LESSON 5.2

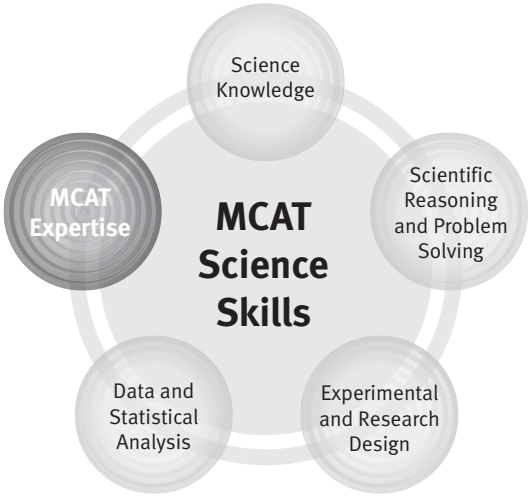
Science Questions: Assess and Plan

In this lesson, you'll learn to:

- Assess a question and its answer choices for difficulty, science topic, and common patterns
- Plan an efficient way to answer a given question

Science Topics:

- Amino Acids, Peptides, and Proteins
- Enzyme Structure, Function, and Regulation
- Nucleic Acid Structure and Function
- Transcription
- Translation



MCAT STRATEGY—SCIENCE QUESTIONS

ASSESS THE QUESTION
Read a question and its answer choices; decide whether to skip it.

PLAN YOUR ATTACK
Decide how best to approach the question, based on your experience with similar questions.

EXECUTE THE PLAN*

ANSWER BY MATCHING, ELIMINATING, OR GUESSING*

**The EXECUTE and ANSWER steps are covered in depth in lesson 5.3.*

LESSON 5.2, LEARNING GOAL 1:

- Assess a question and its answer choices for difficulty, science topic, and common patterns

Common Patterns in Questions and Answers

1. Which of the following is true about DNA synthesis?

A. It occurs in all cells continuously.
B. In prokaryotes, it occurs in the nucleus.
C. It is a semiconservative process.
D. Mitosis is a step of DNA synthesis.

What pattern or patterns are present here?

2. A segment of a DNA strand has the base sequence:

5′—GTTCATTG—3′

What would be the base sequence of the RNA strand transcribed from this DNA?

A. 5′—CAATGAAC—3′
B. 5′—GTTCATTG—3′
C. 5′—CAAUGAAC—3′
D. 5′—CAAGUAAC—3′

What pattern or patterns are present here?

3. A scientist has an unknown sample of an amino acid that has been determined to have an amino group, a carboxyl group, optical activity, and multiple nitrogen groups on its side chain. Of the following values, its most likely isoelectric point is:

A. 2.65
B. 7.10
C. 8.05
D. 11.15

What pattern or patterns are present here?

KAPLAN TIP

The patterns on this page, as well as those in the rest of this lesson, will appear again and again on Test Day. Patterns indicate which strategies will be best to use and how difficult a question will be, so start noticing them now!

Common Patterns in Questions and Answers

What pattern or patterns are present here?

4. Which of the following processes is demonstrated in the regulation of enzyme A, as described in the passage?

A. Competitive inhibition
B. Allosteric inhibition
C. Noncompetitive inhibition
D. Positive feedback mechanisms

5. Which of the following is true of sample C?

A. The amino acids are likely to have aromatic rings and appear on the inside of folded proteins.
B. The amino acids are likely to have charged side chains and appear on the inside of folded proteins.
C. The amino acids are likely to have aromatic rings and appear on the outside of folded proteins.
D. The amino acids are likely to have charged side chains and appear on the outside of folded proteins.

6. Which of the following is the most likely reason for the production of faulty prelamin A in individuals with progeria?

A. The mutation causes a termination sequence in the DNA to appear earlier than is normal.
B. The point mutation causes a stop codon to appear earlier in protein sequencing than is normal.
C. The DNA splices and reforms at the lamin A gene, removing part of the protein's template strand.
D. The protein that is sequenced from prelamin A is less stable as a result of the mutation, and it denatures.

7. Is the mutation seen in paragraph 4 likely to be fatal if present in a gamete during fertilization?

A. Yes, because proteins essential to development will not be sequenced.
B. Yes, because the zygote will not be able to efficiently produce ATP.
C. No, because the zygote will have access to proteins by other means.
D. No, because proteins will be sequenced as normal with the mutation present.

KAPLAN TIP

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How to Assess a Question

Look in these places:

- The question stem
- The answer choices

For these patterns:

- Science "buzzwords"
- Passage references (e.g., "paragraph 3," "Experiment 2")
- Length and complexity of question stem
- Length, complexity, and structure of answer choices
- "Yes/No" patterns in the answer choices
- Numbers or formulas
- Figures, tables, or other graphics
- Anything else that has made questions easy, hard, or otherwise distinctive for you in the past

So you can make these judgments:

- The science being tested
- How hard the question will be for you
- How long the question will take you
- Whether you should skip the question for now

Assessing Discrete Questions

What do you notice in the ...

8. If a point mutation occurs that changes one nucleotide in an mRNA molecule, the final protein product is LEAST likely to be affected if the altered nucleotide is in the

Question stem?

A. original start codon.
B. original stop codon.
C. first letter of a codon.
D. third letter of a codon.

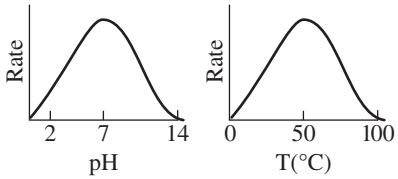
Answer choices?

9. Which set of graphs best depicts the optimal temperature and pH range for pepsin activity?

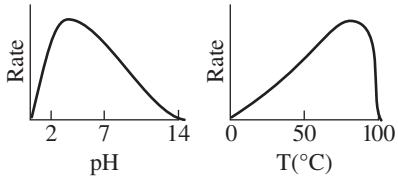
Question stem?

Answer choices?

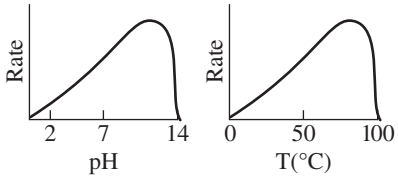
A.



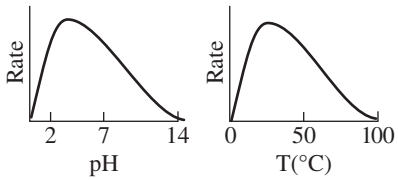
B.



C.



D.



KAPLAN TIP

These question and answer patterns should be relatively easy to recognize. To increase your MCAT score, try to incorporate pattern-recognition skills as you triage and attack questions on Test Day.

LESSON 5.2, LEARNING GOAL 2

- Plan an efficient way to answer a given question

The Question

2. A segment of a DNA strand has the base sequence:

5′—GTTCATTG—3′

What would be the base sequence of the RNA strand transcribed from this DNA?

A. 5′—CAATGAAC—3′
B. 5′—GTTCATTG—3′
C. 5′—CAAUGAAC—3′
D. 5′—CAAGUAAC—3′

Plans to Answer (of varying effectiveness)

"Let me go back to the passage to see where it talks about matching DNA to RNA strands in transcription."

"This is a question where I'll have to figure out the exact answer before I go through the choices. I'd better get to work on my scratch paper!"

"Okay, DNA-to-RNA matching is A-U and C-G, and antiparallel strands mean that the 3's and 5's will be swapped . . . let's hit those answer choices."

The Question

3. A scientist has an unknown sample of an amino acid that has been determined to have an amino group, a carboxyl group, optical activity, and multiple nitrogen groups on its side chain. Of the following values, its most likely isoelectric point is:

A. 2.65
B. 7.10
C. 8.05
D. 11.15

Plans to Answer

"The isoelectric point of an amino acid is its pK_a, and the question says right away that this has an amino group, so I'll pick a basic answer choice."

"I know the test will sometimes expect me to know my amino acids, and I know my amino acids pretty well. Let me figure out which one this is, and then match it with the right isoelectric point in the choices."

"I know that some parts of this long question stem must be more important than others. Let me go through those molecular traits to see what makes this amino acid special, then see if that alone will point me to the right answer."

Why is the third plan the best?

KAPLAN TIP

A good way to summarize this Plan step is by asking yourself the question, "*Where have I seen this before?*" This step is about using your experience—in your science classes, your prep classes, your practice tests, and beyond—and transferring that previous knowledge to the question at hand.

The "Plan" Step with a Passage

Practice Passage I (Questions 10–14)

Hutchinson-Gilford progeria syndrome (HGPS) is a rare genetic disease that affects one in eight million live births. Individuals with progeria exhibit symptoms of aging at an early age and generally only live until their teenage years or, occasionally, their early 20s. Affected individuals experience stunted growth, musculoskeletal degeneration, loss of hair, and have a characteristic appearance.

A point mutation in position 1824 of the LMNA gene coding for lamin A is the typical cause of progeria. A cytosine is replaced with thymine, causing a premature termination of transcription. As a result, a shortened mRNA transcript is generated, which codes for a faulty version of unprocessed prelamin A. During post-translational processing, prelamin A is incapable of losing its farnesyl group (a 15-carbon isoprenoid), preventing the conversion of prelamin A to mature lamin A. Figure 1 shows mutant prelamin A post-translational processing. The mutant prelamin A is known as progerin. The farnesyl group locks progerin to the nuclear rim. While bound to the nuclear rim, progerin cannot offer the necessary structural support to the nuclear envelope. As a consequence, the nuclear envelope is misshapen. The structure of the nuclear envelope is essential for the proper manipulation of chromatin during mitosis.

Normal prelamin A post-translational modification consists of four steps. The processing begins with the farnesylation of the cysteine of the CaaX box (cysteine and three aliphatic amino acids located at the carboxyl terminus of prelamin A) by farnesyltransferase (FTase). Shortly thereafter, the –aaX portion of the CaaX box is removed. Next, the product is methylated. Finally, the carboxyl terminal, as well as the modified farnesyl group, is sliced off by the peptidase ZMPSTE24. Figure 2 illustrates normal prelamin A post-translational processing. FTase inhibitors have been tested with animal models and shown to reverse the malformation of the nuclear envelope caused by progerin.

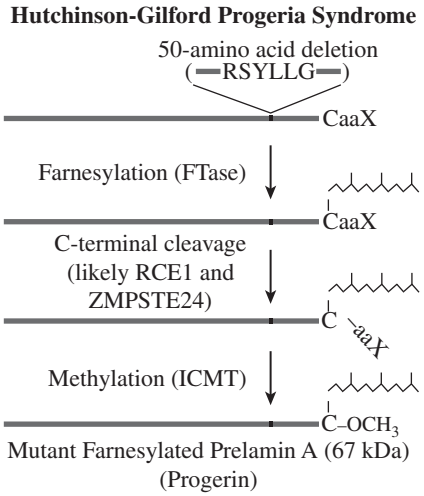


Figure 1. Mutant prelamin A post-translational processing.

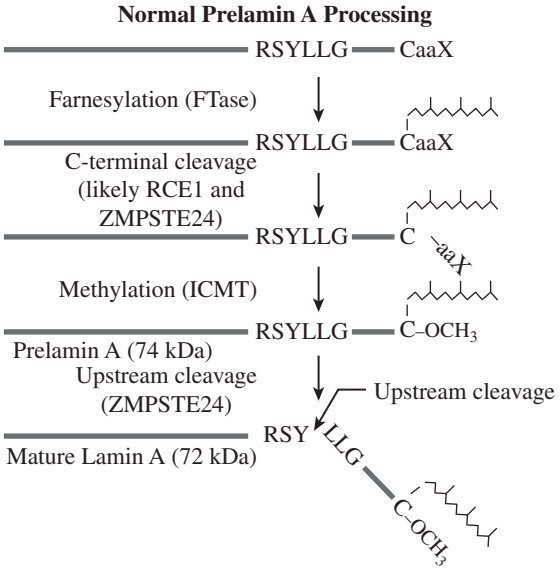


Figure 2. Normal prelamin A post-translational processing.

Making your own plans

10. Why is the malformation of the nuclear envelope reversed in animal models when FTase inhibitors are used?

What's your plan for this question?

A. FTase inhibitors catalyze the upstream cleavage of the modified farnesyl group.
B. No progerin is made in the presence of FTase inhibitors.
C. Normal prelamin A is created when FTase inhibitors are present.
D. FTase inhibitors prevent progerin from locking to the nuclear rim.

11. One of the three amino acids found at the carboxyl terminus of prelamin A could be:

What's your plan for this question?

A. tyrosine.
B. tryptophan.
C. phenylalanine.
D. arginine.

12. Which of the following is the most likely reason for the production of faulty prelamin A in individuals with progeria?

What's your plan for this question?

A. The mutation causes a termination sequence to appear earlier in RNA sequencing than is normal.
B. The point mutation causes a stop codon to appear earlier in protein sequencing than is normal.
C. The DNA splices and reforms at the lamin A gene, removing part of the protein's template strand.
D. The protein that is sequenced from prelamin A is less stable as a result of the mutation, and it denatures.

KAPLAN TIP

One of the most important parts of any plan is deciding *where* you'll be getting the information to answer the question. Usually, you'll be getting the answer from the passage, your passage outline, your mind (i.e., your science knowledge and critical reasoning), or some combination of those.

The "Plan" Step with a Passage (continued)

Practice Passage I (Questions 10–14)

Hutchinson-Gilford progeria syndrome (HGPS) is a rare genetic disease that affects one in eight million live births. Individuals with progeria exhibit symptoms of aging at an early age and generally only live until their teenage years, or, occasionally, their early 20s. Affected individuals experience stunted growth, musculoskeletal degeneration, loss of hair, and have a characteristic appearance.

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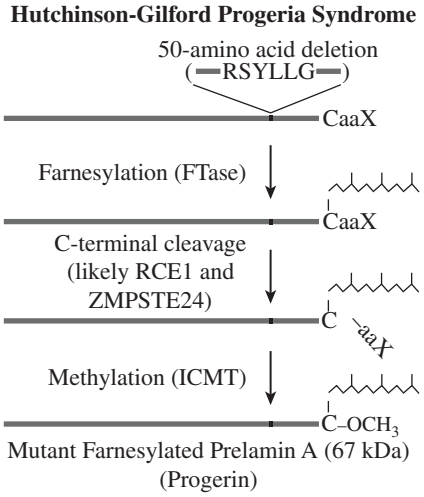

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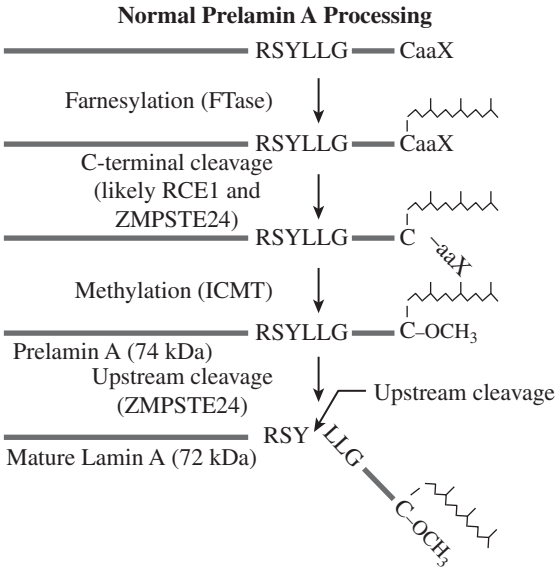


Figure 2. Normal prelamin A post-translational processing.

Making your own plans (continued)

13. Which of the following is most likely to result in stunted growth and musculoskeletal degeneration?

A. Structurally supported nuclear envelopes
B. Loss of the farnesyl group by prelamin A
C. Methylation of prelamin A during post-translational processing
D. The improper manipulation of chromatin during mitosis

What's your plan for this question?

14. What change occurs in DNA structure when a cytosine is replaced with a thymine?

A. One fewer hydrogen bond is formed between base pairs.
B. A pyrimidine is changed into a purine.
C. An –OH group is added to deoxyribose.
D. The phosphate backbone is deformed due to base-pair mismatch.

What's your plan for this question?

KAPLAN TIP

Question 14 is a great example of a "pseudo-discrete" question. This kind of question, which usually shows up once or twice for each passage, is one that demands science knowledge related to the passage, but no information from the passage itself.

LESSON 5.2 REVIEW

The Kaplan Method for Science Questions, Steps 1 and 2

ASSESS MEANS ...

Look for key details in the question stem and answer choices as you read them:

- Science "Buzzwords"
- Passage References
- Length
- Numbers or Formulas
- Common Question and Answer Patterns

Try to determine:

- Science Topic
- Difficulty
- Time Needed to Answer
- Triage (Should you skip it?)

PLAN MEANS ...

Use your judgments from the Assess step to plan your approach to the question.

Use your experience with similar questions to avoid mistakes.

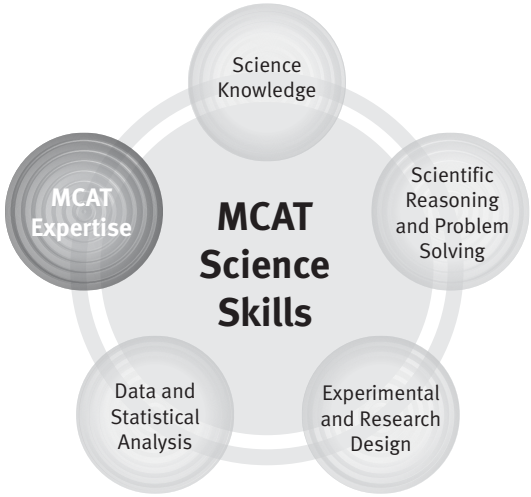
Don't be afraid to change the plan if:

- You find or remember new information
- The question is harder or easier than you first thought
- The question is taking you too long

Science Questions: Execute and Answer

In this lesson, you'll learn to:

- Judge when predicting an answer is a useful strategy
- Make strong and accurate predictions for answers before reading through answer choices
- Recognize when an answer matches a prediction



Science Topics:

- Amino Acids, Peptides, and Proteins
- Enzyme Structure, Function, and Regulation
- Nucleic Acid Structure and Function
- Transcription
- Translation

MCAT STRATEGY—SCIENCE QUESTIONS

ASSESS THE QUESTION*

PLAN YOUR ATTACK*

EXECUTE THE PLAN
Make a prediction based on your plan or decide to use elimination.

ANSWER BY MATCHING, ELIMINATING, OR GUESSING
Find your prediction within the answer choices.

**The ASSESS and PLAN steps are covered in depth in lesson 5.2.*

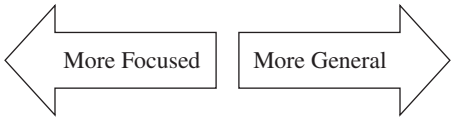
LESSON 5.3, LEARNING GOAL 1:

- Judge when predicting an answer is a useful strategy

Consider these questions:

1. You have two fragments of DNA: fragment A melts (comes apart) at 97°C and fragment B melts at 65°C. What can you conclude about the two fragments with respect to their nucleotide composition?

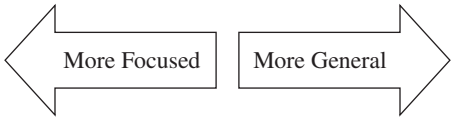
What kind of prediction can you make for this question?



What is the prediction?

2. Which of the following is true about transcription?

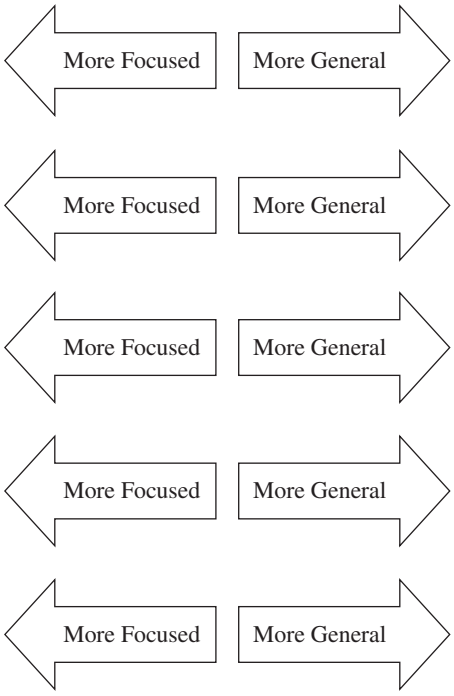
What kind of prediction can you make for this question?



What is the prediction?

Prediction Practice

Indicate the best type of prediction:



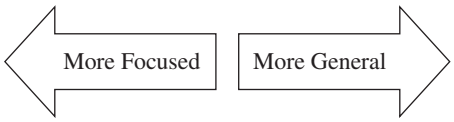
3. Researchers measure the mRNA found in a set of cells for a particular gene, and find it to be elevated. What must be occurring in the cell?

4. Which of the following statements about DNA methylation is the most accurate?

5. Polymerase chain reaction amplifies DNA by first unwinding it using heat rather than DNA helicase. What bonds must be broken in order for this reaction with heat to proceed?

6. A segment of a DNA strand has the base sequence: 5'—GTTCATTG—3'. What would be the base sequence of the RNA strand transcribed from this DNA?

7. The different antigenic blood types (A, B, and O) are inherited through allelic genes. The actual molecular difference between two blood types is in the carbohydrate that is attached to a common molecular backbone. The best explanation for how genes determine blood type, therefore, is that each gene:



8. A person has a mutation in the promoter site of the gene for the lactase enzyme, rendering the promoter site nonfunctional. What symptom(s) will occur?

I. Less digestion of lactose by the person

II. More digestion of lactose by the person's symbiotic gut bacteria

III. Malnutrition due to glucose deficiency

A. I only
B. II only
C. I and II
D. I and III

KAPLAN TIP

You can also make a strategic guess on a question if you're not able to come up with a prediction at all. Eliminate answers for the best reasons you can think of.

LESSON 5.3, LEARNING GOAL 2:

- Make strong and accurate predictions for answers before reading through answer choices

The EXECUTE Step with a Passage

Practice Passage I (Questions 9–13)

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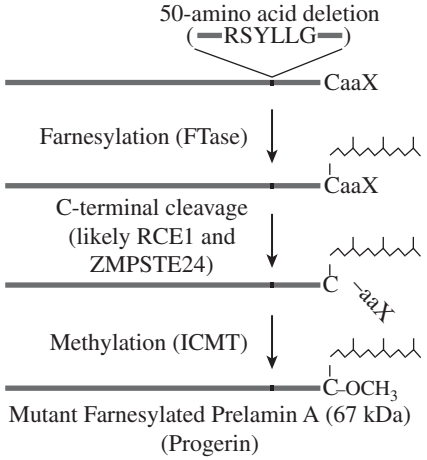

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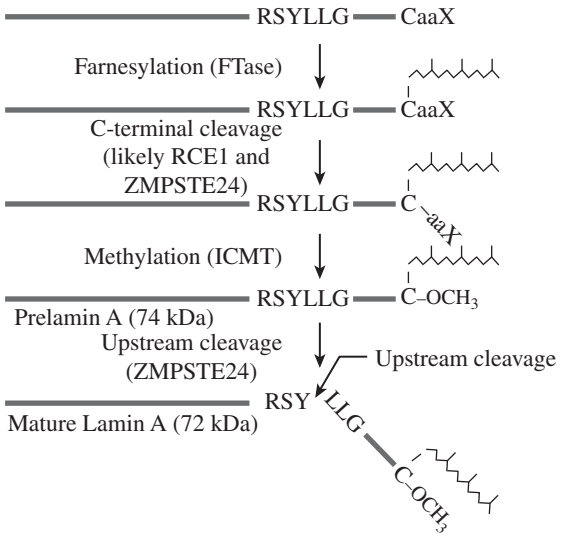

Figure 2. Normal prelamin A post-translational processing.

The EXECUTE Step with Passage Questions

9. Why is the malformation of the nuclear envelope reversed in animal models when FTase inhibitors are used?

Prediction:

10. One of the three amino acids found at the carboxyl terminus of prelamin A could be:

Prediction:

11. Which of the following is the most likely reason for the production of faulty prelamin A in individuals with progeria?

Prediction:

12. Which of the following is most likely to result in stunted growth and musculoskeletal degeneration?

Prediction:

13. What changes occur in the DNA coding when a point mutation changes a cytosine to a thymine?

Prediction:

KAPLAN TIP

Even in tough passages, the prediction you make as part of the Execute step will be valuable in getting you points.

LESSON 5.3, LEARNING GOAL 3:

- Recognize when an answer matches a prediction

The ANSWER Step with Passage Questions

9. Why is the malformation of the nuclear envelope reversed in animal models when FTase inhibitors are used?

A. FTase inhibitors catalyze the upstream cleavage of the modified farnesyl group.
B. No progerin is made in the presence of FTase inhibitors.
C. Normal prelamin A is created when FTase inhibitors are present.
D. FTase inhibitors prevent progerin from locking to the nuclear rim.

10. One of the three amino acids found at the carboxyl terminus of prelamin A could be:

A. tyrosine.
B. tryptophan.
C. phenylalanine.
D. arginine.

11. Which of the following is the most likely reason for the production of faulty prelamin A in individuals with progeria?

A. The mutation causes a termination sequence in the DNA to appear earlier than is normal.
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C. The DNA splices and reforms at the lamin A gene, removing part of the protein's template strand.
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12. Which of the following is most likely to result in stunted growth and musculoskeletal degeneration?

A. Structurally supported nuclear envelopes
B. Loss of the farnesyl group by prelamin A
C. Methylation of prelamin A during post-translational processing
D. The improper manipulation of chromatin during mitosis

13. What changes occur in the DNA coding when a point mutation changes a cytosine to a thymine?

A. One fewer hydrogen bond is formed between base pairs.
B. A pyrimidine is changed into a purine.
C. An –OH group is added to deoxyribose.
D. The phosphate backbone is deformed due to base pair mismatch

KAPLAN TIP
Don't forget your prediction when you're looking through the answers. Make sure you match your prediction carefully in the Answer step.

LESSON 5.3 REVIEW

The Kaplan Method for Science Questions: Steps 3 and 4

EXECUTE MEANS ...

Using the steps you came up with during the PLAN step, solve the problem.

Use that solution, whether general or focused, to make a prediction of the correct answer.

ANSWER MEANS ...

Find the correct answer within the given choices by either:

Choosing the answer that closely matches your focused prediction, or

Eliminating answer choices that don't fit with your general prediction until only one choice remains.

LESSON 1.3

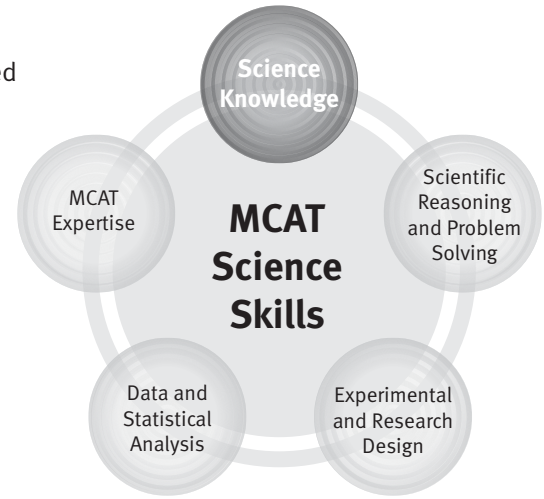
Concepts in Multiple Forms

In this lesson, you'll learn to:

- Identify the same basic scientific concept being presented across disciplines
- Recognize the same concept in multiple representations

Science Topics:

- Oxidation and Reduction
- Non-Enzymatic Protein Function
- Gene Regulation



LESSON 1.3, LEARNING GOAL 1:

- Identify the same basic scientific concept being presented across disciplines

Oxidation and Reduction

In General Chemistry

1. The formation of rust occurs via the reaction below.

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

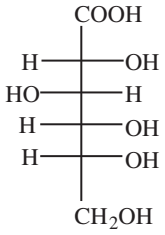
During the formation of rust, iron:

A. acts as an oxidizing agent.
B. gains electrons.
C. is oxidized.
D. is the oxidant.

In Organic Chemistry

2. Aldoses can be reduced with lithium aluminum hydride to compounds known as alditols. What is the product of the reduction reaction of D-glucose?

A.



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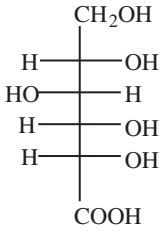

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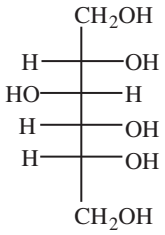

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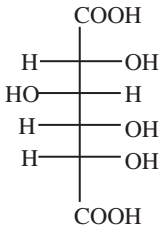


In Biology

3. The binding of oxygen to deoxyhemoglobin leads to a significant decrease in the absorption of red light. This difference:

A. is because iron in the heme groups are reduced from an oxidation state of +3 to +2 when binding oxygen.
B. doe not account for the presence of cyanosis (bluish color of tissues during hypoxia).
C. coincides with a conformational shift in hemoglobin leading to a decreased affinity for oxygen.
D. is because the reduced form of hemoglobin reflects more red light.

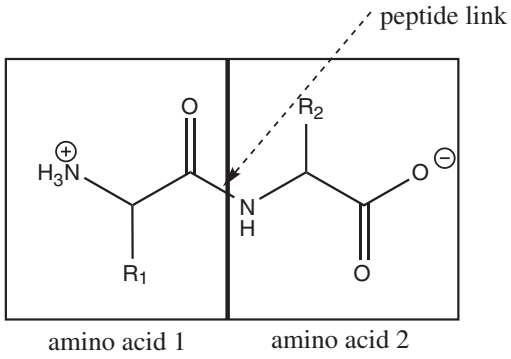
Non-Enzymatic Protein Function

In Biology

4. Because of the peptide bond restriction to planar conformations, all of the following can be concluded about the atoms in the link EXCEPT:

A. the nitrogen lone pair has π-overlap with the carbonyl π-bond.
B. there is considerable positive-charge character on the nitrogen atom.
C. the nitrogen atom is sp^3 hybridized.
D. there is considerable negative-charge character on the carbonyl oxygen.

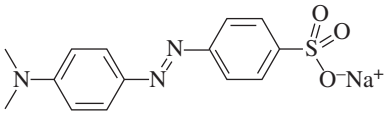
A Peptide Bond



In Organic Chemistry

5. Conjugation within a molecule shifts the absorption maxima to longer wavelengths (approximately 30 nm for each additional double bond in the system). Which of the following molecules is MOST likely to absorb the shortest wavelengths of light?

A.



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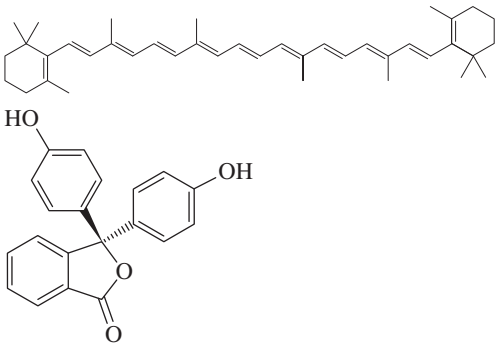

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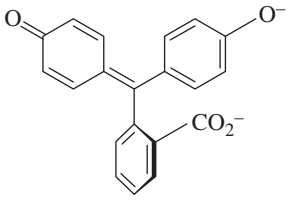

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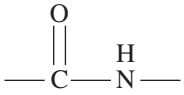
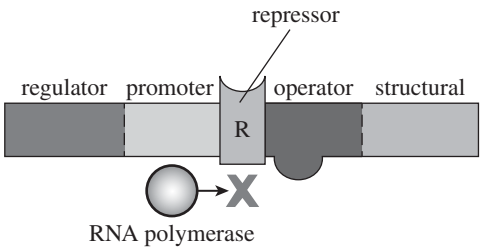


LESSON 1.3, LEARNING GOAL 2:

- Recognize the same concept in multiple representations

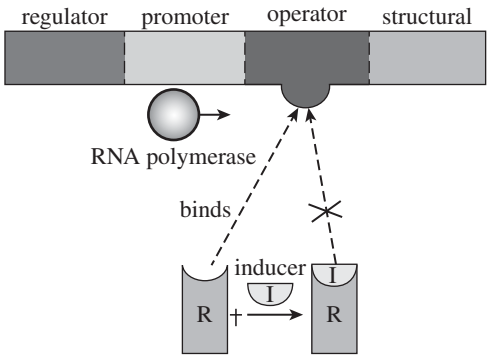
Gene Regulation

The *lac* operon:

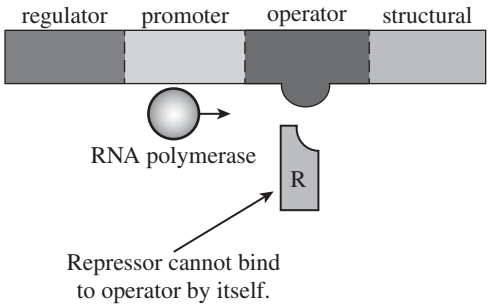


Without an inducer (lactose), the gene is repressed, and lactase is not transcribed

With an inducer, genes can now be transcribed

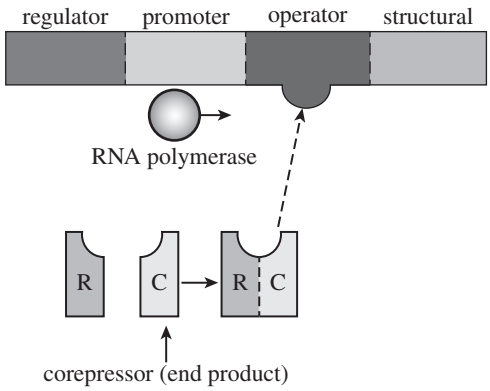


The *trp* operon:



Without a repressor, gene is transcribed

With a repressor (tryptophan), repressor is active and stops transcription



Practice Questions:

6. Normally, dexamethasone (a synthetic glucocorticoid) inhibits ACTH secretion and, consequently, cortisol secretion. A patient with low ACTH and elevated cortisol levels after dexamethasone administration most likely has:

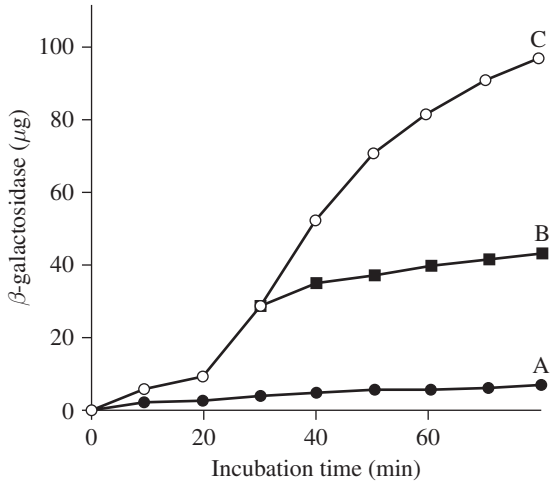
A. an adrenal cortical tumor.
B. a hypothalamic tumor.
C. an anterior pituitary tumor.
D. no pathology in endogenous cortisol production.

7. If the *trp* operon regulatory gene is repressed, the production of tryptophan synthetase, an enzyme coded for by the *trp* structural genes, will most likely occur:

A. only in the presence of tryptophan.
B. only in the absence of tryptophan.
C. in the presence and absence of tryptophan.
D. neither in the presence nor absence of tryptophan.

KAPLAN TIP
Genetics and genetic experiments are topics that are commonly tested. Understanding and recognizing this topic will be helpful for Test Day!

Practice Questions:



8. The figure above shows β-galactosidase levels for three *E. coli* cultures grown on a substrate containing lactose. Sample A was given glucose at 0 mins, Sample B at 30 mins, and Sample C was not given any glucose. The data most strongly suggest:

A. glucose decreases expression of the *lac* operon regulatory gene.
B. lactose is sufficient to cause an increase in β-galactosidase.
C. glucose decreases expression of the *lac* operon in the presence of lactose.
D. glucose is necessary for β-galactosidase production.

9. In order for *E. coli* to utilize lactose as a carbon and energy source, the protein β-galactosidase must be translated. In the presence of both lactose and glucose, *E. coli* will preferentially utilize glucose, conserving the resources necessary to produce β-galactosidase. However, when glucose is absent, lactose will functionally induce the expression of β-galactosidase. This most strongly suggests:

A. glucose decreases expression of the *lac* operon regulatory gene.
B. lactose is sufficient to cause an increase in β-galactosidase.
C. glucose decreases expression of the *lac* operon in the presence of lactose.
D. glucose is necessary for β-galactosidase production.

10. In order to test gene regulation, scientists created mutant strains of *E. coli*. Each haploid mutant contained one mutant sequence of DNA. Trials were conducted with and without glucose and lactose. The results are shown below.

		Substrate:		
		Glucose	Lactose	Glucose and Lactose
Mutated sequence:	*lacZ* (β-galactosidase)	–	–	–
	lac o (operator)	+	+	+
	lacI (repressor)	+	+	+
	wild type	–	+	–

The data most strongly suggest:

A. glucose decreases expression of the *lac* operon repressor gene.
B. lactose is sufficient to increase β-galactosidase production.
C. glucose decreases expression of *lacZ* in the presence of lactose.
D. glucose is necessary for β-galactosidase production.

LESSON 1.3 REVIEW

Remember to ...

Be flexible when a basic scientific concept comes up in any question in any science section.

Remember that science concepts can be represented as:

- Text
- Data Tables
- Graphs of Results
- Equations
- Figures

Biology and Biochemistry 1: Attacking MCAT Science Questions

PASSAGE I (QUESTIONS 1–6)

Oxidative phosphorylation, the final step in the aerobic utilization of glucose for energy, depends on sufficient concentrations of various substrates. Insufficient concentrations of any "essential substrates" can limit the rate of oxidative phosphorylation. Specifically, the concentration of ADP present influences the extent of mitochondrial activity within a cell: mitochondria increase their oxidative phosphorylation activity in the presence of high ADP concentrations. This increase in oxidative phosphorylation can be shown experimentally.

To study mitochondrial activity experimentally, a biochemist prepares a plate of mitochondria without the addition of external substrates. Initially, the biochemist records the basal rate of oxygen consumption by measuring the amount of oxygen present at different times. Next, the biochemist adds 1.0 μmol of glutamate, an amino acid, and records the change in oxygen consumption. The biochemist then adds 0.3 μmol of ADP. After this initial quantity of ADP is consumed, another 0.6 μmol of ADP is added. It is found that the amount of ADP present is directly proportional to the amount of oxygen taken up by the mitochondrion. Figure 1 summarizes the results.

In another experiment, the biochemist repeats the preparation of a mitochondria-rich plate. Initially, 1.0 μmol of glutamate is added, followed shortly thereafter by the addition of approximately 0.8 μmoles of ADP. Next, the biochemist adds oligomycin, which inhibits oxidative phosphorylation. Finally, the biochemist adds dinitrophenol (DNP), which acts to dissipate the proton gradient in the mitochondria. Figure 2 summarizes the results.

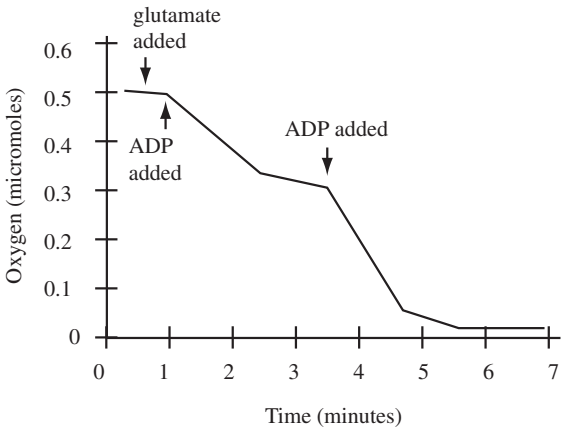


Figure 1. The amount of oxygen (in micromoles) consumed over time with the addition of ADP.

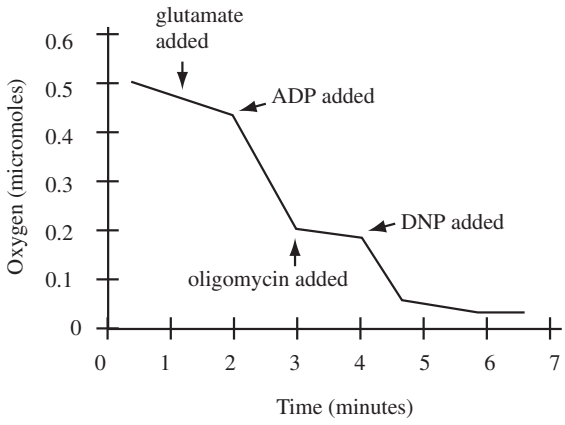


Figure 2. The amount of oxygen (in micromoles) consumed over time with the addition of glutamate, ADP, and DNP.

1. Based on the data in Figure 1, between which times would the rate of acetyl coenzyme A production be lowest?

A. 0.5 to 1.1 minutes
B. 2.8 to 3.3 minutes
C. 4.6 to 5.1 minutes
D. 5.8 to 6.3 minutes

2. Suppose a biochemist begins an experiment by measuring 1.5 μmoles of oxygen in a plate of mitochondria. After adding 1.2 μmoles of ADP, the amount of oxygen left in the plate is:

A. 0.31 μmoles.
B. 0.56 μmoles.
C. 0.94 μmoles.
D. 1.19 μmoles.

3. The absence of which of the following substrates would not be expected to limit the rate of oxidative phosphorylation?

A. NAD^+
B. O_2
C. $FADH_2$
D. Inorganic phosphate

4. According to Figure 2, oxygen consumption ceased upon the addition of oligomycin. Why did the addition of DNP allow the resumption of oxygen consumption?

A. ATP synthase was no longer blocked by DNP action, and ATP production resumed.
B. Protons provided a bypass pathway for DNP to enter the matrix.
C. DNP provided a bypass pathway for protons to enter the matrix.
D. DNP halted any protons from entering the matrix.

5. The chemical valinomycin inserts into membranes and causes the movement of K^+ into the mitochondria. According to Figure 1, if mitochondria are treated with valinomycin, the rate of ATP synthesis in the mitochondria will most likely:

A. decrease, because the K^+ will compete with protons at the active site on ATP synthase.
B. decrease, because movement of K^+ into the mitochondrial compartments will disrupt proton movement into the intermembrane space.
C. increase, because the net positive charge in the mitochondria will increase the movement of protons into the intermembrane space.
D. increase, because the additional positive charge will further activate ATP synthase.

6. According to Figure 1, oxygen consumption was very poor in the absence of ADP. Why?

A. In the absence of ADP, the flow of protons into the matrix via ATP synthase is blocked.
B. In the absence of ADP, protons are too positive to pass through ATP synthase.
C. In the absence of ADP, ATP synthase begins to work backwards.
D. In the absence of ADP, the flow of electrons into the matrix via ATP synthase is blocked.

PASSAGE II (QUESTIONS 1–5)

The immune system is a versatile and complex system that can respond to a wide variety of threats. Both non-specific and specific mechanisms of the immune response help to protect against infection or inflammation. In fact, even the non-specific mechanisms follow specific mechanisms.

During a successful immune response, a pathogen must first be recognized. Appropriate protein cytokines must then be produced by antigen-presenting cells. One specific class of antigen-presenting cells includes dendritic cells. Dendritic cells are some of the first targets of viruses such as HIV (human immunodeficiency virus), simian immunodeficiency virus, and feline immunodeficiency virus (FIV).

A scientist wants to determine which of the cytokines is negatively affected by FIV. In the experimental setup, dendritic cells were collected from both naïve and FIV-infected cats. The total RNA was extracted from these cells. Complementary DNA (cDNA) was made from this RNA. Finally, real-time quantitative polymerase chain reaction (PCR) was performed to quantify RNA levels of the cytokines.

Although the researcher postulated otherwise, once analyzed, the results of the experiment showed that there was no significant difference in expression of the measured cytokine levels between infected cells and cells from naïve cats (as shown in Figure 1).

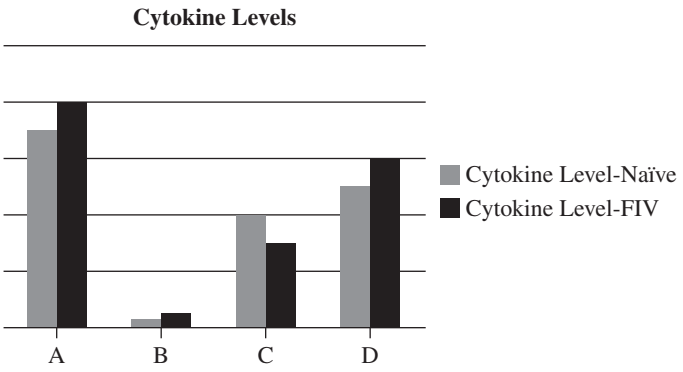


Figure 1. Cytokine levels in naïve and FIV-infected cells.

1. RNA was extracted from the dendritic cells; however, it was made into cDNA. How could this have helped maintain the integrity of the molecules?

A. RNA bases can make only double hydrogen bonds with one another, whereas DNA bases can make triple hydrogen bonds.
B. Due to a variety of factors, DNA is stable enough to make it through PCR, whereas RNA is not.
C. DNA is the molecule from which the genetic code is made; RNA isn't.
D. cDNA forms more stable complexes with RNA than does simple DNA.

2. How does the amount of RNA from the dendritic cells show levels of cytokines?

A. Cytokines are composed of RNA, so RNA levels show cytokine levels.
B. Cytokine DNA is translated directly into RNA molecules.
C. Cytokine mRNA shows evidence of the cell in the process of producing these cytokines.
D. Total RNA shows only cytokine presence in the cell.

3. Polymerase chain reaction amplifies DNA by first unwinding it using heat rather than DNA helicase. What bonds must be broken in order for this reaction with heat to proceed?

A. Hydrogen bonds
B. Phosphodiester linkages
C. Glycosidic linkages
D. Nucleoside–phosphate bonds

4. What modifications will be made to the nascent RNA transcript before it exits the nucleus?

A. A poly-A tail will be added.
B. A 5′ guanosine cap will be added.
C. Introns will be excised.
D. All of the above.

5. There was no significant difference between the cytokine levels found in cells from infected cats versus naïve cats. What does this mean?

A. Dendritic cells are the first step in FIV transmission.
B. T-lymphocytes are completely unaffected by FIV infection.
C. Dendritic cells are not affected by FIV infection.
D. These cytokines are most likely not affected by FIV infection.

PASSAGE III (QUESTIONS 1–5)

Leigh syndrome (LS) is one of many mitochondrial encephalomyopathies due to its unique involvement of the nervous system and striated muscle. It is an early-onset, fatal, neurodegenerative disorder characterized by lesions in the brain stem, basal ganglia, thalamus, and spinal cord.

While most genetic causes of LS are nuclear DNA mutations, a sizable minority of mutations are found in the mitochondrial DNA. Mitochondrial DNA mutations are unique in that, if they are transmitted to the next generation, it is through the mother. The severity of these disorders is affected by heteroplasmy, which refers to the multiple types of mitochondrial DNA within one cell due to the presence of many mitochondria.

Additionally, mutations in genes encoding for electron transport chain complexes I, II, and III have all been associated with LS. Specifically, missense mutations in the SDHA gene, which makes soluble proteins for complex II, have been found in families with autosomal recessive LS. The soluble proteins in complex II contain succinate dehydrogenase activity, while the membrane-associated subunits (SDHC and SDHD genes) contain cytochrome-binding sites for ubiquinone. The latter are responsible for transferring electrons into the ubiquinone pool from FADH-linked molecules. Thus, these mutations can cause less ATP per NADH or $FADH_2$ to be made.

Case 1
A mother with a family history of LS comes to a genetic counselor concerned because she has just found out she is pregnant, according to an at-home pregnancy test. After identifying the type of mutation present in the mother's DNA, the counselor checks the status of the unborn child when it is feasible to do so. Additionally, he checks for the transcription rate of the mutated gene. Results are shown in Figure 1.

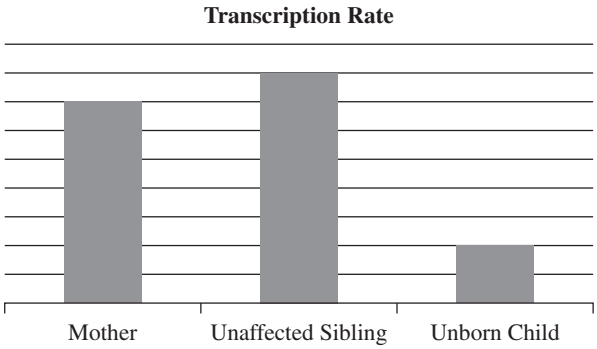


Figure 1. Transcription rate of the mutated gene.

Case 2
Another mother, with a family history of LS in her paternal grandfather, consults a doctor who decides to run a DNA gel electrophoresis to confirm a diagnosis of LS in the fetus. The doctor looks specifically for the presence of the SDHA mutation in the mother, father, unaffected sibling, and fetus. Figure 2 shows the results of the gel analysis.

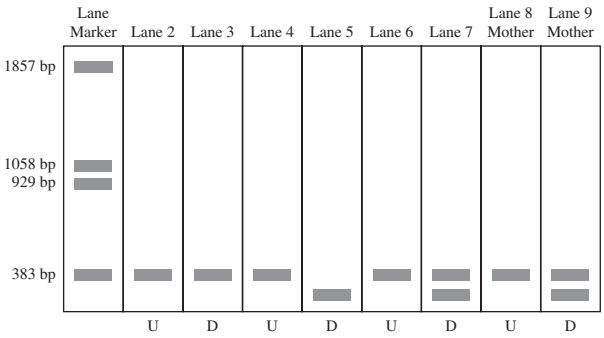


Figure 2. Results of gel analysis where: U = undigested DNA and D = DNA digested with restriction enzyme specific to normal LS gene site

1. A human geneticist working in the same laboratory as a microbiologist was working on elucidating the genetic sequence in the SDHA gene. After some abnormal results, he decided to test the nucleotide content to determine if contamination was present. His results were as follows:

A. Adenine: 40%
B. Guanine: 10%
C. Cytosine: 10%
D. Thymine: 40%

What can be concluded based on this finding?

A. The result shows that bacterial DNA can be ruled out as a possibility for contamination.
B. The result is consistent with human DNA; thus, contamination can be ruled out.
C. The result shows that all viral DNA can be ruled out as a possibility for contamination.
D. The result is consistent with DNA from multiple sources; therefore, another test should be performed.

2. According to the details found in Case 1 and Figure 1, what DNA site is likely affected in this family?

A. Enhancer
B. Promoter
C. Silencer
D. Third codon leading to missense mutation

3. According to Case 2 and Figure 2, what is the most plausible change in the ability to generate ATP for the individual in lane 2/3?

A. NADH generates 2 ATP/mol, while $FADH_2$ generates 1 ATP/mol.
B. NADH generates 2 ATP/mol, while $FADH_2$ generates 3 ATP/mol.
C. NADH generates 3 ATP/mol, while $FADH_2$ generates 1 ATP/mol.
D. There is no change in ATP production.

4. One of the major functions of the mitochondrial genome is to produce proteins necessary for the electron transport chain. Which complex is encoded for at least partially by mitochondrial DNA and is only fed electrons initially from NADH?

A. Complex I
B. Complex II
C. Complex III
D. Complex IV

5. The mutation in LS is a change from adenine to cytosine, which leads to an amino acid change of cysteine to tryptophan. A method of gene therapy was used in which the original functional protein is made using a non-viral vector. In animal models, however, the subjects deteriorate more rapidly than is expected. Which of the following would most likely explain these findings?

A. The vector that was introduced was an infectious organism and induced an immune response that ultimately killed the host.
B. The stop codon UGG was created instead of the missense codon; the protein was truncated and completely nonfunctional.
C. The base change back to adenine was achieved, but the decrease in double-helix stability due to increased hydrogen bonding made the gene harder to access by RNA polymerase.
D. The change of one base was too difficult and precise to achieve and a nonsense codon was created unintentionally.

DISCRETE PRACTICE QUESTIONS (QUESTIONS 1–7)

1. Dinitrophenol (DNP) can allow protons to pass through holes in the inner mitochondrial membrane, other than the one within ATP synthase. What effect would this have on ATP production?

A. Production would decrease, because H^+ movement is no longer coupled to ATP generation.
B. Production would increase, because H^+ movement is now coupled to ATP generation at a higher rate.
C. Production would decrease, because H^+ movement stops synthesis of ATP at these new holes.
D. Production would increase, because H^+ movement synthesizes ATP at these new holes.

2. What can be said of the extracellular environment immediately surrounding the ATP synthases of a prokaryotic cell during a high rate of oxidative phosphorylation?

A. The area gains an increasing concentration of inorganic phosphate.
B. The area becomes more acidic.
C. The area becomes more basic.
D. The area gains an increasing concentration of ADP.

3. Prokaryotes are able to make more ATP per molecule of glucose than eukaryotes. Why is this?

A. Prokaryotes live longer than eukaryotes because of the additional ATP production.
B. Prokaryotes have fewer lysosomal units than eukaryotes, so they use less ATP than eukaryotes in transferring NADH into the lysosome.
C. Prokaryotes use ATP to transfer NADH into the mitochondrion, but eukaryotes have to use more ATP for the same process.
D. Prokaryotes don't have to use ATP to transfer NADH into the mitochondrion, whereas eukaryotes do have to use ATP for this process.

4. Why must the DNA synthesis reaction remain at a high temperature throughout the polymerase reaction in PCR?

A. The polymerase enzyme requires a high temperature in order to proceed.
B. The template strands would reanneal if the temperature was lowered, halting the polymerase reaction.
C. The polymerase enzyme requires the DNA to reanneal in order to proceed with the reaction.
D. The template strands would reanneal if the temperature was lowered, increasing the polymerase reaction.

5. Due to a mutation, a cell lost its ability to create spliceosomes. What is now true of this cell?

A. The cell can no longer do any post-transcriptional processing.
B. The cell can no longer do any splicing as part of post-transcriptional processing.
C. The cell can now only do some types of splicing during post-transcriptional processing.
D. The cell will not be able to create any functional proteins.

6. RNA interference is a process by which a cell can either increase or decrease the usage of an mRNA molecule. How does RNA interference regulate gene expression in a eukaryotic cell?

A. RNA interference regulates whether or not the mRNA is available for translation into the protein.
B. Degradation of mRNA by RNA interference makes translation of tRNA possible.
C. RNA interference regulates whether or not the mRNA is available for transcription into the protein.
D. RNA interference upregulates the translation process by directly stimulating rRNA.