LESSON 5

DNA FOR DINNER?

From Bread to Biotech

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WHAT WE WILL DO

- Learn how yeast uses sugar to make holes in your loaf of bread.
- See how male and female corn cells come together to form the grain on an ear of corn.
- Create a recombinant story using cutting and pasting methods similar to those used for DNA manipulation.
- Find out how PCR can be used to multiply gene fragments.

WHAT WE WILL LEARN

- Literally **biotechnology** means using organisms to do a job, like using yeast to make bread.
- Modern biotechnology uses new genetic tools to modify genomes and speed crop development.
- In the past humans modified genomes by crossing plants with different traits and selecting ones with improved traits.
- A part of modern biotechnology, called **genetic engineering**, involves isolating genes, linking them to on and off switches and introducing them into the same or different organisms.
- Special enzymes are used to cut (restriction enzymes) and paste (ligase) DNA, in a process called **recombinant DNA**.

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* optional

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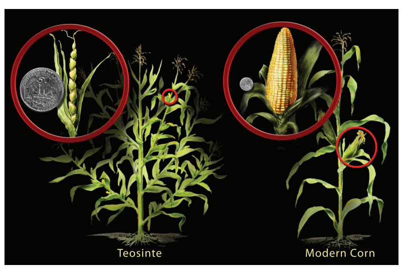
http://aspb.org

This curriculum follows 4-H SET guidelines
http://www.ca4h.org/SET

Appetizer



Teosinte (left), ancestor of modern corn (right)

Most all food comes from plants – either directly by eating them or indirectly from animals that eat them. Plants we eat haven't always looked the way they do today. See on the left how modern corn has changed from its ancestor. This is because people have selected plants for thousands of years that are sweeter, bigger, tastier and able to fight off pests and survive harsh environments.

One way people have done this uses **selective breeding**. Male cells, or pollen, from one plant is crossed with female cells, or eggs, of another related plant. Plants from that cross are observed and ones with the best traits are selected. For example, if we cross one tomato variety with deeper color and more vitamins with another that is sweeter, we look through resulting plants for one with sweeter, darker red, more nutritious tomatoes.

About half of the genes in each parent's genome end up in offspring, but the choice of which genes is random. This is why two brothers look different from each other. Results with plant breeding are the same. Breeders can't control what genes end up in a given plant. They can just choose plants with desired traits.

Today new tools speed breeders' jobs. By developing road maps for the genome showing locations with valuable traits, breeders perform **marker assisted breeding**. Using this tool breeders can identify plants with specific traits using molecular markers. Think of this in terms using a word processing system to find particular words in a document.

Although selective breeding results in genetic modification, it can't be used to move traits from different kinds of organisms, like from apples to tomatoes. This kind of modification is possible using new genetic tools, called by some **biotechnology**, but by others **genetic engineering** or **recombinant DNA**.

What's in a Word?

Words

Biotechnology • Genetic engineering • Genomics
Marker assisted breeding • Recombinant DNA • Selective breeding

Participants will find new words in this lesson. Some may be similar to words they already know and some may not be.

Biotechnology involves the use or manipulation of living organisms to produce useful products. This includes using microbes to produce bread or yogurt or applying genetic engineering to make pest-resistant plants. It comes from the Greek root, *bios*, which means life, and *technē* meaning craft or skill.

Genetic engineering is a new method of genetic modification that involves the scientific alteration of the genome of a living organism, using the tools of recombinant DNA.

Genomics is the study of the genome, which contains most all of the genetic information in an organism that determines its traits. The word is from the German, *gen*, meaning to produce, and the Greek, *ome*, meaning body.

Marker assisted breeding is a process by which a visible, chemical or RNA/DNA-based marker is used to select indirectly plants that have traits of interest.

Recombinant DNA means joining DNA together from two sources, using enzymes that can cut and paste DNA. It is the process used to genetically engineer plants.

Selective breeding is a classical means of genetic modification that involves crossing two different, but compatible, organisms to get offspring that have the desirable traits of both parents.

You may notice other words with these same roots. By finding the root in a word, you may be able to figure out what it means, even if you have never seen the word.

Remembering the Last Lesson's Important Points

Remember these words?

Amino acids • Carbohydrates • Codon • Enzyme • RNA • Starch

Ask These Review Questions

- Describe what an enzyme is and what functions it might have in your body. (Encourage participants to use terms introduced in the last lesson).
- Explain the relationship of RNA to DNA and the importance of RNA in making protein.
- Describe the manner in which the A's, C's, G's and T's in DNA bond to each other within a single strand and between strands.

Main Course

- Activities will introduce participants to the consequences of genetic modification using classical breeding techniques and recombinant DNA technology.
- Three activities are offered in this lesson; two are optional. There is also an activity associated with Dessert.
- In these activities participants will find out how genetic modification has been accomplished in the past and what new tools are used today to study and modify DNA.

ACTIVITY 5.1 Balloons, Bottles and Bread

In this activity we will see the process of yeast producing carbon dioxide after being fed sugar – the same activity that occurs when making bread.

WHAT TO DO AHEAD OF TIME?

- Purchase yeast, sugar and a large rubber balloon.
- Find an empty, heavy glass/plastic beverage bottle.
- Make copy of **Handout 5.1** for each participant.

WHAT IS NEEDED?

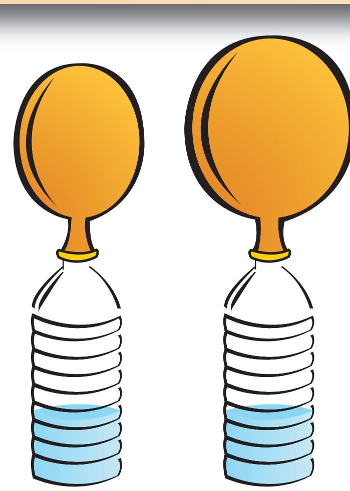
- One package of rapid active dry yeast.
- 1 cup very warm water (105º F to 115º F).
- Two tablespoons of sugar.
- Copy of **Handout 5.1** for each participant.

HOW MUCH TIME IS NEEDED?

20 - 25 minutes.

Directions

1. Before beginning the activity, stretch the balloon out by blowing it up several times and then releasing the air.
2. Add entire packet of yeast and sugar to cup of warm water and stir until sugar is dissolved.
3. Pour mixture into bottle.
4. Attach balloon to top of bottle, making sure bottle is sealed tightly.
5. After several minutes, observe the balloon. If nothing happens right away, wait longer.



Discussion

Nearly 10,000 years ago, humans began using one-celled organisms to make bread. In bread-making the organisms, yeast, are provided with sugars which they can break down. As they consume the sugar, they produce alcohol, which contributes to the aroma of baking bread, and carbon dioxide, which makes the dough rise and form a honeycomb texture.

In this activity the yeast feeds on sugar and produces carbon dioxide. With no place to go but up, this gas slowly fills the balloon. A very similar process happens as bread rises. Carbon dioxide made by the yeast has no place to go and expands the network made by the proteins in the wheat flour to form thousands of balloon-like bubbles. Bubbles gives the bread its "holey" texture texture.

- What do you think would happen if we substituted salt for the sugar?
- Describe what might happen if you used cold water instead of warm water.

When participants finish discussion, ask them to complete **Handout 5.1**.

ACTIVITY 5.2 Birth of Baby Corn (optional)

WHAT TO DO AHEAD OF TIME?

- Purchase ear of fresh sweet corn (preferably with husk and silks).
- Review **Handout 5.2.**

WHAT IS NEEDED?

- Copies of **Handout 5.2** for each participant.
- Ear of sweet corn.
- Table knife.
- Tweezers.
- Disposable plates.
- Magnifying glasses (10X), if possible.

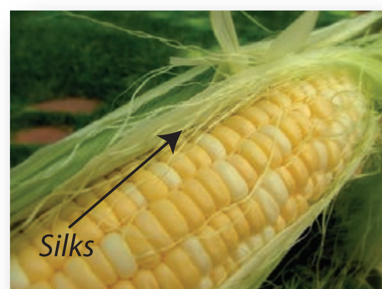
HOW MUCH TIME IS NEEDED?

15 minutes.

Directions

Provide participants with **Handout 5.2** and the following explanation. A mature corn plant has a tassle at the top and one or two ears half-way down the plant (**Photograph 1**). The female corn cell (the egg) resides in the ear of the corn (**Photograph 2**), and the male corn cell (the pollen, **Photograph 3**) comes from the tassel on the top of the plant. When the pollen lands on the corn silk (the hairy part on the top of the ear, **Photograph 4**), the male cell travels down the silk until it mates with the egg inthe ear. When the mating occurs each cell donates half of its genetic information to the fertilized egg. That way the final fertilized egg has exactly the same amount of genetic information as the original corn cells. Once fertilized, the egg develops into a small embryo surrounded by a starchy layer (**Photograph 5**) that provides food for the embryo when it is exposed to water and soil and germinates. One end of the embryo forms leaves and the other the roots. Sometimes when the pollen does not reach the egg to fertilize it, the ear has gaps with no developing grain (**Photograph 6**).

Ask participants to remove husks from ear of corn and pass it around to the other participants. Try to leave the silks attached to the ear. Ask participants to look at the ear and try to identify individual seeds and where the silks attach to the seeds. Once everyone has seen the ear, use a knife and the cutting board to cut off seeds as close to the cob as possible. Place one or two seeds on a disposable plate for each participant. Ask them to use tweezers to open the seed to look inside. Most of what they see is starch but, at the cut end of the seed, they should see a small, firm 1/8-1/4" oval structure, the embryo, embedded in the softer, starchy tissue. Instruct participants to use the tweezers to remove the embryo, placing it on the disposable plate. Tell them to use the magnifying glass to look at the embryo.



- When using the magnifying glass to look at the embryo, describe what you see?
- Speculate about what you think any structures you see might be.
- Why do you think they might be important to the developing seed?

ACTIVITY 5.3 Gene Hunt (optional)

WHAT TO DO AHEAD OF TIME?

- Make copies of **Handouts 5.3** and **5.4** for each participant, as appropriate.
- Secure access to the internet, if possible.

WHAT IS NEEDED?

- Copies of **Handouts 5.3** and **5.4**, as needed.
- Pencils for each participant.

HOW MUCH TIME IS NEEDED?

30 - 40 minutes, as appropriate.

Directions

If you want to engineer a gene and reintroduce it into a plant cell, you have to first find the gene and get enough of it to manipulate it in the laboratory. One way to do this is using PCR, or polymerase chain reaction. Participants will first be introduced to the principles of PCR in **Handout 5.3** and **5.4**.

Before participants begin the activity, share the following. PCR is used to amplify certain fragments of DNA. This is quite similar to activities that you can do with a word processing system. Both handouts cover the principles of PCR. Participants can perform the exercises on **Handout 5.3**, **Handout 5.4** or both, depending upon interest. Give each participant a copy of the appropriate handout and give them time to complete this exercise.

If participants are going to complete the exercises in both handouts, wait until the participants finish Handout 5.3 before giving them Handout 5.4. The activity in Handout 5.4 will allow them to perform the process of PCR on DNA on paper - just like it occurs in a test tube in the laboratory.

After participants complete **Handouts 5.3**, **5.4** or both, challenge them with the following.

- Describe ways in which PCR is similar to actions that are performed with a word processing system.
- Explain what the meaning of the acronym Pick, Copy, Repeat means with regard to the process of PCR.

If participants completed Handout 5.4, ask them the following questions.

- How does the sequence of the complementary strand, Copy-C1, in Step 4 cycle differ from that of C-1 made in Step 3?

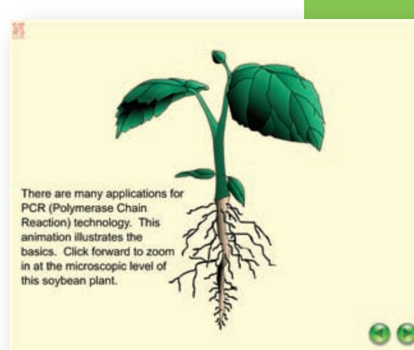
  Hint to Leader: If participants have difficulty answering this question, ask them to write out the two sequences, one right under the other.

- Why does this difference occur?
- Describe what you think will happen when you repeat these cycles over and over.

  Hint to Leader: During each cycle after the 2nd cycle, the proportion of Copy-C1 and Copy-C2 fragments will increase, resulting in thousands of copies of Copy-C-1 and Copy-C-2. The number of original strands (S-1 and S-2) will not increase. This results in a large amount of the Copy-C1 and Copy-C2 fragments.

If participants have access to the internet, the URL provided gives a brief tutorial on the principles of PCR.

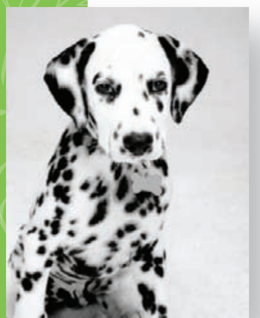
http://plantandsoil.unl.edu/croptechnology2005/pages/animationOut.cgi?anim_name=PCR.swf



University of Nebraska, Institute of Agriculture and Natural Resources

Final Course

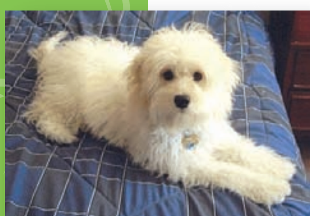
Discussion with Participants



Read or paraphrase:

- Ask participants who have dogs as pets to describe their pet. What color is its coat? How big is it? How long is their coat?

People have developed dog breeds as different from one another as a spotted, short-haired dalmatian and the solid-colored, long-haired collie. The many different breeds of dogs we have today are due to **selective breeding**. People decide which dogs to breed - that is, which dogs they want to have puppies. But, when you breed two dogs together, you don't have control over exactly what the puppies will look like because you can't control which genes are kept and which are lost.



Breeding allows genomes of parents to mix together and offspring obtain genes from both parents. This is especially noticeable when you breed two very different dogs, like a poodle and a cocker spaniel. Then you get a Cockapoo.

- Describe what you think the puppies from such a mating would look like.
- Explain what you believe would happen if you tried to mate a dog with a cat?

And you can only breed between organisms that are closely related – dogs with dogs, not dogs with cats. The same is true with plants. One apple variety can be crossed with another apple variety, but not with a tomato. With genetic engineering, it is possible to cut out a single gene from the genome of one organism, like a tomato, and paste it back into a tomato or into the genome of another organism, like apple. This process is called recombinant DNA because it involves chemically recombining DNA.

- Describe why you think it is possible to move a gene from a tomato into an apple.
- Explain why you think moving a single gene from a tomato into apple would or would not make the apple red and seedy like a tomato.

Dessert

Recombinant Folk Tale

This activity builds on the information contained in this and earlier lessons. Participants will construct recombinant folk tales by exchanging phrases between the two stories. But phrases can only be exchanged if the "target sites", on both ends of the text that is exchanged is the same. This is the same process that in principle is used when performing genetic engineering in plants.

WHAT TO DO AHEAD OF TIME?

- Determine access to word processing system on computers to demonstrate the process of cutting and pasting folk tales.

  - or -

- Make copies of **Handouts 5.5** and **5.6** for each participant.

WHAT IS NEEDED?

- Computer with word processing system

  -or-

- Pencils.
- Scissors.
- Clear tape.
- Paper copies of **Handouts 5.5** and **5.6** for each participant.

HOW MUCH TIME IS NEEDED?

25 - 30 minutes.

Directions

Request that each participant read the two folk tales and then ask them to describe the solution to each folk tale.

*Note to leader. Answer to folktale in **Handout 5.5**: Frog's swimming around began to churn the cream into soft fresh butter. Answer to folktale in **Handout 5.6**: Frog saw the sunlight reflecting off the sides of the mountain in the west while Deer was watching the plain in the east. Mountains, being higher, always catch the suns rays first as the earth turns to face the sun.*

After they describe the solutions, read or paraphrase the following.

Now you are going to create recombinant folktales from the two folktales in the handouts. You will do that by cutting out text from both stories and recombining them into new stories. But you can't choose just any text to exchange - only text that begins and ends with the same words.

Look at the two handouts with the folktales,"The Frog" and "Sunrise" and find the following phrases, "the sides of the" and "hours and hours". These are the *target sites*. Use scissors and tape to remove the text between the target sites in the two stories and switch them. The new story is called a "recombinant" story.

After participants finish the exchange, ask them to look at their recombinant stories.

- Explain why you think the new fairytale is considered a recombinant story.
- Describe what happened to the story when the exchanges were made.
- Explain what effects might occur if the target site was only one word, like "frog", instead of several words.
- What would be the consequences if the replaced text was only one word instead of full sentences?

Stuffed, but Hungry for More?

Genetic engineering has been used to modify and put into commercial production some of the major agricultural crops in the world, canola, corn, cotton, soybeans and sugarbeet. But these are not the crops that are of the most importance to agriculture in developing countries. Different crops are important for human consumption in countries, like India, the Congo, Malaysia, Zimbabwe. Some of these foods might be familiar to us, like banana, rice and eggplant, but others we might never have heard of, like cassava and sorghum.

Golden Rice

Golden rice is a variety of rice that was engineered using recombinant DNA to produce provitamin A or beta-carotene, which can be converted to vitamin A in the human body. While in developed countries we get adequate vitamin A in our diet, in developing countries people suffer from vitamin A deficiencies, which can cause night blindness. In South-east Asia, it is estimated that a quarter million children go blind each year because of nutritional deficiencies. Also lack of vitamin A makes certain other diseases more severe. Since rice is a staple, and sometimes the only, food for many of the world's poor and because rice lacks the provitamin, scientists in Switzerland and Germany engineered rice with two plant genes and one bacterial gene to produce provitamin A in the grain.

For more information on Golden Rice, see http://cls.casa.colostate.edu/transgenicCrops/hotrice.html

MATH MENU

1. If one gram of dry yeast contains 25 billion cells, how many cells would be in one milligram of dry yeast? Hint: 1 milligram is 1 one-thousandth of a gram.
2. If an ear of corn has 15 rows of kernels and each row contains on average 18 kernels, approximately how many kernels are on the ear? Express your answer in a power of ten.

See answers in Leader Supplement

NEXT TIME WE MEET

Now we know genetic engineering can be used to cut genes that code for a protein out of the genome of one organism and paste it into the genome of another organism. We also know there are approximately 30,000 to 40,000 genes in plant genomes. Next time we will discuss the concept of relative risk and we will explore the potential risks and benefits involved in genetically engineered crops, particularly Golden Rice.

SET CONCEPTS ADDRESSED

Discovery-based research and scientific method

National Science Education Standards in Life Sciences Grades 5-8, addressed: Content Standard C, Reproduction and heredity; structure and function in living systems

SET Process Skills Used: Hypothesize; interpret/analyze/reason; use numbers; use tools

For more information & additional lessons, please visit **http://ucbiotech.org/dnafordinner**

Leader Supplement for Lesson 5

Answers to Math Menu

1. 25 million cells.
2. 270 or 2.7×10^2

DNA FOR DINNER?

LESSON 5
HANDOUT 5.1

Balloons, Bottles and Bread

Draw a line to match the ingredient on the left with its role in bread-making on the right.

Sugar	Provides texture for the bread
Flour	Prevents the dough from drying out
Oil	Consumes sugar and creates bubbles in bread
Yeast	Provides food for the yeast to eat

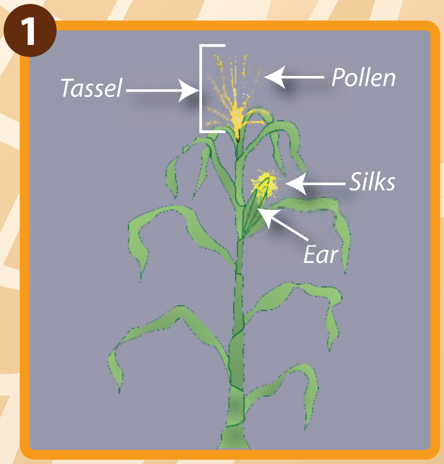
DNA FOR DINNER?

LESSON 5
HANDOUT 5.2

Birth of Baby Corn

How a Corn Plant Grows

1



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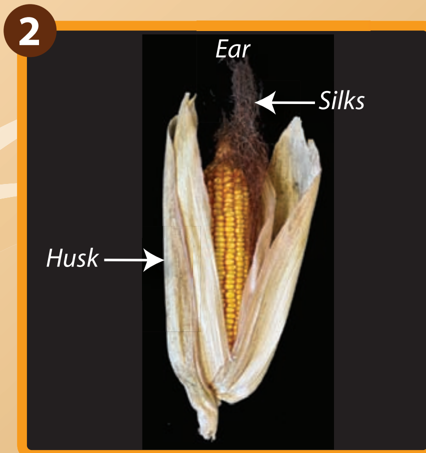

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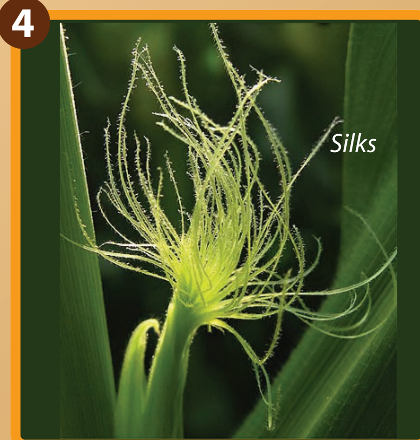

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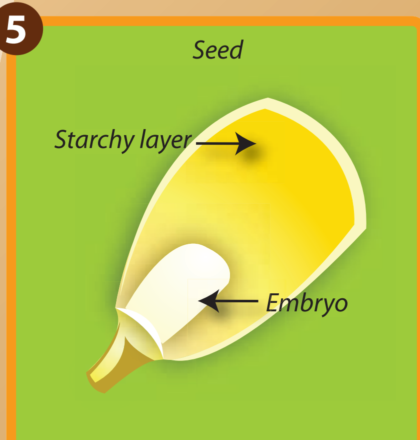

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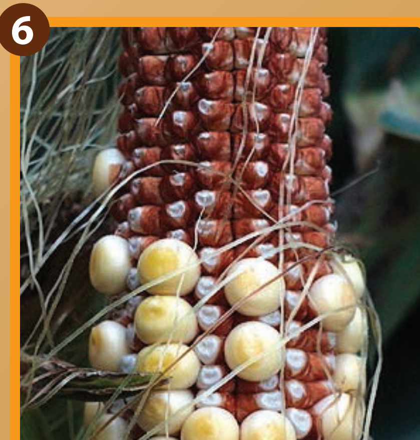


Image credit:
(1) Plant and Soil Science eLibrary, University of Nebraska;
(2) Joshua Wong, University of California, Berkeley;
(3 , 4 & 6) Bob Nielsen, Purdue University;
(5) Barbara Alonso, University of California, Berkeley.

For more information & additional lessons, please visit
http://ucbiotech.org/dnafordinner

DNA FOR DINNER?

LESSON 5
HANDOUT 5.3

Pick Copy Repeat 1

Instructions

Read through the text below and follow the instructions on the right.

In a previous lesson participants learned that genes contain coded information. The coded information in a single gene normally provides the organism with the blueprint to make a single protein. The information for proteins is contained in DNA in four chemical units or bases, termed A, C, G and T. Information in DNA is copied into the bases A, C, G and U in messenger RNA ("U" substitutes for "T" in RNA). The bases in RNA are then read by the cell machinery in sets of three, called a codon, which specifies one of 20 amino acids. Strings of amino acids make proteins. The sum of all proteins gives the organism its characteristics.

- Use your own eyes or a word processing system FIND command to identify the word, "provides" in the text on the left. Underline its location on the page.
- Next find the word, "blueprint" and underline it.
- Select the text starting with "provides" and ending with "blueprint" and copy it below, or use the copy command with the word processing system.

____

- In word processing open a new document and paste the text.
- Write the text over and over again below. Or in word processing, paste the text again, and again, and again!

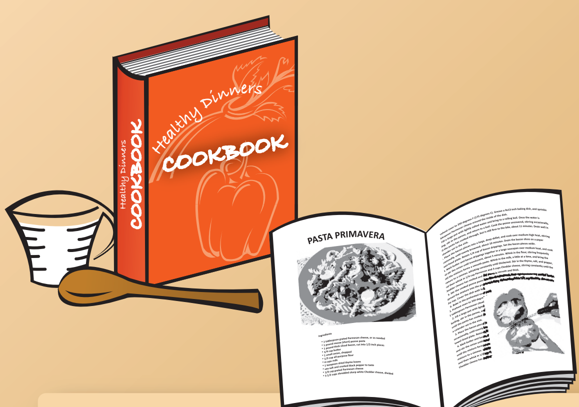
____

____

____

____

- In principle, this is the process of PCR, which results in amplification of the information between the two key words, which are termed primers in PCR.



Comparing Word Processing to PCR

Word Processing	PCR Technology
Series of electronic cookbooks	Entire genome
Page from one cookbook	Specific DNA fragment
Words at beginning and end of a sentence on page	Primers that recognize beginning and end of fragment
Copy command	Enzyme that copies DNA (polymerase)

Pick Copy Repeat 2

Instructions

In this exercise, you will use your pencil in a step-by-step process to perform PCR. It is just like the copying that would occur in a test tube.

STEP 1

During PCR, copies of a DNA segment of interest in the genome are made. In this exercise, the first complementary DNA strand is called **Strand-1 (S-1)**.

- *Write the nucleotide sequence of the complementary strand, **Strand-2 (S-2)**.*

Segment of interest

```
S-1   3' T C G G C T A C A G C A G C A G A T G G T A C  5'

S-2   5' _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _  3'
```

STEP 2

Small DNA pieces, called primers because they prime or initiate the PCR process, are made that have A's, C's, G's and T's complementary to those in the DNA segment of interest. Remember an A is complementary to a T and a G is complementary to a C. One of the primers matches one end of the fragment (5') and one matches bases on the other end (3').

- *Write the four complementary bases for the **5' Primer**.*
- *Fill in **S-2** bases written down in Step 1.*
- *Write the four complementary bases for the **3' Primer**.*

Segment of interest

```
S-1   3' T C G G C T A C A G C A G C A G A T G G T A C  5'

      5'     _ _ _ _
                          (5' Primer)
S-2   5' _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _  3'

      3'                                _ _ _ _    5'
                                              (3' Primer)
```

Activity obtained from Iowa State University
http://www.biotech.iastate.edu/lab_protocols/PCR_Activity.html

Pick Copy Repeat 2

STEP 3

Every time the PCR cycle is repeated, a copy of each of the two original strands (**S-1**, **S-2**) will be made. Copying begins at the 3' end of the primer and continues to the 5' end of the original strand.

- *Write the sequence of the copies (**C-1**, **C-2**) made from the **S-1** and **S-2** strands.*

Segment of interest

```
S-1   3' T C G G C T A C A G C A G C A G A T G G T A C  5'

C-1   5'     C C G A _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _  3'

S-2   5' A G C C G A T G T C G T C G T C T A C C A T G  3'

C-2   3' _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ A T G G        5'
```

STEP 4

During the 2nd PCR cycle, copies are made from **S-1** and **S-2** and from **C-1** and **C-2**, obtained in cycle 1.

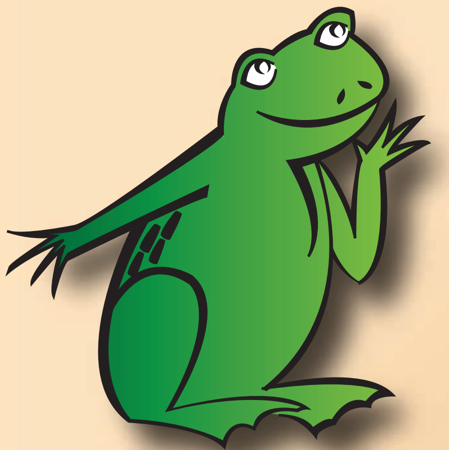
- *Write the sequence of **C-1** formed during the replication of **S-1** in cycle 2. Also write the copy of the sequence formed from priming off of the copy **C-1** made from the original sequence, **S-1**.*

Segment of interest

```
S-1      3' T C G G C T A C A G C A G C A G A T G G T A C  5'

C-1      5'     C C G A T _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _  3'


C-1      5'     C C G A T G T C G T C G T C T A C C A T G  3'

Copy-C1  3'     _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _      5'
```

Activity obtained from Iowa State University
http://www.biotech.iastate.edu/lab_protocols/PCR_Activity.html

The Frog



Once long ago on a summer day, a frog, who was hot from the sun, was out looking for adventure. He found a wooden bucket filled with fresh cream, smiled to himself and jumped right in! "This feels wonderful, all cool and silky against my skin," said Frog. He played and splashed and swam from left to right.

After a while he was ready to go home and tell everyone about what he had done. He was ready to go, but he couldn't get out. The bucket was too deep for him to touch the bottom and push out through the cream. There were no rocks or logs like the ones in his pond, and the sides of the bucket were too slippery to climb. He was trapped. He knew his only choice was to keep swimming or drown.

Frog couldn't bear the thought of drowning, especially in cream. He swam around and around for hours and hours till his arms and legs were too tired to move.

It's no use, he told himself. This is the end. I might as well get it over with.

He swam to the center of the bucket and began to sink, but as soon as the cream covered his mouth, he sputtered out, "No," and started swimming again.

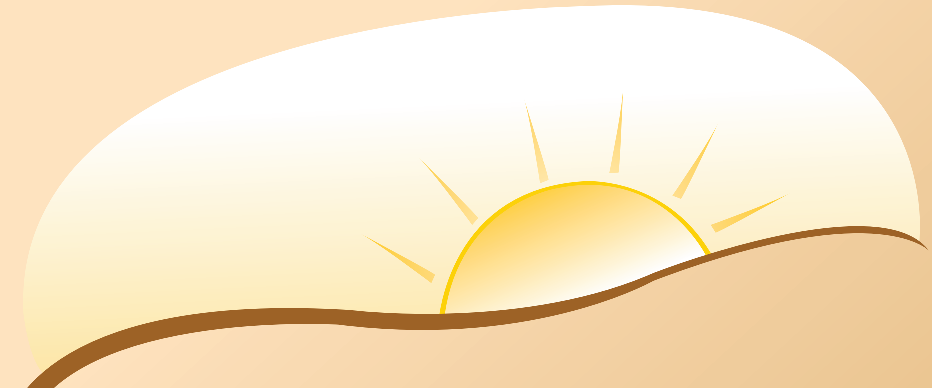
After a while his arms and legs again grew too tired to move. Again he swam to the center and began to sink. And once again, when the cream began to cover his face, he sputtered out, "No," and started swimming.

But the fifth time this happened he sank only a little bit before he felt something beneath his feet. It was soft and slippery, but still solid enough to hold him.

Frog pushed down and hopped out of the bucket and back to his friends as fast as he could go. When he told them what happened, they all wanted to know how he finally got out, but the frog didn't know. Do you know how?

A Russian Folktale, adapted from "Lazies: Tales of the Peoples of Russia"

Sunrise



One night long ago in Mexico, a frog and a deer had an argument at frog's home. They decided to settle their differences with a bet.

"Twenty-five flies for the one who can see the first rays of the sun," said Frog.

Deer laughed and quickly agreed. "I will look to the east." He knew that the sun
always rises in the east. "You must look some other place."

Frog agreed. He quietly sat watching the sides of the highest mountain to the west while Deer stared into the darkness of the eastern plain. After hours and hours of waiting and watching, Frog suddenly yelled, "Look! I see the first rays of the sun. I win."

When Deer turned to look west, he had to agree that Frog had been the first to see the rays of the sun and Frog had seen them by looking away from the sun.

How could this be?

A Mexican Folktale, adapted from "Tongues of the Monte" by J. Frank Dobie and "More Stories to Solve: Fifteen Folktales from Around the World" by George Shannon