California Foundation For Agriculture In The Classroom

Design Yer Genes

Purpose

This lesson introduces students to the relationships between chromosomes, genes, and DNA molecules. It also provides activities that clearly show how changes in the DNA of an organism, either naturally or artificially, can cause changes in an organism.

Time

5-6 forty-five minute sessions

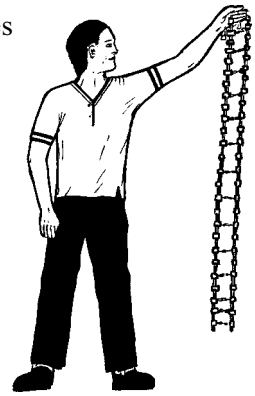
Materials

For each team of two students:

- Colored markers or pencils
- DNA Gene Cut-Out Models *(one set per team)*
- "Design Yer Genes" Lab Sheets Parts 1, 2 & 3 *(one set per team)*
- Envelopes or plastic bags
- Fresh strawberries *(2)*
- Glue or tape
- Phosphate, Sugar and Base Pair cut-out sheets *(one set per team)*
- Scissors

Background Information

Start this activity with some review of basic terms and definitions: sugar groups, phosphate groups, adenine, guanine, cytosine, thymine, gene, chromosome, and DNA. The students should remember that their traits (and the traits of all organisms) are controlled by genes on chromosomes. These genes are made up of a set of molecules that are the same for all living things — sugars, phosphates, and bases. The order in which the molecules are arranged and their numbers, however, are what make the students human and a slug something entirely different. The 23 pairs of human chromosomes contain over 100,000 genes.



If appropriate, review with the students that codons are specific three-nucleotide sequences of bases that specify the cell to make particular amino acids. These amino acids then combine in specific ways to create different proteins.

This activity is hypothetical and very simplistic. The goals are for students to understand the general structure of DNA, the natural changes that occur in a DNA strand, and then the concept of genetic engineering. The lab activity itself is broken into three parts. Part 1 has the students create a model of a small portion of a strawberry chromosome, complete with 3 genes. Part 2 requires the students to model a naturally occurring mutation. They will remove a segment of their DNA model (four base pairs) and replace it with a new piece (gene) inserted where the old one had been. This change will cause a different trait to appear in the strawberry's phenotype. (Real genes can be hundreds of base pairs in length, but for the sake of model size, the genes here will be four base pairs.) In Part 3, students work as "genetic engineers" and alter the strawberry's DNA.

The following background information on strawberries can be shared with your students at appropriate times during the activity.

- California produces 80% of the U.S. strawberry crop annually and is the world's largest producer of strawberries.
- Agriculture is California's biggest business and strawberry revenues rank in the top 10 of all cash crops.
- Eight medium-sized strawberries contain 140% of the U.S. RDA for Vitamin C.

California Foundation For Agriculture In The Classroom

Design Yer Genes

Content Standards

Grade 7

Science
- Genetics • 2, 2c, 2e
- Investigation and Experimentation • 7d, 7e

Reading/Language Arts
- Reading • 1.0, 1.3, 2.2
- Writing • 1.0, 1.1, 1.2, 1.3, 1.7
- Written and Oral Language Conventions • 1.0, 1.4, 1.6, 1.7

Mathematics
- Mathematical Reasoning 1.0, 1.1, 1.3, 2.2, 2.4, 2.5, 3.1, 3.2, 3.3

Grade 8

Science
- Chemistry of Living Systems • 6c

Reading /Language Arts
- Reading • 1.0
- Writing • 1.0, 1.2, 1.3
- Written and Oral Language Conventions • 1.0, 1.4, 1.5, 1.6

Grade 9

Science
- Organic and Biochemistry 10a, 10c
- Genetics • 5a, 5b, 5c, 5d, 5e
- Investigation and Experimentation • 1d, 1g, 1m

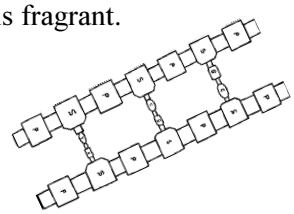
- Breeding programs using traditional hybridization methods continue to keep California at the forefront of strawberry production.

- Strawberries have 8 chromosomes, each containing thousands of genes.

- Many research articles have been written about the origin of the name for the fruit, but none seem clearly definitive. Here are some theories on how the strawberry got its name:

  - Historically, straw was placed under the fruit to prevent bruising.
  - Early cultivators noticed the vines grew all over the place or were "strewed" or "strawed."
  - English children threaded the berries onto straw and offered them for sale.
  - Strawberry runners resembled straw.
  - The ancient Latin word "stragum" means fragrant.

Procedure



Design Yer Genes — Part I

This activity illustrates the components of DNA molecules and shows how they hook together to make genes and chromosomes. The students will use this model to develop their understanding of DNA mutations and genetic engineering.

1. Review and complete the entire lesson yourself so you can get a feel for the concepts and sequence. Jot down notes that will help the lesson flow smoothly with your students. Save your completed model of the strawberry DNA to use as a visual example for your students.

2. Begin this activity by referring to Darwin's finch experiences or the peppered moths of England. Let the students know that this lesson will shed light on how a living species, such as the birds in the Galapagos, can evolve into a different species due to the changes in their genetic blueprint.

3. Distribute a fresh strawberry to each student. As they enjoy eating it, discuss some interesting facts about strawberries. (As always, be aware of student food allergies before having a student eat the fruit.) Brainstorm a list of observations about the berries.

4. Distribute the student *Design Yer Genes—Part 1* lab sheets to your students. Discuss and clarify the problem the students are trying to

Design Yer Genes

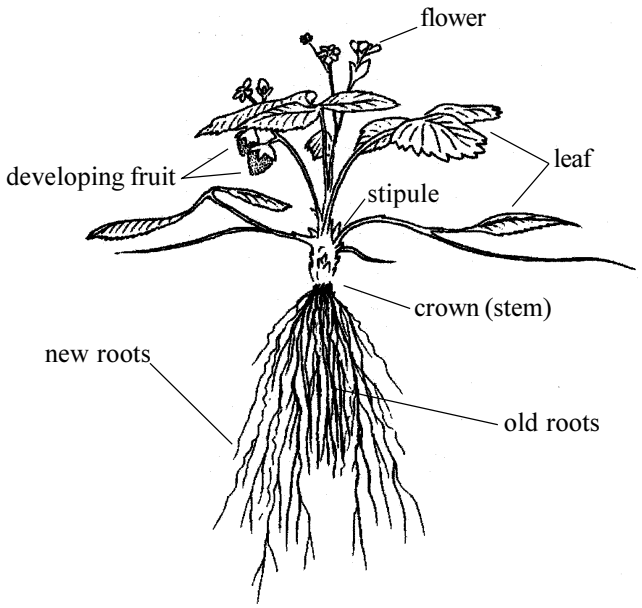
Content Standards
(continued)

Reading/Language Arts
Reading • 1.0, 2.6
Writing • 1.0, 1.5, 1.9, 2.4c
Written and Oral Language Conventions • 1.0, 1.1, 1.2, 1.3, 1.4

History/Social Science
Chronological and Spacial Thinking • 2

solve. Explain to your students that they are going to build a simple model of a strawberry DNA molecule to better understand genetics.

5. Review the procedure for building the strawberry DNA with your students. Pair your students together into working teams of two.



Monitor their work continuously. Provide plastic bags or envelopes for your students to organize and store their work. Allow the students to figure out how the base pairs should match with the sugar units by trial and error. Display your DNA model. Remind students that sugar units alternate with phosphate units and that base pairings must be A-T and C-G. *Do not have your students tape or glue their models together until they "dry-fit" their model and get it approved by you!* Refer the students to the strawberry "Gene Key" at the appropriate time.

Note: As the students complete their models, check them for accuracy. You want your students to be successful in this portion of the activity so they will be encouraged to learn the science concepts rather than get bogged down with the coloring and cutting activity. Coloring only the left or right side of the sugar-phosphate links may be an option for student groups who are having difficulty.

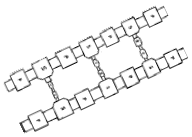
6. Discuss the meanings of the Part 1 questions. Assign these questions for homework if they do not finish them in class.

7. During and after DNA model completion, check your students for understanding regarding traits and genes. Have the students twist

their completed models into the classic double helix and discuss how X-ray diffraction led Watson and Crick to the discovery of DNA's shape. Stress that DNA and the manipulations of DNA done by geneticists are much more complicated than their models suggest.

8. Prepare the students for Part 2 of this lesson by asking for their opinions on how the strawberry could be improved. You might also want to inquire about their knowledge regarding gene splicing or genetic engineering. Consider having students do research on how farmers have "changed" certain produce items through selective crossing or hybridization. Examples include the production of seedless watermelons and grapes, strains of corn and wheat that are disease resistant, dwarf trees, and the production of tangelos and broccoflowers. The chart *Where Do Genes Come From?* on page 46 may be useful in this discussion.

Design Yer Genes — Part 2



Part 2 of this activity shows students how a change in the genetic code (mutation) can result in an altered phenotype of the organism. The strawberry will be used as an example. Students will remove one of their strawberry genes and replace it with another. In nature, this is a random event and rarely provides an immediate benefit to the organism.

1. Explain to your students that the DNA model they developed in Part 1 of this lesson is just that—a model. Briefly discuss how DNA molecules are reproduced and how easy it is to make a slight error during DNA replication. You might even discuss how errors were made in the production of the student DNA models. An error in DNA replication is called a mutation. Genetic engineering is when a DNA molecule is purposely altered. Explain to the students that they will act as geneticists and purposely alter a strawberry DNA molecule by removing a gene and inserting another.

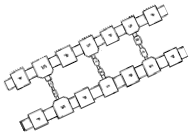
2. Review the problem and procedure of "Design Yer Genes — Part 2." Working in the same groups as they did in Part 1, have students carefully follow the described procedure. Extra cut-out sheets may be needed. Again, your prepared model will help students visualize what it is they are to do. As with Part 1 of this activity, remind students that they are modeling a very complex procedure—DNA (genetic) replication. It is much more complicated than can be represented by this model.

3. After the students have completed altering their strawberry DNA model, have each group explain to the class (or in writing) what characteristic they altered.

4. Have the students answer the "Design Yer Genes — Part 2 Questions." These questions can be an in-class assessment or a homework assignment. Previewing and discussing the questions will be helpful to the students. Here are some points to discuss with your students prior to their work on the questions:

   - Question 4 could benefit from references to the Galapagos finches and the peppered moths. Negative effects of DNA mutation can be discussed by referring to the many human genetic disorders such as Huntington's Disease, Cystic Fibrosis and Sickle Cell Anemia. It is important to stress that there may also be positive effects to what we call negative genetic disorders. For example, people who carry the Sickle Cell gene (Ss) but do not express the trait (ss) are resistant to Malaria.

   - You might wish to assign question 6 as a research paper rather than as one of the regular questions. Again, the students will gain more insight for this question if you guide them in a discussion of the positive and potentially negative implications of genetic engineering. Refer to the *Background Information on Biotechnology* at the beginning of this unit. Enlighten your students as to how the scientific and political communities are dealing with public concerns.



Design Yer Genes — Part 3

This part of the unit provides students with a basic understanding of "real" genetic engineering that occurs in the laboratory. Your students will need some basic information on how genes are taken from one organism and then inserted into the genetic code of another organism. The Background Information on Biotechnology section at the beginning of this unit provides some information. Some other facts you may find useful are listed below.

- In part 2 of this lab, students created a natural mutation by removing one gene and replacing it with another. Until recently, this could not be done purposely in the laboratory. These "removal and insertion" changes occur most often in natural situations.

- The desired gene can come from any organism—a dog, cat, tree, bacterium, etc. The trick is to make the organism accept the gene from another organism.

Design Yer Genes

- Genes are genes. For example, a gene for the production of a protein like insulin is the same for all organisms and can theoretically be inserted to make insulin in any organism if the gene is accepted into the DNA molecule.

- In most commonly used genetic modification processes, genes are added, not removed or replaced. It is technically much easier to insert genes into a chromosome than it is to remove or replace them.

- Inserting a gene does not guarantee that the desired trait will be expressed in the new organism. There are many factors controlling gene expression, and in many cases successful gene transfer is a process of trial and error.

1. Review the problem and procedure of "Design Yer Genes—Part 3" with your students. Discuss that what makes this lab more like genetic engineering than the Part 2 activity is that one gene is not removed or altered from the DNA; rather a new gene is added.

2. The students will need four gene cut-out sheets to choose from—Gene A, Gene B, Gene C and Gene D. Explain that each gene codes for or controls a specific trait, which you will reveal after the students have chosen and added one or more of the traits to their strawberry DNA model.

3. Have the students complete the activity. Remind the students that, when adding their new gene, they can insert the new gene anywhere in the molecule as long as the three previous genes are not destroyed. They can insert the new gene between two other genes, at the end of one gene, etc.

4. After the students have completed their genetic manipulations, reveal what the hypothetical new genes do:

    - **Gene A comes from a bacterium and causes an increase in sugar production in the strawberry for a super sweet berry.**

    - **Gene B comes from red algae and causes an increase in beta-carotene pigment production for very red berries.**

    - **Gene C comes from a banana and causes the strawberry to have a banana taste.**

- **Gene D comes from a virus and causes the strawberry to become resistant to a certain bacteria that makes strawberries rot. Therefore, this altered strawberry resists rotting.**

5. Have the students complete the "Questions" section of this lab.

6. Discuss the implications of some of the hypothetical genes mentioned above. For example, if a strawberry plant does not produce sweet berries, Gene A might do wonders for the strawberry industry. If Gene B is added to a light pink strawberry, it might make the berry more appealing to the consumer. However, if Gene B is added to an already red strawberry, the increase in red color may cause the berry to be so red it could appear brown or black. Gene C may or may not affect the saleability of the strawberries while Gene D could reduce the need for pesticides.

7. Discuss that some unwanted side affects may result from genetically modifying the strawberry plant. For example, a gene may insert itself into the blooming mechanism of the plant and produce sterile flowers or no flowers at all. If this is the case, the redder color or change in taste may not work because strawberries could not be produced to show the new trait. This is one reason why the process of transgenics is so complex and time consuming.

8. Review the fact that the students' models are only simplified versions. A strawberry plant has eight chromosomes, each made of thousands of genes. Each gene is made of thousands of base pairs!

9. Emphasize that the study of genetics is very complex and that if the students like this activity they may want to pursue taking more classes in genetics.

Variations

- Have students create "edible" DNA models out of marshmallows, gum drops, etc., and then have an "Eat Your Genes" party in class.

- Make "Gene D" a funny or unusual trait, such as a "skunky" smell. This may add humor as well as show that genetic engineering does not always produce desired results.

Design Yer Genes

Extensions

- Have your students complete the following research and writing assignment. In-class reference books and the Internet may be good resources for students. Refer to the Teacher Resources and References section of this unit for reference articles, books, organizations, and useful web sites.

  - As you have learned, genetic engineering is in some ways, similar to changes that occur naturally. However, geneticists are not always successful in getting a new gene to function in a different chromosome. It is very time consuming and expensive to take DNA from one organism and put it into another. So, why do scientists do it? Assume the role of a genetic engineer who must convince the public of the value of genetic engineering. Write a short newspaper editorial stating what genetic engineering is and how it can benefit people. Your editorial should have some examples of genetically engineered plants and/or animals. You will have to do a little research for this assignment. Discuss possible reference sources with your teacher.

- Invite a geneticist into your classroom to discuss his/her occupation.

- Invite a farmer or agri-business representative into your classroom to explain how their commodities have changed from biotechnology and/or scientific research.

- Vegetatively reproduce strawberry plants in class by rooting the vines that grow off a parent strawberry plant. Discuss the genetics of the new plants and the benefits and risks of vegetative reproduction.

- Research and report on the newest developments in genetically modified agricultural products.

Design Yer Genes

Where Do Genes Come From?

Crop	Source of Genes	Name of Gene	New Trait
Canola	Various plants	Enzymes for oil (lipid) synthesis	Lower saturated oils
	Various plants	Synthesis	Special oil compositions like building blocks for shampoo, synthetic lubricants, shortenings
Chrysanthemum	Bacteria	Antisense pigment genes	Pure white petal color
Cotton	Soil microbe	Enzymes that degrade herbicides	Provides resistance to herbicides
	Bacteria	Bt	Insect control
	Bacteria and plants	Pigment genes	Genetically colored fiber
Papaya	Plants	Ripening genes	Increased flavor and firmness
	Virus	Viral coat protein	Viral resistance
Potato	Bacteria	Starch	Increased starch content
Rice	Bacteria	Enzymes involved in pathway to make □-carotene	Rice rich in Vitamin A known as "Golden Rice"
Soybean, **Sunflower**, **Canola**	Legumes and nuts	Storage proteins	Makes the plant by-products have more protein so it can be used for nutritious animal feed
Squash, Cantaloupe	Virus	Viral coat protein	Viral resistance
Strawberry, **Raspberry**	Plants	Ripening genes	Increase firmness and size
Tomato	Tomato	Antisense enzyme(s)	To soften more slowly; allows tomato to remain on the vine longer
	Virus	Viral coat protein	Viral resistance
	Bacteria	Enzyme to make sugar	Extra sweet
	Bacteria	Enzymes involved in pathway to make □- carotene	Increase in Vitamin A content

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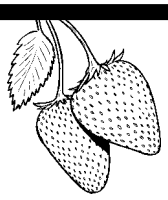
Name _____



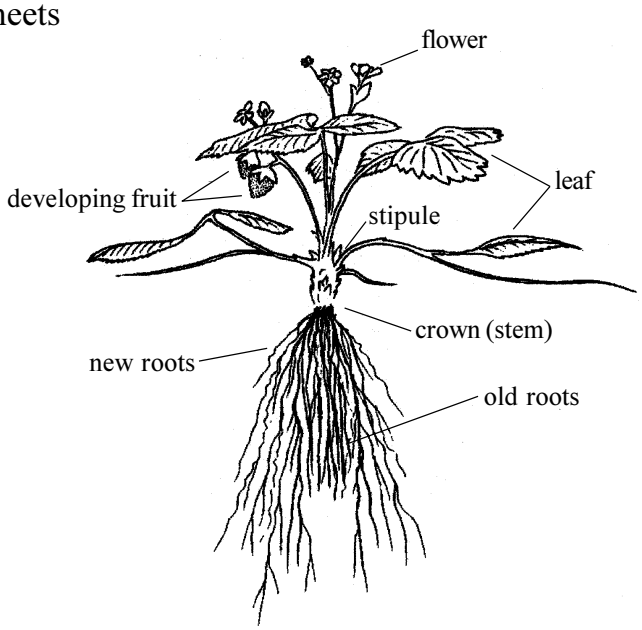
Part 1

Problem

How is a DNA molecule put together? What are genes?

Materials

- Colored markers
- *Design Yer Genes — Part 1* lab sheets
- Envelopes or bags to hold cut pieces
- Glue or tape
- Phosphate, sugar and base pair cut-out sheets
- Scissors



Procedure

1. Color the sugar units, phosphate units and base units. All of the sugar units must be the same color, all of the phosphates must be the same color, and each of the four different base units must be their own color. **You will use six different colors**.

2. Cut out the pieces you have just colored. **Be careful not to cut off the tabs; they will be needed to attach the model together.**

3. Figure out how these pieces fit together. Hints: the tabs must match; the phosphate molecules must attach to sugar molecules.

4. Using the *Gene Key for Strawberries*, choose which three traits you will put on your model.

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(Part 1 continued)

Gene Key for Strawberries

Gene Number	Base Pairs in Gene	Trait	Base Pairs in Gene	Trait
1	T-A A-T A-T A-T	Fruit has seeds in normal pattern	C-G C-G G-C C-G	Fruit has no seeds
2	A-T C-G C-G A-T	Fruit is sweet, has high sugar content	C-G A-T C-G A-T	Fruit is tart, has low sugar content
3	A-T A-T C-G C-G	Fragile skin	A-T C-G G-C G-C	Tough skin

A-T = Adenine & Thymine base pair C-G = Cytosine & Guanine base pair

Write the following information on your *own* paper.

My strawberry will have the following base pair sequences:

Gene 1 = _____

Gene 2 = _____

Gene 3 = _____

In one sentence, describe how your strawberry will appear (its phenotype):

_____

_____

5. Put together the four base pairs that match the traits you have chosen above. Each group of four bases represents one gene.

6. Dry fit your model. Make sure you have followed your teacher's directions about alternating sugars and phosphates and have matched base pairs correctly. Your model should look like a ladder and have three genes. Have your unglued model approved by your teacher. As soon as you are sure your model is correct, glue or tape it together at the tabs.

Design Yer Genes

Name _____

(Part 1 continued)

Questions

Answer the following questions on your own paper. Title your paper *Design Yer Genes — Part I Questions*.

1. The bases only fit together in certain pairings. What are these pairings?

2. The sides of the DNA ladder are made up of what two units?

3. Where is the only place for the base pairs to connect to the ladder?

4. If a "gene" were really a distinct segment of four base pairs along the DNA molecule, how many "genes" have you created in your model?

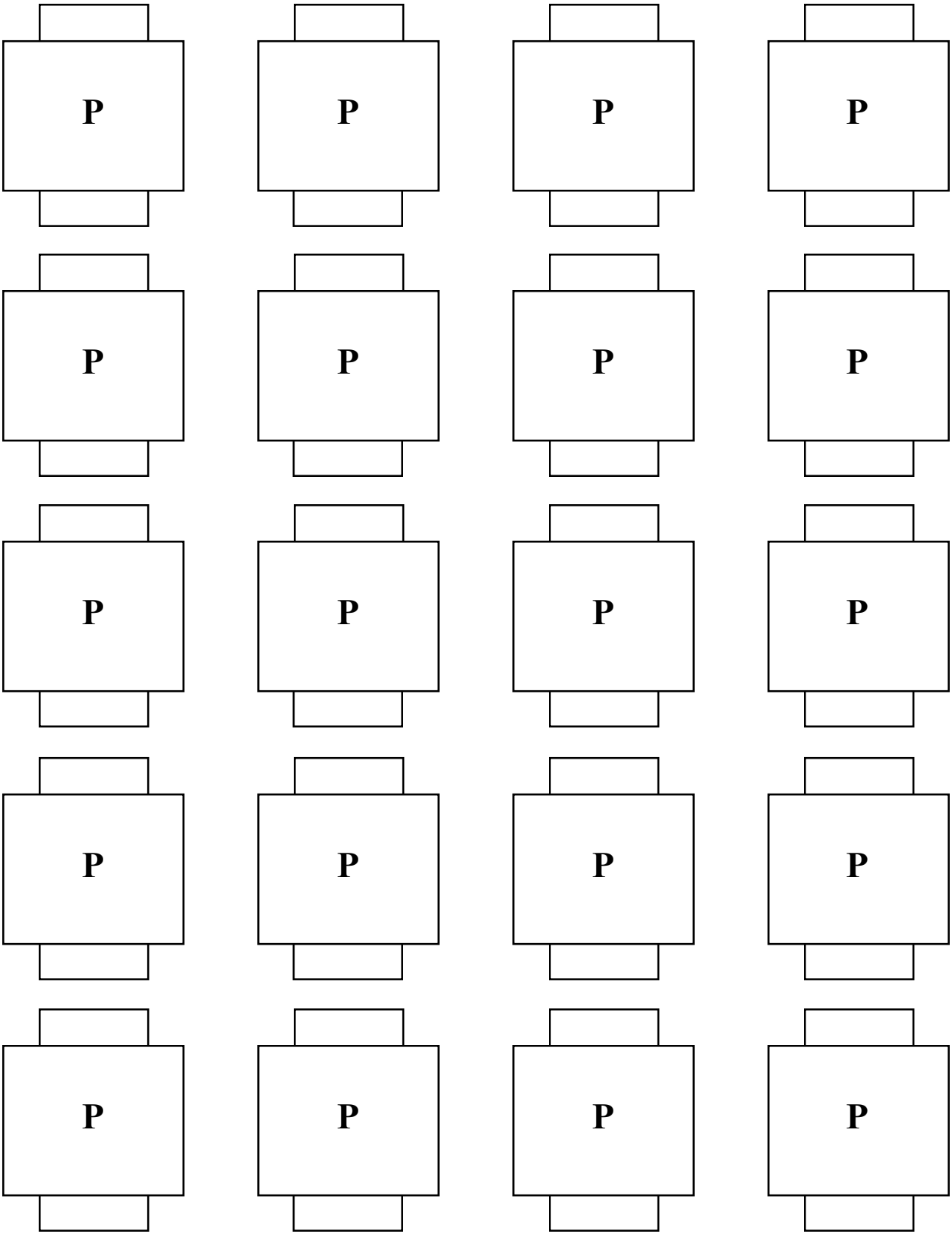
5. Look back at the *Gene Key for Strawberries*. Explain why it might be beneficial to have some strawberries with seeds and other strawberries without seeds. Why might it be beneficial to have some varieties of strawberries with fragile skins and other varieties with tougher skins?

6. Describe at least two things you have learned about DNA and genes that you did not know before.

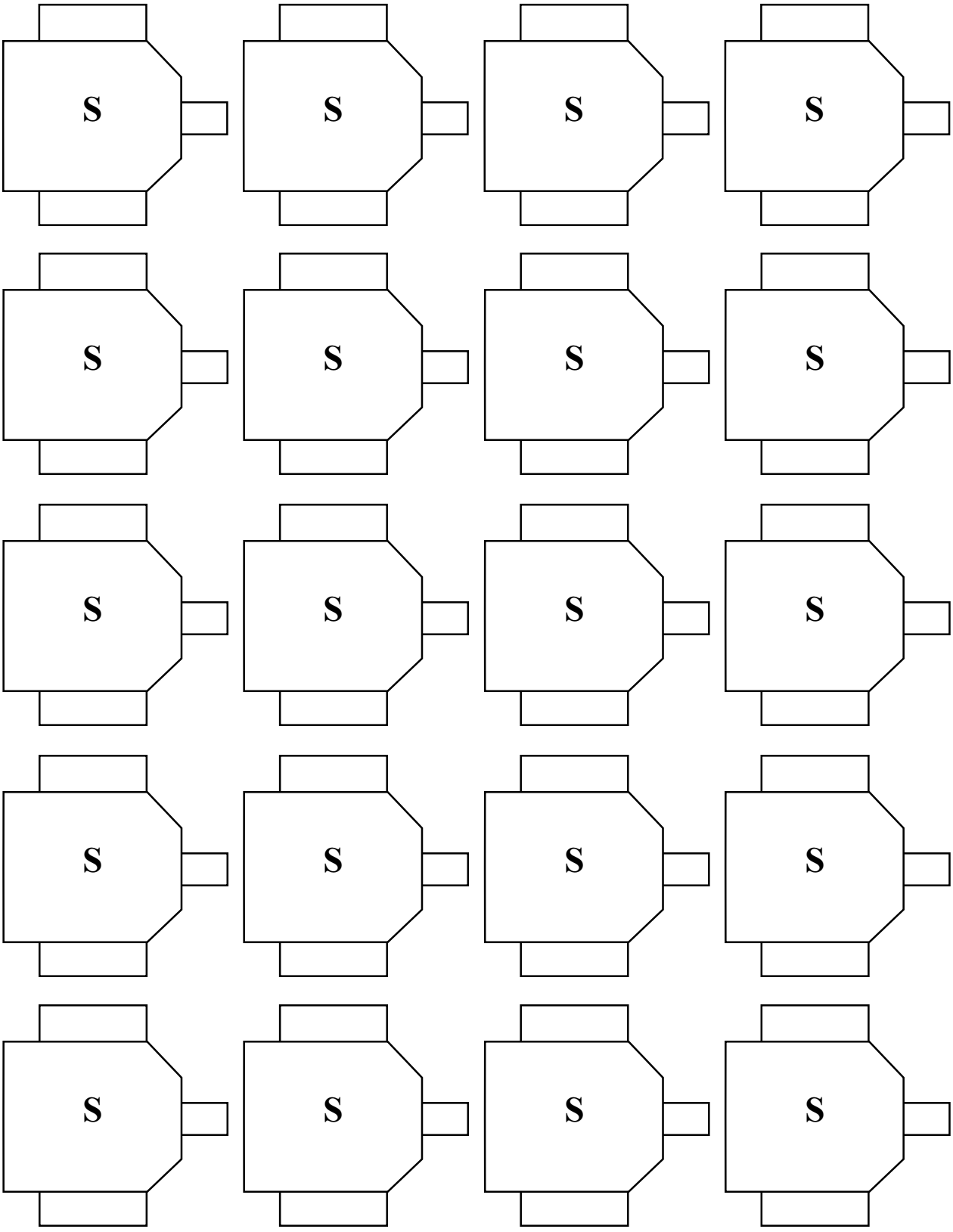
Extension

Extra! Extra! We know genes control our traits or phenotypes. How many genes are on a typical human chromosome?

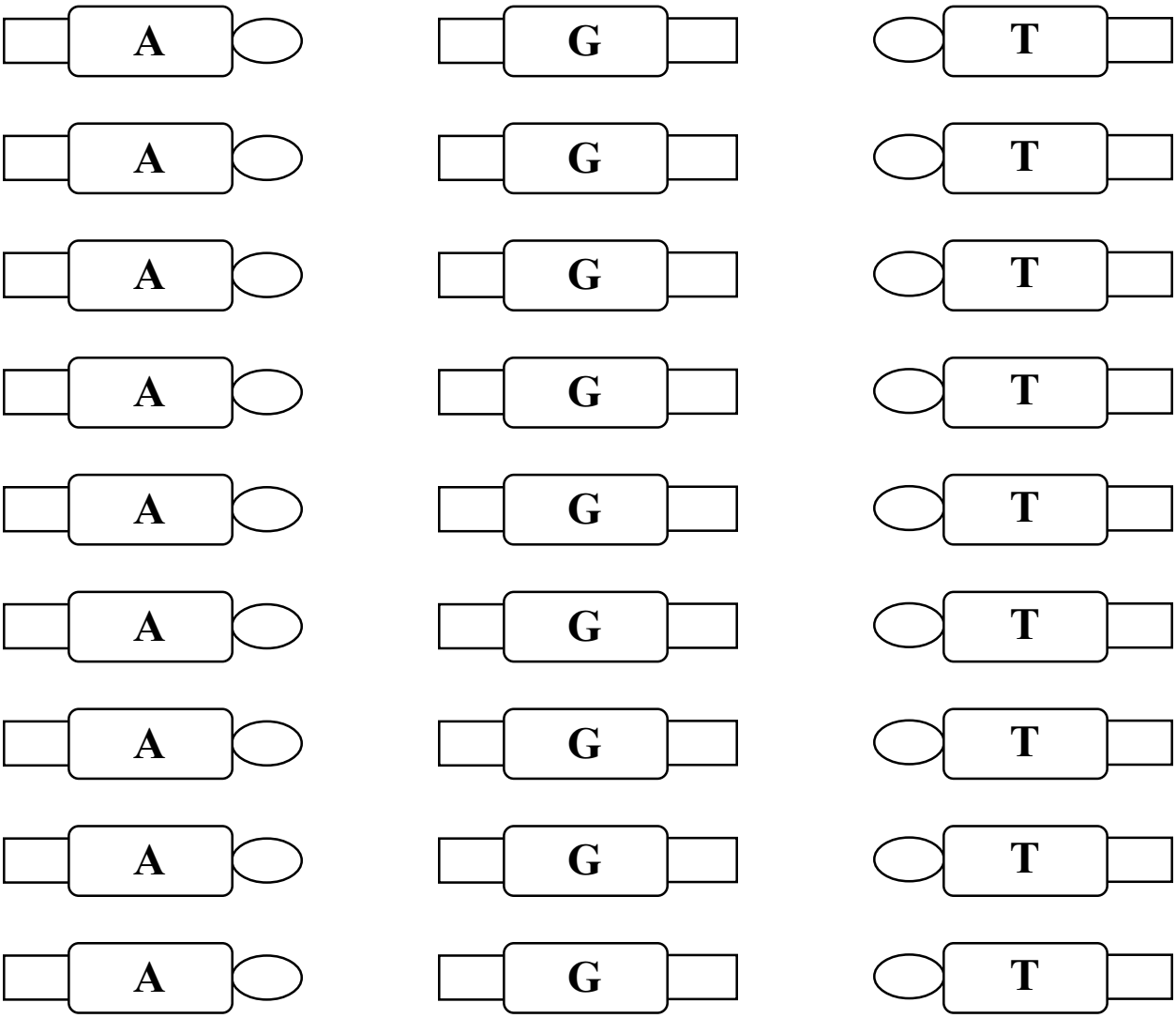
Phosphate Units for the DNA Model

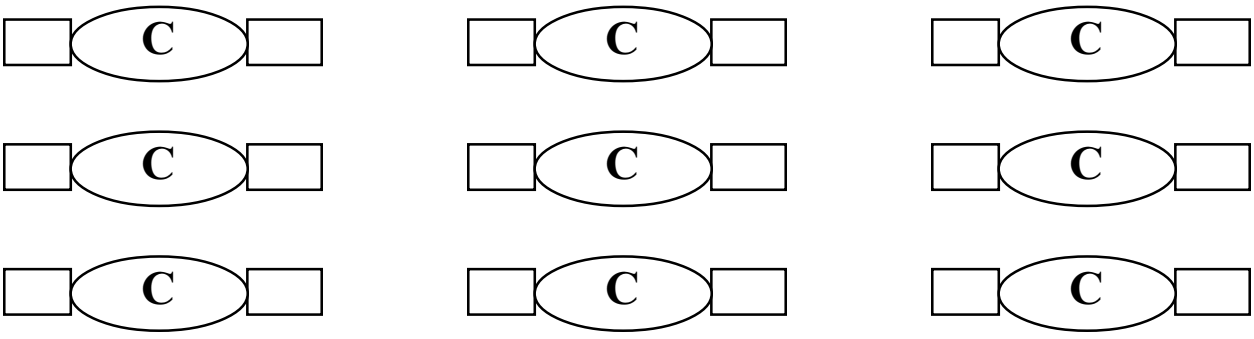


Sugar Units for the DNA Model



Base Pairs for the DNA Model





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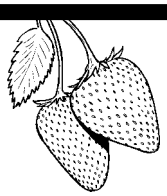


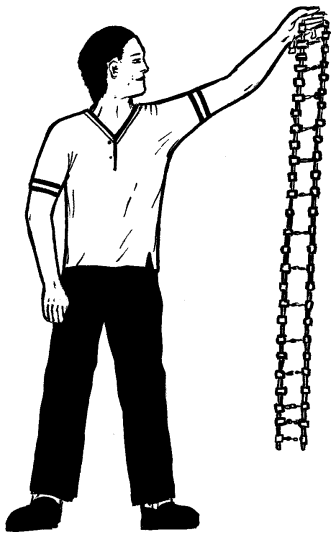
Part 2

Problem

How does a geneticist change a strawberry's trait?

Introduction

You are about to alter your strawberry DNA model. You must remember that the science of genetics is very complex and that changes in DNA occur naturally in nature as well as artificially in a laboratory. You can pretend that the changes you make in your model are occurring naturally (called a mutation) or artificially (called genetic engineering or transgenics).



Materials

- Colored markers or pencils
- *Design Yer Genes — Part 2* lab sheet
- DNA models from Part 1
- *Gene Key for Strawberries*
- Glue or tape
- Phosphate, sugar, and base pair cut-out sheets
- Scissors

Procedure

1. Refer to the *Gene Key for Strawberries* in Part 1 of this lab. You chose three traits from this list to put on your strawberry DNA molecule. Recall what three genes you chose. You will change one of these three traits. Pick the one you would like to alter and locate it on your DNA model.

2. Remove the trait you wish to change by cutting out the four base pairs (gene) from the sugar units. In nature, genes are changed at random. In the laboratory, genetic engineers try to control which genes are altered.

3. Referring to the *Gene Key for Strawberries* in Part 1, make a new gene to replace the one you just removed. Remember, this new gene must consist of four base pairs and must be different than the other two genes that are already on your DNA molecule. For

example, you may not add a fragile skinned gene if there is a fragile skinned or tough skinned gene already on the chromosome. After you are certain that the change you are making is compatible with the rest of your DNA, color the base pairs, cut them out and insert this gene at the sugar units.

3. Tape or glue the new gene in place.

Questions

Answer the following questions on your own paper. Label your answers "Design Yer Genes — Part 2."

1. What trait (gene) did you remove from your model of strawberry DNA?

2. What trait (gene) did you insert into your model of strawberry DNA?

3. Compare the traits of your old strawberry plant to your new strawberry plant.

4. Explain why you chose to insert the new trait into your strawberry DNA. In your answer, discuss how this new trait might benefit the strawberry, the environment and/or humans. Discuss any problems that may arise.

5. When a real section of DNA changes, it is called a mutation:

   - How could a naturally occurring mutation help a species? List at least two examples.

   - How could a natural mutation hurt a species? List at least two examples.

6. Some people are uncertain or even fearful of genetically altering an organism. Write a short essay on:

   - What you think people might be worried about.

   - What you think the problems and/or benefits are in changing the genes in an organism.

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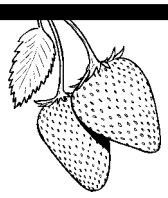
Part 3



Problem

How do real geneticists change or "engineer" the DNA of a strawberry?

Introduction

In real recombinant genetics technology, the scientists cannot yet easily remove one unwanted gene and stick in another, as you did in your last activity. However, they are able to add genes to a DNA molecule. Your teacher will provide more information on this. Using the materials provided, find out what kind of strawberry you can produce.

Materials

- Colored pencils or markers
- DNA models *(from Part 2)*
- *Design Yer Genes — Part 3* lab sheets
- Glue or tape
- *Part 3 Gene Cut-out sheets*
- Scissors

Procedure

1. Review the three genes (and the traits they control) on your strawberry DNA model from Part 2.

2. Observe the four new gene cut-out sheets and choose *one* that you will attempt to insert into your DNA model.

3. Color (using the same colors as in Parts 1 and 2) and cut out the chosen gene.

4. Tape or glue your new gene onto:

    - Either end of your model, or

    - Into the middle of your model without destroying one of the other genes.

Design Yer Genes

Name _____

(Part 3 continued)

Remember: In real DNA, the genes "fit" themselves onto the chromosome wherever they can. Scientists cannot control where they attach.

5. Find out what trait your new DNA model produces in your strawberry. Your teacher will help you with this.

Questions

Answer the questions on your own paper. Title your answers "Design Yer Genes — Part 3."

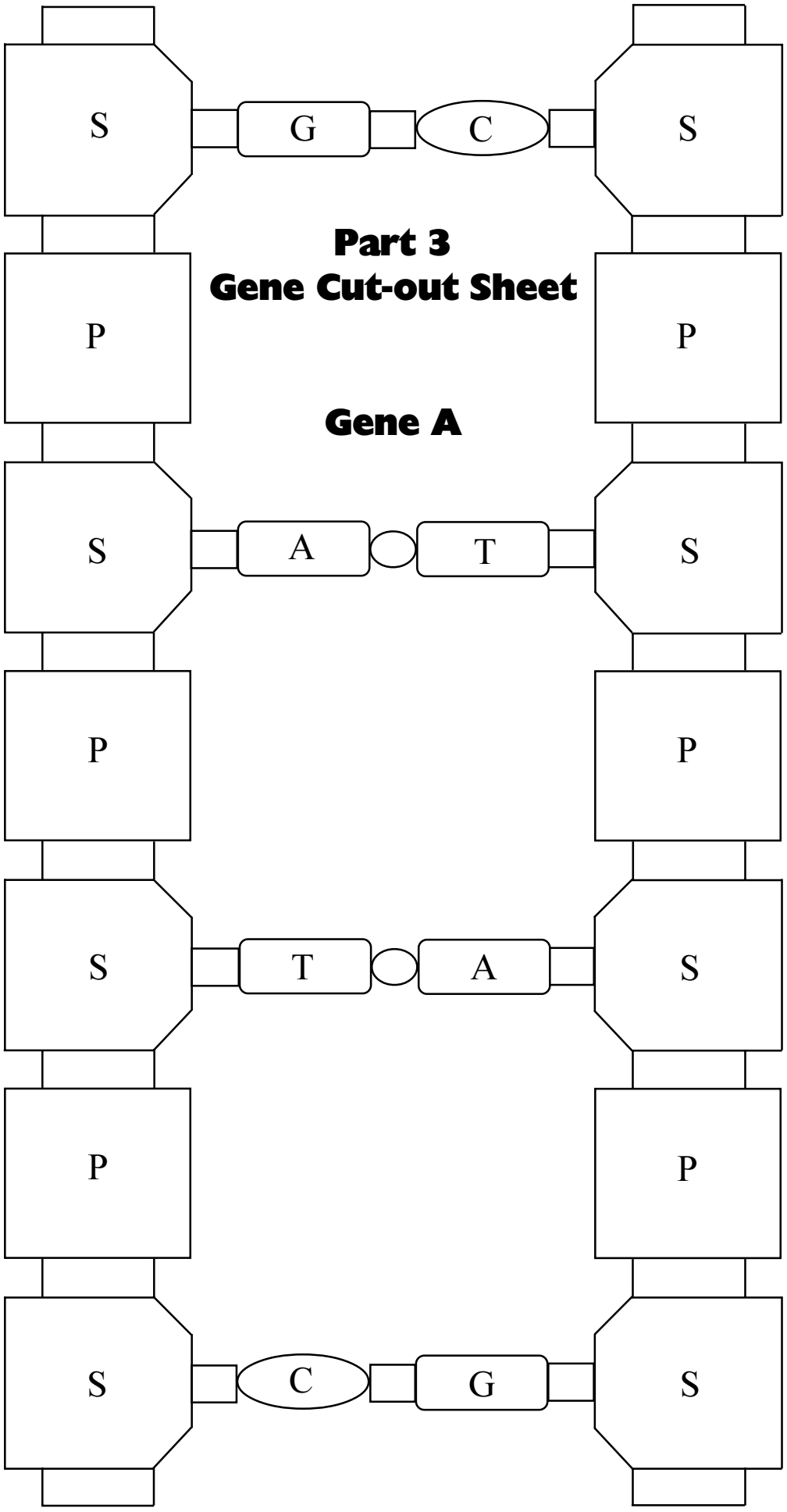
1. What were the four base pairs in the gene you added to your model?

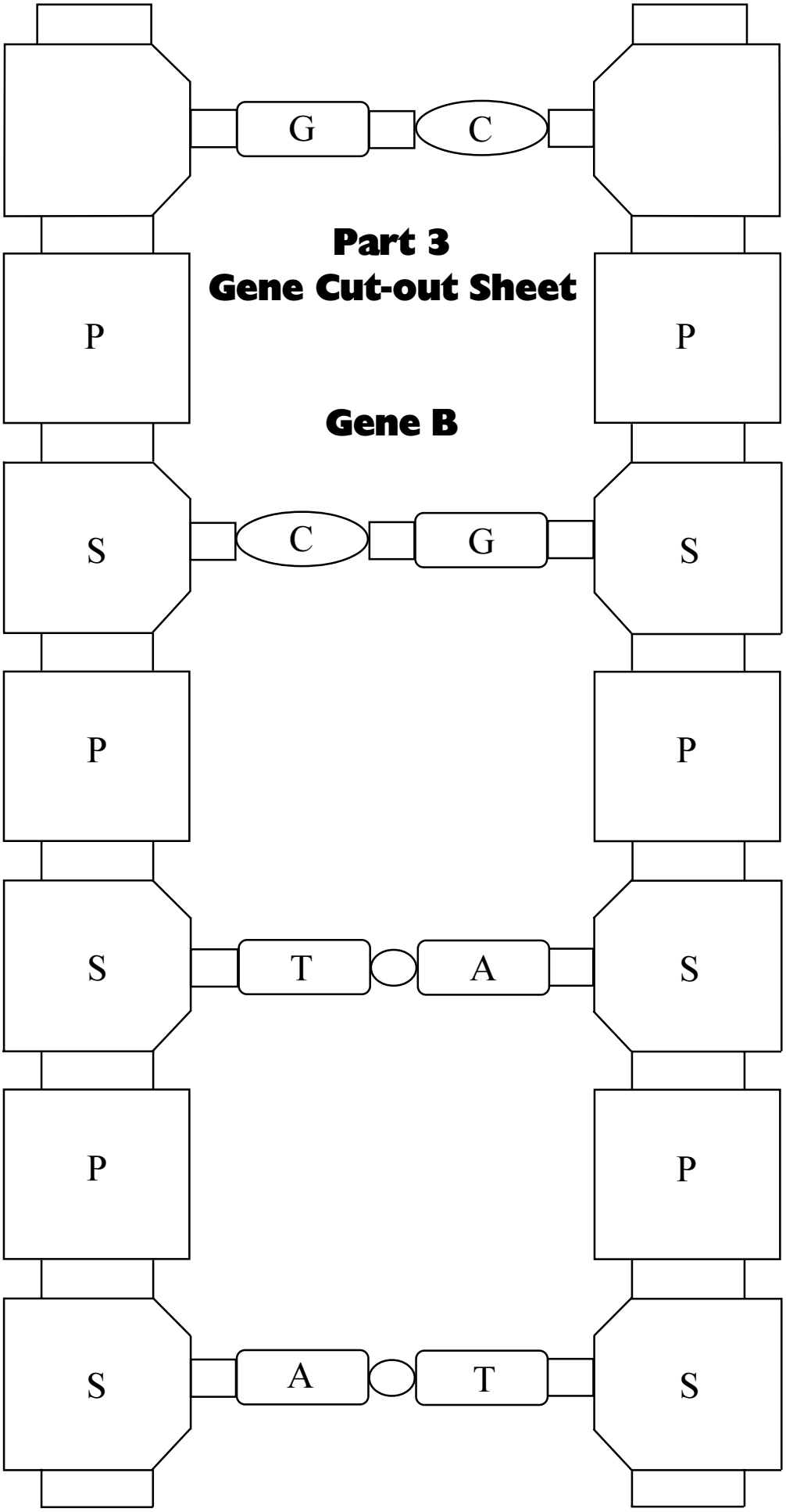
2. What trait does this new gene control?

3. Do you believe this new trait will help or hurt the strawberry species? Explain your answer.

4. In one to three well written paragraphs, explain what you have learned about all of the following:

   - The DNA molecule
   - Mutations
   - Genetic engineering
   - How agriculture and/or consumers are affected by genetic engineering
   - Any other information you found interesting


S
G
C
S
Part 3
Gene Cut-out Sheet
P
P
Gene A
S
A
T
S
P
P
S
T
A
S
P
P
S
C
G
S


G
C
Part 3
Gene Cut-out Sheet
P
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Gene B
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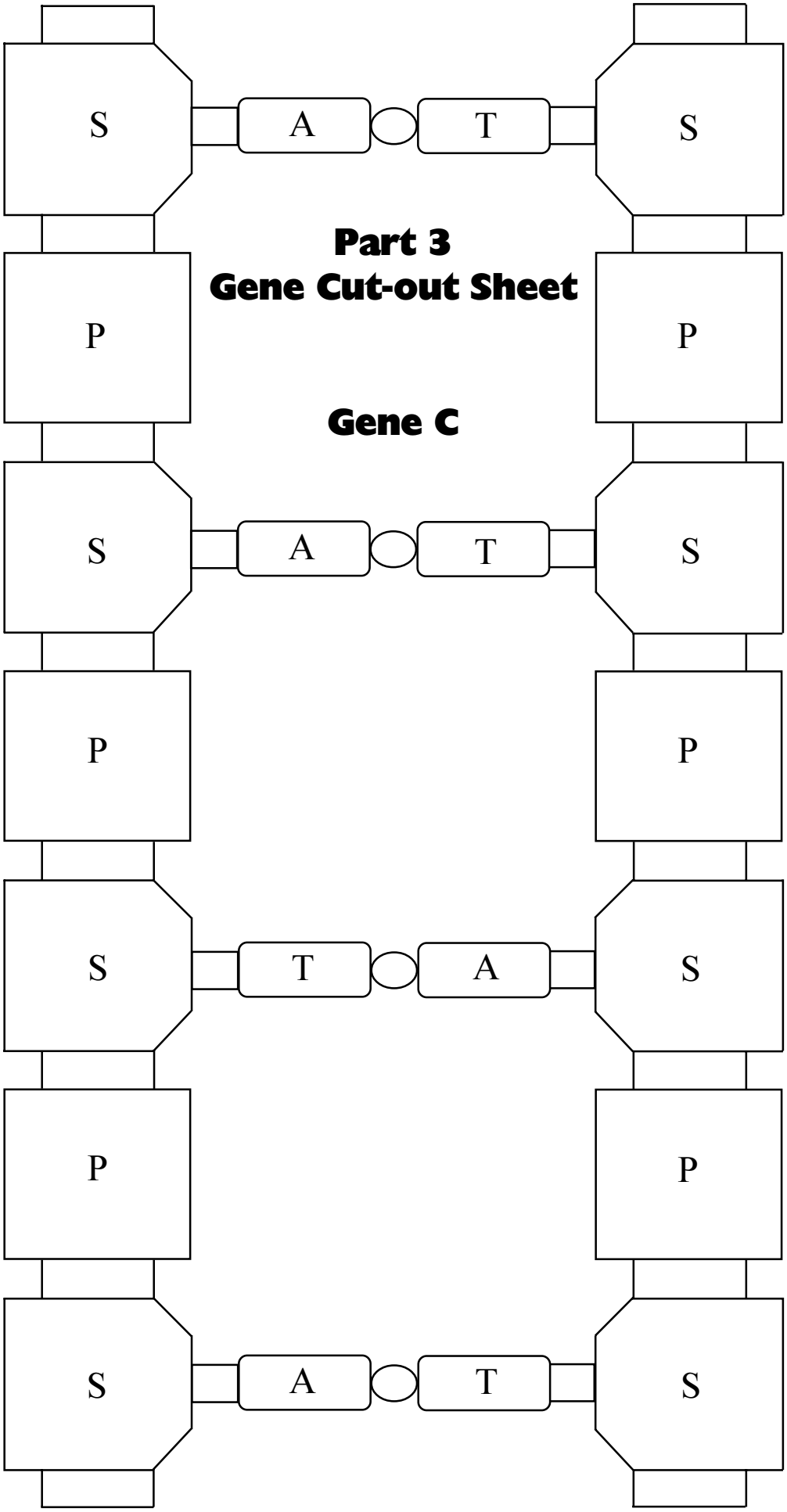
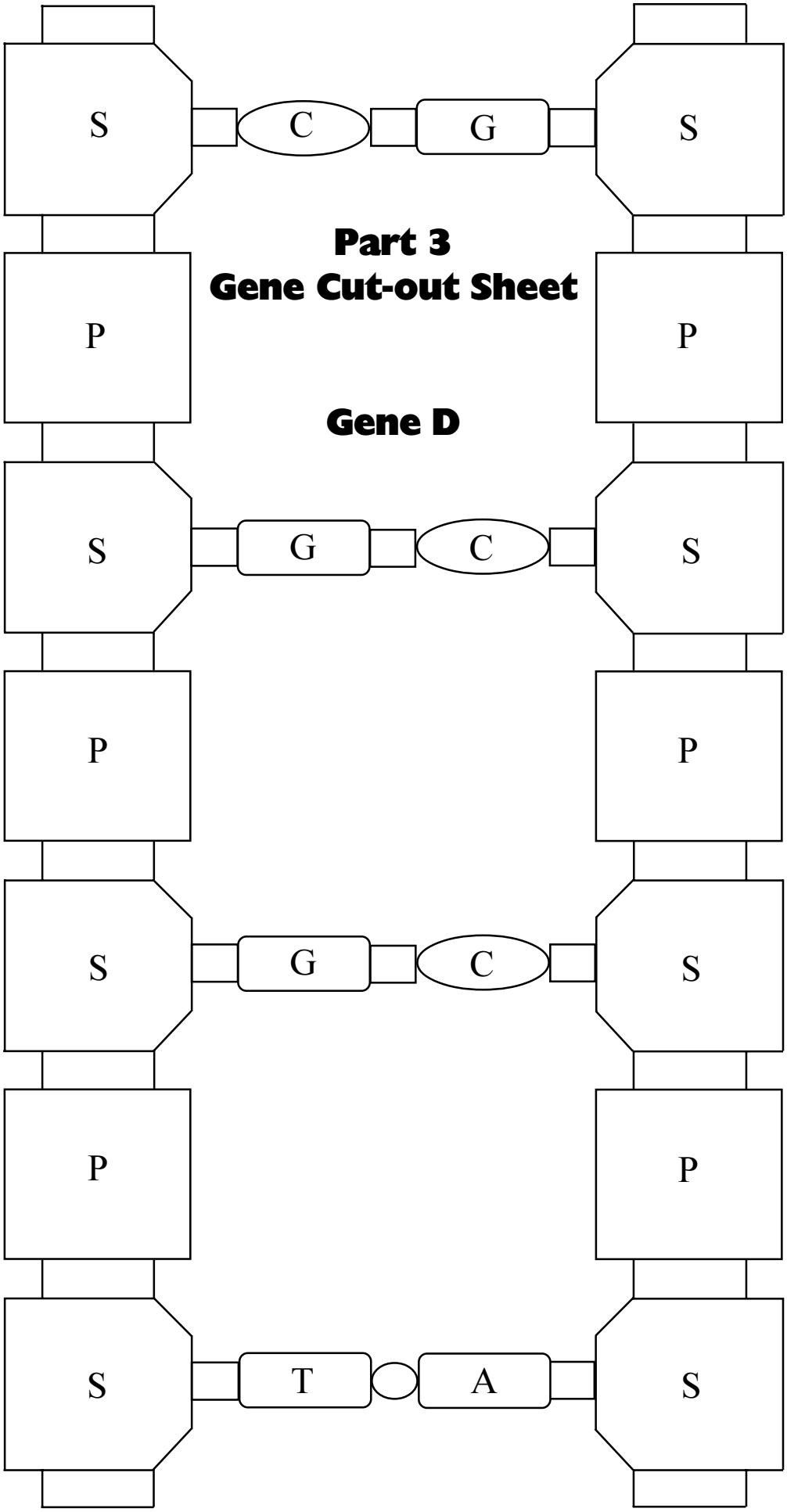


Part 3
Gene Cut-out Sheet

Gene C


S
C
G
S
Part 3
Gene Cut-out Sheet
P
P
Gene D
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G
C
S
P
P
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G
C
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P
P
S
T
A
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