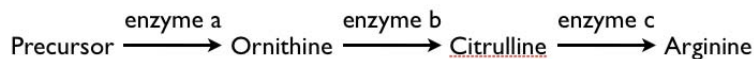
- a. 5' AUG-GUA-ACG-UGA 3'
- b. 5' AGG-GUU-ACA-UAC 3'.**
- c. 5' AUG-CTG-CAG-TAT 3'.
- d. 3' TCC-CCG-ATG-GUU 5'.
- e. 5' UCC-CAA-UGU-AUG 3'.

		Second base				
		U	C	A	G	
U	UUU	UCU	UAU	UGU	U	
	UUC	UCC	UAC	UGC	C	
	UUA	UCA	UAA Stop	UGA Stop	A	
	UUG	UCG	UAG Stop	UGG Trp	G	
C	CUU	CCU	CAU	CGU	U	
	CUC	CCC	CAC	CGC	C	
	CUA	CCA	CAA	CGA	A	
	CUG	CCG	CAG	CGG	G	
A	AUU	ACU	AAU	AGU	U	
	AUC	ACC	AAC	AGC	C	
	AUA	ACA	AAA	AGA	A	
	AUG	ACG	AAG	AGG	G	
G	GUU	GCU	GAU	GGU	U	
	GUC	GCC	GAC	GGC	C	
	GUA	GCA	GAA	GGA	A	
	GUG	GCG	GAG	GGG	G	

Justification/Explanation	Where did you find this information?
<p>Show your work:</p> <p>We are looking to make an Arg-Val-Thr-Tyr protein.</p> <p>Answer D can be eliminated because the mRNA strand is read 5' to 3'. That leaves us with A, B, C, and E as options.</p> <p>The bases that code for Arg are AGA or AGG, meaning that answer E is not possible, but answers A, B, and C are still possibilities.</p> <p>The bases that code for Val are GUU, GUC, GUA, or GUG. This eliminates answer choice C, but answers A and B are still possible.</p> <p>The bases that code for Thr are ACU, ACC, ACA, and ACG. Both A and B have one of these combinations.</p> <p>The bases that code for Tyr are UAU and UAC. As we can see, only answer choice B has one of those combinations. In fact, answer choice A codes for a stop codon.</p>	
<p>Justify your answer: We know that mRNA is read by the ribosome in a 5' to 3' manner, and that the code of the mRNA is used to determine the amino acid that is added to the chain. By going codon by codon you can determine the amino acid sequence coded for by the mRNA.</p>	

According to the table and figure below, representing data similar to the Beadle and Tatum experiment, which enzyme is defective in mutant #2?

- a. DNA polymerase
- b.** The enzyme that converts ornithine to citrulline
- c. The enzyme that converts precursor to ornithine
- d. The enzyme that converts citrulline to arginine
- e. The enzyme that converts precursor to enzyme a



Mutant #	Medium + no ornithine no citrulline no arginine	Medium + ornithine no citrulline no arginine	Medium + no ornithine citrulline no arginine	Medium + no ornithine no citrulline arginine
1	no growth	growth	growth	growth
2	no growth	no growth	growth	growth
3	no growth	no growth	no growth	growth

Justification/Explanation	Where did you find this information?
A. The production of enzymes is what is holding up these cells. There is no evidence that DNA is not being properly replicated. In fact, we can see that all three mutants can grow in certain cases, meaning that replication must be occurring normally.	
B. By comparing the second and third medium results, we see that when provided ornithine only, mutant 2 cannot grow, but when provided citrulline only, mutant 2 can grow. This means that the cells are incapable of converting ornithine to citrulline.	
C. We assume that only one enzyme is broken in mutant 2. In the second medium, if the enzyme that converts the precursor to ornithine was the only mutant enzyme, then we would see growth. Since we do not see growth, we know that this cannot be correct.	
D. We can see that mutant 2 is able to grow in the third medium, which includes citrulline but no arginine. If this enzyme were defective, the cell would not be able to grow because it would not be able to convert citrulline into arginine. Because it does grow, we know that the enzyme must be functional.	
E. This answer is not plausible. The precursor compound is not converted to enzyme a. the diagram shows that enzyme a is used to convert the precursor molecule into ornithine.	

Which of the following mutations, if it occurred in the DNA, is potentially the LEAST damaging to the resulting polypeptide?

a. A base substitution in the first position of one codon in the middle of the gene.

b. A frame shift mutation close to the beginning of the gene.

c. A silent mutation close to the translation stop site.

d. Removal of the start codon.

e. A nonsense mutation close to the 5' end of the mRNA.

Justification/Explanation	Where did you find this information?
A. The codon-to-amino acid translation code has some flexibility, multiple codons can code for the same amino acid. However, typically these differences occur in the third base of a codon. Changes in the first base almost always result in a different amino acid.	
B. Frame shift mutations are actually quite damaging to the protein because the shift in reading frame will likely cause a large number of the amino acids to be coded in a new way, likely causing a misshapen and nonfunctional protein.	
C. A silent mutation, although a mutation, does not actually affect the final protein structure. Because some amino acids can be coded for by slightly different codons, silent mutations can occur without affecting the protein structure.	
D. The removal of the start codon will mean that the protein will either not be made at all, or if there is another start codon within the remaining sequence of bases, the protein will start being translated there and a smaller nonfunctional protein will be made. In either case this is harmful to the protein.	
E. A nonsense mutation close to the 5' end of the mRNA will be very damaging to the protein. Since the mutation is occurring near the 5' end, this means it occurs near the beginning of the sequence. The nonsense mutation will code for the protein to stop being translated, resulting in a short non-functional protein.	

Transcription in prokaryotic and eukaryotic cells share all the following, EXCEPT...

- a. RNA Polymerase is required.
- b.** a 5'-Cap and a 3'-Poly-A tail are required before translation can start.
- c. transcription starts before translation can begin.
- d. transcription stops at a transcription stop site.
- e. ribonucleotides are monomers used in the synthesis of the mRNA.

Justification/Explanation	Where did you find this information?
A. Transcription involves converting genetic material into mRNA. In both eukaryotic and prokaryotic cells, RNA polymerase is used to make pre-mRNA, which is then modified to make the final mRNA.	
B. These are examples of post-transcriptional modifications that are specific to eukaryotes. After transcription, eukaryotes have what is called "pre-mRNA", which is then altered slightly to make the final, mature mRNA. The 5'-cap and 3'-Poly-A tail are added for stability.	
C. Central dogma dictates that DNA or RNA is made into mRNA which is made into protein. Transcription (the making of mRNA) must occur before translation (the making of protein) can begin.	
D. This occurs in both eukaryotes and prokaryotes. Each cell type needs to recognize where to start and stop transcription, otherwise they cells would waste energy transcribing and translating unnecessary genetic material.	
E. ribonucleotides are the RNA version of the nucleotides that are used to make DNA. These ribonucleotides are composed of a ribose sugar and use uracil instead of thymine (compared to DNA which uses a deoxyribose sugar and thymine). They are used by both cell types to make mRNA.	

The process of TRANSLATION...

a. adds ribonucleotides, in groups of 3, to make a polypeptide.

b. converts the genetic information stored in mRNA into a polypeptide.

c. converts the genetic information stored in DNA into mRNA.

d. converts each nucleotide into 3 amino acids.

e. occurs before transcription starts.

Justification/Explanation	Where did you find this information?
A. the terms in this answer are incorrect. Translation adds amino acids, not ribonucleotides, after reading ribonucleotides in groups of 3 (called a codon).	
B. this description correctly describes translation. The key word here is “converts”. Transcription essentially is a copying process, where DNA or RNA is copied into mRNA. Translation is the process that interprets that code and makes proteins from it.	
C. this describes the process of transcription, the process that occurs before translation. Central dogma states that replication occurs before transcription and transcription occurs before translation.	
D. each set of three nucleotides on the mRNA molecule are read and code for one amino acid.	
E. central dogma states that translation can only occur after transcription has started. This is because translation is done using an mRNA template, which must be made first during transcription.	

Which of the following could potentially have the **HIGHEST** Darwinian fitness?

- a. A childless personal trainer who works out at the gym every day.
- b. A childless scientist who devotes herself to science and wins the Nobel Prize.
- c. A woman who has one child and takes very good care of her.
- d. A man who home schools his two children (one male and one female).
- e.** A man who lives to be 100 years old and fathers 45 children who also all reproduce.

Justification/Explanation	Where did you find this information?
A. A personal trainer may be very physically fit however Darwinian fitness refers to the reproductive success of an individual. If an individual has no children then they have 0 Darwinian fitness.	
B. Again, this individual may be mentally fit but Darwinian fitness refers to success in producing offspring and therefore in passing on genes. A childless person has 0 Darwinian fitness.	
C. Having one child results in higher fitness than either of the first two options, this is the highest fitness choice so far.	
D. A person who has two children has higher Darwinian fitness than a person who has only one child because they pass on a greater number of their genes.	
E. An individual who has 45 children who then go on to reproduce has extremely high Darwinian fitness, much higher than any other option here.	

Which of these statements is **INCORRECT**?

a. Environmental change plays a role in evolution

b. The smallest entity that can evolve is an individual organism

c. Individuals can adapt in response to new environments or situations

d. Inherited variation in a population is a necessary precondition for natural selection to operate.

e. Natural populations tend to produce more offspring than the environment can support

Justification/Explanation	Where did you find this information?
A. Environmental changes are often the driving force for evolutionary changes. When an environment changes previously well-adapted species may suddenly have much lower fitness and be selected against.	
B. A single organism cannot evolve. Evolution refers to changes in traits over multiple generations.	
C. An individual cannot evolve however they can adapt. For example an individual might change its feeding behavior patterns in response to a new prey moving into their environment. The species already had the genetic capacity for this change (phenotypic plasticity)	
D. This must be true. Natural selection acts to select the random genetic variants with the highest fitness, if there is no inherited genetic variability than natural selection has nothing to act upon.	
E. This is true, natural selection operates because the number of offspring produced is greater than the carrying capacity of an environment. As a result of this pressure, only the fittest individuals survive and reproduce.	

Currently the only predator of the Galápagos marine iguana is the Galápagos hawk. Iguana body size is not correlated with the risk of hawk predation, although small iguanas can run faster than large iguanas. If a new predator (e.g., cats) that preferably catches and eats slower iguanas is introduced to the island, iguana body size is likely to _____ in the absence of other factors due to _____ selection.

- a. increase; directional
- b. increase; disruptive
- c. decrease; directional**
- d. decrease; stabilizing
- e. stay the same; stabilizing

TA note: this question has a lot of extraneous information, might be worth having students identify the key information in this question via underlining

Justification/Explanation	Where did you find this information?
A. Small iguanas can run faster than large iguanas so large iguanas are disproportionately eaten by the new predator. This selection pressure against large iguanas should lead to a decrease in body size rather than an increase.	
B. Disruptive selection describes a situation in which middle phenotypes are selected against (<i>i.e.</i> , extreme phenotypes in either direction have higher fitness) resulting in phenotypic divergence in the population. In this case the highest selection pressure is against one extreme (large body) rather than the middle phenotype.	
C. The selection pressure on slower, large body iguanas will push the population towards a smaller phenotype by increasing the number of small body alleles in the population's gene pool. When a population's phenotype is shifting towards one extreme this is known as directional selection.	
D. Stabilizing selection describes a situation in which all extreme phenotypes are selected against causing the population to settle around a middle phenotype. In this case, only one extreme is selected against.	
E. The selection against large body iguanas will eliminate many large-body alleles from the population and lead to an increase in small phenotypes in the population. The average iguana size in the population will decrease, not stay the same.	

Which of these conditions **would always** cause populations to evolve by Natural Selection?

Condition 1: The population must vary in traits that are heritable.

Condition 2: Some heritable traits increase reproductive success.

Condition 3: Individuals pass on all traits they acquire during their lifetime.

- a. Condition 1 only
- b. Condition 2 only
- c. Condition 3 only
- d. Conditions 2 and 3
- e. Conditions 1 and 2

Justification/Explanation	Where did you find this information?
<p>Condition 1 – If all members of a population receive identical traits then natural selection cannot occur because the individuals that reproduce successfully have the same traits as those who do not reproduce successfully. The overall traits of the population will not change over time.</p>	
<p>Condition 2 - This describes the concept of Darwinian fitness – some traits will give a reproductive advantage over other traits. When even minor differences exist in the fitness of two traits, natural selection will result in the less fit trait being pushed toward extinction over many generations.</p>	
<p>Condition 3 – This condition refers to the discredited idea of Lamarckian evolution. Lamarck proposed that offspring would receive traits that reflected traits acquired by parents over their lifetime. The discovery of separately maintained germline and somatic cells helped explain why this is not the case.</p>	
<p>Answer Choice – Both condition 1 and 2 are necessary; some traits must give a fitness advantage and these traits must only be received by some of the population. If these two are true, natural selection must occur.</p>	

A farmer uses a triazine-based herbicide to control pigweed in her field. For the first few years, the triazine works well and almost all the pigweed dies; but after several years, the farmer sees more and more pigweed. Which of these explanations **BEST** describes this observation?

a. Natural selection caused the triazine to mutate so that it no longer kills pigweed.

b. Pigweed seeds must be blowing in from a neighbor's farm.

c. Only triazine-resistant weeds survived and reproduced, so each year more pigweed was triazine-resistant.

d. Her crops must be absorbing the triazine herbicide, thus allowing the pigweed to grow.

Justification/Explanation	Where did you find this information?
A. Triazine is a chemical not a living organism and therefore cannot mutate.	
B. If pigweed seeds enter the field from an outside source the triazine would still kill the majority of it.	
C. This is the most likely scenario. Some of the pigweed in the field had natural variability that resulted in triazine resistance, as non-resistant pigweed was killed off the resistant strains were able to reproduce until the majority of the population was triazine-resistant.	
D. If this was the case then the triazine should never have worked to kill pigweed.	

Cyanobacteria, a photosynthetic prokaryote, were important to the evolution of life on earth because...

a. they are probably the first organisms to colonize the oceans.

b. they are probably the first organisms to release O₂ into the atmosphere.

c. they are the earliest known fermenting organisms.

d. they are the closest relatives of early fungi.

e. they formed symbioses with animal cells to become the first plant cells.

Justification/Explanation	Where did you find this information?
A. Cyanobacteria were not the first organisms to colonize the ocean (chemoautotrophs).	
B. Cyanobacteria are the earliest organisms to undergo photosynthesis. One by-product of photosynthesis is Oxygen so they are likely responsible for the oxygenation of the Earth's atmosphere.	
C. Cyanobacteria undergo fermentation but so do organisms which predate them (anoxic heterotrophs)	
D. Fungi first evolved around 500 million years ago, nearly 2 billion years after cyanobacteria first appeared. Fungi are more closely related to the Animal kingdom than the Bacteria kingdom.	
E. Evidence suggests that chloroplasts in modern plant cells are derived from cyanobacteria incorporated via endosymbiosis however animal cells were not involved in this process.	

The Dunkers are a religious group that moved from Germany to Pennsylvania in the mid-1700s. They do not marry with members outside their own immediate community. Today, the Dunkers are genetically unique and differ in gene frequencies, at many loci, from all other populations including those in their original homeland. Which of the following are the **MOST** likely explanations for the genetic uniqueness of this population?

- a. Population bottleneck and Hardy-Weinberg equilibrium
- b. Heterozygote advantage and stabilizing selection
- c. Sexual selection and inbreeding depression
- d. Mutation and natural selection
- e.** Founder effect and genetic drift

Justification/Explanation	Where did you find this information?
A. Neither of these terms is accurate here. Population bottleneck refers to a sharp reduction in population size usually due to drastic environmental events. Furthermore, populations in Hardy-Weinberg equilibrium, by rule, cannot have changing gene frequencies.	
B. Heterozygote advantage refers to a situation when heterozygous individuals have a fitness advantage over both dominant and recessive individuals. There is no evidence that heterozygosity confers any advantage in this population. Stabilizing selection occurs when a middle phenotype is favored by natural selection and extreme phenotypes are selected against; this is unlikely to lead to two distinct gene pools.	
C. Inbreeding depression describes when a population has lower fitness as the result of increased inbreeding, this may be occurring here because the population is heavily inbred however the question does not indicate a reduction in fitness for the new population. Furthermore, the question does not state that mates are chosen as a result of having a particular trait so sexual selection is unlikely to be a major factor here.	
D. Mutations will have occurred in both the old and new populations resulting in unique alleles however in the 10-12 generations that have occurred since the mid-1700s these mutations are unlikely to have caused major shifts in the gene pools of these populations.	
E. When genetic diversity is lost due to a small population migrating from a larger population this is called the founder effect. This small founding population is a random sample of the population at large and therefore is unlikely to reflect the overall allele frequency of the population. Random mating between individuals with this unique allele frequency will naturally lead to gene pool differences between the two groups; this process is called genetic drift.	

In a Hardy-Weinberg population with 2 alleles, A and a, that are in equilibrium, the frequency of a is 0.4. What proportion of the population is heterozygous for this allele?

- a. 4%
- b. 16%
- c. 32%
- d. 48%
- e. 60%

Show Your Work

$$p + q = 1$$

$$A = p \quad a = q$$

$$A = p \quad a = 0.4$$

$$p + 0.4 = 1$$

$$p = 0.6$$

$$p^2 + 2pq + q^2 = 1$$

$$A^2 + 2Aa + a^2 = 1$$

$$0.6^2 + 2(0.6)(0.4) + 0.4^2 = 1$$

$$0.36 + 0.48 + 0.16 = 1$$

Justify your answer choice

In this population, 36% of the individuals are AA, 48% are Aa, and 16% are aa. The question wants to know the percentage that is Aa therefore the answer is 48%, D.

Which of the following is **NOT** evidence for common ancestry?

- a. The similarities between bat wings and butterfly wings.
- b. The homology between human arms and cat forelimbs.
- c. All organisms use the same amino acids and nucleotides.
- d. Human embryos have gill slits and tails.
- e. The fossil record showing ancestors of horses having 5 toes.

Justification/Explanation	Where did you find this information?
A. These two structures are analogous but not homologous. This means that the two structures serve similar functions but result from different evolutionary histories. Analogous structures are the result of convergent evolution and do not indicate common ancestry.	
B. The human arm and cat forelimb have similar bone structures (1 bone upper limb, 2 bone lower limb) suggesting that they evolved from the same ancestral mammal limb state. This shared evolutionary history is evidence for common ancestry.	
C. The fact that all life is based on the same small set of molecules is strong evidence that all life shares a single common ancestor.	
D. Structures like gill slits and tails appear not only in human embryos but a wide range of evolutionary relatives. Similarities in development provide evidence of common ancestry.	
E. All species of modern horses have hooves as well as vestigial toes. These vestigial toes are evolutionary remnants of ancestors with 5 toes.	

Which of the following is an example of a **post-zygotic** reproductive barrier between species?

a. One pine species sheds its pollen 2 months before another pine species.

b. Two bird species, the Eastern Meadowlark and Western Meadowlark have different songs.

c. A hybrid between two species of plants produces deformed flowers and no pollen.

d. Black Sage flowers are pollinated by honeybees and White Sage flowers by wasps.

e. One species of Garter snake lives mainly on land and another mainly in water.

Justification/Explanation	Where did you find this information?
A. The reproductive barrier between these two species of pine is due to the time difference in their pollen sheds. Because no fertilization occurs, this is pre-zygotic.	
B. Assuming these birds choose their mates by their songs this would be an example of behavioral reproductive barrier. This is pre-zygotic because no fertilization will occur.	
C. The offspring in this cross are viable (they develop from zygote to adulthood) but they are infertile. If all offspring are infertile, this is an example of a post-zygotic reproductive barrier.	
D. If the flowers are pollinated by different bees then no fertilization will occur therefore this is a pre-zygotic barrier.	
E. If two species live in different environments then they have both a behavioral and geographic barrier preventing them from reproducing together. This is pre-zygotic.	

Which term describes the most brightly colored male peacocks mating more frequently than drab colored peacocks?

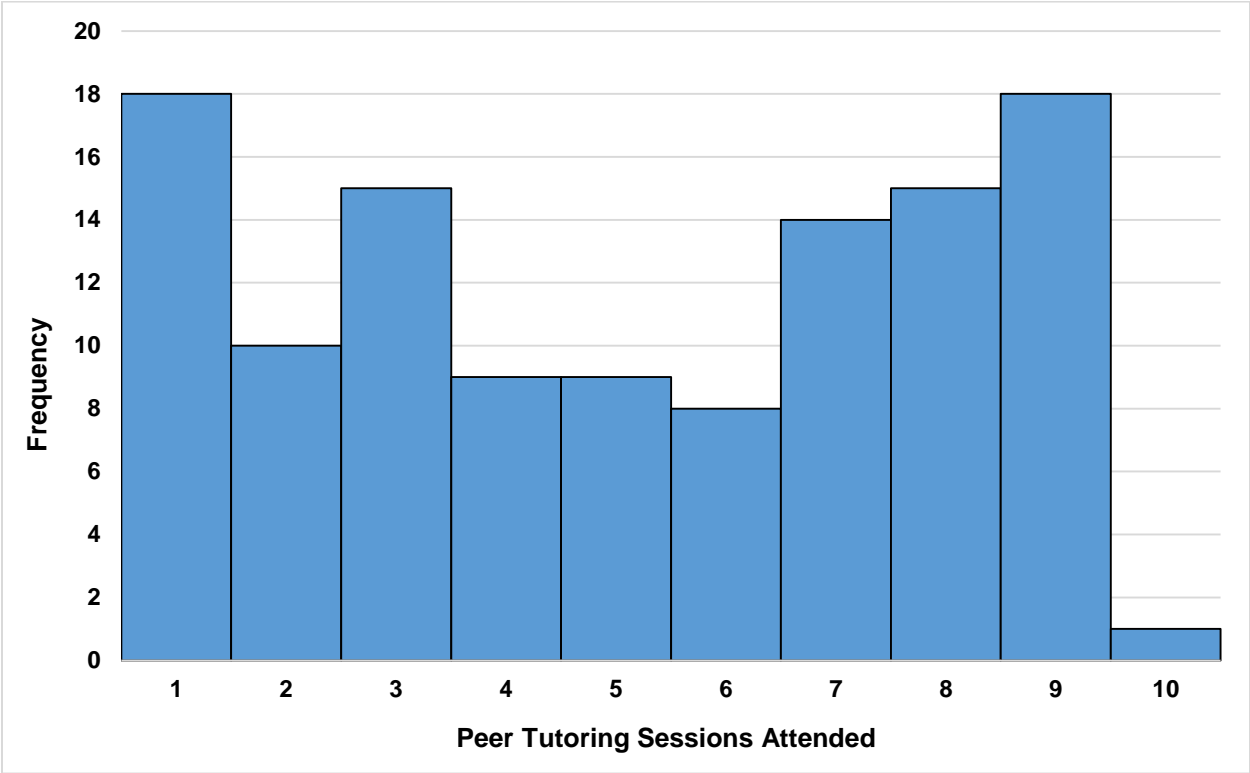
- a. artificial selection
- b. genetic drift selection
- c. sexual selection**
- d. stabilizing selection
- e. disruptive selection

Justification/Explanation	Where did you find this information?
<p>A. Artificial selection is when individuals are selected by humans to mate in order to produce desired traits. There is no human-intervention here so this isn't artificial selection.</p>	
<p>B. Genetic drift describes shift in allele frequency resulting from the random nature by which individuals with similar fitness levels are able to mate and pass on their alleles.</p>	
<p>C. Sexual selection describes a situation in which some individuals are more fit because they are better at attracting mates. Here the brightest peacocks attract more mates and therefore produce the most offspring.</p>	
<p>D. Stabilizing selection refers to natural selection against extreme phenotypes. In this case, stabilizing selection would be acting if peacocks with very bright and very drab feathers were less fit than peacocks with somewhat-bright feathers.</p>	
<p>E. Disruptive selection occurs if multiple extreme phenotypes are simultaneously favored by natural selection. For this example, disruptive selection would mean that very drab and very bright peacocks both had higher fitness than somewhat-bright peacocks.</p>	

Supplemental Figure 3. Shifts in exam scores for struggling students who accept and decline peer tutoring. For struggling students who accepted peer tutoring, the average number of sessions attended is noted for each difference in exam score category.

	Difference between average exam 2-5 score and exam 1 score				
	< -10	-10 to 0	0 to 10	10 to 20	>20
Declined Peer Tutoring	5.0%	16.9%	25.6%	32.5%	20.0%
Accepted Peer Tutoring	1.9%	12.6%	18.5%	29.1%	37.9%
Avg. # Sessions Attended (Accepted Students)	2.5	3.6	5.1	5.9	6.2

Supplemental Figure 4. Histogram of number of peer tutoring sessions attended by struggling students who accepted peer tutoring.



Mean: 5.15 sessions
Std. Dev: 2.87 sessions

Supplemental Figure 5. Multiple regression model of factors contributing to mean performance on intervention period exams for students attending at least one peer tutoring session. In this analysis, the factor Synapse Logins is removed.

	$\beta^* \pm SE$	p
Peer Tutoring Program		
# of Sessions Attended	1.00 \pm 0.44	0.02
Engagement		
Video/Study Guide Views	0.15 \pm 0.05	0.01
Lectures Attended	0.53 \pm 0.23	0.02
Note Openings	-0.05 \pm 0.06	0.35
Gradebook Checks	0.02 \pm 0.02	0.64
Demographics		
SAT Score	0.04 \pm 0.01	<0.01
Year in School (1 \rightarrow 2 \rightarrow 3 \rightarrow 4)	2.55 \pm 2.03	0.21
Gender (Male \rightarrow Female)	2.60 \pm 2.80	0.35
Home County (Rural \rightarrow Urban)	2.28 \pm 2.78	0.41
Require More Biology? (No \rightarrow Yes)	1.05 \pm 2.73	0.70
Ethnicity (Non-Minority \rightarrow Minority)	0.57 \pm 3.25	0.86

* β indicates the expected change in the mean exam score (in percentage points) given a unit change in the parameter of interest. For categorical variables, β indicates the predicted change in score that results from a categorical change in the direction indicated by the arrows in parentheses (e.g. changing the level of "Gender" from "Male" to "Female" increases the expected mean exam score by 2.60 percentage points).

Supplemental Figure 6. Multiple regression model of factors contributing to CLASS-Bio posttest scores for struggling students. In this analysis, the factor Synapse Logins is removed.

	$\beta \pm SE$	p
Peer Tutoring Program		
Accepted Peer Tutoring	5.74 ± 2.45	0.02
Engagement		
Video/Study Guide Views	0.08 ± 0.05	0.11
Lectures Attended	0.35 ± 0.24	0.15
Note Openings	-0.03 ± 0.05	0.56
Gradebook Checks	-0.01 ± 0.02	0.86
Demographics		
SAT Score	-0.01 ± 0.01	0.08
Gender (Male → Female)	4.86 ± 3.23	0.09
Year in School (1 → 2 → 3 → 4)	-0.52 ± 2.14	0.18
Ethnicity (Non-Minority → Minority)	-2.30 ± 3.23	0.48
Home County (Rural → Urban)	1.86 ± 3.26	0.57
Require More Biology? (No → Yes)	0.29 ± 2.93	0.92
CLASS-Bio		
Pretest Score	0.72 ± 0.06	<0.01

* β indicates the expected change in the CLASS-Bio posttest score given a unit change in the parameter of interest. For categorical variables β indicates the predicted change in score that results from a categorical change in the direction indicated by the arrows in parentheses (e.g. changing the category of “Gender” from “Male” to “Female” increases the expected CLASS-Bio posttest score by 4.86 points).