Unit 8

Genes and Proteins

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Test-Taking Challenges

The Regents Exam expects students to have a comprehensive understanding of DNA, protein synthesis, enzyme function, and recombinant DNA. However, because the New York state vocabulary list restricts the use of some terms, knowledge is often tested conceptually with the use of figures. For example, rather than asking a question about mRNA, the Regents Exam sometimes asks students to identify it as a molecule in an intricate diagram or graphic organizer. This approach requires students to have a strong understanding of the material as well as the ability to recognize symbolic representations of many of the processes involved.

This unit is not intended as an introduction to protein synthesis or recombinant DNA. It is meant to serve as a review. If students are having difficulty with any of the concepts, they should review the relevant chapters in their textbooks. Once they are comfortable with the information, they can focus on the concepts and terms presented in this *Advantage* course, as these are the ones that have been tested most often on the Regents Exam in the past.

Unit Objectives

In this unit, students will review:

- the structure and function of DNA.
- how DNA is translated into proteins.
- the causes and effects of mutations.
- the shape and function of proteins.
- the effects of pH and temperature on enzymes.
- recombinant DNA and cloning.

Correlation to New York State Learning Standards for Mathematics, Science, and Technology:

Standard 1: Scientific Inquiry Key Idea 3

Standard 4: Science, Living Environment Key Ideas 1, 2, 3, 5, 6, and 7

Thinking KAP

It is your third day in the rainforest and you are starting to get worried about your dog. Her hair is falling out in huge clumps. You have been watching her carefully. She has been drinking only sterilized water and she has not eaten any animals or plants from the forest. She loves chasing the lizards and parrots and she seems energetic and happy.

You take her to the doctor who is traveling with your group and explain her symptoms. After checking her eyes and mouth, the doctor asks you what the weather was like in New York when you left. You explain that there was snow on the ground and everyone was wearing heavy coats. "In that case," the doctor says, "there's nothing to be worried about."

What connection could there be between moving your dog to the hot climate of Mexico and her loss of hair? How is this related to gene expression?

Task

Students will analyze a real-world situation as a lead-in to a discussion about gene expression and protein synthesis.

Teacher's Note

Students may not be able to answer this question, but it is a good starting point for a review of the role that DNA plays in controlling cell functions.

Delivery

Welcome students to class and have them turn to page 205 in their *Advantage* books. Assign the Thinking KAP as an introductory activity to start the lesson. Let students know that there are many acceptable answers.

When students are finished, ask a few volunteers to share their answers as well as how they found their answers.

Thinking KAP: Sample Answer

The dog is probably losing hair because the longer daylight period and hot climate send the message that it is summer, and give the dog the signal to shed. Special proteins cause the hairs to fall out, and other proteins cause the hair to only grow a short length. Each protein comes from a different gene.

Remind students that signals from the environment constantly determine the way our bodies function. Have students brainstorm some examples in their own lives (e.g., waking up is harder during the winter, people sweat in hot temperatures, the smell of food makes us salivate and our stomachs growl).

Moving On

"It can be difficult to figure out how the weather could cause genes to make dog hair fall out. Let's break it down and look at the steps."

DNA

DNA plays a role in everything from how big a yucca plant can grow to why hot climates make your dog's hair fall out. The Regents Exam expects you to understand how DNA regulates protein synthesis. Let's begin by reviewing the structure of DNA.

Key Knowledge

DNA is made of bases (also called nucleotides).

In DNA, the four bases or nucleotides are adenine (A), thymine (T), guanine (G), and cytosine (C).

DNA is a double helix.

DNA is made of two strands that look like a twisted ladder. The poles of the ladder are made up of phosphate groups and simple sugars called deoxyribose. The rungs are formed by nucleotide base pairs that bond together (A-T and C-G).

DNA can replicate.

To make copies of DNA, the two strands separate or unzip from each other. An enzyme matches the bases of each old strand with new bases to make new strands when the cell replicates.

DNA is packaged in chromosomes.

In animal cells, DNA is compressed into chromosomes during cell division to keep it organized.

keep in mind

Look out for different words that express the same idea. The terms *gene, DNA sequence, bases, nucleotides,* and *template* are all used on the Regents Exam to mean very similar things.

Task

Students will review the structure of DNA.

Teacher's Note

The Regents Exam frequently tests DNA and protein synthesis without the use of some relevant vocabulary terms. The terms *RNA* and *codon* cannot appear anywhere in the test but Section D. (This is a New York State requirement.) However, students are often still held responsible for the concepts on other parts of the Regents Exam through the use of figures and graphic organizers. Question 2 on the next page is a question that requires students to make connections by using a diagram.

Delivery

Call on students to read the text and Key Knowledge. Call on a student to read the Keep In Mind. Tell students that they should know every term in this Keep In Mind.

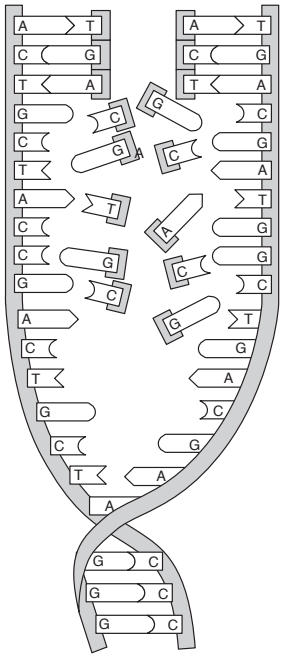
Moving On

"Let's try answering questions about DNA on the next page."

Try It Out!

- ***Use Text/Labels/Shape on the diagram below.***

The diagram below shows a process that occurs in animal cells.



What does the text tell you? _____

Are there labels in the diagram? _____

What does the diagram look like? _____

1 What is the name of this process? [1]

_____

2 In which organelle does this process occur? [1]

_____

keep in mind

Questions on DNA and protein synthesis often use diagrams, but they may represent DNA and amino acids differently. Look for different representations throughout this unit.

Task

Students will apply their knowledge of DNA.

Delivery

Call on a student to read the Keep In Mind. Then work through the diagram using Text/Labels/Shape as a class.

Try It Out: Answers

1 DNA replication

What does the text tell you? *that it is a process in animal cells*

Are there labels in the diagram? *yes–A, G, T, and C*

What does the diagram look like? *a zipper being unzipped*

Students should focus on the labels A, T, C, and G and use them to identify the structures as DNA. Students should also notice the unwinding of the two strands and the shapes that fit into each other like puzzle pieces, using these two shape observations to identify the process as DNA replication. If students have difficulty with this question, have them circle and identify parts of the diagram.

Related Standard: Standard 4, Key Idea 2

2 nucleus

Students should underline the keyword *organelle.* They can restate the question as, "Where does DNA replicate in the cell?" Even if students have difficulty identifying the process as DNA replication, they can restate the question as, "Where is DNA found in the cell?" and use this restatement to obtain the correct answer. All DNA is found in the nucleus in animal cells. This information was also included in Unit 6.

Related Standards: Standard 4, Key Ideas 1 and 2

Moving On

"Now that we have reviewed the structure of DNA, let's review how DNA is actually used by the cell."

Protein Synthesis

DNA is a **template** that controls and stores the information for the proteins that are made by the cell.

Key Knowledge

One gene makes one protein.

A gene is the sequence of bases that gives instructions for making one protein.

DNA is transcribed as mRNA.

Messenger RNA (mRNA) is a single strand of bases made from a gene. It matches the DNA, except that mRNA uses the base uracil (U) instead of thymine (T). mRNA is created in the nucleus, and then travels to the ribosome to be used for protein synthesis.

mRNA is made of codons.

A codon is a sequence of three nucleotides, such as CAC.

Each codon specifies an amino acid.

In the ribosome, codons from the mRNA are matched to the amino acids they code for. For example, the codon CAC codes for the amino acid histidine (His).

Proteins are made of amino acids.

As the ribosome finds each amino acid to match the mRNA, it connects the new amino acid with the old ones. This growing chain of amino acids eventually becomes a protein.

Protein shape determines protein function.

The order of amino acids determines how a protein will fold up. The shape of a protein determines what it does.

keep in mind

Ribosomes make proteins. If you see a picture of dots on a membrane, it probably represents ribosomes making proteins.

Task

Students will review the steps of protein synthesis.

Delivery

Call on students to read the text and the Key Knowledge. Point out that the information in the Key Knowledge box is written in order, from DNA to protein. Students should have a general idea of the steps of protein synthesis, but they do not need to memorize vocabulary terms like *tRNA*, *transcription*, *translation*, or *codon*.

Moving On

"Now let's try answering questions about protein synthesis on the next page."

Try It Out!

STEP 1: Understand the Question

- ***Read the question and underline keywords.***
- ***Glance at the answer choices. Describe them.*** _____
- ***Restate the question.*** _____

1 An organism's genes are best described as the sequence of

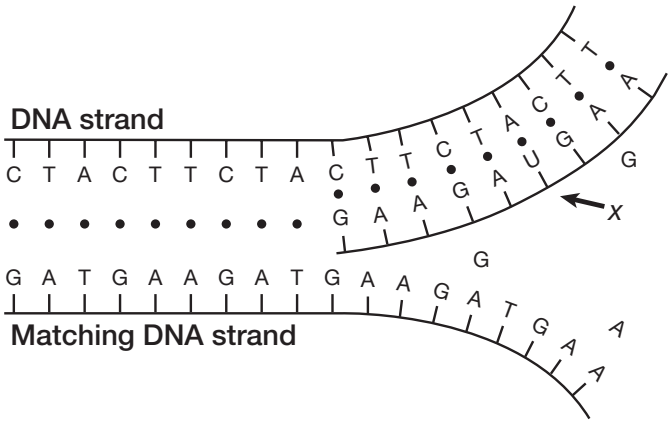
(1) codons in its RNA
(2) nucleotides in its DNA
(3) amino acids in its proteins
(4) carbon in its carbohydrates

keep in mind

You can remember that the T of DNA is replaced by U in RNA because the two letters appear in that order in the alphabet.

- ***Use Text/Labels/Shape in the diagram below.***

2 The diagram below shows one step in the process of protein synthesis.



What does the diagram represent? _____

What do the labels tell you? _____

What does the diagram look like? _____

What does the structure labeled *X* represent?

(1) amino acids
(2) DNA
(3) mRNA
(4) chromosomes

Task

Students will answer questions about the steps of protein synthesis.

Delivery

Have students complete the Try It Out. Point out that although the diagram in question 2 looks very different from the one on the previous page, both figures represent DNA. It may be helpful for students to compare the previous diagram with this one. Have them identify the parts of the diagram that are the same, even though they are represented differently.

Try It Out: Answers

1 (2)

STEP 1: Understand the Question

- ***Read the question and underline keywords.***

An organism's genes are best described as the sequence of

- ***Glance at the answer choices. Describe them.*** parts of larger molecules
- ***Restate the question.*** What are genes?

Students should then predict that the answer involves DNA. Genes are DNA nucleotide sequences that store instructions for making proteins.

Related Standard: Standard 4, Key Idea 2

2 (3)

What does the diagram represent? protein synthesis

What do the labels tell you? There are two strands of DNA and an extra strand with a U.

What does the diagram look like? a new strand being made

Students should use Text/Labels/Shape. Using all three of these observations, students can conclude that this strand is RNA rather than DNA.

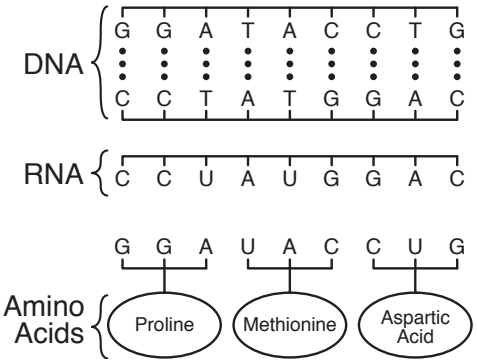
Related Standard: Standard 4, Key Idea 2

Moving On

"Now that we have talked about how proteins are made, let's examine the steps in the process of making a protein."

Transcription and Translation

The Regents Exam may ask you to transcribe DNA into RNA or to translate from RNA into a protein, as shown in the diagram below.



keep in mind

For the Regents Exam, you should know which RNA base matches each DNA base. Some people remember that both C and G have curved shapes.

Try It Out!

1 DNA is transcribed into RNA in the nucleus. Transcribe the sequence below from DNA into RNA.

DNA	RNA
C	G
G	C
A	U
T	A

G A C T T A C G G A T C G A A T A

_____

Task

Students will practice the process of transcription.

Teacher's Note

On past Regents Exams, students have been asked to translate directly from DNA to proteins, without showing intermediary RNA molecules. This type of question provides a chart that lists sequences of DNA and the amino acids that each encodes. On future exams, students may be asked about transcription from DNA to RNA in Section D, as this concept is part of the Relationships and Biodiversity required laboratory activity. For this reason, we review both approaches; the Independent Practice uses the direct DNA to protein approach that has been used on the Regents Exam in the past.

Delivery

Call on a student to read the text, and remind the class to use Text/Labels/Shape to understand the figure. Call on a different student to read the instructions for transcription and explain what she notices about the DNA/RNA chart. Point out the replacement of T with U. Review the mnemonic that uses these letters' positions in the alphabet to remember which replaces which. Have a student read the Keep In Mind.

Have students transcribe the DNA on their own. Have students check their answers with a partner and address any difficulties as a class.

Try It Out: Answer

G A C T T A C G G A T C G A A T A

C U G A A U G C C U A G C U U A U

Related Standard: Standard 4, Key Idea 2

Moving On

"Good work. Now let's see what happens to the RNA next."

2 Once it is formed, mRNA leaves the nucleus and is translated into an amino acid chain (or protein) in a ribosome. Several different mRNA codons can match up to just one amino acid. The chart below shows just a few of the 16 amino acids and 64 codons.

RNA	Amino Acid
AUA, AUC, AUU	Ile
AUG	Met
CAA, CAG	Gln
GAC, GAU	Asp
UGG	Trp
UUC, UUU	Phe

A U G C A A G A U U G G U U C A U C

_____

Use the table above to translate the RNA to amino acids.

- ***Draw a line after every three nucleotides in the RNA sequence to find the codons.***
- ***A codon list like the one above will be given to you on the Regents Exam. All codons in the same row have the same first letter.***

Don't worry about memorizing which codons match up to different amino acids. If there is a question on translation, the Regents Exam will give you a chart for these pairings.

Task

Students will practice the process of translation.

Delivery

Have a student read the information about translation and describe what he notices. Point out the two tips about translation given below the table. Have students complete the Try It Out. After reviewing the solution, call on a student to read the Keep In Mind.

Try It Out: Answer

AUG CAA GAU UGG UUC AUC

Met Gln Asp Trp Phe Ile

Related Standard: Standard 4, Key Idea 2

Moving On

"Good work. Now let's examine the roles of proteins in the body."

Proteins

Every cell in your body contains the same DNA. However, your muscle cells look very different from your brain cells. This is because different cells produce different proteins. But what do proteins in cells do, and how do different cells in your body know which ones to make?

Key Knowledge

Some proteins are structural.
The protein collagen is part of the connective tissue present in skin, ligaments, tendons, and bones.

Enzymes are proteins used in digestion and metabolism.
Enzymes are catalysts, which are molecules that cause chemical reactions to occur by decreasing the amount of energy needed for the reaction. For example, lactase breaks down lactose, protease breaks down proteins, and DNA polymerase builds DNA molecules.

Genes are turned on and off.
A protein is created when the nucleus receives a signal to make that protein. For example, muscle cell proteins signal their nuclei to make more muscle cell proteins. Different signals stop production. In an embryo, growth hormones signal the nuclei in stem cells to make different proteins and develop into different organs.

Environmental conditions can turn on genes.
Eating food causes your body to produce more digestive enzymes. Shorter daylight periods cause some animals to stop making the proteins that color their fur, which is why they have white fur in the winter.

Extreme conditions can change proteins.
Proteins fold into special shapes to do their work. In extreme temperature or pH, their chemical bonds may break and their shape may change, which causes them to stop working.

keep in mind

Although enzymes take part in most chemical reactions that occur in living organisms, they are not used up or changed during them.

Task

Students will review the roles that proteins play in the body.

Delivery

Call on students to read the text. After reading the first two Key Knowledge ideas, have students define the term *enzyme*. Students should know that the main purpose of enzymes is to speed up chemical reactions. Some of the common reactions they speed up are reactions used in digestion and metabolism.

Have students read the next three parts of the Key Knowledge. Reinforce the idea that although every cell in the body has the same DNA, different cells produce different proteins at different times. Have students make connections back to the Thinking KAP at the beginning of the unit. Call on a student to read the Keep In Mind.

Moving On

"Now that we have talked about what proteins do, let's answer some questions about proteins.

Try It Out!

STEP 1: Understand the Question

- ***Read the question and underline keywords.***
- ***Glance at the answer choices. Describe them.*** _____
- ***Restate the question.*** _____

1 Alligators generally lay 30 eggs at a time and place them in a nest. Eggs near the edge of the nest are generally warmer and will develop into males. Eggs at cooler temperatures will develop into females. Unlike mammals, alligators do not have sex chromosomes. Which explanation best describes sex determination in alligators?

(1) The DNA is different in male and female embryos, giving some a genetic advantage.
(2) The embryos produce different sex-determining proteins at different temperatures.
(3) High temperatures mutate the DNA in some eggs to produce male proteins.
(4) Female alligators prefer cold weather, and will only appear in cool temperatures.

keep in mind

Different proteins are produced when different genes are turned on. This results in different characteristics and functions in the cell.

Task

Students will apply their knowledge of proteins.

Delivery

Have a student read the Keep In Mind. Then allow students to complete the questions.

Try It Out: Answer

1 (2)

STEP 1: Understand the Question

- ***Read the question and underline the keywords.***

Which explanation best describes sex determination in alligators?

- ***Glance at the answer choices. Describe them.*** long and complex
- ***Restate the question.*** What causes an alligator embryo to become male or female?

This is a good question for practicing the elimination of wrong answers. Students should eliminate (1) because the question states that alligators do not have sex chromosomes, which are the source of the main difference between male and female DNA in other species. (3) can be eliminated because if male proteins were only produced as a result of specific mutations, very few male alligators would exist. Mutations do not happen with such regularity. No support for (4) can be found in the passage, nor is there evidence that alligator embryo preferences exist. Though all of the eggs have very similar DNA, they express different proteins. The expression of these different proteins is what causes them to develop into different sexes.

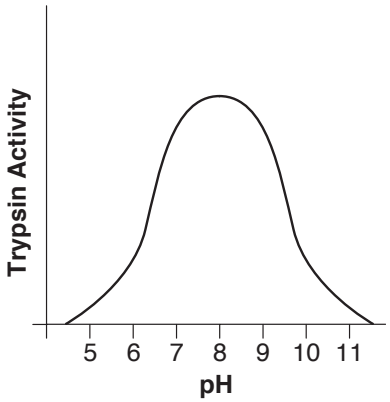
Related Standard: Standard 4, Key Idea 2

Moving On

No transition is needed. Students should continue working through the Try It Out on the next page.

■ ***Use Text/Labels/Shape to answer the following question.***

2 The graph below shows how the activity rate of the human enzyme trypsin, which breaks down proteins in the digestive system, varies with pH.



keep in mind

Acids have pH levels between 0 and 7. Bases have pH levels between 7 and 14. You can remember that *acid* comes first alphabetically, and acidic pHs come first numerically.

What does the text tell you? _____

What do the labels tell you? _____

What are the trends in the shape of the graph? _____

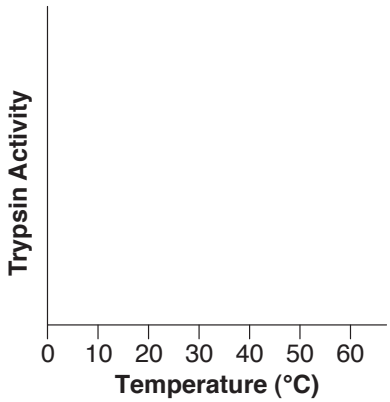
At what pH does trypsin function most effectively? [1]

_____

3 The human stomach is very acidic, while the small intestine is slightly basic. Where is trypsin likely to be found? [1]

_____

4 Based upon your knowledge of enzymes and the human body, complete the graph below to show how temperature affects trypsin activity.



What shape should your graph have? _____

Task

Students will continue to apply their knowledge of proteins.

Delivery

Students should continue working on the Try It Out. Point out the Keep In Mind when students reach question 3.

Try It Out: Answers

2 8

What does the text tell you? *the activity of an enyzme varies with pH*

What do the labels tell you? *the pH ranges from 5 to 11*

What are the trends in the shape of the graph? *It peaks in the middle.*

Trypsin works most effectively at the highest point on the graph. Students should use the shape of the graph to determine the location of this point. If students have difficulty with this question, have them analyze the graph moving left to right along the *x*-axis on the graph.

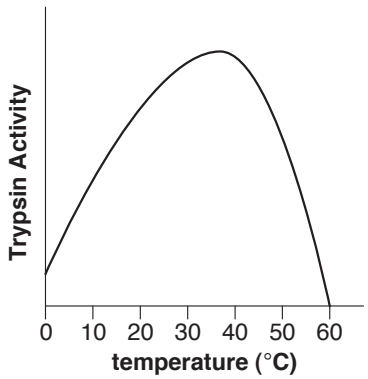
Related Standards: Standard 1, Key Idea 3; Standard 4, Key Idea 5

3 small intestine

Student should underline the keywords *stomach*, *acidic*, *small intestine*, and *basic*. Enzymes have evolved to be highly efficient at the pH and temperature at which they are normally used by an organism.

Related Standards: Standard 4, Key Ideas 1 and 5

4



What shape should your graph have? *a peak*

This graph shows the actual efficiency curve for trypsin. The graph must show a peak around 37°C. Students should know that 37°C is normal human body temperature.

Related Standard: Standard 1, Key Idea 3; Standard 4, Key Idea 5

Moving On

"Good work on these questions. Now let's look at how DNA can change."

Causes of Mutations

Mutations in DNA occur when bases are deleted, changed, added, or moved. This change may cause a change in the shape of a protein, which will then affect its function.

Key Knowledge

Some mutations do not change protein function.

Some changes to DNA are harmless. For example, GAC and GAU both code for aspartic acid (Asp). If a mutation changed the C to U, it wouldn't matter because the mutated amino acid sequence (or protein) would be exactly the same as the original one.

Some mutations change protein function.

Some mutations change the shape of the protein, which changes its ability to do its job. If the codon GAC became GAA, glutamic acid (Glu) would replace aspartic acid (Asp) in the protein. This would change the protein's shape and interfere with its function.

Some mutations are random.

Mutations naturally happen during mitosis or meiosis. They contribute to genetic diversity if they are passed on to offspring.

Some mutations are caused by mutagens.

Mutagens are environmental agents that cause mutations. Some examples are UV radiation (from the sun), x-rays, nicotine, pesticides, many illegal drugs like heroin, and some prescription drugs like DES, which is no longer used.

You should know two specific mutagens and two specific genetic diseases for the Regents Exam.

Task

Students will review the basic causes of mutations.

Delivery

This page organizes the topic of mutations by several subcategories. After reading each set of information, ask a student to summarize the distinction within each subcategory (e.g., some mutations are random while some are caused by mutagens). Call on a student to read the Keep In Mind.

Moving On

"The Key Knowledge continues on the next page."

Effects of Mutations

People usually think of mutations as bad, or occasionally evil. However, mutations are responsible for genetic variation in a population, which results in evolution.

Key Knowledge

Mutations in body cells can cause cancer.
Cancer occurs when cells reproduce without stopping and eventually invade other areas of the body. Mutated genes cannot make the proteins that would normally prevent a cell from reproducing. Each daughter cell keeps reproducing since it contains the same mutated DNA as the original cell.

Mutations in gametes are passed on to offspring.
Changes in DNA can only be passed on to offspring if they are present in the gametes of a parent.

Some mutations lead to genetic diseases.
Sickle-cell anemia, cystic fibrosis, Marfan syndrome, Huntington's disease, and hereditary hemochromatosis each result from adding, changing, or removing DNA in a gene or genes.

Some mutations lead to genetic advantages.
All evolution results from minor genetic mutations in a population. Individuals with helpful mutations can survive unfavorable conditions to have more offspring, who will also have the mutation.

Mutations provide a way for scientists to track species ancestry.
Species with similar nucleotide sequences in a particular gene are more closely related than species with sequences that are less similar.

keep in mind

Remember that DNA mutations to a single body cell cannot change the traits throughout the whole body. Changes to the whole body depend upon how genetic material from the parents is expressed.

Task

Students will review the effects of mutations on body cells, offspring, and populations.

Delivery

Continue to have students read and summarize each subcategory. Emphasize that every piece of information on these two pages is important and is likely to show up on the Regents Exam. Genetic advantages and species ancestry will be readdressed in Unit 10. Call on a student to read the Keep In Mind. Have students circle or highlight the two mutagens and two genetic diseases they want to know for the Regents Exam.

Moving On

"Let's see how comfortable you are with these ideas by trying a few practice questions."

Try It Out!

STEP 1: Understand the Question

- ***Read the question and underline keywords.***
- ***Restate the question.*** _____

1 Sickle-cell anemia comes from abnormal hemoglobin molecules that cannot bond well to oxygen. These molecules result from the replacement of T by A in nucleotide 17 of the hemoglobin gene. Explain how the substitution of a single nucleotide can cause this severe genetic disease. In your response be sure to include:

- how a mutation in DNA can affect a protein [1]
- the role of protein shape [1]

_____

_____

_____

keep in mind

When comparing the DNA or amino acids of several species, use a pencil to circle every difference. This makes it easy to count and compare the number of differences.

STEP 1: Understand the Question

- ***Read the question and underline the keywords.***
- ***Restate the question.*** _____

2 Which species is most closely related to Species *X*? [1]

Species *X* T C G A G T T C G G A T A T A

Species *Y* T C C A G T A C G G A A A T A

Species *Z* T C C A G T T C G G A T A T A

_____

3 Mutations are passed on to offspring when they are present in

STEP 2: Make a Prediction

- ***Make a prediction.*** _____
- ***Check whether your prediction matches any of the answer choices.***

(1) brain cells
(2) sex cells
(3) skin cells
(4) muscle cells

Task

Students will apply their knowledge of mutations.

Delivery

Begin by instructing a student to read the Keep In Mind. Allow students to work on the questions. Then go over the answers as a class.

Try It Out: Answers

1 *Sample Answer:* Mutated DNA results in mutated RNA, which may result in different amino acids being used in the protein. If the wrong amino acids are used, the hemoglobin protein will not fold correctly, and this will prevent it from picking up oxygen.

STEP 1: Understand the Question

- ***Read the question and underline the keywords.***
- how a mutation in DNA can affect a protein
- the role of protein shape
- ***Restate the question.*** How do mutations affect a protein and its shape?

This question can be answered without reading the passage. Students should check the bullets to ensure that they answer the question completely.

Related Standard: Standard 4, Key Idea 2

2 Species *Z*

STEP 1: Understand the Question

- ***Read the question and underline the keywords.***

Which species is most closely related to Species *X*?

- ***Restate the question.*** Which pair of nucleotide sequences is more alike, X and Y, or X and Z?

Students should count the number of differences between nucleotide sequences to determine which species are more closely related. This type of question is likely to appear in Section D because the concept appears in the Relationships and Biodiversity required laboratory activity.

Related Standard: Standard 4, Key Idea 3

3 (2)

STEP 2: Make a Prediction

- ***Make a prediction.*** cells that go on to become offspring

Related Standards: Standard 4, Key Ideas 2 and 3

Moving On

"Good job. On the next page, we will look at how humans modify DNA for scientific and technological purposes."

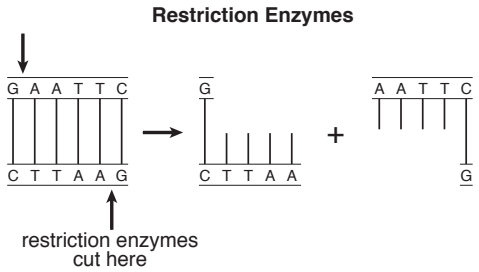
Recombinant DNA

Many fruits and vegetables produced in the US have been genetically modified to resist drought and insects as well as to grow bigger, healthier, and tastier. Genetically modified bacteria are used to produce important human enzymes like insulin and growth hormones. This process is called **cloning** and the result is **recombinant DNA** because the DNA from two species is combined.

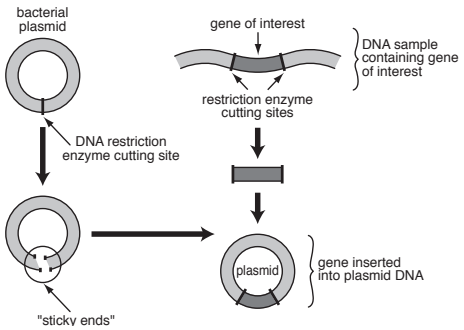
Let's use the example of artificially producing insulin in a bacterium. First, a scientist cuts or **splices** the gene for making insulin out of a human cell. A **restriction enzyme** splices DNA at a certain nucleotide sequence. The resulting cuts in the DNA are called **sticky ends** because they can be rejoined together.

keep in mind

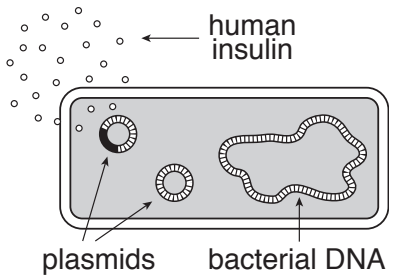
Cloning DNA involves copying a single gene, frequently to produce more enzymes from recombinant DNA. Cloning an organism involves using a body cell to grow a genetically identical organism.



Next, a piece of circular DNA called a **plasmid** is taken from a bacterium. This DNA is also spliced with the same restriction enzymes to give it matching sticky ends. The insulin gene from the human fits the sticky ends of the plasmid from the bacterium.



Finally, the modified plasmid is put back into the bacterium, which can now make the enzyme insulin.



Task

Students will review how recombinant DNA is made.

Delivery

Have students read the text and then prompt the class to use Text/Labels/Shape on each diagram. Tell students that most recombinant DNA questions that have appeared on the Regents Exam in the past have used similar diagrams. If students ask, explain that plasmids are extra or floating rings of DNA in bacterial cells. Some plasmids carry evolutionary advantages that will be passed on when bacteria reproduce.

Moving On

"Let's practice answering questions about recombinant DNA."

Try It Out!

1 List *one* compound that is produced using recombinant DNA technology and explain how it has benefited humans. [2]

_____

This question is worth two points. What are the two things you must do to answer the question? _____

_____

STEP 1: Understand the Question

- ***Read the question and underline keywords.***
- ***Glance at the answer choices. Describe them.*** _____
- ***Restate the question.*** _____

keep in mind

You should know two examples of proteins that are produced by recombinant DNA.

2 Factor 8 is a blood clotting protein found in humans. Hemophiliacs are individuals who cannot make this protein, and can bleed to death from accidents that most people would be able to treat with a bandage. In the past, some hemophiliacs have contracted hepatitis or HIV because of the numerous blood transfusions they must receive. Now, a safer method has been found. Ordinary plants are being used to produce factor 8, which can then be administered to hemophiliacs. These plants can make this human blood clotting protein because

(1) selective breeding encouraged plants to produce this protein
(2) the plants were given factor 8 proteins in their water
(3) a gene that encodes factor 8 was placed in plant cells
(4) plants and hemophiliac patients have undergone coevolution

Task

Students will apply their knowledge of recombinant DNA.

Delivery

Complete the Try It Out as a class. Have students lead you through the 4-Step Method for question 2, starting with the process of understanding the question before reading the paragraph.

Try It Out: Answers

1 *Sample Answers*: Insulin can prevent the complications of diabetes; growth hormones are used in older adults to increase bone density; estrogen is used by women to prevent the side effects of menopause.

This question is worth two points. What are the two things you must do to answer the question? *name a substance produced by recombinant DNA and explain how it is helpful*

Students should check the bullets after answering the question to ensure that they answer it completely. Tell students that insulin is a good hormone to memorize, as it is often tested on the Regents Exam.

Related Standards: Standard 4, Key Ideas 2 and 5

2 (3)

STEP 1: Understand the Question

- ***Read the question and underline the keywords.***

These plants can make this human blood clotting protein because

- ***Glance at the answer choices. Describe them.*** *long and complex*
- ***Restate the question.*** *How can plants make human proteins?*

Students should then predict that the answer involves some form of genetic engineering because two different species are involved. Human proteins will only be produced by plants when the genes are placed in the plants' cells as recombinant DNA.

Related Standard: Standard 4, Key Idea 2

Moving On

"We have reviewed everything about DNA and proteins that appears frequently on the Regents Exam. Now let's try a practice question together."

Guided Practice

1 A human body temperature between 38°C and 40°C indicates a common fever, which is helpful in fighting an infection or healing an injury. However, temperatures above 40°C can cause permanent brain damage, blindness, deafness, or even death. Explain how a high body temperature could affect enzymes in the human body. In your answer, be sure to include:

- an explanation of the role of enzymes in the human body [1]
- the effect of high body temperature on enzymes [1]
- the reason that high fevers can be fatal [1]

keep in mind

Check the bullets every time. It doesn't take much time and it can really improve your score.

STEP 1: Understand the Question

- ***Read the bullets and underline the keywords.***
- ***Do you need to use the passage to answer the bullets?***

STEP 2: Hit the Bullets

- ***Answer every bullet.***

STEP 3: Check the Bullets

- ***Read the first bullet and your answer to it.***
- ***If your answer makes sense, put a check by the bullet.***
- ***Repeat for each bullet.***

Task

Students will follow along as the 3-Step Method for Constructed-Response Questions is modeled.

Delivery

Model each strategy in the 3-Step Method for Constructed-Response Questions for your students as if you were taking the test yourself. After reading the bullets, read the Keep In Mind. Verbalize all of your thought processes.

Guided Practice: Sample Answer

STEP 1: Understand the Question

- ***Read the bullets and underline keywords.***
- an explanation of the role of enzymes in the human body
- the effect of high body temperature on enzymes
- the reason that high fevers can be fatal
- ***Do you need to use the passage to answer the bullets?*** not all of them

STEP 2: Hit the Bullets

- ***Answer every bullet.***

Enzymes are required for all metabolic processes in the human body. At high temperatures, their shapes can change, making them unable to work. Some enzymes carry oxygen to cells, which is used by cells to release energy from sugar. Without this energy, cells may die.

STEP 3: Check the Bullets

Model checking each bullet by placing a check mark next to each one after identifying where it is answered in your response.

Related Standard: Standard 4, Key Idea 5

Moving On

"Now you will have a chance to work on your own. Use the hints to help you answer the questions."

Name_____ Date_____

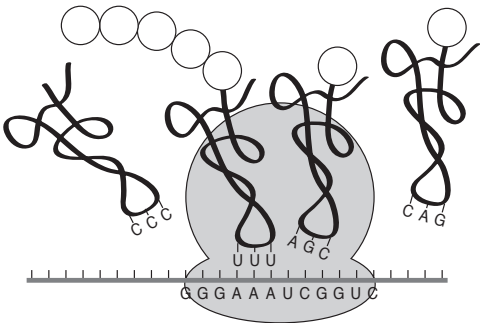
Independent Practice

1 Single gene mutations are caused by

(1) having three copies of a chromosome
(2) a change in a DNA base sequence
(3) errors in protein synthesis
(4) inheriting traits from two parents

hint *Use the 4-Step Method: Understand the Question, Predict the Answer, Eliminate Wrong Answers, and Make an Educated Guess.*

2 What process is shown in the diagram below?



(1) protein synthesis
(2) DNA replication
(3) immune response
(4) cell signaling

hint *Figures on the Regents Exam may not look like the ones in your textbook. Remember that DNA uses the nucleotide T, RNA uses U, and amino acids are written with three letter codes such as Lys (lysine) or Pro (proline).*

3 Ptarmigans are a type of grouse that inhabit the northern tundra of Canada and Alaska. During summer months, the females are a speckled brown color, while the males have red chests, dark brown back feathers, and white bellies. In the winter, both sexes molt to replace their colored feathers with pure white ones. This camouflage allows them to blend in with the snow and avoid predators. What genetic principle explains the change in the color of ptarmigan feathers from colored to white each winter?

(1) Ptarmigans have unstable DNA in some of their genes.
(2) Cold weather can cause mutations in ptarmigan DNA.
(3) The environment can affect gene expression.
(4) All colorful ptarmigans are killed by predators.

hint *This question uses a lot of unfamiliar words, but you do not need to know them to answer the question. How can you restate the question to make it sound more familiar?*

Answers

1 . . . . . .

2 . . . . . .

3 . . . . . .

Task

Students will answer multiple-choice and constructed-response questions independently or in pairs, using hints to guide them.

Delivery

These exercises should not be teacher-led. Students should answer the questions on their own or in pairs. Give students about 10 minutes to complete the Independent Practice. Remind students to apply the methods and strategies they have learned and to circle questions that they are unsure about.

After students have finished, review individual responses as a class. When reviewing multiple-choice questions with the class, focus on why the correct answers are correct and how the methods and strategies should be used, not why the wrong answers are wrong. Going through each wrong answer takes a long time and usually is not helpful. However, if students are confused about a particular wrong answer, that answer should be addressed.

Independent Practice: Answers

1 (2)

Student should underline the keyword *single gene mutations*. This question provides a good opportunity to practice eliminating wrong answers. A single gene mutation is defined as a nucleotide change in a DNA sequence. Having three copies of a chromosome may cause the unhealthy overproduction of some proteins, but this is not a mutation of a single gene, eliminating (1). Errors in protein synthesis are an effect of mutations, not a cause. This eliminates (3). Mutations might occur during meiosis, but they are not caused by sexual reproduction, eliminating (4).

Related Standard: Standard 4, Key Idea 2

2 (1)

Students should use Text/Labels/Shape on the diagram. Students should focus on the labels and use them to identify this process as protein synthesis. If students have difficulty with the tRNA molecules in the diagram, encourage them to focus on identifying the bottom letters as RNA and concluding that RNA must be used to make proteins from amino acids (the circles).

Related Standard: Standard 4, Key Idea 2

3 (3)

Temperature and other environmental factors constantly affect which genes are expressed. For example, stepping outside on a hot day will cause your cells to produce proteins that signal your pores to sweat. Cold weather does not directly cause mutations, eliminating (2). No species has "unstable DNA," eliminating (1). (4) gives a potential evolutionary reason for this trait, but the passage explains that the birds get new feathers.

Related Standards: Standard 4, Key Ideas 2 and 6

Moving On

No transition is needed. Students should work straight through to page 223.

Name_____ Date_____

4 Which characteristic is shared by all enzymes?

(1) They all affect the rate of chemical reactions.
(2) They all produce energy during chemical reactions.
(3) They all work best in an environment with pH 7.
(4) They all work best in an environment at 37°C.

hint *Enzymes are everywhere. Cold-blooded reptiles, microorganisms, and plants all have enzymes in every cell.*

5 The milk from both humans and cows contains the sugar lactose. Lactose is broken down in the small intestine by a molecule called lactase. Lactase is a type of

(1) organelle
(2) sugar
(3) enzyme
(4) mitochondria

hint *What type of molecule always ends in –ase?*

Answers

4 . . . . . .

5 . . . . . .

Independent Practice: Answers

4 (1)

Students should underline the keywords *all* and *enzymes*. Enzymes are defined as organic molecules that increase the rate of chemical reactions. In this case, students could predict a variety of characteristics that are true for all enzymes and not have them match the answer choices. Eliminating wrong answers would be useful on this question. (2), (3), and (4) are true for some, but not all enzymes. Some enzymes participate in reactions that release energy (such as ATPase and proteins in the mitochondria), but others participate in reactions that require the use of energy (such as DNA polymerase, which uses energy to make bonds between nucleotides).

Related Standard: Standard 4, Key Idea 5

5 (3)

Molecules whose names end with *-ase* are always enzymes. Students should predict that the answer will be something that breaks down molecules. Sugars do not break down other sugars. Mitochondria are organelles that break down sugars, but they break down many types of sugars and do not float freely in the small intestine. Though some organelles are involved in breaking down molecules, they are made of membranes and substructures that are far more complex than a single molecule.

Related Standard: Standard 4, Key Idea 5

Moving On

No transition is needed. Students should work straight through to page 223.

Name _____ Date _____

6 Each amino acid in a protein chain corresponds to a three-base sequence of DNA. Some amino acids are encoded by multiple DNA sequences. The three-base sequences for some amino acids are shown below.

Amino Acid	Amino Acid Abbreviation	DNA Code Sequence
Phenylalanine	Phe	AAA, AAG
Tryptophan	Try	ACC
Valine	Val	CAA, CAC, CAG, CAT
Glutamine	Glu	GTC, GTT
Methionine	Met	TAC
Asparagine	Asp	TTA, TTG

In the space below, write the sequence of amino acids that would be produced using the following DNA strand: [1]

T A C A A A C A T G T C A C C T T A T T G

_____

hint *Use your pen to separate the nucleotides into codons (three-base sequences). All codons found in the same row have the same first letter.*

7 A cell containing the DNA sequence above is exposed to radiation and the DNA sequence changes as shown.

Original DNA: T A C A A A C A T G T C A C C T T A T T G

Mutated DNA: T A C C A A C A T G T C A C C T T A T T G

What effect would this mutation have on the protein that uses this template? [1]

_____

hint *Use the amino acid table from question 6.*

8 Another cell containing the original DNA strand is also exposed to radiation. The DNA of this cell changes as shown:

Original DNA: T A C A A A C A T G T C A C C T T A T T G

Mutated DNA: T A C A A G C A T G T C A C C T T A T T G

This cell produces normal proteins that function in exactly the same way as proteins made from the original DNA. Give *one* reason why this mutated DNA did not affect the function of the protein. [1]

_____

hint *Separate the sequence into codons, find the mutation(s), and then answer the question. This will make solving genetic sequence questions much easier!*

Independent Practice: Answers

6 Met Phe Val Glu Try Asp Asp

Students should draw lines after every third nucleotide to separate the sequences of DNA that code for amino acids. This will help them to avoid making mistakes.

Related Standard: Standard 4, Key Idea 2

7 *Possible Answers*: Phe is replaced by Val; the protein might fold differently; the protein might not function because it has a new shape.

Students should circle mutation(s) and separate the codons. Students should look up the mutated DNA sequence in the chart.

Related Standard: Standard 4, Key Idea 2

8 *Possible Answers:* AAA and AAG both encode Phe; the shape is not changed; the mutated DNA still makes the same amino acid.

Students should use a similar approach to question 8 as they used on questions 6 and 7.

Related Standard: Standard 4, Key Idea 2

Moving On

"Now let's try answering some questions without the help of hints. Make sure your desks are clear of everything except your book and a pen."

Name_____ Date_____

Test Practice

When your teacher tells you, carefully tear out this page. Then begin working.

Answer Sheet

1 . . . . . .

2 . . . . . .

3 . . . . . .

4 . . . . . .

5 . . . . . .

Teacher's Note
This section of the *Advantage* unit should replicate the testing conditions of a Regents Exam.

Delivery

Have students tear out and use the Answer Sheet to record their answers for the multiple-choice questions. This will help students develop proficiency in transferring their answer choices to a separate page. At the end of the Test Practice, students should also tear out and hand in the pages with their answers to the constructed-response questions, if you wish to give them feedback and check their progress.

Do not answer questions or help students during this section. If you notice students are having trouble in a particular section, make note of it so that you can discuss it later.

Schedule time to review answers with students, either immediately after completion of the Test Practice, or after you have read and commented on students' work. When reviewing multiple-choice questions with the class, focus on why the correct answers are correct and how the methods and strategies should be used, not why the wrong answers are wrong. Going through each wrong answer takes a long time and usually is not helpful. However, if students are confused about a particular wrong answer, that answer should be addressed.

Moving On

"You may now begin working. You have 18 minutes."

Name _____ Date _____

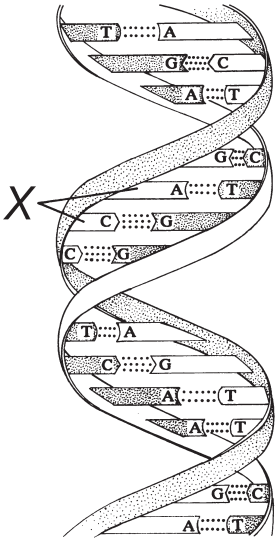
1 The functions of all enzymes, hormones, and antibodies are most dependent upon

(1) the DNA contained in the molecules of each one
(2) the shape caused by the order of their amino acids
(3) the use of inorganic molecules in their bonds
(4) the part of the cell in which they are produced

2 A team of scientists in Oregon has produced monkeys that use jellyfish proteins to glow. Under fluorescent light, the monkeys' hair follicles and fingernails give off a glowing green color. To give the monkeys this ability, the scientists had to

(1) selectively breed monkeys with high mutation rates
(2) expose monkey egg cells to jellyfish proteins
(3) insert jellyfish DNA into monkey egg cells
(4) give the monkeys food containing jellyfish DNA

3 The diagram below shows a molecule found inside cells.



What label should replace the letter *X* in the diagram?

(1) complex sugars
(2) bases
(3) amino acids
(4) phosphate groups

4 Pepsin is an enzyme that breaks down proteins in the stomach. A healthy human stomach has a pH of 3. If pepsin were exposed to proteins at a pH of 7, it would probably

(1) be more effective
(2) be less effective
(3) work the same
(4) gain a new function

Task

Students will practice solving test-like problems under simulated test conditions.

Test Practice: Answers

1 (2)

Students should underline the keywords *function* and *dependent upon*. Students should then predict that the answer involves the shape of the molecule. DNA determines an amino acid sequence, which determines protein shape, which then determines protein function.

Related Standard: Standard 4, Key Idea 2

2 (3)

Students should predict that genetic recombination is part of the correct answer. Then they should eliminate the answer choices that do not relate to the steps of genetic recombination. In order for monkeys to produce jellyfish proteins, they must have jellyfish DNA in their cells. The only way to put recombinant DNA into all cells of an organism is to place it in the zygote. Exposing eggs to proteins or feeding monkeys DNA will not insert the DNA into cells.

Related Standard: Standard 4, Key Idea 2

3 (2)

Students should use Text/Labels/Shape on the diagram. The double helix shape should indicate to students that it is DNA, even if the diagram appeared different from pictures of DNA in their textbooks or earlier in this unit. The backbone or "sides of the ladder" are composed of alternating phosphate groups and sugars. The "rungs of the ladder" are base pairs.

Related Standard: Standard 4, Key Idea 2

4 (2)

Students can restate the question as, "How would pepsin work at a different pH?" Enzymes work efficiently at the pH and temperature that they are normally used at. pH 7 is significantly more basic than pH 3, so pepsin would have trouble functioning at this pH.

Related Standard: Standard 4, Key Idea 5

Moving On

No transition is needed. Students should work straight through to page 228.

Name_____ **Date**_____

5 A molecular biologist is studying two proteins that are found in muscle cells. Protein *Y* is found only in the cell membrane and protein *Z* is found only in the nucleus.

Which statement about proteins *Y* and *Z* is most likely to be correct?

(1) Proteins *Y* and *Z* have the same function and the same amino acid chain.
(2) Proteins *Y* and *Z* have different functions and different amino acid chains.
(3) Proteins *Y* and *Z* have different functions and the same amino acid chain.
(4) Proteins *Y* and *Z* have the same function and different amino acid chains.

6 Name *one* environmental factor that could result in a change in the base sequence of DNA. [1]

_____

7 Individuals with Tay-Sachs disease have abnormally high levels of a specific fat in the nerve cells of the brain. Though all human beings produce this fat, individuals with Tay-Sachs are unable to break it down because they lack a protein called hexosaminidase. This condition is caused by a change in one DNA base on the 15th chromosome. Children with Tay-Sachs develop normally for a few months, and then become deaf, blind, and paralyzed. Even with modern medical care, they do not often survive past the age of five.

Explain how changing one DNA base can cause this fatal disease. Your answer must include at least:

- an explanation of how the change of one base can change a protein [1]
- an explanation of how the change of a protein can cause these symptoms [1]

_____

_____

_____

_____

8 Protein synthesis is a multistep process. Describe the steps involved in this process in a human cell. In your answer be sure to include:

- the name of the molecule that acts like a blueprint for proteins [1]
- the name of the building blocks from which proteins are built [1]
- the location in the cell where proteins are synthesized [1]
- *one* way that cells use proteins [1]

_____

_____

_____

_____

Test Practice: Answers

5 (2)

Students should underline the keywords *cell membrane* and *nucleus*. From their understanding of organelles in cells and protein functions, students should conclude that the two proteins have different functions.

Related Standard: Standard 4, Key Idea 2

6 *Possible Answers:* radiation, x-rays, UV radiation, nicotine, some illegal drugs, some pesticides, DES (a synthetic hormone given to pregnant women in the 1940s to prevent miscarriages)

Students should underline the keywords *environmental*, *change*, and *DNA*. Students can then restate the question as, "What is one thing in the environment can cause mutations?" Students should check that they have supplied only one answer. Additional answers will not be scored. Remind students to supply the answers that they are most comfortable with on constructed-response questions.

Related Standards: Standard 4, Key Ideas 2 and 7

7 *Sample Answer:* Changing the base can change the amino acid, which can change the shape. If the protein has the wrong shape, it cannot break down fat.

Students should realize that they need to read the passage to answer the second bullet. They can answer the first bullet without reading the passage.

Related Standards: Standard 4, Key Ideas 2 and 5

8 *Sample Answer*: DNA is the blueprint. Amino acids are linked to form a protein in the ribosome. Cell recognition

Writing fragments is acceptable and even encouraged, as long as it is clear which bullet is being answered. Writing "DNA, amino acids" would be confusing because answers can appear in any order, and it is unclear whether DNA or amino acids are being identified as the blueprint. However, only one part of the question asks about usage, so "cell recognition" is an acceptable answer to this bullet.

Related Standard: Standard 4, Key Idea 2

Moving On

"Before we move on, let's take a few minutes to review what you learned in Unit 8."

Name _____ Date _____

Unit 8 ReKAP

Fill in the blanks below to review what you have learned in this unit.

1. The four bases of DNA are _____, _____, _____, and _____.
   In RNA, _____ is used instead of _____ .

2. DNA is made out of _____ and proteins are made out
   of _____ .

3. The function of a protein is determined by its _____ .

4. Mutations in _____ are passed on to offspring, where they can
   cause helpful _____ or harmful _____ .

5. Stomach cells are different from skin cells because they produce
   different _____ .

6. Plasmids are cut by _____ in order to make _____ .

7. List two examples of mutagens. _____
   _____

8. List two examples of genetic diseases. _____
   _____

9. List two examples of proteins produced by recombinant DNA.
   _____

Task

Students will review what they learned in Unit 8.

Delivery

This ReKAP exercise can be a useful homework assignment or introductory activity for a day following the lesson. It can also serve as a quick review before the Test Practice exercise. Students may use their notes or work from memory.

ReKAP: Answers

1. The four bases of DNA are *A, C, G,* and *T*. In RNA, *U* is used instead of *T*.
2. DNA is made out of *nucleotides or bases* and proteins are made out of *amino acids*.
3. The function of a protein is determined by its *shape*.
4. Mutations in *gametes or sex cells* are passed on to offspring, where they can cause helpful *genetic or evolutionary advantages* or harmful *genetic diseases*.
5. Stomach cells are different from skin cells because they produce different *proteins*.
6. Plasmids are cut by *restriction enzymes* in order to make *recombinant DNA or cloned DNA*.
7. List two examples of mutagens: *UV radiation (from the sun), x-rays, nicotine, pesticides, most illegal drugs, or DES*
8. List two examples of genetic diseases: *Sickle-cell anemia, cystic fibrosis, Marfan syndrome, Huntington's disease, or hereditary hemochromatosis*
9. List two examples of proteins produced by recombinant DNA: *insulin, growth hormones, factor 8, or blood clotting proteins*

Moving On

"Let's review some of the important vocabulary terms from this unit."

Vocabulary List

Acid	A solution with a pH below 7.
Amino acid	The building blocks of proteins. The order of amino acids determines the shape of the protein.
Base (pH)	A solution with a pH above 7.
Chromosomes	Distinct pieces of DNA that contain hundreds of genes. Humans have 23 from each parent.
DNA	The template for making proteins. Consists of the bases A, C, G, and T.
Double helix	The twisty ladder shape of DNA.
Enzyme	A protein that increases the rate of a chemical reaction without being changed by the reaction.
Gene	A piece of DNA that encodes one protein.
Genetic disease	A disease that is passed on to offspring by the DNA in gametes.
Mutation	A change in one or more bases of DNA.
Mutagen	Anything that causes a mutation, such as radiation, tobacco, and some drugs.
Nucleotide	The building blocks of DNA (A, C, G, T) and RNA (A, C, G, U). The order of nucleotides in a gene determines the order of amino acids in a protein. Also called bases.
Plasmid	A circular piece of extra DNA that floats in a bacterial cell. Recombinant DNA is inserted into a plasmid then placed in a bacterium that creates proteins.
Protein	A folded amino acid chain whose function is determined by its shape.
Protein synthesis	The ribosome uses an RNA strand as a template to create a string of amino acids that fold into a protein.
Recombinant DNA	DNA taken from one organism and inserted into the DNA of another organism, allowing the host to make proteins normally made by the donor.
Restriction enzyme	An enzyme that cuts DNA at special locations allowing it to combine with other pieces of DNA, forming recombinant DNA.
RNA	A strand of nucleotides that copies a gene of DNA and then moves to the ribosome to be translated into a protein.

Task

Students will study vocabulary words from Unit 8.

Teacher's Note

The vocabulary list is designed so that students can fold the paper to cover the definitions while still revealing the vocabulary words. You may choose to have students tear the vocabulary list out of the book, though this increases the chance of students losing it. For this reason, you may wish to make photocopies.

Delivery

Students can be assigned to study this vocabulary list before beginning this unit, in between class days (e.g., after the lesson and before the Test Practice), or after the unit is completed as a review. It is important for student to understand every word on this list, but they do not need to memorize the exact definitions shown here. Encourage competency in the concepts, not the memorization of the exact phrases. Understanding of the vocabulary terms may be assessed with mini-quizzes on a few terms and vocabulary games, or by having students create diagrams, sentences, and graphic organizers involving these terms.

Moving Beyond

Use these activities throughout the year to review the content presented in this unit.

- Students should focus on understanding the processes addressed in this unit to prepare for the Regents Exam. They do not need to go into greater detail or memorize words that are not on the vocabulary list.
- Students can solidify their knowledge by creating flowcharts of processes (e.g., protein synthesis or cloning DNA) and drawing graphic organizers of ideas (e.g., causes and effects of mutations or relationships between DNA, RNA, and proteins).
- Past Regents Exams are available online and are an excellent way for students to practice strategies and methods. Many biology textbooks also have sample standardized test questions at the end of each unit.
- Encourage students to get in the habit of looking up unfamiliar concepts in their class notes or biology textbooks.