Cracking the Code

The Continuing Saga of Genetics

The Gene Machine

This episode takes an historic look at the Central Dogma governing all life's processes. The content begins with a discussion of the 1953 publication of Watson and Crick's pivotal paper in *Nature* describing the structure of DNA and hinting at the role that DNA likely plays in heredity—and ends by recounting events and the fears precipitated by Cohen and Boyer's discoveries using plasmids and restriction enzymes to produce recombinant bacterial DNA.

Lesson Planner

Day 1: Activity: 1953 *Nature* article
- View Segments 1, 2, and 3
- Activity: Think-Pair-Share vocabulary terms
- Activity: The Class Gene Machine
- Homework: RNA Tie Club

Day 2: View Segments 4 and 5
- Activity: Restriction Enzyme Paper Lab
- Homework: Word Splash

Day 3: View Segment 6
- Activity: A Matter of Opinion
- Activity: Rube Goldberg Gene Machine
- Journal notes: reflection

National Science Education Standards

Content Standard E

. . . students should develop abilities of technological design science and understandings about science and technology.

SEGMENT ONE: *A DNA CHRONICLE*

The segment opens with the DNA song. There is a brief section, less than three minutes, which provides an overview of DNA replication, base pairing rules, and a short preview of information storage and life processes choreographed by DNA.

Key Words

base pairing rules
chromosomes
complementary
DNA
double helix
heredity
mutation
replication
transforming

Learning Objectives

Students will:

- Recount the basic structure and replication process of the DNA molecule.
- Review DNA base pairing rules.
- Define the key words for this segment.

Pre-Viewing Activity

Students can begin their historical walk through the unraveling of DNA's mysteries by reading the pivotal paper, "Molecular Structure of Nucleic Acids," published in *Nature* by Watson and Crick in 1953. It can be found at www.nature.com/nature/dna50/index.html. Activity questions to accompany the article can be found in the teacher notes at the end of this lesson.

Viewing Activities

Have students prepare a table with three columns labeled "Known Terms," "Unknown Terms," and "Notes" prior to viewing this video segment. Ask students to write terminology heard in the video under the column that describes their level of understanding of those terms. Don't worry about the "Notes" column for now. CUE the tape at the beginning of the segment including the opening graphic and PLAY ▶ until you see the picture of Sidney Brenner, before he begins to speak. STOP ■ the tape. Tell students they will view this section one more time to review any terminology that may have been missed and that they should now focus on taking notes on the terms that were unknown. They will have an opportunity to share notes later. REWIND ◀ tape to the beginning. PLAY ▶ through again; STOP ■ at Brenner's picture.

Post-Viewing Activities

Review the terms by conducting a "Think-Pair-Share" discussion activity (see information on this strategy found in the introduction of this teacher guide). First, ask students to look at the terms and to think of how the term could be used in a sentence. Then pair students together to see how their list compares to another student's list. Ask them to keep notes on their discussions in the notes column. Finally, use a flip chart or board to record discussion of terms as student pairs share their lists with the class.

SEGMENT TWO: *PROTEIN PRODUCTION*

This segment begins by summarizing Sidney Brenner's discussions with Watson and Crick about how biological information stored in DNA leads to the production of protein. Sydney Brenner and Francis Crick teamed up to discover how genes produce proteins. They recognized two inherent problems: they needed to determine how the information in DNA left the nucleus and was transported into the cytoplasm, and they needed to understand the mechanism for determining how DNA was translated into protein. RNA seemed to hold some clues to solving this puzzle. As a single-stranded molecule, RNA was found both in the nucleus and in the cytoplasm and was known to be involved in protein synthesis.

Key Words

3-D shapes	nucleus
amino acids	protein synthesis
cytoplasm	ribosome
function	RNA
interpretation	structure

Learning Objectives

Students will:

- Define the key words for this segment.
- Identify some of the milestones in discovering the steps in the Central Dogma: DNA → RNA → Protein.

Viewing Activities

CUE the tape from the last stopping point, just before Sydney Brenner speaks; resume PLAY ▶. Follow the video through to the dictionary graphic. When the narrator says, ". . . that translates the language of DNA into the language of protein." PAUSE ❚❚ the tape.

Discussion Point

Reiterate the problems scientists faced regarding the DNA-to-protein puzzle. Ask students to recall what they saw and heard and then to list some reasons why RNA would be a good candidate for solving a piece of this molecular puzzle.

SEGMENT THREE: *THE CENTRAL DOGMA*

This segment elaborates on the DNA-to-protein tenet, central to the study of biological sciences. An interesting historical account of the RNA Tie Club is highlighted during the explanation of the events that led to cracking the code.

Key Words

adaptor	RNA bases
anticodon	polymerase
Central Dogma	promoter
codon	template DNA strand
covalent bond	transcription
cueing up	transfer RNA
enzyme	translation
messenger RNA	triplet

Learning Objectives

Students will:

- Review DNA and RNA base pairing rules.
- List key points for transcription.
- Reiterate the steps in translation.
- Identify the relationship between a codon (triplet) and its amino acid.
- Record the function of a promoter and important enzymes such as RNA polymerase.
- Define the key words for this segment.

Viewing Activities

CUE tape from last stopping point, just before David Schlessinger begins speaking; resume PLAY ▶. Follow the video through until you hear Sydney Brenner say, ". . . there will be an enzyme to unwind it, don't worry." PAUSE ⏸ the tape.

Discussion Point

Review the Central Dogma, and discuss DNA and RNA base pairing rules. Ask students what Sydney Brenner meant when he said, "such was the power of the base pairing idea."

Resume PLAY ▶ through to the point you hear the narrator say, "Sure enough, there were different adaptors and enzymes for the 20 amino acids." The screen will show an mRNA (messenger RNA) strand with adaptors and amino acids attaching to the strand. PAUSE ⏸ tape.

Discussion Point

Hold a brief discussion on why the codon was probably three bases long and not more or less than that.

Resume PLAY ▶. The opening image is a black screen; a graphic of DNA appears. Follow the video through to the point where Brenner is speaking and says, "Within a very short space of time . . . the whole thing was laid out." STOP ■ tape.

Post-Viewing Activities

The Class Gene Machine

Provide teams of students with the Key Word list. Ask students to summarize the basic steps in transcription and translation using the key words. Each team should be asked to provide a piece of the "gene machine." For example, team one may describe the unwinding of DNA using enzymes; team two continues with RNA polymerase attaching to a promoter which then reads the template DNA strand using RNA base pairing rules; etc.

Alternatively, ask students to use analogies to describe the basic steps in transcription and translation. For example, the unwinding of DNA could be analogous to unraveling two strands of twisted licorice; RNA polymerase attaching to a promoter which then reads the template DNA strand using RNA base pairing rules could be likened to pulling the main switch (promoter) on a car assembly line, etc. (See the Introduction section of this teacher guide for more information on using analogies.)

Homework: RNA Tie Club

The club was started by George Gamow and exemplified the importance of collaboration in science rather than working in isolation. It also linked physicists with biologists around a common area of interest. An article written by Richard Pizzi and published by the American Chemical Society, "Modern Drug Discovery: From Concept to Development," describes the genesis of the club:

> To foster communication and camaraderie, Gamow founded the RNA Tie Club of 20 hand-picked scientists—corresponding to the 20 amino acids—who would circulate notes and manuscripts on the coding problem and (not inconsequentially) consume wine, beer,

and whiskey at periodic meetings. Each member of the club was given the moniker of an amino acid, and all were presented with a diagrammed tie and tiepin made to Gamow's specification. Although geographically dispersed, the Tie Club brought physical scientists and biologists together to work on one of the most challenging and important problems in modern science. (2001, v. 4 No. 3, pgs. 65–66)

George Gamow gave all members of the club a tie and pin. Have students design a graphic that could represent one of the ties belonging to a member of the RNA Tie Club, choosing an amino acid. Ask them to explain their designs in the space provided on the worksheet.

SEGMENT FOUR: *SCOOPED!*

This segment discusses mutagenic agents and resultant base configurations. It also summarizes the events culminating in the cracking of the genetic code.

Key Words

64 codons
acridine dyes mutations
base additions
base deletion
base shifting
base substitutions
cell free system
mutagenesis
phenylalanine
uniform
uracil

Learning Objectives

Students will:

- Review possible forms of mutation.
- Review the methods by which the 64 codons were determined.

Viewing Activities

CUE tape to the last stopping point; PAUSE the tape immediately after Sidney Brenner says, ". . . and we did bury them."

Discussion Point

From the information presented in the video segment, ask students to generate a list of the kinds of base changing events that can cause a mutation. Save the list.

Resume PLAY from the last stopping point. A graphic with the word "transportation" crossed out, will be shown. PLAY until you see the list of RNA Tie Club members. The narrator says, ". . . the rest of the RNA Tie Club had been scooped." STOP the tape.

Post-Viewing Activities

Consider using the following Web site.

What Is a Mutation?

http://gslc.genetics.utah.edu/units/disorders/mutations

This page from the Genetic Science Learning Center at the University of Utah allows students to connect the significance of a genetic mutation with common sentence structure. While on this page, in the upper right-hand corner, students have the option to mutate a DNA sequence by clicking on the link, "Mutate a DNA sequence."

SEGMENT FIVE: *MOLECULAR MANIPULATION*

This segment discusses the tools employed in genetic engineering. It begins with Cohen and Boyer discovering the uses of restriction enzymes and plasmids as devices for manipulating genes. The use of bacteria as model systems is highlighted. This model system was then applied to higher organisms and resulted in controversy within the scientific community and the general public. Eventually, this new technology became an internationally accepted practice for the development of new products such as insulin.

Key Words

bacteria
clone
fermentors
mitochondria
plasmid transfer
plasmids
recognition sites
recombinant
restriction enzymes
universal code

Learning Objectives

Students will:

- Explain what is meant by the "universal code."
- Determine restriction enzyme cut sites in a segment of DNA.
- Describe the characteristics of bacterial plasmids.
- Use key words to create a story line about genetic engineering.
- Create a time line for the history of genetic engineering.

Viewing Activities

CUE tape to the last stopping point; PAUSE tape when Jan Witkowsky says, ". . . thought that was the end of the story for them."

> ***Discussion Point***
> Ask students to explain what is meant by the "universal code." Students should be asked to recall the exception referred to in this segment.

It may be beneficial to REWIND tape and PLAY this segment again; this time, PAUSE tape at the graphic of DNA with an illuminated middle segment depicting the fusion of the sticky ends, when the narrator says, ". . . a sticky end produced at one site can attach to a sticky end produced at any other site through the base pairing rules."

CUE tape to the last pause point; PLAY and STOP tape when you see the graphic of the palm trees and the ocean.

> ***Discussion Point***
> Ask students to describe some characteristics of bacterial plasmids. Some examples of responses that you might expect from students are: small rings of DNA, replicate themselves like chromosomal DNA, plasmids can be transferred from one bacterial cell to another, or may contain genes that fight off antibiotics.

CUE the tape to the graphic of the palm trees and ocean, PLAY tape and STOP when you see the lab bench containing petri dishes, bunsen burner, hotplate, and various flasks.

Post-Viewing Activities

Restriction Enzyme Paper Lab

Distribute the student lab packet, "Restriction Enzyme Paper Lab," and have students work in pairs to complete this activity. This should take 10–20 minutes. At the conclusion of the lab, discuss the process of gene manipulation.

Word Splash

Provide the students with a copy of the "Word Splash" worksheet found at the end of this unit and a copy of the scoring rubric for the assignment. As a homework assignment, students will create a short story using terms from the "Word Splash"; underline the terms in the story. The following day students can share their creative narratives in pairs or small groups. Each group or pair should select a really good sentence or two from each paper to share with the class.

SEGMENT SIX: *WRAP-UP*

This final segment serves to wrap up the early history of genetic engineering.

Pre-Viewing Activity

After students share their word splash stories, REWIND and PLAY Segment Five of the tape again to allow individuals to verify their understanding of the terms and tools used in genetic engineering. Invite questions and discussion during the viewing, pausing frequently, if needed.

CUE tape to the lab bench containing petri dishes, bunsen burner, hotplate, and various flasks; PLAY to the end of the tape including the music. STOP tape.

> ***Discussion Point***
> Ask students to recount the events shown as scientists began to explore genetic modification. Guide the discussion to include these topics: scientists expressed fears that geneti-

cally engineered microbes might escape the laboratory; research on genetically engineered organisms was halted voluntarily by scientists; an unprecedented international meeting of scientists was held to discuss policy regarding protocol for scientific research on genetically engineered organisms; some scientists opened the door to anti-scientific ideologies; the public began forming groups advocating more political control over scientific endeavor; experiments began again in a very few high-risk containment facilities; fears that recombinant DNA technology was not safe were not supported; industry recognized the potential of genetic engineering; lifesaving insulin was produced by bacteria; because of the success with insulin production, genetic science is used to produce many products used by consumers.

Post-Viewing Activities

A Matter of Opinion

Divide students into groups of two or three and have each group create a cartoon or comic strip detailing one of the events portrayed in the video. Begin by brainstorming about what groups have competing or conflicting interests in the endeavors of genetic science. Use the "A Matter of Opinion" worksheet and scoring rubric to guide the groups' work.

Rube Goldberg Gene Machine

Create a gene machine, Rube Goldberg style, to allow students to demonstrate that they understand the process that scientists used to modify genetic information. An activity worksheet and scoring rubric are provided.

Journal Notes

Assign students to carefully reflect on the impact that genetic science may have had on their personal lives. Invite them to interview parents and friends or to research issues. Suggest local or contemporary issues such as wildlife management, medicine, or agriculture to get them started.

National Science Education Standards

http://nap.edu/readingroom/books/nses/html

Content Standard E

As a result of activities in grades 9–12, all students should develop abilities of technological design science and understandings about science and technology.

Understanding about Science and Technology

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry, often emerge at the interface of two older disciplines.

- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.

- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.

- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

- Technological knowledge is often not made public because of patents and the financial potential of the idea or invention. Scientific knowledge is made public through presentations at professional meetings and publications in scientific journals.

Links

The BioTech Life Sciences Dictionary
http://biotech.icmb.utexas.edu/search/dict-search.html

A searchable database that can provide you with many resources.

PBS—Harvest of Fear: Engineer a Crop
www.pbs.org/wgbh/harvest/engineer

Two interactive activities for selective breeding and genetic engineering of organisms.

RNA Interviews: Dr. Sydney Brenner
www.ambion.com/techlib/tn/103/7.html

This site provides an interview with Sydney Brenner concerning the RNA Tie Club.

RNA Tie Club
www.laskerfoundation.org/awards/kwood/watson/vignettes/1954.html

This site gives a brief synopsis of the RNA Tie Club.

Inserting a DNA Sample into a Plasmid
www.accessexcellence.org/RC/VL/GG/inserting.html

This Web page has an excellent graphic representation of plasmid insertion.

Genetic ciphering
http://pubs.acs.org/subscribe/journals/mdd/v04/i03/html/03timeline.html

This site discusses how Nirenberg and Matthaei deciphered the genetic code.

GENETIC ENGINEERING SONG

It's the same vocabulary
In the cat and the canary.
All that's living shares
The same genetic code.

This amazing fact it now appears
Has opened up amazing new frontiers.
It's given us amazing new careers.
Genetic engineers all say three cheers.

It's no longer just a dream.
We've got the glue and scissors;
We're fast becoming wizards
In cutting out and pasting in a gene.

It was a scary thought that we could play
With life in such a way.
But recombining DNA
Has not produced that feared doomsday.
It's here to stay, it's

Opened up new opportunities
And started up a whole new industry.
Bacteria in biofactories,
Retooling them has now become a breeze.

Each day is total bliss.
We're adding whole new features
To all sorts of other creatures.
Sometimes they work and sometimes they just
miss.

We're adding whole new features
To all sorts of other creatures.
The secret of this miracle is this:

It's the same vocabulary
In the cat and the canary.
All that's living shares
The same genetic code.

WORKSHEET

Student Name: ______________________________

The Gene Machine

1953 *NATURE*: WATSON & CRICK

Read this article: Watson, J.D. & Crick, F.H.C. (1953) "Molecular Structure of Nucleic Acids," *Nature* 171, 737–738.

Make notes and be prepared to discuss the following questions:

1. What type of structure did Watson and Crick propose for deoxyribonucleic acid?

2. According to the Watson-Crick model, in what positions would you find the bases and phosphates?

3. What does the ribbon represent in Figure 1?

4. What do the horizontal rods represent?

5. Two types of chemical bonding were discussed in the article. Which type of bond is crucial to base pairing?

6. In the *Nature* article, what base pairing rules did Watson and Crick postulate?

7. Which bases are purines, and which are pyrimidines?

8. Using the above postulate of base pairing rules, if a DNA sample had 30 percent adenine, what percent cytosine would be present?

9. At the end of the article, Watson and Crick made a powerful suggestion in regard to the genetic material. What was it?

The Gene Machine

1953 *NATURE*: WATSON & CRICK

Activity to accompany: Watson, J.D. & Crick, F.H.C. (1953) "Molecular Structure of Nucleic Acids," *Nature* 171, 737–738.

Questions for Discussion (*Answers in italics*)

1. What type of structure did Watson and Crick propose for deoxyribonucleic acid?

   Two helical chains coiled around the same axis with base pairs forming horizontal rods, rather like the rungs of a ladder. Also refer to Figure 1 in the article for a diagrammatic representation of the double helix.

2. According to the Watson-Crick model, in what positions would you find the bases and phosphates?

   Bases are on the inside of the helix, and phosphates are on the outside.

3. What does the ribbon represent in Figure 1?

   Two phosphate-sugar chains.

4. What do the horizontal rods represent?

   The pairs of bases holding the chains together.

5. Two types of chemical bonding were discussed in the article. Which type of bond is crucial to base pairing?

   Hydrogen.

6. In the *Nature* article, what base pairing rules did Watson and Crick postulate?

   Adenine pairs with thymine; guanine pairs with cytosine.

7. Which bases are purines, and which are pyrimidines?

   In DNA, cytosine and thymine are pyrimidines; guanine and adenine are purines.

8. Using the above postulate of base pairing rules, if a DNA sample had 30 percent adenine, what percent cytosine would be present?

   Twenty percent cytosine. If adenine is 30 percent, then thymine must also be 30 percent—equaling 60 percent of the total DNA sample. The remainder DNA sample is equal to 40 percent; 20 percent must be cytosine, and 20 percent must be guanine.

9. At the end of the article, Watson and Crick made a powerful suggestion in regard to the genetic material. What was it?

   They suggested a possible copying mechanism for the genetic material.

WORKSHEET

Student Name: ______________________________

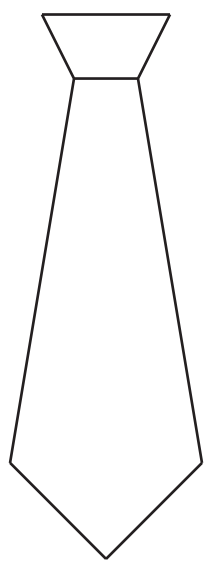
The Gene Machine

RNA TIE CLUB

Choose one of the 20 amino acids found in RNA, and write your selection in this box:

Amino acid:

Design a tie to represent this amino acid, using the template below, and explain your choice of colors and design elements in the box:



Explanation:

RNA Tie Rubric for Assessment

	Acceptable	**Good**	**Exceptional**
DESIGN 30 points	An amino acid from RNA is chosen. 20 pts.	The representation in the design is representative of the amino acid. 25 pts.	The design displays creativity in correctly representing an amino acid from RNA. 30 pts.
EXPLANATION 70 points	The explanation is plausible. 55 pts.	The explanation is detailed and plausible enough to show some understanding of the attributes of the amino acid. 63 pts.	The explanation is creative, detailed, and plausible and shows in-depth understanding of the attributes of the amino acid. 70 pts.

Student name: ____

DESIGN score ______________________

EXPLANATION score ______________________

TOTAL SCORE: ______________________

The Gene Machine

RESTRICTION ENZYME PAPER LAB

Discussion Activities

Activity 1: Restriction Enzymes

The following restriction enzyme, EcoR1, has a recognition sequence in bacterial DNA of **GAATTC, both forward and backward, depending on the strand**. The enzyme cuts this sequence between the **G** and **A** : **G ↑ AATTC**

The other strand will have the same sequence, going in the **opposite** direction, and is called a pallindromic sequence. **CTTAA ↑ G**

Other examples of palindromes in the English language could include:

Direction of one sequence → EYE, MADAM, MOM, DAD
EYE, MADAM, MOM, DAD ←

1. Given the following sequence of DNA, identify with an arrow the places where the EcoR1 restriction enzyme will cut.

    5' T T G C C G A A C C G A A T T C T T G G T A G G A T C G A A T T C C C A A G A 3'
    3' A AC G G C T T G G C T T A A G A A C C A T C C T A G C T T A A G G G T T C T 5'

2. Locate the first arrow in the 5'–3' direction. Extend the point of the arrow in the horizontal direction moving between the complementary bases until you reach the point of the arrow found in the complementary 3'–5' strand. Using scissors cut the zigzag line. Repeat this procedure for the next cut site found in the 5'–3' strand. You should now have three pieces of DNA. All pieces will have what is known as “sticky ends.”

3. The fragment in the middle with *two* sticky ends would most probably be chopped up by other restriction enzymes. The other two fragments each have one sticky end, and this would allow the sticky end from the 5'–3' direction to complementarily base pair with the sticky end from

the 3'–5' direction. Bacteria have hundreds of enzymes recognizing different sequences, which in turn would continue to cut the viral DNA fragments into smaller and smaller pieces.

4. Using tape, *glue* the sticky end from each of the other two fragments. The *glue* that seals the sticky ends together is another enzyme called ligase. Do you see that the same restriction enzyme, EcoR1, can re-enter and make further cuts?

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RESTRICTION ENZYME PAPER LAB

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1. Given the following sequence of DNA, identify with an arrow the places where the EcoR1 restriction enzyme will cut.

```
                  ↓                                   ↓
5' T T G C C G A A C C G A A T T  C T T G G T A G G A T C G A A T  T  C  C C  A A G A 3'
3' A AC G G C T  T G G C T T A A G A A C C A T C C T A G  C T T A A  G  G G  T T  C T 5'
                              ↑                                    ↑
```

2. Locate the first arrow in the 5'–3' direction. Extend the point of the arrow in the horizontal direction, moving between the complementary bases until you reach the point of the arrow found in the complementary 3'–5' strand. Using scissors, cut the zigzag line. Repeat this procedure for the next cut site found in the 5'–3' strand. You should now have three pieces of DNA. All pieces will have what is known as "sticky ends."

```
                    ↓                                     ↓
5' T T G C C G A A C C G |A A T T  C T T G G T A G G A T C G| A A T  T  C  C C  A A G A 3'
3' A AC G G C T  T G G C T T A A| G A A C C A T C C T A G  C T T A A|  G  G G  T T  C T 5'
                               ↑                                     ↑
```

3. The fragment in the middle with *two* sticky ends would most probably be chopped up by other restriction enzymes. The other two fragments each have one sticky end, and this would allow the sticky end from the 5'–3' direction to complementarily base pair with the sticky end from

the 3′–5′ direction. Bacteria have hundreds of enzymes recognizing different sequences, which in turn would continue to cut the viral DNA fragments into smaller and smaller pieces.

4. Using tape, *glue* the sticky end from each of the other two fragments. The *glue* that seals the sticky ends together is another enzyme called ligase. Do you see that the same restriction enzyme, EcoR1, can re-enter and make further cuts?

If you wish, you can discuss the function of the enzyme ligase at greater length. A Web site that may be useful to you, called the MadSci Network, is located at:

www.madsci.org/posts/archives/apr99/925400340.Mb.q.html

Another useful site that provides animation of a restriction endonuclease creating sticky ends can be located at:

www.biologie.uni-hamburg.de/b-online/library/bio201/stickyend.html

WORKSHEET

Student Name: ______________________________

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WORD SPLASH

Assignment: Use the following terms correctly in a short story. Underline these terms in your story.

ligase

bacteria

delicatessen

genetic engineering

glue

plasmid

DNA

splice

sticky ends

foreign gene

restriction enzyme

enzyme

cut

clones

multiply

Word Splash Rubric for Assessment

	Acceptable	**Good**	**Exceptional**
TERMS Correct use of terms. 50 points	At least 10 terms are used in a proper context and 4 or more are specific to their meaning in genetic engineering. 40 pts.	At least 12 terms are used in a proper context, and 6 or more are specific to their meaning in genetic engineering. 45 pts.	All terms are used in proper context and at least 8 are specific to their meaning in genetic engineering. 50 pts.
STORY Plausible and relevant story. 25 points	A story related to genetic engineering in some way. 15 pts.	The story portrays a subject that is a plausible representation of genetic engineering. 20 pts.	The story is plausible and presents a relevant topic or controversy in genetic engineering. 25 pts.
STYLE Creativity and writing style. 25 points	The story has a beginning, a middle, and an end. 10 pts. Sentences have good structure. 5 pts. 3–5 spelling errors. 3 pts.	Interesting introduction, engaging middle, and good conclusion. 12 pts. Good sentence structure. 5 pts. 1–2 spelling errors. 4 pts.	Great introduction, engaging middle, and a smashing conclusion. 15 pts. Great sentence structure. 5 pts. No spelling errors. 5 pts.

Student name: ____

TERMS score ______________________

STORY score ______________________

STYLE score ______________________

TOTAL SCORE: ______________________

Student Name: ______________________________

The Gene Machine

A MATTER OF OPINION (GENETICS CARTOON)

Cartoons express opinion. Cartoonists often use metaphors, parody, or sarcasm to get their points across. A cartoon may personify an animal to represent some thing, trait, or issue—for example, a bull may signify stubbornness or an eagle may represent the United States.

Think about your personal opinion on genetic engineering.

Make a list of the organizations or groups that may benefit or be harmed by genetic engineering and write them below.

May benefit from genetic engineering	May be harmed by genetic engineering

Think about how this science may be used. List one or more absurd use(s), and one or more noble use(s) below.

ABSURD:

NOBLE:

Now choose a group or organization from your list and some use of genetic engineering either harmful or beneficial and imagine a clever way to show how these organizations or groups interact with this science. Use clues to let your viewer know the setting of your cartoon: smoke stacks for manufacturing, corn stalks and a barn for a farm, a building with a bell tower to represent a school, beakers and test tubes to indicate a laboratory, or a red cross for a medical facility. On a separate piece of paper, draw your cartoon in pencil. Add an explanation of what you drew.

Genetics Cartoon Rubric for Assessment

	Acceptable	**Good**	**Exceptional**
OPINION 50 points	Opinion of student can be understood by cartoon or by text. 40 pts.	Opinion of student can be understood by cartoon and text. 45 pts.	Opinion can be understood and is a poignant representation of a point of view. 50 pts.
REPRESENTATION 40 points	One or two useful representations of groups, people, setting, issues, etc. 30 pts.	Three or four useful representations of groups, people, setting, issues, etc. 35 pts.	Many representations of groups, people, setting, issues, etc. employing satire, metaphor, personification, or parody. 40 pts.
CREATIVITY (Note: Do not assess the artistic ability of the student. The creativity of the message is to be assessed.) 10 points	Some creativity. 5 pts.	More creativity. 7 pts.	Creativity is compelling. 10 pts.

Student name: ____

OPINION score ____________________

REPRESENTATION score ____________________

CREATIVITY score ____________________

TOTAL SCORE: ____________________

WORKSHEET

Student Name: ______________________________

The Gene Machine

RUBE GOLDBERG GENE MACHINE

Draw or build a gene machine, Rube Goldberg style, to demonstrate that you understand the process that scientists used to modify genetic information. Be sure to number the items in your drawing so that the sequence of events is clear. On a separate sheet of paper, write a brief explanation of your drawing, including each numbered step. Your drawing will be assessed according to this scale: **70 points** for including all the steps, **85 points** for the all of the steps in the correct order, and **100 points** for all the steps, in the correct order, with creative interpretation of the events shown in your drawing.

To learn more about Rube Goldberg, visit this Web site: www.rube-goldberg.com. You can read a brief overview of Goldberg's contributions to science, technology, and engineering; view examples of past Rube Goldberg machines; and read about the current Rube Goldberg national challenge, as well as previous challenges.

Draw your machine here:

Rube Goldberg Rubric for Assessment

	Acceptable	Good	Exceptional
	Each step of the gene modification process is included. 70 pts.	Each step is included in the correct sequence. 85 pts.	Each step is included in the correct sequence and student employs creativity in the drawing of the machine. 100 pts.

Student name: ____

TOTAL SCORE: ______________________