WHIF

(WHat's In Food)
Food Safety Education Program

University of California

Biotechnology and Food

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Available in the 4-H WHIF Series

- Additives and Food
- Pesticides and Food
- Biotechnology and Food
- WHIF Trainer's Manual

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What Is 4-H WHIF?

4-H WHIF is a family food safety education program, the first of its kind, designed by scientists and educators from many research disciplines. WHIF stands for WHat's In Food.

Purpose

The purpose of 4-H WHIF is *to encourage 11- and 12-year-old adolescents and their parents*[1] *to develop greater awareness, and understanding of food safety issues.*

Audience

The 4-H WHIF target audiences are 11- and 12-year-olds with parents and 13-and 14-year-olds without their parents. Eleven and twelve year olds are usually enthusiastic about working with their parents. This is often not true of 13- and 14-year-olds, who are more peer-oriented.

How Is 4-H WHIF organized?

There are three 4-H WHIF modules and a WHIF Trainer's Manual. The three modules are:

- Additives and Food
- Pesticides and Food
- Biotechnology and Food

Each module is organized into six to eight lessons. Within each module, there are many learning experiences. 4-H WHIF focuses on experiential learning ("hands-on learning") methods. 4-H WHIF encourages youth and adults to use problem-solving skills and critical and creative thinking to make informed decisions about the safety of their food.

How the Activities Are Organized

In each lesson you will find

Words

We will learn

Do ahead

You will need

Time

Background for the Leader

Suggestions for the Leader

For review

Ask these questions

Adventures

Word Rap

Discussion with Participants

Hungry for More?

Next time . . .

[1] **For this program, the term "parent" refers to any significant adult the child chooses to include. Examples might be a grandparent, aunt, uncle, step-parent, older-sibling, foster parent, etc.**

The background information is designed to help you, the leader, prepare for the *adventures* that follow. If you prefer, you may share background information with the participants.

Following *Background for the Leader*, is a set of "hands-on" activities and experiments called *adventures*. Study the *adventures* before presenting them. The supplies you need, preparation to do ahead, and the time to allow for the *adventures* are listed in a box on the side of each *Adventure* page.

Hints for the Leader

During the pilot testing of these materials, children and their parents, asked many questions whose answers required scientific knowledge. Don't let that discourage you. WHIF has been designed to encourage questioning, problem solving, and decision making by the participants. Your role as the leader is to encourage inquiry by participants. You are not expected to have all the answers.

If a question arises for which you do not have the answer (and there will be many), encourage participants to collaboratively identify and implement methods to get the answers for themselves. That might mean a trip to the local library or writing letters to scientists. Your local Cooperative Extension Advisor can help and guide you.

Dare to Be Different

1

Background for the Leader

One of the most fascinating things about life is the millions of different living things in the world. For example, there are 8,000 different species of birds, about 350,000 different species of plants, and more than 800,000 known species of insects in the world. Scientists discover 7,000 new insect species annually. This huge variety of life is called **diversity**.

From now on, we will substitute a new word for *living thing*—and that word is **organism**. **Organism** means any living thing, such as a plant, an animal, a bacterium or a human. We are able to distinguish one **organism** from another by its **characteristics**. Very often, two or more **organisms** within a species have similar characteristics. The more the organisms have in common, the more likely they are to be related.

An organism's **characteristics** are recorded in its **genes**. Each gene is a recipe for something called a *protein*. Most people think of proteins as nutrients in foods, like cheese, meat and beans. In the WHIF Project, we are introducing a new twist. Proteins and protein production are linked to our genes. For example, we eat beef proteins produced by a steer. Our bodies break down the beef proteins and use the products to produce new proteins according to our human gene recipes. An organism's genes are like a cookbook or box of recipes. Although scientists don't know exactly how many genes a human or a wheat plant has, they believe these organisms have more than 100,000 genes—recipes for over 100,000 proteins. These proteins determine the **characteristics** of an **organism,** such as smooth or scaly skin, sweet or bitter taste, gills or lungs, fins or legs. Other characteristics include fuzz on a peach, smell from an onion, and color in an apple skin.

Words

characteristic

diversity

gene

organism

We will learn

- All living things are **organisms.**
- The huge variety of organisms is called **diversity**.
- Diversity results from the different **genes** each organism possesses.
- **Organisms** with many similar characteristics, and thus many similar genes, may be related.

Suggestions for the Leader

This lesson will introduce participants to the concept of diversity. You will explore how diversity occurs.

There are three adventures suggested for today, of which two are optional. Use the discussion section following the activities.

For these adventures, the fresh produce or pictures you choose should represent whole plants (not just their fruits), such as carrots or beets with tops, green onions, or radishes. Use the produce or pictures as props to show the diversity of plants. This will lead to the concept that organisms with many similar characteristics, and thus many similar genes, may be related.

First Things First

Word Rap[1]

Participants probably will learn many new words in these lessons. Some may be similar to words they already know because the words may have a familiar root. A root is the core or base word from which other words are derived.

Characteristic is derived from the word *character*, which originally came from a Greek word meaning "sharpen, engrave, cut," as well as from words meaning "pointed stake" and "engraved mark." The original Greek word was used as a stamp marking one thing to make it different from another thing.

Diversity is related to the words *verse*, *version*, *vertebra*, and *divert*. These English words came from Latin and French as early as 700 hundred years ago during the thirteenth century. The Latin word is derived from two parts meaning "turn" and "aside," as with "turn in new directions" in the word *divert*. Later "turned aside" became "separate, different," which lead to the English words *diverse* and *diversity*.

Gene comes from the old European root "gen-" which means "to produce" and is related to *general* and *generate*. Other words that come from "gen-" are *genetic* and *genome*. You learned that your genes have information that makes you, you. So your genes "produce" you, which is what the root word "gen-" means!

You may notice other words with this same root. By identifying the root in a word, you may find you already have some idea what it means, even though you have never seen the word before. Other words containing "gen-" as their root are *gender*, *genealogy*, *generate*, *generous*, *genesis*, *genie*, *and genius*.

Organism means living thing, such as a person, an animal, or a plant. The Greek word for organ is "tool, instrument, implement." *Ism* means "system." So *organism* refers to a "system of tools." The human body could be thought of as a "system of tools."

[1] Many of these definitions are from *Dictionary of Word Origins* by John Ayto, New York, Arcade Publishing, 1990.

Adventure 1:1

Bet You Can't Guess My Name

In the first adventure participants guess fruit or vegetable names, by knowing only some of the characteristics. Repeat the game with other fruits and vegetables.

Directions

Give each child a piece of fresh fruit or vegetable in a brown paper bag. Have each participant make a written list of the fruit's or vegetable's characteristics on a large sheet of shelf paper taped to a table. Characteristics include color, size, shape, taste (sweet or sour), skin thickness and texture, and noticeable markings or sections. Does the fruit or vegetable grow above or below the ground? Does it grow on a tree or a vine? Offer information that might help others guess what it is.

Each person recites the characteristics of her or his produce. Participants guess what the food is. Make this a game.

Do ahead

- For the first and second activities, provide produce or ask members to bring samples. Encourage them to bring unusual fruits or vegetables so you don't end up with 20 apples.

You will need

variety of fresh produce or pictures

lunch bags, pencils, shelf paper

20-30 minutes

Adventure 1:2

Cousins

Optional

Have participants group foods together that seem related based on common characteristics. See the *Fruit and Vegetable Families Reference Guide*, provided on the following page. Participants will group fruits and vegetables in ways different from the Reference Guide. Encourage this kind of thinking. For example, tangerines and nectarines are both orange in color, but are not members of the same family. You may want to explain that if you look at other characteristics, such as seeds, a tangerine is more like an orange than a nectarine. Arrange the produce according to degree of similarity based on whatever characteristics the children choose.

Do ahead

Review *Reference Guide*

You will need

variety of fruit and vegetables

Reference Guide

20-30 minutes

Adventure 1:3

Field Trip

Optional

Arrange a field trip to the produce section of a supermarket to examine the diversity among fruits and vegetables.

Do ahead

Contact the produce manager to arrange trip

You will need

Parental permission and transportation for participants

Fruit and Vegetable Families

Citrus Family

Orange
Lemon
Grapefruit
Lime
Tangerine
Tangelo

Palm Family

Coconut
Date

Rose Family

Peach
Apricot
Nectarine
Apple
Pear

Grape Family

Grape

Sunflower Family

Artichoke
Lettuce
Sunflower

Mustard Family

Cauliflower
Broccoli
Brussels sprout
Cabbage
Radish
Turnip
Red cabbage
Mustard greens
Bok choy

Lily Family

Asparagus
Onion
Garlic
Leek
Green onion

Potato or Nightshade Family

Tomato
Potato
Sweet potato
Peppers
- Green
- Red
- Yellow
- Jalapeno
- Anaheim

Legume Family

Beans
Peas
Bean sprouts
Snow pea
Lentil
Jicama

Cucumber Family

Cucumber
Watermelon
Cantaloupe
Squash
Chayote

Goosefoot Family

Swiss chard
Spinach

Carrot Family

Carrot
Parsnip
Celery
Cilantro
Coriander

1

Last Things Last

Discussion with Participants

- Read or paraphrase

There are new words and information introduced in these lessons, but don't worry, just take a deep breath and listen carefully. All the important stuff will be repeated later, so you will have many opportunities to learn anything you don't understand. Be sure to ask questions. Remember, all questions are good questions.

The world is full of living things called **organisms**. Every **organism** has **characteristics** that make it different from all other organisms.

☆ Does a plant have pointy or curved leaves, red or orange fruits?
☆ Think about different animals in the zoo, such as a giraffe and a tiger. What are the similarities? What are the differences? [Give participants time to respond.]

Some **organisms** are very different from each other, like a snail and an elephant. Some are just a little different, like trees that make red or yellow apples. At the grocery store, you see how different the fruits and vegetables are. Imagine how different the plants they grew on might be. [Share some foods from the grocery store that are whole plants.] Look at how different a carrot plant is from a green onion or lettuce. This varying degree of difference is known as **diversity**.

Even though all **organisms** are different, they have certain **characteristics** in common. You need air and water to live. So does an apple tree, and so did the dinosaurs.

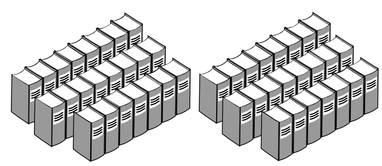
☆ What is it in living things that make them both different and similar at the same time?
☆ Why does an apple tree make apples and not tomatoes?
☆ What makes a house cat smaller than a lion?
☆ What makes you, you?

You will need

Examples of whole plant foods such as carrots with tops, green onions, lettuce, radishes, and sprouts for participants to observe as indicated in the discussion

Cookbook or recipe box

Every **organism** contains all the information needed to become what it is. In organisms, this information is kept in a file like a recipe box or a cookbook encyclopedia. [Show a cookbook or recipe box.] In organisms, this cookbook encyclopedia is full of recipes called **genes**. Although scientists don't know exactly how many there are, they know your cookbook contains more than 100,000 **genes**. Each **gene** is a recipe for something called a protein. We'll learn more about proteins later.



All the **genes** in your cookbook encyclopedia came from your mom and dad. You can tell whether two **organisms** are closely related by the similarity of their cookbooks. Over 99 out of every 100 of your recipes or **genes** are the same as the person sitting next to you. About one third of your **genes** are the same as the **genes** in a fly. Some of your **genes** are probably very similar to those of the dinosaurs. Although you look very different, you actually are similar to a dinosaur in some ways.

Questions

- Which are likely to have more genes in common—orange and apple, or orange and lemon? *Orange and lemon. They both have sections, leathery skin, a sour taste, a citrus smell..*
- With what organisms do you think we share the same or similar genes? *We have some genes in common with all animals. For example, all have eyes, most have noses, etc. All animals breathe oxygen from air (birds, mammals, etc.) or from water (fish). The genes involved in this process of respiration are the same in a pig, whale, trout, and snake—in fact, the process is the same in all animals. We even have genes in common with plants.*

Hungry for More?

Do you know that some plants we eat produce natural toxins, which if consumed in large quantities are harmful to humans? Plants produce these toxins to protect themselves from predators, such as insects, since they cannot run away from their "enemies" like humans can. The nightshade plant, a close relative of the potato and tomato, has genes for producing a toxin. Some cultures, like the Hmong, a mountain people of Laos, use nightshade as a food source.[2] They feed very small amounts to their children so they can get used to the poisons in the plant. This is called building up a tolerance. By the time the children are older, they are able to eat lots of nightshade. If others, who had not built a tolerance, ate the same amount, they would get very sick.

The tomatoes and potatoes in our markets have been bred so that they don't contain damaging levels of toxins in the plant parts we eat. Breeders monitor these foods to check toxin levels according to government laws. The level of toxin in potatoes can be increased by exposing the potatoes to sunlight. When they turn a light greenish color, they contain higher levels of toxin. So, don't eat potatoes that are turning green!

[2] Duchon, Deborah A., *Solanum-Nigrum, Food, Medicine or Poison?* Boston. Unpublished paper presented to the Society on Ethnobiology, March 1993.

Next time we meet . . .

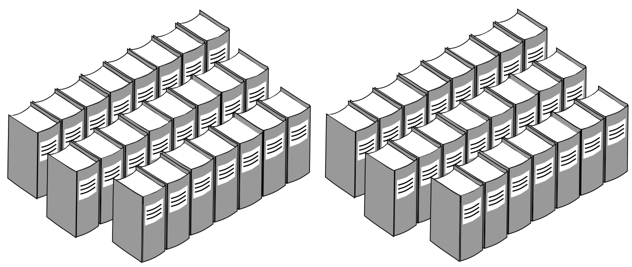
Information contained in genes (or recipes) is recorded in a special alphabet called the genetic code. Next time we will explore how a code can be used to record information about a characteristic.

Secret Codes

2

Background for the Leader

Participants have learned that diversity results from differences in the genetic recipes of every organism. The complete gene set present in an organism is called a **genome**. A genome is like a cookbook encyclopedia.



A cookbook encyclopedia is like a genome.

The genome encyclopedia is recorded on deoxyribonucleic acid (**DNA** for short) in a code called the **genetic code.** We'll talk more about **DNA** later.

Information recorded on **DNA** is like the recorded information on a recording tape, on a computer disk, or on paper in a cookbook. The tape, disk, **DNA,** and paper all serve as media for recording information.

Suggestions for the Leader

For the first adventure, participants select a genome and decode it using the *WHIF Decoding Key*, Handout 2. With the decoding key, participants then send messages and decode those they receive.

Later, participants compose their own code and trade messages with another group. They might first try decoding the message without the code. This can be done if you know some tricks. First, since the most common letter in English is *e*, the symbol for *e* will occur most often. Another trick is to try solving the code for short words like *a*, *it*, and *and*, especially if they contain an *e*, as in *the.* You don't need to spend too much time on this but it leads to an understanding that decoding is difficult without the code.

Words

code

DNA

genetic code

genome

symbol

mutation

We will learn

- An organism's genes are collectively called a **genome**.
- Some of the genome information of every organism is the same, while some is different, but the code **symbols** are the same.
- The code used to record the **genome** is called the **genetic code**.
- Information in the genome is recorded in **genetic code** on **DNA.**

2

First Things First

For review

characteristic

diversity

gene

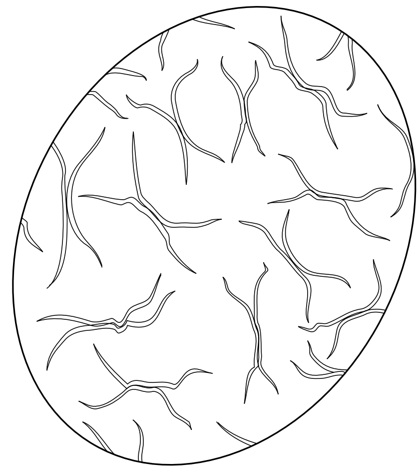
organism

Ask these questions

- What does the word diversity mean? *Lots of variety. All the different characteristics found in living things.*
- Where are the characteristics of an organism recorded? *In the genes.*
- What percentage of genes do all people have in common? *About 99% or 99 genes out of every 100 genes are the same.*
- Are there advantages in having a wide diversity of organisms in the world? *Yes.* What are they? *The vast diversity of species increases the likelihood that the food chain can support itself, and allows organisms to adapt to new climates and environments. Another advantage is there are more foods for us to eat. There are more varieties of apples from which to choose.*

Discussion with Participants

We have learned the world is full of different kinds of living things called organisms. Every organism has a set of instructions like a cookbook encyclopedia containing recipes to make that organism what it is. We also know the recipes are called genes and contain information leading to the characteristics of an organism. This cookbook encyclopedia is called a **genome**.



Genome

Math Box

- Family members share about 199 out of 200 genes. If we have 100,000 genes, how many genes do we share with our mothers and fathers? *About 99,500.*
- Therefore, how many genes are different from our mothers and fathers? *About 500.*

Every organism has a different **genome** (or cookbook encyclopedia), containing some of the same recipes and some different ones. Because identical twins have exactly the same set of genes, their **genomes** are also identical. Family members share most of the same genes—about 199 genes out of 200. Unrelated people share about 198 genes out of 200 genes. People and animals share many of the same genes.

Your **genome** encyclopedia contains more than 100,000 genes—recipes for over 100,000 proteins. These proteins interact to produce your characteristics.

It takes many proteins interacting to produce a complex characteristic like eye or hair color, and many times more proteins to produce a whole eye. Every organism possesses some characteristics that make it different from every other organism. People may have brown or black hair that is curly or straight. People may have dark or light skin. People may be tall or short. These are some characteristics that combine to make each of us different and unique. The genes (recipes) for making the proteins that produce these characteristics are contained in the **genome**. Can you think of other characteristics controlled by your **genome**? *Shape of nose, size of ears, amount and texture of hair.*

A cookbook encyclopedia uses letters as a code to make meaningful words and messages. Twenty-six letters make up the English alphabet. Have you ever tried to communicate without using the alphabet? Another way to communicate is using the Morse code. The Morse code uses only two symbols, a dot (·) and a dash (-).

An organism's **genome** is not written down on paper like a regular encyclopedia. The information in the genome is recorded on deoxyribonucleic acid (**DNA** for short) in a code called the **genetic code**. While the English language is based on a 26-symbol alphabet, the genetic language is based on a 4-symbol alphabet. The genetic code uses the 4 symbols—G, A, T and C—in groups of 3. Every 3 symbols codes for a part of a protein. Even though the genome of every organism is different, the 4 symbols in the code used to make up the genome are exactly the same. We'll learn more about **DNA** and proteins later.

Word Rap

Code is a system for communication which is usually secret. The word *code* came from French and Latin words meaning "set of laws".

DNA (deoxyribonucleic acid) is a substance on which the genetic information for all organisms is recorded.

Genetic code is a specific example of a code containing biochemical instructions for organisms. The code uses a 4-symbol alphabet, G, A, T, C. From which word is *genetic* derived? *Answer: gene.*

Genome (gē.nōme) is the complete set of genetic instructions for an organism. Think of it as a multi-volume encyclopedia or cookbook.

Mutation means a change or alteration. For these lessons, mutation is a change in the genome leading to a different characteristic in the organism. For example, in the movie *Teenage Mutant Ninja Turtles*, the Ninja Turtle mutants have an unusual appearance because of mutations to their genomes.

Participants should understand that "mutants" and "mutations" are not terms laden with negative connotations. Mutations are the agents of genetic change in evolution, affecting nearly every process in the body. Every person carries dozens of mutations in her or his genome.

Symbol is a letter, sign, or number used to represent something else. For example, the symbol "&" means the word *and*.

2

Adventure 2:1

Let's Learn the WHIF Code

In this adventure, participants select one of six genomes in Handout 1 and decode it using the WHIF Decoding Key, Handout 2. With the Decoding Key, participants identify the characteristics for the organism and then guess the name of the organism.

Directions

• Form teams of two. Give each team one genome from Handout 1 and one part of the Decoding Key from Handout 2.

• Read or paraphrase

Today you are WHIF scientists working on the WHIF code. Each of you has a genome and part of the Decoding Key—but not all of it. Your job is to decode the genes written in the WHIF code.

• Give teams about five minutes to decode the genes in one of the six genomes.

• Read or paraphrase

Scientists share information they learn. That is how they learned to read the genetic code. Many scientists worked on pieces of the large puzzle. Each of you as scientists has discovered a part of the WHIF code used today. Now share your team's part of the code with other teams of WHIF scientists to see if the entire group can decode the genes in the six genomes.

• Give teams another five minutes to solve the coded message and guess the name of the six organisms.

Do Ahead

(For every twelve participants)

Duplicate handouts 1 and 2

Cut along dotted lines

You will need

For Adventures 1, 2, 3 and 4: pencils, scratch paper, handouts

15 minutes

Answer Key for Handout 1

• Here are the solutions to the coded characteristics for the six organisms, as based on a selected part of their genomes.

Organism	Characteristics in Code
#1 elephant	trunk, tusks, floppy gray ears
#2 rose bush	thorns, green leaves, fragrant flowers
#3 tiger	fangs, striped fur, claws
#4 apple tree	tall, green leaves, branches, trunk, apples
#5 eagle	sharp beak, wings, feathers, claws
#6 shark	fins, gills, sharp teeth, scales

Ask these questions

What is your organism?

Can organisms possess some of the same characteristics, yet turn out to be different animals and plants?

Yes, both rose bushes and apple trees have green leaves.

Handout 1 for Adventures 2:1, 2:2 and 2:3

Genomes

Genome 1

9A%$!

9%H!H

T2GZZ?/WAX?/&XAH

Genome 2

95GA$H

WA&&$/2&XR&H

TAXWAX$9/T2G8&AH

Genome 3

TX$WH

H9AQZ&K/T%A

Y2X8H

Genome 4

9X22

WA&&$/2&XR&H

@AX$Y5&H

9A%$!

XZZ2&H

Genome 5

H5XAZ/@&X!

8Q$WH

T&X95&AH

Y2X8H

Genome 6

HYX2&H

TQ$H

WQ22H

H5XAZ/9&&95

Handout 2 for Adventures 2:1, 2:2 and 2:3

WHIF Decoding Key

X = a @ = b Y = c K = d	$ = n G = o Z = p 7 = q
& = e T = f W = g 5 = h Q = i	A = r H = s 9 = t % = u R = v
V = j ! = k 2 = l P = m	8 = w B = x ? = y J = z / = space

For Adventures 2:2 and 2:3, give participants all parts of the decoding key.

Adventure 2:2

Sending and Receiving WHIF Codes

• Read or paraphrase

Devise your own message using the code. Exchange messages with another group and decode the new message.

You will need

- pencils
- scratch paper
- handouts (1 set per team)

15-30 minutes

Adventure 2:3

Characteristics in WHIF Code

• Read or paraphrase

Write the characteristics in code for the fruits or vegetables used in Lesson 1 (either individually or in teams). Exchange the coded characteristics with another participant or team and decode the list of characteristics. Try to guess the fruit or vegetable.

You will need

- pencils
- scratch paper
- handouts (1 set per team)

10-20 minutes

Adventure 2:4

Your Own Code

• Read or paraphrase

Devise your own code. Write a message, and trade messages with another group. Try making up a more difficult code than the one used for Adventures 1, 2, and 3. For example, have a group of symbols represent one letter. Now, try to solve the other group's message without using the decoding key.

You will need

- pencils
- scratch paper

30-45 minutes

Ask these questions

- Could you solve the message if you didn't know the code? *Maybe, but it would be difficult.*
- How important is it to have the code? Can you read the message without the code? Once you have the code, is the message easier to read?

  Yes.

Adventure 2:5

Reading the DNA Code

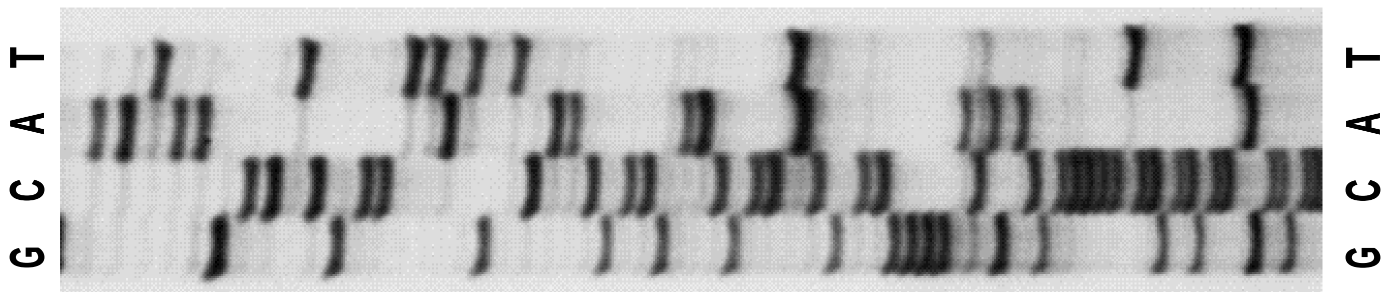
You will need

No materials

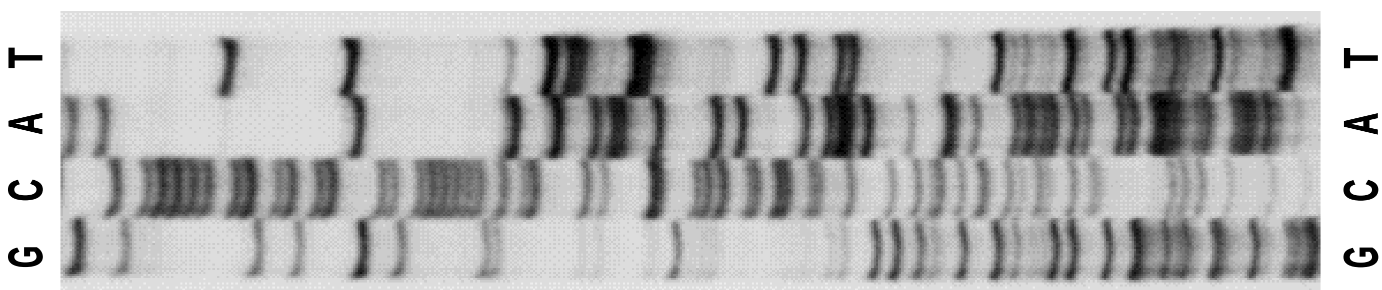
5-10 minutes

• Read or paraphrase

These photographs are called DNA sequencing gels. They show the sequence and order of the four symbols G, C, A, T (and the chemicals they represent) in the genetic code. If you were to run sequencing gels on the DNA from every person in the world, each of the gels would be different from all the others. You are you and you are unique. The only exception would be identical twins.



➥ Start reading here ➟



➥ Start reading here ➟

Do you have trouble reading the sequencing gels in these photographs? It is not surprising. After all, could you read words on this page using the twenty-six symbols of the English alphabet without several years of schooling?

Well people who study genes require years of training to learn how to prepare the gels and read the four symbols of the genetic code in these photographs.

Just for fun, try your hand at reading these gels. Start with the gel on top and begin reading at the left side where you see the arrow. Each dark band represents one chemical unit in the DNA. There are four different chemical units represented by the symbols or letters G, C, A, and T. Read the bands in order from left to right, just like English writing. The first eight letters are A, A, T, A, A, G, C, C. Sometimes, the letters are hard to read and scientists have to do the experiment again or in a different way.

Last Things Last

Additional Things to Think About

- What would happen if you made a mistake when decoding the genome? *The decoded gene would produce a different characteristic, or it would make no sense.* When a change occurs in the genome, the change is called a mutation. An example of mutations is all the different colored kernels (seeds) on Indian corn. Another example is the different, tasty, crunchy eating apples at the market. All these mutated originally from one strain of wild apple—the crabapple. (Show a crabapple alongside a modern apple, if you have them.)
- If the second gene for the elephant was mutated to 5%H!H from 9%H!H, what would the mutant gene characterize? *Tusks would change to husks.*
- Would the mutation change the whole animal or only part of it? *Only part of it.*
- The real genetic code in plants, animals, and humans has only 4 symbols (G, C, A, T), but it uses 3 at a time, enough for 64 different combinations (4 x 4 x 4)! Can you design a code using only 4 symbols to communicate information? The Morse code uses 2 symbols—a dot and a dash.

Hungry for More?

Even though it took people a long time to understand how the genetic code worked, people have been using codes for thousands of years. All languages are codes. Some people make up codes so they can send information without other people knowing what they are saying. During war, some armies use codes to communicate with their allies/friends while other armies employ people to decipher the code so they can understand what their adversaries/enemies are saying.

During World War II, the American army used Navajo Indian radio operators to transmit information in the Navajo language.[1] Other armies tried and tried to "break" the code the Americans were using, but they were never able to figure it out.

[1] Margaret T. Bixler *Winds of Freedom: The Story of the Navajo Code Talkers of World War II*, Darien Conn., Two Bytes Publishing Co., 1992.

Next time

We know information in gene recipes is recorded in a code on DNA, but what is DNA? Next time, we will learn more about DNA. We will do an experiment so you can see and touch DNA. Just keep this thought in mind until we meet again: DNA is in every organism—every plant, every animal, and every human. We eat DNA every day.

DNA for Dinner

3

Background for the Leader

In the first two lessons, participants learned that information to make an organism is contained in its genes; and collectively, genes are like a cookbook encyclopedia called the genome. They also know genes are recipes for things called proteins (more on proteins later), and genetic information in genomes is recorded on DNA in the genetic code. The bodies of almost all living organisms are made of tiny building blocks called *cells*. [See photographs 8, 9, 10, 11, and 12.] Cells are like the bricks that make a building. [See photograph 11.] You have about 100 trillion (100,000,000,000,000 or $1X10^{14}$) cells in your body. Each cell has a complete set of all your genes in its nucleus. [See photograph 12.] Your body is made of many different kinds of cells: heart cells, blood cells, nerve cells, and many others. Can you name some of the other cells in your body? *Muscle cells, epidermal (skin) cells, adipose (fat) cells.*

With few exceptions, DNA is found in every living cell. [See photograph 13.] Although information in one organism's DNA may differ from DNA found in other organisms, the chemicals of the genetic code, represented by the four symbols G, C, A, and T, are the same in all organisms.

Our bodies are made of chemicals, as are the food, water, and air we need to live. The foods and drinks that humans need to survive are made up of chemicals called proteins, carbohydrates (sugars and starches), fats, vitamins, and minerals. DNA is a chemical on which the coded information is recorded to build any organism. DNA is found in the nucleus of cells. [See photograph 12.]

Suggestions for the Leader

As an introduction, you may want to show some ways to record information, such as a cassette or a videotape, a computer disk and a book. DNA serves a similar function as a recording medium for genetic information.

For today's experiment participants will extract DNA from a cow's sweetbreads or from an onion. Available in supermarkets, sweetbreads are one of a cow's organs, called the *thymus*. DNA can be extracted from almost any part of any organism, but the thymus is one of the easiest. Try the DNA extraction beforehand to make sure it works properly. If you feel like a challenge, try a DNA extraction from an onion instead, but it may not work as well.

Words

chemical

cell

chromosome

We will learn

- Every organism is made up of tiny compartments called ***cells.***
- Every cell in all organisms contains a set of genes called a ***genome.***
- An organism's genome in each cell is recorded on a chemical called ***DNA.***
- The message coded on **DNA** determines what characteristics are present in each organism.
- **DNA** is a chemical, as are water, sugar, proteins, and vitamins.
- **DNA** can be isolated from any organism, including the foods we eat.
- Genome cookbooks are recorded in volumes called **chromosomes.**
- An organism gets one of each pair of **chromosomes** from its mother and the other from its father.

For review

characteristics
diversity
genes
organisms
code
DNA
genetic code
genome

Ask these questions

- What is the name of the code in which gene recipes are written? *The genetic code.*
- What is the name of the cookbook for an organism's gene recipes? *A genome.*
- About how many genes are in the human genome? *More than 100,000.*
- How many genes are in the wheat plant? *More than 100,000.*
- On what chemical are the genes in a genome recorded? *DNA.*
- How many symbols does the genetic code use? *Four.*
- Name some human characteristics that are recorded in our genomes. *Eye and hair color, height, skin color.*
- Why would nature choose this code for recording the information to make organisms? *Scientists don't know.*

First Things First

Discussion with Participants

We know that diversity of life results from differences in the genes present in every organism and that each gene is a recipe for a single protein. (We'll talk more about proteins the next time we get together.) The gene recipes are like a cookbook encyclopedia called the *genome*. We also know the genome is recorded on DNA in the genetic code. What exactly is DNA?

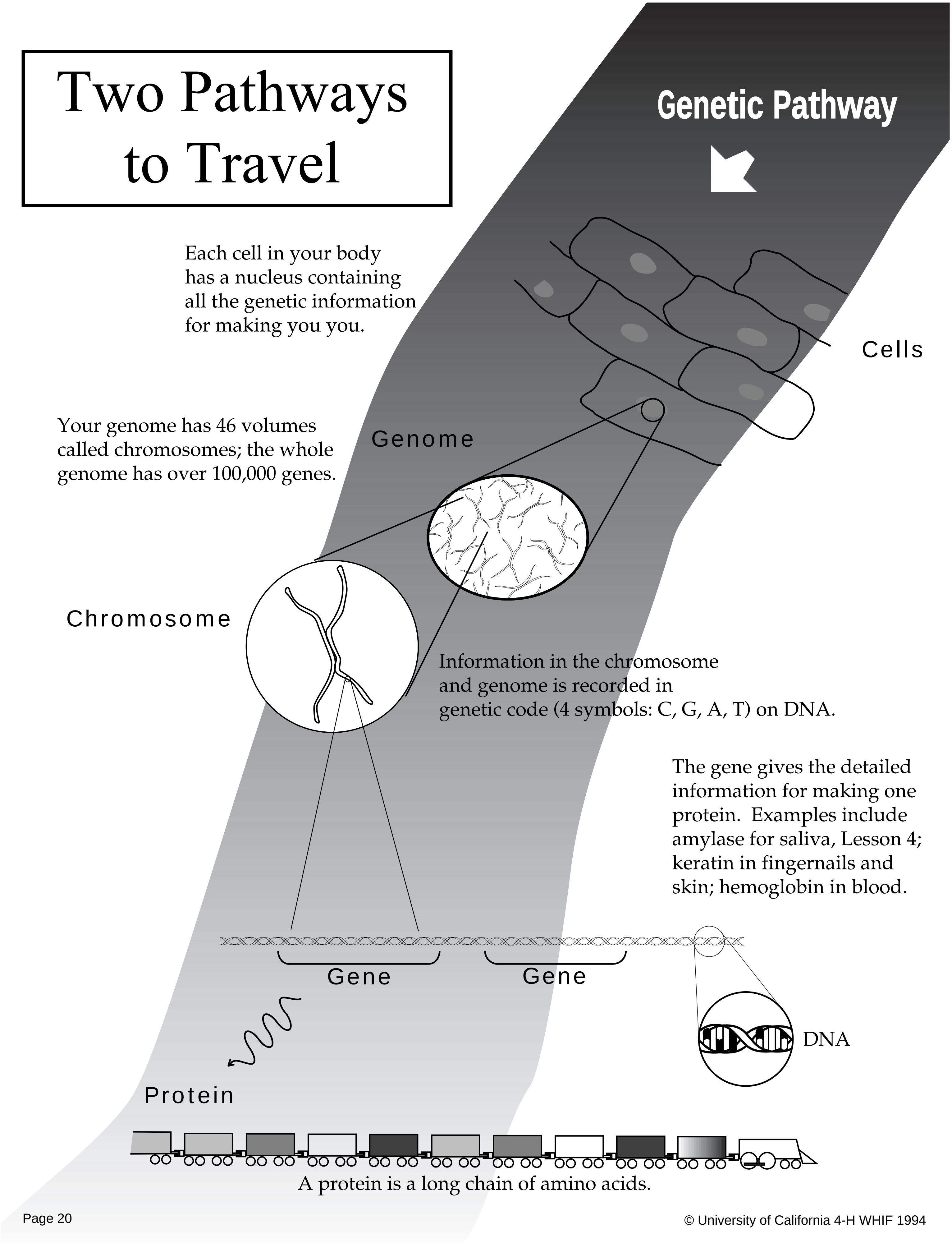
DNA is a chemical. Our bodies are made of chemicals. The food, water, and air we need to live are made of chemicals. Many of the chemicals that make up our bodies and food we eat consist of long chains of smaller chemicals. Starch consists of a long string of sugars; proteins consist of long strings of amino acids. DNA consists of a long string of smaller chemicals too. In fact, DNA consists of four different chemicals. As you learned in the decoding lesson, scientists use the symbols G, A, T, and C to represent these chemicals.

If we know all organisms contain a genome, then all organisms must contain the chemical DNA also. If we eat parts of many different organisms, then we must be eating lots of different DNAs, too. Everything we are made of and everything we eat—such as water, protein, sugar, fat, and vitamins—are chemicals.

In the last Lesson, we talked about genomes. We know that most genomes are not small. For example the human genome is made up of 46 different volumes, more like a cooking encyclopedia than a cookbook. [Refer to the graphics on pages 20 and 21.] We call each single volume a **chromosome,** and each of us possesses 23 pairs of **chromosomes** for a total of 46. We get one chromosome of each pair from our mother and one from our father. Each chromosome is a single piece of DNA. In the human genome, and the genome for tomato, there are over 100,000 genes. Each human chromosome has more than 2,000 genes. This is like having 2,000 recipes in each volume of our genome cookbook. Not all genomes are organized like the human genome. For example, the tomato genome is composed of 12 chromosome pairs, and the corn genome is made up of 10 pairs of chromosomes.

- Use the Handout on the next two pages to illustrate the concepts discussed. Emphasize these points.
  - ☆ A genome is like a cookbook encyclopedia containing the information for making an organism.
  - ☆ The genome is divided into volumes called chromosomes. The human genome has 46 chromosomes.
  - ☆ A chromosome contains thousands of genes and is made from the chemical DNA.
  - ☆ A gene is a recipe for making a protein.
  - ☆ Genetic information is recorded in code on DNA.
  - ☆ DNA is found in cells of living organisms — plants, animals, humans.

Two Pathways to Travel



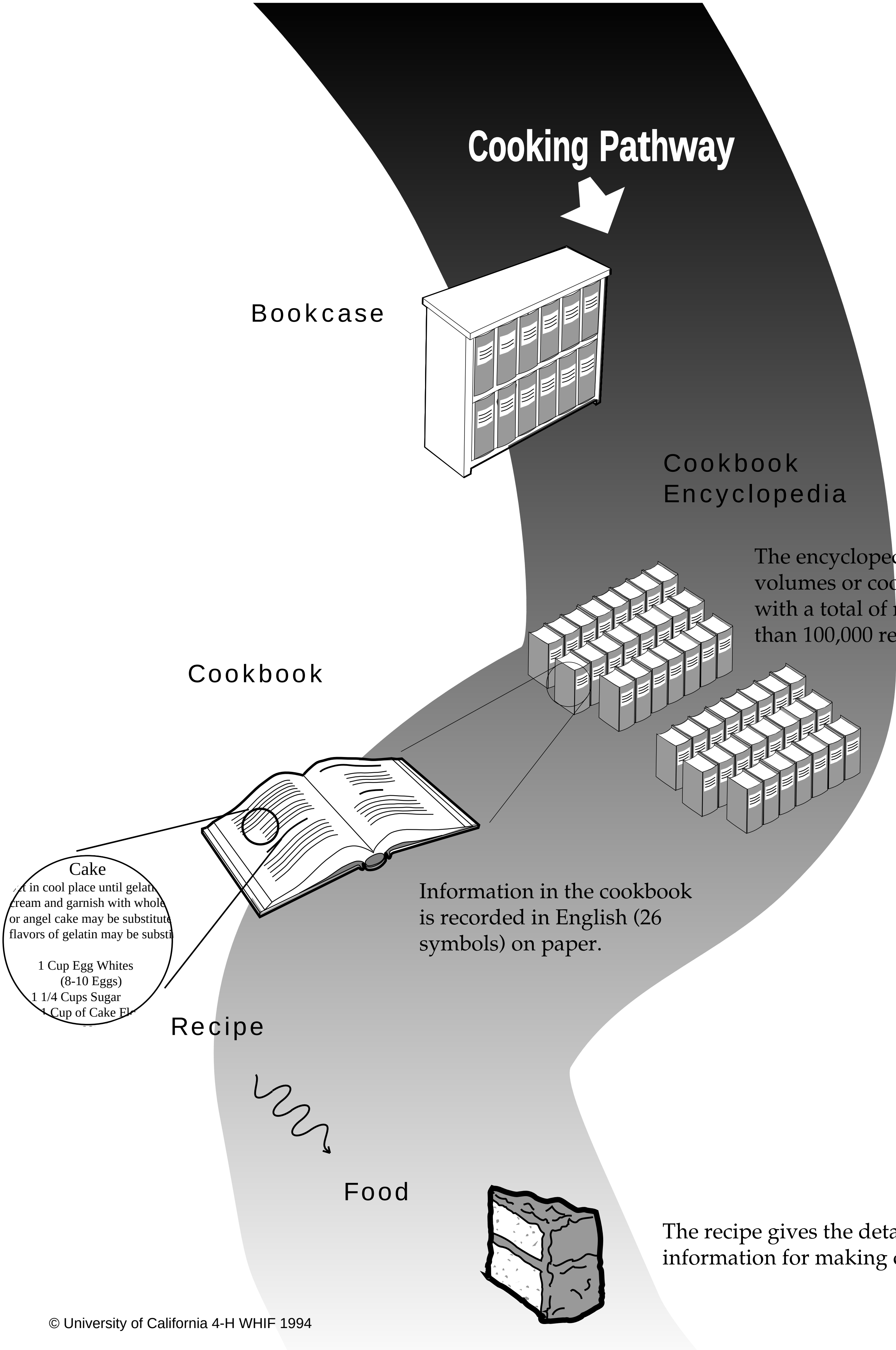
Each cell in your body has a nucleus containing all the genetic information for making you you.

Your genome has 46 volumes called chromosomes; the whole genome has over 100,000 genes.

Information in the chromosome and genome is recorded in genetic code (4 symbols: C, G, A, T) on DNA.

The gene gives the detailed information for making one protein. Examples include amylase for saliva, Lesson 4; keratin in fingernails and skin; hemoglobin in blood.

A protein is a long chain of amino acids.


Cooking Pathway
Bookcase
Cookbook Encyclopedia
The encyclopedia has 46 volumes or cookbooks, with a total of more than 100,000 recipes.
Cookbook
Cake
1 Cup Egg Whites
(8-10 Eggs)
1 1/4 Cups Sugar
Information in the cookbook is recorded in English (26 symbols) on paper.
Recipe
Food
The recipe gives the detailed information for making cake.

3

Adventure 3:1

DNA, Paper, Tape

As an introduction to DNA for Dinner, share ways information is stored.

Directions

• Read or paraphrase

Information is recorded and stored in many ways. Here are some examples of ways to store information in the 20th Century: videotape, book or encyclopedia, photographs, telephone answering machine, audio cassette tape, and computer diskette.

I have five books here. In what language are they written? [Give participants time to examine the books.] What symbols are used? [Give participants time to answer.] They are written in the same language, such as English, using the same 26 symbols or letters of the alphabet. With Spanish, there are 30 symbols.

Do they contain the same stored information or printed messages? [Give participants time to answer.] No, each book contains different messages. Letters and many words may be the same, but the messages are different.

DNA works in a fashion similar to the print of text on paper in a book. It is the recording medium for genetic information in the genome, just like the letters in the alphabet are the recording medium for the information in these books. The four symbols in the genetic code, and the medium, DNA, are the same in every organism: plant, animal or human. But the order in which the symbols are arranged in each organism is different. The order determines the content of the stored messages, and is unique to each organism.

In the same manner, the order in which the symbols (26 letters) of the English alphabet are arranged determines the content of the stored messages in a book.

• In your discussion with participants, use the Reference Guide on the next page for other examples of how information is stored. Participants may have additions to the examples in the *Reference Guide.*

Do ahead

• Review *Reference Guide* on following page.

You will need

• Examples of ways information is recorded, such as:

videotape
photographs
computer diskette

• Five books, all in the same language, for example, either all in English or all in Spanish.

10-15 minutes

Adventure 3:2

Tour of an Onion

Directions

• Read or paraphrase

Today we are taking a tour of this onion. [Pass around an onion.] I am going to cut the onion just as you see in photographs 1, 2, and 3. Now I am cutting a small slice (photograph 4) and removing a very small square of onion (photographs 6 and 7). If we had a microscope, this thin piece of onion would look like this. [Show photographs 8, 9, 10, and 11.] The pale lumps in two cells in photograph 11 are nuclei, which house the genome. Each arrow in photograph 12 points to a nucleus. Inside the nucleus are chromosomes containing genes, whose information is stored on the chemical DNA.

You will need

photographs 1 - 13
onion
paring knife
tweezers
cutting board

15 minutes

Reference Guide for the Leader for Adventure 3:1

Ways to Store Information

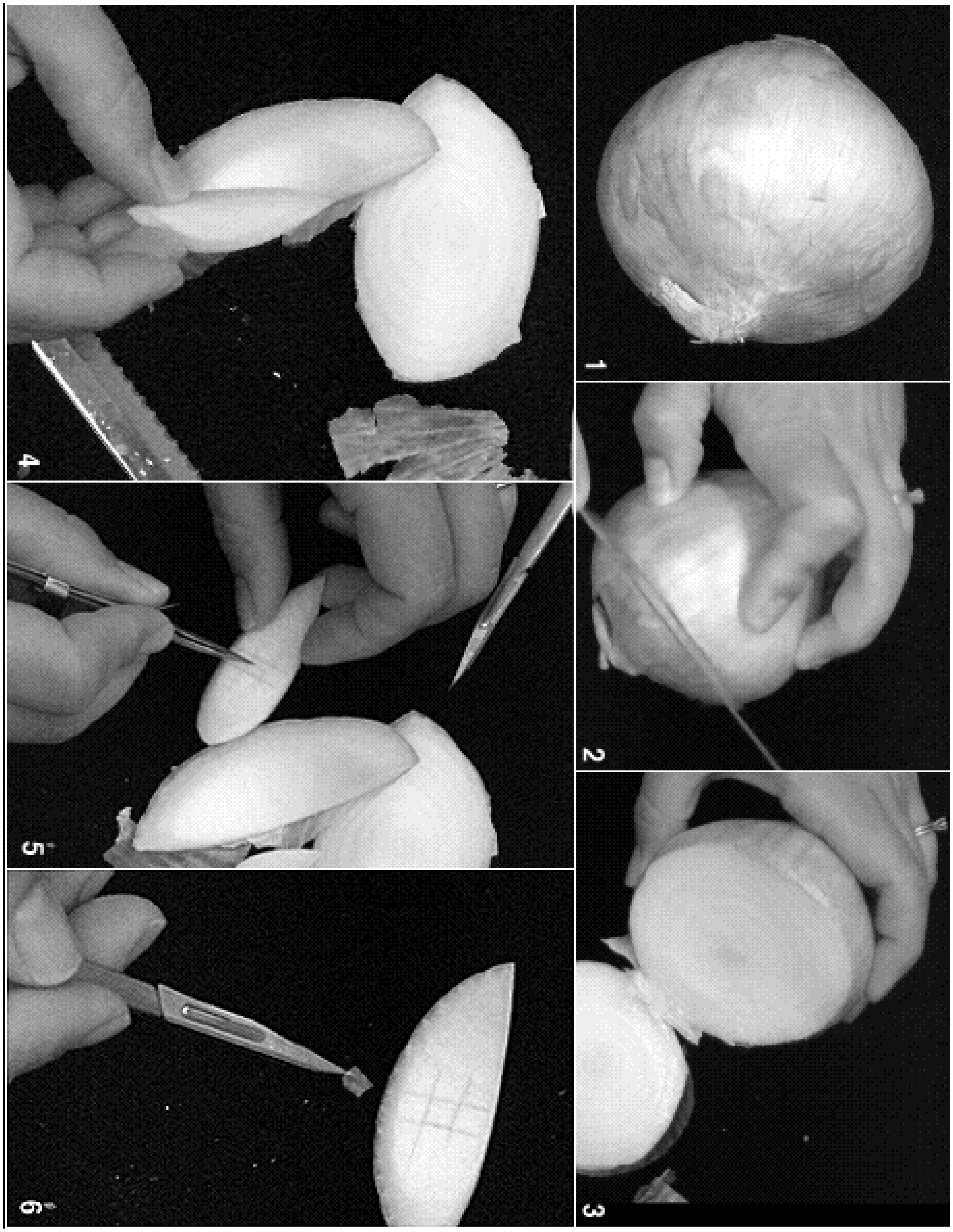
Stored information or stored messages	Code / Symbols or Format	Medium
Book or encyclopedia	English language with 26 symbols called letters or Spanish language with 30 symbols called letters or [Identify another language.]	Print on paper
Photograph	Layers of chemicals	Photographic paper, film or negative
Videotape	VHS, Beta	Magnetic tape
Computer diskette	Computer languages with hundred of symbols called commands	Magnetic tape
Genome (plant, animal, human)	Genetic code with 4 symbols (G, C, A, T)	DNA

3

Adventure 3:2

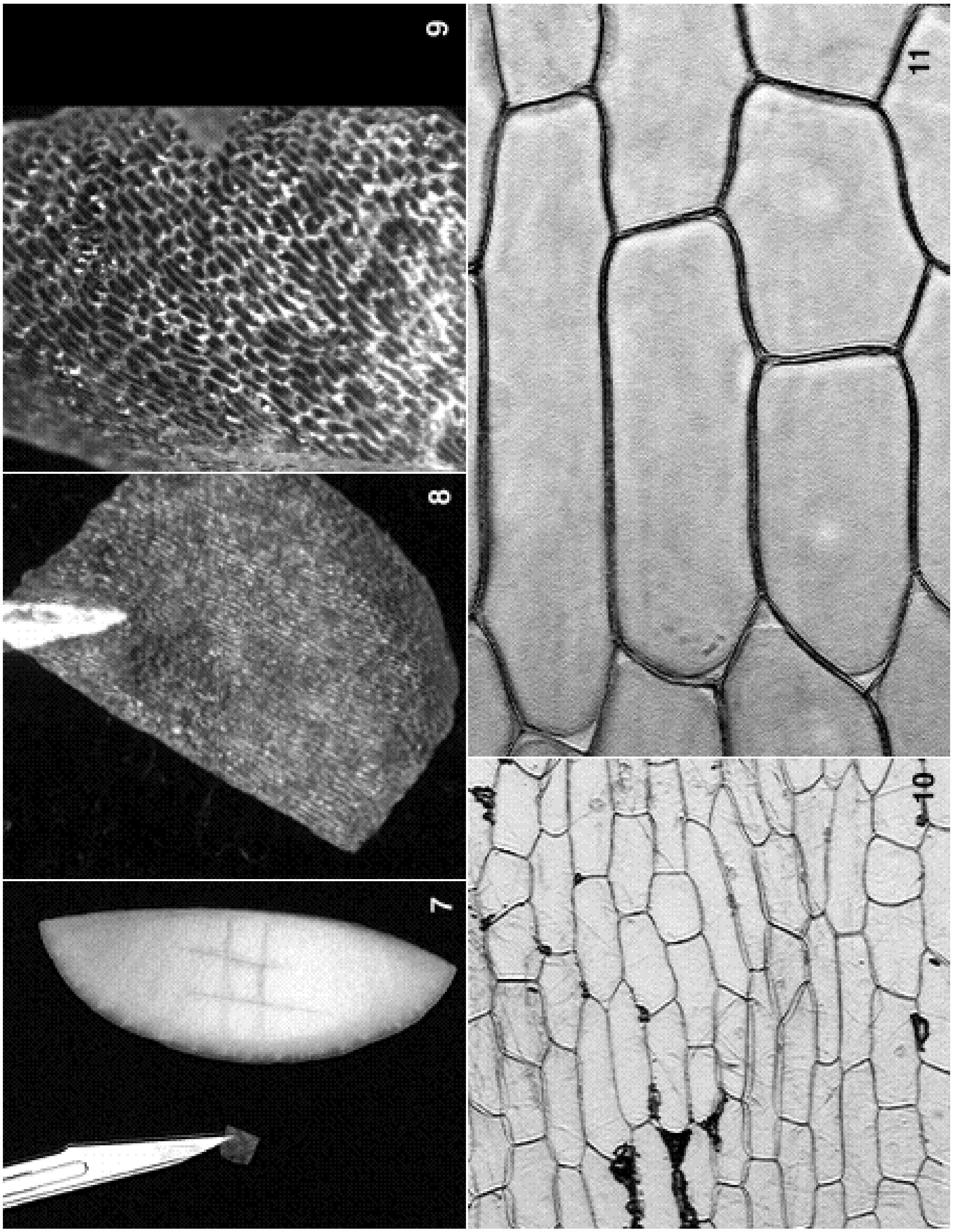
Photographs 1-13 of the onion cells were taken by Dr. Steven Ruzin in the Plant Biology Department on the University of California, Berkeley campus for the 4-H WHIF Project.

Tour of an Onion



Photographs 1 - 6

These six photos show the preparation of an onion sample for viewing under the microscope.



Photographs 7 - 11
The small square of onion tissue (photo 7) is enlarged in photo 8. Individual cells from the small square of onion tissue can be seen in photos 9, 10 and 11. The magnification for photo 11 is 200X.

Adventure 3:2

Photograph 12
The cells in photo 11 are now magnified to 500X. Photo 12 shows all or part of eight onion cells. Arrows point to the nuclei in two of the cells.

Adventure 3:2

Photograph 13

The cell in the center of photo 12 is now magnified to 1000X. You now see the nucleus with its strands of onion DNA, as viewed through an electron microscope.

Adventure 3:3

DNA from Thymus

☑ Do ahead

- Practice the procedure.
- Store alcohol in freezer overnight.
- Chop thymus.

You will need

(For each team)

1 copy of directions

1 oz chopped thymus

1 Ziploc® freezer bag (2.7 mm thick)

1 Tbsp sand, and water

several layers of cheesecloth or 1 tightly woven washcloth or clean rag

1 Tbsp dishwashing detergent

1 small, clear glass (1-3 oz)

isopropyl (rubbing) alcohol

twist-tie or paper clip

table salt

60 minutes

Option 1

• **Read or paraphrase**

In the onion photographs, you saw DNA inside a cell. And we talked about the fact that in every organism, cells contain DNA. Have you ever wondered what DNA looks and feels like? Now is your chance to find out.

Directions

1) Chop a piece (1 oz) of thymus tissue as finely as possible and place in a Ziploc® freezer bag (2.7 mm thick).

2) Add 1 Tbsp sand and enough water to cover the mixture.

3) Seal the bag, and grind the contents by rubbing it between your hands until the water is very cloudy.

4) Strain the contents of the bag through several layers of cheesecloth, a washcloth, or a clean rag (tight weave is best) by gently squeezing the cloth.

5) Add 1 tsp dishwashing detergent to the solution, and shake it up. Let stand 5-10 minutes.

6) Pour some of the mixture into a small, clear glass or other small, clear container to about 1/2 full. A liqueur glass works well. Add 1-3 pinches of salt and shake again.

7) Let the mixture sit for a minute, then carefully add ice cold isopropyl alcohol (stored in the freezer) until the glass container is 3/4 full. The alcohol should float on top of the thymus mixture.

8) At the layer between the thymus juice and the alcohol, you will see a whitish, snotty-looking substance (see Figure 1). This is DNA. Tear the paper off a twist-tie and make a small hook on one end. Reach in and hook the stringy DNA, and pull it out. Sometimes it helps to stir the tie gently to wind the DNA onto your hook.

• Share information in "What's Going on Here?" on the following page.

Congratulations, you're on your way to becoming a genetic engineer!

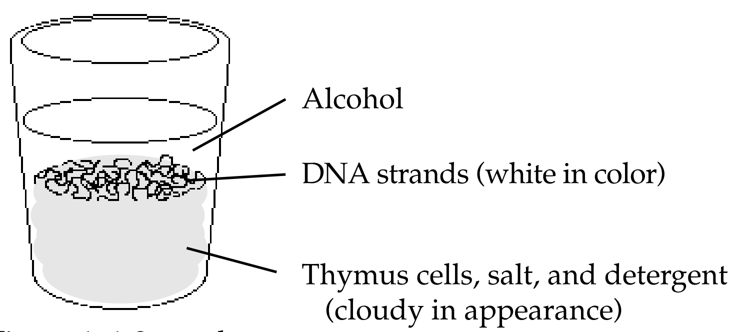


Figure 1: 1-3 oz. glass

Brand names are used as examples only; this is not an endorsement of any product.

DNA from Onion

Option B

Directions

• Read or paraphrase

1) Chop 1/2 of a small onion (should be fresh)[1] into very fine pieces. Add 1/4 cup water, 1/2 tsp salt and chop fine in a blender for 30 seconds at low speed. Place mixture in a Ziploc® bag with 1 Tbsp dishwashing detergent and 1/8 tsp meat tenderizer. In a pan with hot water and a thermometer, heat the plastic bag containing the onion mixture at 60° C (140° F) for 10 minutes. Add 2 Tbsp sand and grind between hands or on a flat surface until the onion is ground to a fine slurry.

2) Strain the well-blended onion through a washcloth, a clean tightly woven rag, or several layers of cheesecloth.

3) Add some of the strained mixture to a small, clear glass or other small clear container until it is 1/4 full. (A liqueur glass works well.) Add a pinch of salt, cover and shake hard for 1 minute.

4) Let sit for a minute. Then carefully add cold isopropyl alcohol that has been in the freezer overnight until the container is 3/4 full. The alcohol should float on top of the onion mixture.

5) At the layer between the onion juice and alcohol, you will see a whitish, snotty-looking, substance. (See Figure 1, page 28.) This is DNA. Tear the paper off a twist-tie, and make a small hook on one end. Reach in and hook the stringy DNA, and pull it out. Sometimes it helps to stir gently to wind the DNA onto the hook. You can invert the glass once or twice to mix the layers if you want.

Congratulations, you're now on your way to becoming a genetic engineer!

Do ahead

• Put alcohol in freezer overnight.

You will need

For each team

1 copy of directions

1/2 small fresh white onion (about $^1/_3$ cup, chopped)

1/4 cup water

1/2 tsp salt

1 blender

1 Ziploc® freezer bag (2.7 mm thick)

1 Tbsp dishwashing detergent

1/8 tsp meat tenderizer

2 Tbsp sand

cloth for straining

isopropyl (rubbing) alcohol

1 twist-tie or paper clip

1 small, clear glass (1-3 oz)

candy or meat thermometer

source of hot water

60 minutes

What's Going on Here?

When you chop the onion (or thymus) in the blender, you are breaking it up into small groups of cells. Mixing the onion in the plastic bag with sand breaks open the cells and allows the nuclei (more than one nucleus) to spill out. The detergent dissolves the wall of the nuclei and allows the DNA to spill out in long chains, called *chromosomes*. You will see a white, snotty-looking layer between the alcohol layer on top and the onion mixture below. You will be able to pull out the long chains made of the chemical DNA with a twist-tie hook.

If you over-blend the onion, the nuclei will break open, and the DNA chains will be ripped to small pieces by the blender. You will see the white, snotty-looking layer, but you will not be able to remove the short DNA chains with your twist-tie hook.

[1] Look for a firm white onion with a tight outer skin and inner layers. Yellow onions dehydrate faster than the white variety.

3

Last Things Last

Next time

We know the DNA isolated today has gene recipes for proteins recorded in genetic code. Next time we will learn a little more about proteins and what they do.

Ask these questions

• Did you eat DNA for breakfast and lunch today? *Yes, most foods contain DNA. The foods that do not are highly processed foods such as jelly beans and lollipops.*

• What foods contain DNA? *Meat, fruit, fish, vegetables, poultry, beans, grains, nuts, seeds. These foods are made of cells, as you see in photographs 10, 11, and 12. Each cell has a nucleus containing DNA.*

• Why would scientists want to separate DNA from food? *Separating DNA from an organism can help scientists understand how cells work.*

Word Rap

Chemicals are the buidling blocks of all living, and nonliving things. Symbols in the genetic code are the building blocks of the genome, just as bricks are the building blocks of a house.The word *chemical* is related to the words *chemistry*, *chemist*, and *alchemy*.

Encourage participants not to think of chemicals as "good" or "bad." Instead, the usefulness of a chemical depends on how you use it and how much you use. For example, participants will probably agree that water is essential for life. Yet too much water during the rainy season can cause flooding and therefore a disaster. Too little water leads to a drought. Whether water is "good" or "bad" depends on how it is used and how much.

Chromosome is a long strand of DNA, located in the nucleus of a cell. People have 46 chromosomes, arranged in 23 pairs, in each cell. The word *chromosome* comes from "chromo," meaning *color*. "-some" is a suffix meaning "body," so a chromosome is a colorful body. This is because scientists often use colored substances that stick to DNA so that they can see it.

Cell is the basic building block of every organism just like bricks are the basic building blocks of a building. More broadly, *cell* means "a small room or apartment".

Let's Build an Organism

4

Background for the Leader

Participants learned genes contain coded information for making **proteins**. A human genome contains more than 100,000 genes. Coded information in a single gene tells the organism how to make a single protein. And these **proteins** help produce the organism's characteristics. **Proteins** are chemicals; each accomplishes a different task. Some **proteins** are used to build the organism's body, while others work to keep it going. For example, in animals, **proteins** direct the building of all cells, such as muscle and bone, send messages from one nerve cell to another, and perform thousands of other tasks. In plants, some **proteins** direct the growth of leaves, fruit, and flowers, while other proteins protect the plant from sunburn. Still other proteins help the plant capture the sun's energy and turn it into food for the plant.

Suggestions for the Leader

This lesson is designed to show participants what kinds of jobs proteins do. Start with *Adventure 4:1, Jell-O® and Pineapple*, so the gelatin can set while you do other adventures.

Adventures 4:3 and 4:4 are related. Adventure 4:4, *Saliva Protein*, just demonstrates the starch breakdown in a different way.

Words

amino acid

amylase

carbohydrate

digest

protein

starch

We will learn

- Genes contain information for making **proteins.**
- Different **proteins** do different jobs in our bodies.

Brand names are used as examples only; this is not an endorsement of any product.

4

First Things First

Discussion with Participants

For review

chemical

cell

chromosome

DNA

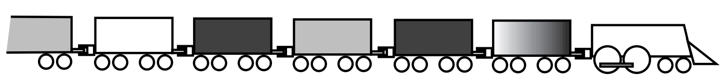
Ask these questions

- What did you isolate from sweetbread or onions last time? *DNA.*
- Which foods contain DNA? *Almost all foods, such as fruit, beans, vegetables, and meat, contain DNA.*
- How many organisms contain DNA? *All organisms have DNA, except some viruses.*

What is a **protein**? You know your **genome** encyclopedia has over 100,000 genes, and each gene is a recipe for building a chemical called a **protein**. With more than 100,000 genes, our bodies make over 100,000 different proteins.

We also know it takes many **proteins** working together to produce complicated characteristics like eye, hair, or skin color. **Proteins** accomplish many tasks in our bodies. Some **proteins** hold us together. Some make our muscles work. Some **proteins** change chemicals in our bodies into other chemicals. For example, today's Adventure 4:4 looks at a protein called **amylase,** which changes **starch** into sugars. This change happens in our mouths when we eat starchy foods like bread or potato.

Proteins are long chains of smaller chemicals called **amino acids** all hooked together like a train. There are only 20 different **amino acids**, but they can be joined in different combinations to make thousands of different **proteins**. A single protein might be a chain of 100 or 1,000 **amino acids**. The number and sequence in which **amino acids** are hooked together determine what that **protein** does. We know the recipe for a single protein is written on the chemical DNA in special **symbols** called the **genetic code**. Every three symbols of the **genetic code** represent one **amino acid**. When your body needs to produce a **protein**, it reads that gene three symbols at a time, hooking each new **amino acid** to the chain of amino acids. When all **amino acids** are hooked together like the cars of a train, the result is called a **protein**.



The genetic code for making **proteins** is the same for all organisms: plants, bacteria, and animals including people. It's the universal language of life!

Proteins you may know include *hemoglobin*, a **protein** in blood that holds on to oxygen. *Keratin* is a **protein** found in hair and in fingernails. You may have seen the word *keratin* on shampoo labels. *Gelatin* is a **protein** that makes Jell-O® hold together. As you will see from today's experiment, a **protein** in our saliva called **amylase** breaks up or **digests** the starch we eat.

Brand names are used as examples only; this is not an endorsement of any product.

Word Rap

Amino acid is a building block of proteins. Amino acids are hooked together like the cars of a train to make a protein.

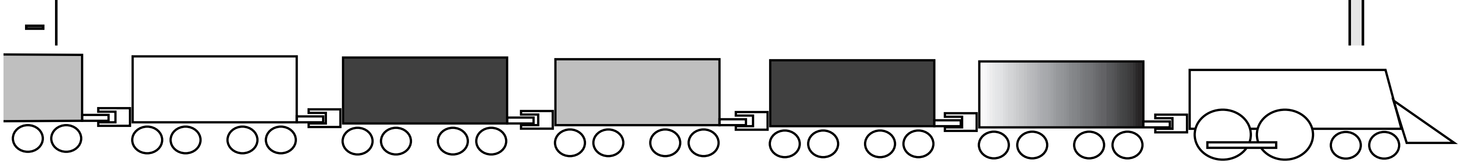
Amylase is a protein found in both plants and animals. It "digests" (breaks down) starch into sugars.

Carbohydrate is a major component of food, including starches, sugar, and fiber.

Digest means to break down food, so it can be used by the organism.

Starch is a type of carbohydrate made of many sugars linked together in a chain.

Protein is a word coined by a Dutch chemist in the 1830s. It is derived from a Greek word meaning "primary." Proteins, comprised of long chains of amino acids, are the "primary" building blocks of the body. Here is a cartoon sketch of a protein.



Adventure 4:1

Jell-O® and Pineapple

> ## *You will need*
>
> 1 box of Jell-O®
>
> 2 bowls
>
> 1 fresh pineapple
>
> 1 small can of pineapple, drained
>
> 10-15 minutes

Directions

Make Jell-O® at the beginning of the session. Follow directions on Jell-O® box. Then pour half into each of two bowls. To one bowl add chunks of fresh pineapple. To the other bowl add canned pineapple. Refrigerate. Observe results after other adventures are completed.

More Discussion

• Read or paraphrase

Have you ever wondered why Jell-O® is wobbly? The ingredient in Jell-O® that makes it wobbly is actually a **protein** called gelatin. When it is dissolved in hot water and allowed to cool, the **protein** chains link together to make what is called a *matrix*. Other examples of matrices are sponges, fishing nets, and spider webs. The matrix is flexible and makes the Jell-O® wobbly. Water is trapped inside the matrix just like water is trapped in a sponge. When the Jell-O® solidifies, we say the gelatin has "set." It means the **protein** in the gelatin has linked together.

Sometimes **proteins** can't do their jobs like making Jell-O® solidify. There is a **protein** in fresh pineapple that prevents the gelatin from linking together to make a matrix. The Jell-O® with fresh pineapple can't set. If canned pineapple is used, the gelatin can set normally. Here is why. To make a good matrix, the protein chains must be long. Fresh pineapple has a special protein that breaks the long gelatin protein chain into short pieces. The gelatin protein is still there, but the pieces are too short to form a matrix and make the Jell-O® set. The heat of canning changes the fresh pineapple protein so it cannot break up the gelatin protein chain. Jell-O® with canned pineapple will set. Fresh papaya has the same special protein as fresh pineapple. Jell-O® will not set with fresh papaya.

From Code to Protein

• Read or paraphrase

In Adventure 4:1 we worked with the gelatin **protein** in Jell-O®. In this adventure, we will look at how the code helps the gene use its information to make a **protein**.

• **Directions**

1) Cut secret messages in Handout 1 into 6 strips for up to six participants. Give one strip to each participant. Have participants cut out the 12 shapes in eight copies of Handout 3.

2) Select one of the messages in Handout 1. These messages are part of a real gene in rice. Read the message in groups of 3 symbols at a time, instead of one symbol at a time, as we did in Lesson 2, when we worked with codes. Use the Decoding Key *(Answer Key for the Leader)* to find out which shape represents the group of symbols. Find the first letter in the column marked "first letter." Find the "second" and "third letters" from the groups beside the "first letter." For example: CGC is the fifth shape and AAA is the first. Each shape represents an amino acid.

3) After identifying the first shape, read the next 3 symbols in the code. Identify the shape the next 3 symbols stand for, and connect it to the first shape. Continue until you have made the entire chain of shapes coded in the message. This chain represents one protein, a string of amino acids all hooked together like the cars of a train or the words in a sentence.

• The Answer Key for the six secret messages follows Handout 1.

You will need

For up to 6 participants

Handout 1 (1 copy)

Handout 2 (3 copies)

Handouts 3 (8 copies)

scissors

tape

40-60 minutes

Handout 1 for Adventure 4:2

Secret Messages[1]

1) CGC AAA GAG AAA TAT GCT CCC TTT GTA GAC ATT CTC CGG GCT GCT CAG

2) TGG GCA ATC GAA CAG CTT GTT GAT TGA CAC ACC TAC AGC AAC TTT GTT

3) CTT CCG CAT TAT TTT GAG AGC CTT CAT GGG CTC TAA TCA TCC CAT AGA

4) AAG GCA CGA TTA TAT GTG ATG CCA ATT GGT GGT CAG GTT GTG TAC ATT

5) TTG GAC CAA GTC CGC TCT AGG GAG AAT GAG ATG CTT CGT TTT GAT GTC

6) AGG CCA TTC CTG CGA ACA TAC ACT GAG GAT GTT TCA AAC CGA ATT ATC

[1] These six DNA sequences are actual sequences found in the rice genome.

Secret Messages[1]

1)

CGC	AAA	GAG	AAA	TAT	GCT	CCC	TTT	GTA	GAC	ATT	CTC	CGG	GCT	GCT	CAG
5	1	7	1	11	8	5	12	9	7	3	6	5	8	8	4

2)

TGG	GCA	ATC	GAA	CAG	CTT	GTT	GAT	TGA	CAC	ACC	TAC	AGC	AAC	TTT	GTT
12	8	2	7	4	6	10	8	11	3	1	10	2	1	12	10

3)

CTT	CCG	CAT	TAT	TTT	GAG	AGC	CTT	CAT	GGG	CTC	TAA	TCA	TCC	CAT	AGA
6	5	4	11	12	7	2	6	4	9	6	10	11	11	4	2

4)

AAG	GCA	CGA	TTA	TAT	GTG	ATG	CCA	ATT	GGT	GGT	CAG	GTT	GTG	TAC	ATT
1	8	5	12	11	9	3	4	3	9	9	4	10	9	10	3

5)

TTG	GAC	CAA	GTC	CGC	TCT	AGG	GAG	AAT	GAG	ATG	CTT	CGT	TTT	GAT	GTC
12	7	3	9	5	11	2	7	1	7	3	6	6	12	8	9

6)

AGG	CCA	TTC	CTG	CGA	ACA	TAC	ACT	GAG	GAT	GTT	TCA	AAC	CGA	ATT	ATC
2	4	12	6	5	1	10	2	7	8	10	11	1	5	3	2

[1] These six DNA sequences are actual sequences found in the rice genome.

Decoding Key

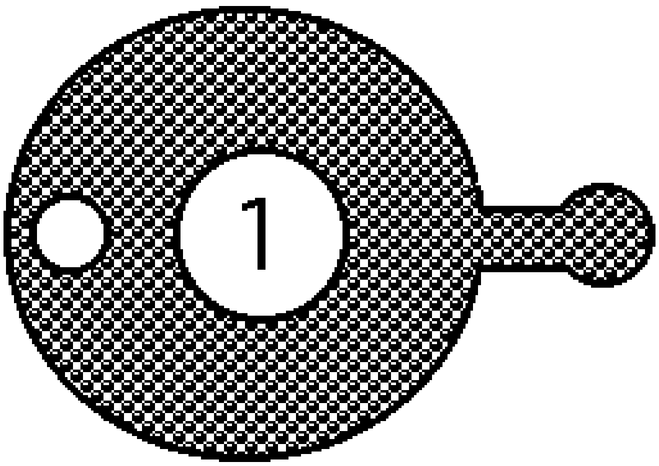
Adventure 4:2 Handout 2

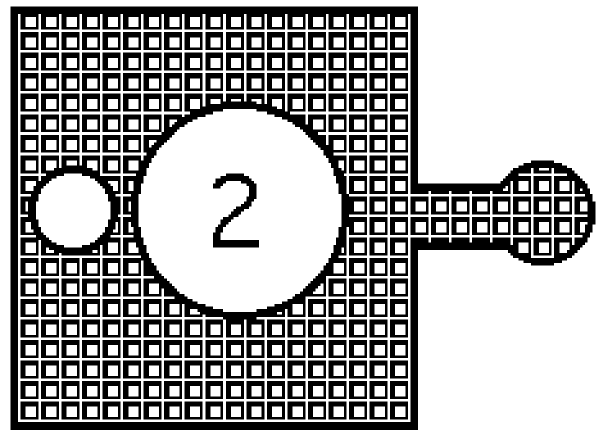
First Letter	Second Letter	Third Letter	Shape
A	A	A	1
		C	
		G	
		T	
	C	A	
		C	
		G	2
		T	
	G	A	
		C	
		G	
		T	
	T	A	
		C	
		G	3
		T	
C	A	A	
		C	
		G	4
		T	
	C	A	
		C	5
		G	
		T	
	G	A	
		C	
		G	
		T	6
	T	A	
		C	
		G	
		T	

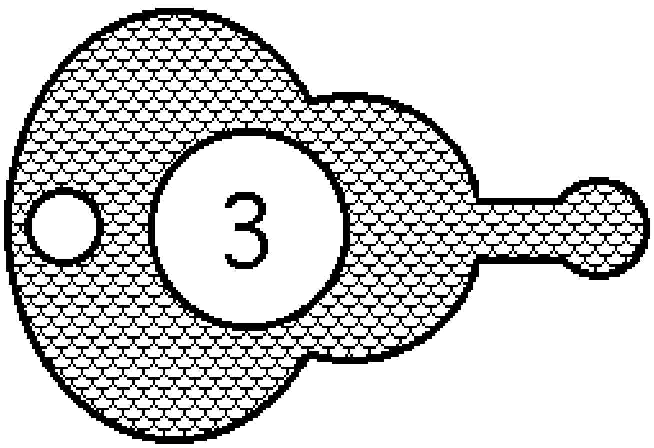
First Letter	Second Letter	Third Letter	Shape
G	A	A	7
		C	
		G	
		T	8
	C	A	
		C	
		G	
		T	
	G	A	
		C	
		G	9
		T	
	T	A	
		C	
		G	
		T	10
T	A	A	
		C	
		G	11
		T	
	C	A	
		C	
		G	
		T	
	G	A	
		C	
		G	12
		T	
	T	A	
		C	
		G	
		T	

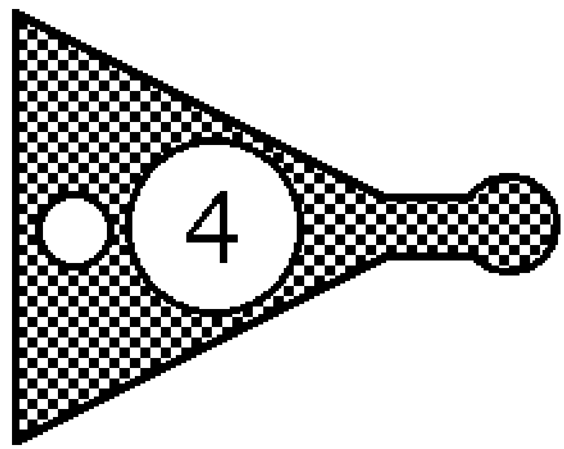
Amino Acid Shapes 1-6

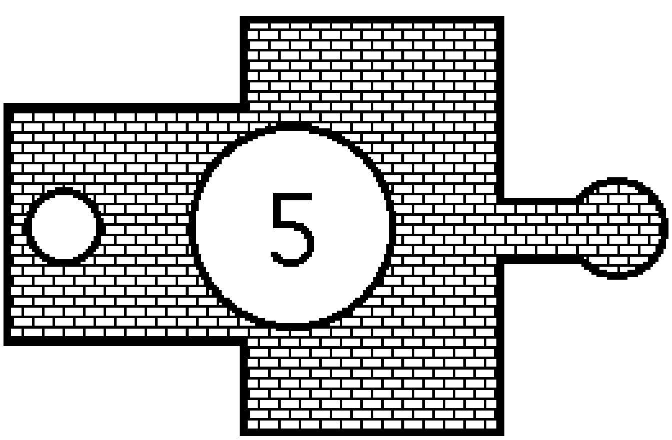
Adventure 4:2 Handout 3

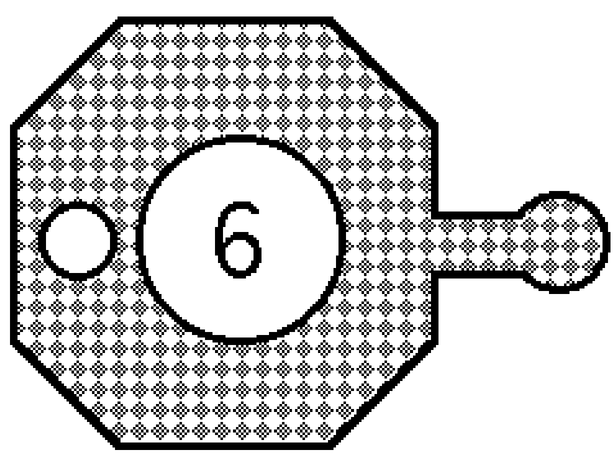






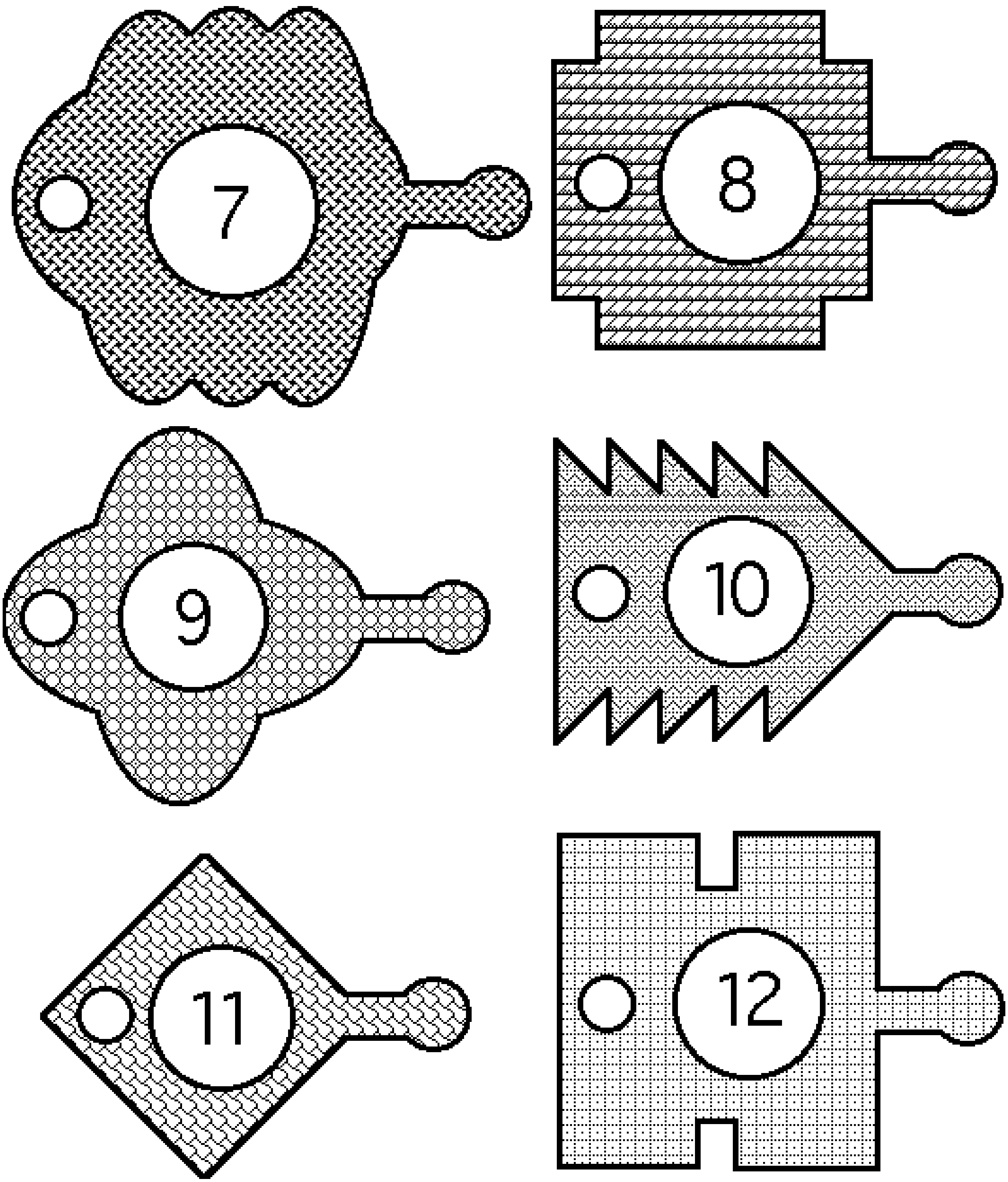






Amino Acid Shapes 7-12

Adventure 4:2 Handout 3



What's in Spit ?

Directions

• Read or paraphrase

1) Chew a saltine cracker in your mouth but don't swallow. What does it taste like? *Probable answer: Salty.*

2) Continue chewing the cracker. Don't swallow. After a few minutes you may notice the flavor changing. Now the cracker tastes sweet. Why? *The amylase in your saliva **digests** the **starch** into sugars. Sugars taste sweet. Starch doesn't, though it is a long chain of sugars hooked together like the cars in a train.*

You might want to use unsalted crackers or matzo that contain less sugar and salt as initial ingredients. These crackers work better in this adventure because they do not have an initial salty or sweet taste. When you get a sweet taste, you will know it is due to the breakdown of starch into sugar.

You will need

Saltine crackers or matzo (1 cracker per participant)

napkins

15 minutes

Discussion with Participants

• Read or paraphrase

An example of a protein we have in our bodies is **amylase**. This **protein** is found in saliva. It digests **starch** (long chains of sugars) into single sugars. Humans have **amylase** in saliva (spit) because saliva gland cells can make **amylase** from the **amylase** gene in our genome. Our bodies use **amylase** in the mouth to begin breaking down starchy foods we eat, so our bodies can get energy out of the starch.

Humans have **amylase,** but other organisms have **amylase** too, such as the barley that we use to make breakfast cereals, bread, and beer. The barley **amylase** does the same job as the **amylase** in human saliva. It breaks down starches in the seed so the young plant can use them for energy. Humans and barley both have a gene with information to make this **protein**. The gene for **amylase** in barley would work in humans, and vice versa. No matter where you put the gene for **amylase**, it would always produce the same **protein**, **amylase**, and the **protein** would always do the same job.

Adventure 4:4

Saliva Protein

Discussion

• Read or paraphrase

We eat many foods containing the chemical **starch. Starch** is a long chain of sugars. Potatoes, rice, bread, and many other foods contain **starch**. We need the sugars in **starch** to live. Sugar and **starch** belong to a family of chemicals called **carbohydrates**. For the body to use the sugars in **starch** for energy, **starch** needs to be separated into the sugars from which it is made.

A **protein** in our saliva breaks up or *digests* the starch we eat. This **protein** is called **amylase.** Other organisms like rice and barley also contain **amylase**. The **amylase** gene from rice, barley, and humans contains information to produce the **amylase** protein. We always have **amylase** in our saliva. Rice and barley seeds make **amylase** when they sprout, because plants also need "food" to grow.

Today we are going to do an experiment using **amylase** in our saliva to show how **amylase digests starch** in a cracker. This activity shows the protein **amylase** changes **starch** into sugar when starch interacts with saliva in your mouth.

Iodine turns blue when mixed with starches. In this adventure, iodine is used as an *indicator* for starch.

You will need

(For each team)
crackers
2 cups (8 oz)
1 Tbsp saliva
1/8th tsp cornstarch
1-2 drops iodine[1]
water
1 coffee stirrer
1 eyedropper
1 marking pen

30 minutes

Directions

• Read or paraphrase

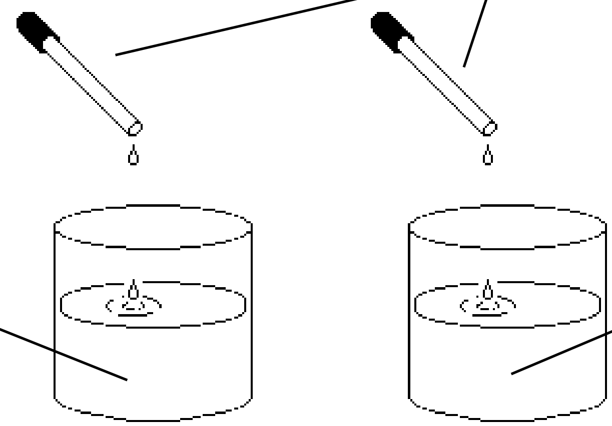
1) Label one cup "no saliva" and the other "+ saliva". Refer to the illustration on the following page.
2) Mix about 1/8 tsp cornstarch in 1/2 cup water in the "no saliva" cup. Pour half this mixture into the "+ saliva" cup.
3) Spit into the "+ saliva" cup a couple of times and stir the mixture.

   What color is the iodine? *A dark, reddish brown.*

   If I add 2 drops to each cup, what do you think will happen? [Give participants a chance to guess or make predictions.]

4) After a few minutes, put 1-2 iodine drops in each cup. Swirl solution in cup until thoroughly mixed. What happens? *The mixture in the "+ saliva" cup is red or yellow, but the mixture in the "no saliva" cup turns blue.* Why? *The amylase protein in saliva digested the starch into sugars. Iodine turns blue in the presence of starch, not sugars. If the red color of the iodine turns blue, starch is present.*

[1] Iodine is poisonous. It can be obtained from most pharmacies/drug stores. Ask your pharmacist for the smallest size. Iodine left over from this adventure can be used as an antiseptic.



Last Things Last

Hungry for More?

Proteins are chemicals. Most **proteins** are not toxic but some are. Poisonous snakes have toxic **proteins** in their venom. Snake venom is only poisonous when a snake bites you and releases its venom into your bloodstream. If you were to drink snake venom or suck it from a snake bite on your leg, it wouldn't make you sick at all. Can anyone guess why? *We have a **protein** in our digestive tracts that **digests** (breaks down) the venom before it gets to the bloodstream.*

As we saw from our experiment today, we have the protein amylase in our mouths to digest starch into sugars.

Next Time

We know each gene recipe contains information for producing **proteins,** and now we know what some of these **proteins** do. Next time we will see how a special group of scientists, known as genetic engineers, have been able to locate a specific gene recipe for a desirable characteristic in one genome and move it to another genome.

Ask these questions

- We have amylase in our saliva to digest starch into sugar. We eat wheat, rice, and barley seeds because they contain starch and other food. Why do rice and barley seeds make a lot of amylase when they sprout? *Because seeds have starch that is changed into sugar to nourish the sprouting plant.*
- If you took the amylase gene out of the barley genome and put it into the rice genome, what new protein would the rice make? *No new protein, because rice already makes its own amylase.*

Cut and Paste

5

Background for the Leader

All our food comes from living organisms, mostly plants. People have been changing the characteristics of plant foods for thousands of years to make them sweeter, tastier, better able to fight disease, and grow better in different climates. One way we have done this is by **selective breeding**. Ranchers breed the strongest horses so their offspring will be stronger than the parents. They breed the leanest cows so their offspring will be leaner than the parents. If we have two tomatoes with desirable characteristics, one with a brighter red color and another with a sweeter taste, we cross them and try to get a sweeter, brighter red tomato. Breeding is one of the oldest tools of **biotechnology**.

Selective breeding works because each parent gives some of the gene recipe in its genome to the offspring. The transfer of genes from parents to offspring happens naturally. Parents each give their children some of their gene recipes.

By carefully selecting certain plants as parents, we have created much of the diversity we find in the food we eat. We now have over a thousand apple varieties, red and green and yellow. Only a few varieties existed thousands of years ago. Today's varieties were developed by **selective breeding**. The foods we eat today do not look like they did originally. The original tomato, for example, was green, about an inch across, and bitter-tasting. But it was also more resistant to disease. By selecting for juicier and sweeter tomatoes, tomatoes have lost some of their disease resistance. With **selective breeding,** we don't always get the characteristics we want. Sometimes we lose some, or we get characteristics we don't want. Even though we carefully pick the parents, we can't control how their genomes mix or interact. With **selective breeding**, we can't mix the genomes of different kinds of organisms, like apples and tomatoes.

We have been using biotechnology for thousands of years to change the foods we eat. **Biotechnology** means "using living things as factories for making products." It means using organisms to make things for us, like yeast to make bread and wine, and bacteria to make yogurt and sour cream. Many people think **biotechnology** is new, but some **biotechnology** has been with us for thousands of years. Using yeast to make bread, beer, and wine are probably the oldest examples of **biotechnology**. Today, however, new kinds of **biotechnology** let us change organisms in different ways, so they can do their jobs more efficiently or do new jobs they couldn't do before.

Words

biotechnology
genetic engineering
genetic engineer
selective breeding

We will learn

- Scientists can isolate a gene from the genome of an organism.
- The isolated gene can be put back in the same or a different organism.
- Scientists use special proteins to cut DNA apart and glue it back together.
- These scientists are called ***genetic engineers.***
- ***Biotechnology*** began when people started using yeast to make bread, beer, or wine.

For review

protein
gene
organism
code
DNA
genetic code
genome
symbol

5

> ☞ *Ask these questions*
>
> - Which of the following are chemicals? Water, salt, sugar, DNA, proteins, amino acids. *All of them*.
> - What do proteins do? *Jobs that help organisms obtain water and energy they need to live, and lots of other things. We are made of proteins and other chemicals that are produced by proteins.*
> - Of what are proteins made? *Building blocks called amino acids.*
> - Can you name some proteins? *Collagen, keratin, hemoglobin, gelatin, rennin, amylase.*
> - What does the protein amylase do? *Breaks down (digests) starch into sugars.*
> - Where is amylase found? *In saliva and in grains when they sprout.*
> - What is gelatin? *A protein.*
> - Why doesn't gelatin set if it contains fresh pineapple? *A special protein in the pineapple prevents the gelatin from making a matrix.*

Today's genetic engineers have come a long way from crossing tomatoes and breeding swift, strong horses. In the modern **biotechnology** lab, scientists called **genetic engineers** are eliminating all the guesswork in the old field of "selective breeding." Where in the past, we w21ould focus on changing one or two characteristics and gamble on how the rest of the organism would be affected, today's **genetic engineers** can pick out a specific characteristic, while leaving the rest of the characteristics basically untouched. This process is like a computer seeking out a single word in a fifty page document, copying it, and pasting it in another part of the same or a different document.

For example, **genetic engineers** can take a single gene out of the genome of one organism, like a tomato, and put it into the genome of another organism like an apple. This process is called **genetic engineering**, the newest tool in **biotechnology**. **Genetic engineering** has advantages over selective breeding because one gene at a time can be moved. Genes can be moved between organisms that can't be crossed, like a tomato and a potato.

Genetic engineers use special proteins that function like a pair of scissors and a bottle of glue. These proteins work as *scissors* to cut the gene from one genome and then as *glue* to stick the gene back into another genome. For example, there is a gene for a protein known as Bt. Bt comes from a bacterium and causes insects to die. Bt has been used for years by gardeners to protect their plants. **Genetic engineers** have now put the gene for Bt into the genome of the potato, cotton, corn, and tomato plants. Although Bt makes insects sick when they eat these plants, it doesn't make people sick. Because of Bt, farmers may not have to use as many pesticides to keep insects from eating these plants.

Suggestions for the Leader

This adventure demonstrates how **genetic engineers** cut information from one organism and paste it into another. We will cut and paste stories instead of DNA.

Word Rap

Biotechnology means "using living things as factories for making products." During breadmaking, we are using yeast as a factory to make gas bubbles to raise the dough. It comes from the old Greek root, "bios," which means *life*. Other words containing "bio" as their root are *biology*, *biography*, *bionic and bioengineering.*

Genetic engineering, the newest method in biotechnology, makes it possible to take a gene from one organism, such as a pear, and put it into the genome of another organism, such as an apple. The goal of genetic engineering is to produce an organism with a new characteristic, like firmer skin, brighter color, or better nutritional value.

Genetic engineer is the name for the scientist who moves a gene from one organism and puts it into the genome of another organism.

Selective breeding, the classical method of biotechnology, is the crossing of different plants or animals, to get offspring that have the desirable characteristics of both parents. This classical method in biotechnology has been used for thousands of years by cultures all over the globe.

Recombinant means to rejoin together. Recombinant DNA is recombined or rejoined from two sources of DNA.

Adventure 5:1

Mad Libs®

Participants will change a story by inserting parts from another story. They can replace any part of one story with any part of another, as long as the ends of the part they insert are the same as the ends of the part they remove. This is the same thing that happens when genetic engineers cut and paste DNA. In order for the protein scissors to cut DNA, they must find a particular code in the DNA. They also need an identical code to paste the DNA in another place.

Do ahead

Duplicate handouts. (Fold each page along the dotted lines to hide the folktale's answer.

You will need

handouts (1 or 2 sets for every two participants)

scissors, glue or tape

30 minutes

Directions

• Participants read the two folktales, "The Frog," from Russia, and "Sunrise," from Mexico. [Give participants a chance to solve the mystery in each folktale.]

• Read or paraphrase

You are going to create a new story from two existing folktales. Here are two folktales that you will change by cutting out parts of one story and gluing them into the second story. The rule is that you can glue in only pieces that begin and end with the same words as the piece you removed.

• The two folktales,"The Frog" and "Sunrise," contain some underlined phrases. These underlined phrases are *target sites*. For example, two of the underlined phrases, or target sites, are **a frog** and **hours and hours**. Using scissors and glue or tape, participants remove the sentences which connect the two target sites in "The Frog," and replace them with the sentences between the same target sites in "Sunrise." The new story is called a "recombinant" story because it is recombined using some new story parts. [Ask participants if they have ever heard of recombinant DNA or read about it in the newspaper.]

• Participants share their recombinant stories or Mad Libs®.

Adventure 5:2

Recombinant Story (Optional)

You will need

paper, pencils, scissors, glue or tape

30 minutes

Directions

Choosing new target sites, kids construct a new story by splicing phrases from one story, "The Frog," into another, "Sunrise." They can replace only those story parts between certain underlined phrases, called *target sites*—that is, story parts with identical target sites on each end. The first and last words from the story parts selected must match.

Brand names are used as examples only; this is not an endorsement of any product.

Adventure 5:1 Handout 1

The Frog

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

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?

(Fold back)

— —

Frog's swimming around began to churn the cream into soft fresh butter.

5

Adventure 5:1 Handout 1

Sunrise

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

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?

(Fold back)

Frog saw the sunlight reflecting off the sides of the mountain in the west while Deer was watching the lower plain in the east. Mountains, being higher, always catch the suns rays first as the earth turns to face the sun.

Last Things Last

Discussion with Participants

• Read or paraphrase

Have you ever noticed how many kinds of dogs there are? People have developed dog breeds as different from one another as the 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 together—that is, which dogs they want to have puppies. They decide this based on the parents' characteristics, hoping the puppies will possess all or some of those characteristics. If the parents are different breeds, the puppies usually look very different from the two parent dogs. For example, if you breed a cocker spaniel with a poodle, you get a cockapoo, which doesn't look exactly like a poodle or a cocker spaniel. This is called **selective breeding**. People have also used **selective breeding** to make new kinds of plants, like apple trees. We now have over a thousand different kinds of apples, from red to green to yellow, all made from a few varieties that existed thousands of years ago. These apples look very different from their ancestors (which looked more like the crabapples of today), and all have been produced by **selective breeding**.

When you mix two breeds or varieties together, the offspring possess some characteristics of both parents, just as you possess some characteristics of your mother and some of your father. This is because breeding allows the genomes of the parents to mix together. The offspring obtain genes from both parents. Unfortunately when you breed two things together, you don't always get the characteristics you want: some are lost, some you don't want. This is because you can't control how the genomes mix and also because many genes are being mixed up at once. Also, you can only breed the same kinds of organisms together—dogs with dogs, corn with corn, cows with bulls.

Selective breeding is one tool of **biotechnology**. **Biotechnology** is a word we hear in the news and see in the newspaper. One of the oldest examples of **biotechnology** is using yeast to make bread, beer, or wine. Today we have a new **biotechnology** tool called **genetic engineering**. Scientists who use this tool are called **genetic engineers**. With **genetic engineering**, scientists can take a single gene from the genome of one organism and put it into the genome of another. They do this by using **proteins** that cut DNA in certain places. Other **proteins** are used to glue the cut DNA back together. Gluing DNA back together works only if the ends are the same, just as in our Mad Libs® and Recombinant Story adventures. This DNA is called recombinant DNA because **genetic engineers** have "recombined" DNA from two different sources.

This new **biotechnology** tool is used to move specific genes for a characteristic from one genome to another. It can also be used to move genes between two organisms that can't breed, like a potato and a tomato.

Today, we "cut and paste" two folktales, using scissors and glue. We could also use the "cut" and "paste" commands in a word processing program on a computer. Genetic engineers "cut and paste" DNA in order to move a specific gene to another genome. They use special proteins that work like scissors and other proteins that work like glue.

Hungry for More?

What are the risks in cutting genes out of the genome of one plant and pasting them into another? This is a big risk if the cut gene contains information for making a toxic **protein** and if this **protein** is made in the part of the plant we eat. Even if the **protein** is not toxic, there are risks if a person is allergic to that **protein**.

There are also risks in **selective breeding** of plants. In Canada several years ago, some people wanted to breed an insect resistant potato. They tried cross breeding a food potato with a wild potato. (Potatoes are related to the nightshade plant we talked about in Lesson 1. The potatoes we eat don't make the toxins that are in nightshade, but some wild potatoes do.) Breeding the eating potato with the wild potato resulted in a new potato that produced some toxin. These new potatoes were never sold in stores. This example demonstrates how risks can be associated with procedures like breeding that have been used for thousands of years.

With **selective breeding** and **genetic engineering**, it is important to test and study the new plant carefully to make sure it has no dangerous characteristics. The Food and Drug Administration (FDA) has strict rules for testing genetically engineered foods to make sure they are safe for human consumption.

Next time

Now we know genetic engineers can cut the gene recipe for a protein out of the genome of one organism and glue it into the genome of another organism. We also know there are over 100,000 genes in a large genome like the genome for a human. Next time we will learn that one gene is really a very small part of a whole genome. We will also talk about the risks in using new technologies.

It's My Decision

6

Background for the Leader

We now know that information for most characteristics is recorded on the genes in the genome, that our genome is like a cookbook with over 100,000 gene recipes for different proteins, and that the genetic information in the genome is recorded on DNA. Since we also have special proteins that can cut DNA and glue it back together, why not take the gene for a useful characteristic from the genome of one organism and put it into another? This is actually more complicated than just cutting and pasting, but genetic engineers are now able to do it. This process has advantages over selective breeding because it is more specific. That is, it can be used to move a single characteristic from one living thing to another. It also has some disadvantages. It is harder to do, and we don't always know how a gene will function in a new genome.

As with any technology, there are safety and ethical issues involved in genetic engineering. People want to know if the technology is safe, if the potential benefits are worth the risks, and if we should be modifying the genomes of living things.

Words

risk

benefit

We will learn

- Genetic engineering is the newest tool of biotechnology.
- All technologies carry **risks** and **benefits.**

Suggestions for the Leader

With genetic engineering, we are moving one gene in 100,000. What does this look like? The first set of activities is designed to demonstrate the concept of 1 in 100,000. To help participants visualize 1 in 100,000, choose one of the options in Adventure 6:1. Or you may have other ideas that are just as effective.

Adventure 6:2 is designed to demonstrate the uses of genetic engineering and the issues surrounding its application. Adventures 6:3 and 6:4 give participants the opportunity to make their own decisions after looking at the risks and benefits.

Word Rap

Risk is a hazard, or exposure to loss or injury.

Benefit comes from "bene-," which is Latin for *well*, or *good*. A benefit is something positive. Other words containing "bene-" as their root are *beneficial, benefaction and benediction.*

6

First Things First

Discussion with Participants

• Read or paraphrase

We have learned a lot about organisms. We know that genes in the genome contain the information for making proteins, that proteins determine the characteristics an organism has, and that the genome is recorded on the chemical DNA. We also know that scientists called genetic engineers can cut DNA apart and glue it back together with special proteins. This means we can take the gene for a useful characteristic from the genome of one organism and put it into the genome of another. This is called genetic engineering, and some organisms have been modified this way.

As with any technology, genetic engineering has risks in addition to the benefits. We know cars and fire are dangerous, but the benefits seem greater than the risks, so we use cars and fire all the time.

• Ask these questions

☆ What are the benefits of cars?

A car is transportation, saves time, can visit fun and interesting places or friends, can travel long or short distances

☆ What are the risks?

Must buy insurance, many accidents, need the Highway Patrol, loss of life, expensive

☆ What are the benefits of fire?

Warmth, source of energy, cook food

☆ What are the risks?

Explosion, forest fire, loss of animal and human life, loss of property

The danger is not in the technology itself, but in how we use it. The same is true for biotechnology; care needs to be taken in how we use it.

For review

genes

genome

genetic engineering

biotechnology

genetics

Ask these questions

- What is biotechnology? *Using living things as factories for making products.*
- What are some products of ancient biotechnology? *Bread, yogurt, cheese, wine, beer.*
- What are some of the products of modern biotechnology or genetic engineering? *Crops that can be protected with less pesticides; many new medicines; healthier cooking oils; non-allergenic crops; crops that are more drought tolerant.*
- Why do genetic engineers cut DNA apart and glue it back together? *So they can move a specific gene from one organism to another or rearrange genes in the same organism.*
- What do genetic engineers use to cut DNA apart and glue it together? *Proteins.*

• Read or paraphrase

Some people are worried that genetic engineering will be used to make dangerous plants or animals. They want to know if it is safe, if the potential benefits are worth the risks, and if we should even be modifying the genomes of living things.

In the movie *Jurassic Park*, genetic engineers build dinosaurs from dinosaur DNA found in prehistoric insects trapped in amber. We know from the earlier lessons that it takes proteins from many genes to make a characteristic like hair or eye color and many more to make an entire eye. This is because eyes are very complex structures. And a whole dinosaur is even more complex. Unlike the fictitious scientists in *Jurassic Park,* real genetic engineers are not able to build a dinosaur from bits and pieces of DNA.

• Ask these questions

☆ What are the benefits of selective breeding? What are the risks?

When people use selective breeding to move a characteristic from one organism into another of the same kind, they usually move a lot of other characteristics as well, some they want and maybe some they don't want. This is because many genes at a time are mixed with selective breeding.

☆ What is a benefit of genetic engineering that is not available with selective breeding?

With genetic engineering, only the genes for the characteristic you want are moved, and the organisms don't have to be the same kind or species. This allows genetic engineers to modify organisms with genes for useful proteins from the genomes of other organisms. For example, we discussed Bt protein in Lesson 5. The gene for this protein has been put into the genome of several kinds of plants, like potatoes and tomatoes. The protein makes insects die when they eat these plants. The nice thing about the Bt protein is that it doesn't bother people. Since some insects die from eating plants that have this protein, we don't need to put pesticides on the plants to keep the insects from eating them.

• Read or paraphrase

The information for making a human or a wheat plant is kept in a cookbook called a genome. This cookbook contains over 100,000 recipes for different proteins. That is too many recipes for one cookbook, so your genome cookbook is like a cooking encyclopedia with 46 volumes. We call each volume of the genome encyclopedia a **chromosome,** and each one contains more than 2,000 gene recipes. When we move a gene from one organism to another, how much of

☞ *Ask these questions*

- Why are people interested in moving genes from one organism to another? *Many answers are correct. For example, to develop cures for human diseases, to improve food crops, to develop new medicines.*
- What do genetic engineers move from one genome to another? *Specific genes.*
- Is genetic engineering dangerous? *Not inherently, but all technologies carry risks.*
- Could you move a gene from a tomato plant to an apple tree with selective breeding? *No.*

  With genetic engineering? *Yes.*
- Can someone control the characteristics an offspring receives through selective breeding? *No.*

  With genetic engineering? *Yes.*

the genome are we actually moving? Today's activity will give us an idea of just how small a single gene is. If the human genome contains 100,000 genes, then one gene is 100,000 times smaller than the whole genome. Not very big. If we think of our cooking encyclopedia example again, when two organisms breed, complete volumes of the 46 chromosomes are being shuffled together to end up with 46 new chromosomes. When one gene is moved using genetic engineering, it is like moving less than one recipe from one volume of a cookbook encyclopedia to another volume in a second cookbook encyclopedia.

Today's adventure will give you an idea of how small a part of a genome one gene really is. Then we will explore some ethical issues about using genetic engineering.

A Drop in the Bucket

- Read or paraphrase

Just like the tomato plant, your genome contains over 100,000 genes. If we were to add the gene for amylase from wheat to the tomato plant, we would be adding one gene to 100,000 genes. The concept of 1 in 100,000 is difficult to understand. This adventure is designed to help you visualize the genetic engineer moving one gene from wheat to the tomato genome which contains 100,000 genes.

Option 1

1 in 100,000 is 1 drop in 2 gallons of water.

- Start with 1 drop of food coloring or ink and 9 drops of water. How dark does 1 drop of ink in 10 look? This is *1/10*. Put these 10 drops into 2 teaspoons of water. Now how dark is it? This is *1/100*.
- Now put those two teaspoons in 1/3 cup of water. This is 1/1,000. How dark is it now? Put this 1/3 cup into a quart of water. This is 1/10,000. Can you tell there is any ink there at all?
- Finally, into a bucket or washtub, preferably white, pour the quart of ink water, and add 7 more quarts of water. This represents 1 drop of ink in 100,000 or 1/100,000. How dark is the water? If you didn't know the answer, would you think there was any ink in the water at all?

You will need

ink or food coloring
eye dropper
containers
water
measuring spoons
cups

15 minutes

Option 2

1 in 100,000 is 1 millimeter in 100 meters of string.

- Measure out 100 meters of string or thread. This is about the same as 110 yards. The distance between the fingertips of your outstretched arms is almost 2 yards, so 2 yards, multiplied by 50, is more than 100 yards, or about 100 meters.
- Pull the string out straight and draw a line around the string with a fine-tip felt marker that is 1 millimeter wide. This is 1/100,000 of the string.
- Now wind the string into a ball. Then see how long it takes you to unwind the ball to find the colored line.

You will need

string or thread
felt-tip marker

15 minutes

Adventure 6:2

Designer Genes

Do ahead

- Duplicate this sheet for each team
- Cut, or fold along dotted lines to hide answers

You will need

(For each team)

- pencils
- 1 copy of this page

20 minutes

• Read or paraphrase

Below are descriptions of three people who need your help to genetically engineer one or more plants that they can grow for food in their local environment. Design a plant from List A with some of the genes from List B that will provide what those people need.

1) An African who lives in a hot, dry climate.

2) A Canadian who lives in a climate too cold for bean plants and has an insect that eats potatoes.

3) An American farmer whose only field is occasionally flooded by sea water.

List A	List B
Plants	**Genes**
Peas	Pest resistance
Beans	Cold tolerance
Potatoes	Drought resistance
Wheat	Heat tolerance
Corn	Salt tolerance
Rice	Flood tolerance

Changes are not singular events. One small change may have a ripple effect. How would the new plants you developed change the communities where these people live?

(Cut or fold back)

Some possible answers are

1) A drought-resistant, heat-tolerant wheat, potato.

2) Pest-resistant potatoes, cold-tolerant beans.

3) Flood-tolerant rice, salt-tolerant corn.

Decisions, Decisions!

• Discuss the implications of one or both of these biotechnology scenarios.

Option 1

a) You are a genetic engineer. You have a gene that can make wheat poisonous to insects. If you could put this gene into wheat plants so that wheat farmers didn't need to use pesticides, would you do it? Why or why not?

Direct a discussion so each participant comments on this situation. Emphasize there are no incorrect answers. After discussing this situation, introduce the next situation.

b) What if the gene also made the wheat toxic to people?

c) What if the protein from the toxic gene was only made in parts of the plant people didn't eat?

You will need

No materials

15 minutes

Option 2

a) You are a genetic engineer who has been offered a position with an American tobacco company to study "Clonal Propagation of High Grade Tobacco Plants" (this means making millions of tobacco plants that are genetically identical without having to grow them from seeds). Although this research may encourage production of much less expensive tobacco and perhaps less expensive cigarettes, it may also allow more poor people to smoke. In light of these predictions, would you still accept this position?

Direct a discussion so each participant comments on this situation. Emphasize there are no incorrect answers. After discussing the first part of this scenario, continue with the next part.

b) Although this research would make for cheaper tobacco production and thus an increase in the numbers of smokers worldwide, it could also be applied to other foods resulting in increased food production. How would this influence your decision? How would your decision impact your community.

c) Although this research makes for cheaper food production, it also allows the tobacco company to patent the process, thereby making it illegal for anyone else to use the process without permission. The patent limits the technology to rich countries who don't need the food as much as poor countries. Would you stay with the company if the company obtained such a patent and limited outside access to the technology?

d) Even though the company limits access to the technology, your high salary would allow you to start your own company and study other ways to increase food production. How would this influence your decision?

You will need

No materials

20-30 minutes

Adventure 6:4

It's My Decision

Do ahead

- Make a copy of the handout "Roles" and cut apart the various roles.

You will need

- a copy of the handout "Roles"

30 minutes

• Read or paraphrase

Deciding about the risks and benefits of genetic engineering is difficult. Groups have an interest in the decision based on the risks and benefits they see. Some of those groups include: consumers, farmers, politicians, environmentalists, business people, and governmental officials. Today, you will have the opportunity to assume the role of an individual from one of these groups. The issue is whether or not to ban genetically engineered RediRipe™* tomatoes.

Directions

Give each participant a role to play from the Handout. If there are more roles than individuals, select roles that represent many different viewpoints. Give participants time to study their roles.

• Read or paraphrase

Your group has been selected to help the Food and Drug Administration (FDA) decide if a genetically engineered tomato should be grown at all, and, if sold in the marketplace, if it should be labeled “genetically engineered.” This tomato has an artificial gene that keeps it from softening too quickly. It can be left on the vine longer to get more flavor and still be hard enough to successfully ship to market.

The FDA has listened to many arguments for and against genetically engineered foods. The company that produced the new tomato claims there is not a danger to health or the environment from this tomato. It is said to be as juicy and flavorful as a homegrown vine-ripened tomato. It will be available when good tomatoes are hard to find because of its extended shelf life. The nutritional value of this tomato is unchanged. It is expected to be slightly more expensive than conventional tomatoes.

Many people are concerned about these tomatoes. Some worry that the artificial gene could be transferred to other plants. Others argue that the gene could produce a protein that causes an allergy. Some say the new tomato could be produced by selective breeding. Others say that genetic engineering is faster and more precise. Although the new tomato is the same nutritionally as a conventional tomato when picked, some people think it will lose more nutrients than the conventional tomato before it is eaten.

* This product name is fictitious.

The company that developed the tomato has tested it extensively, but people feel that you can't trust the industry to police itself. Others argue that the company has more to lose by selling an unsafe product than a safe one.

- When ready, tell participants they have been called together to decide whether the RediRipe™ tomato should be banned.
- After the role playing, discuss how each person feels about his or her role, and about the verdict.

If time permits, share "Tomato History."

Tomato History[1]

The fresh tomato has come a long way from its original green, inedible ancestors that grew only to the size of grapes in the wilds of Peru's Andean Mountains several thousand years ago. That's because ancient gardeners in what is now Mexico and other countries of Central America domesticated wild tomatoes by selectively breeding for larger, edible red tomatoes.

Ever since, gardeners and tomato lovers around the world have been busy crossing various wild and domesticated tomato varieties trying to improve everything about tomatoes—from their color and taste, to their ability to resist diseases and pests, and their ability to withstand droughts and other environmental stresses.

Can you imagine a pasta dish without tomatoes? Italian cookery did not include the tomato until Christopher Columbus brought this American food to Europe in the late 15th Century.

[1] References

International Food Information Council, "Choices: Tasty Tomatoes in the Heart of Winter," *Food Biotechnology*, 1993.

Toussaint-Samat, Maguelonne, *History of Food*, Blackwell Publishers, Cambridge MA, 1987.

Handout for Adventure 6:4

Roles

Consumer 1

• You love tomatoes. Your family eats them on sandwiches, salads, or pizza almost every day. You dislike the bland, hard tomatoes you get in the market, especially in the winter. They seem tasteless. If genetic engineering can produce tomatoes with good texture and flavor available year-round, you're all for it. You would even pay a little more for them.

Consumer 2

• You love tomatoes and eat them almost every day. You grow your own tomatoes in the summer. You rarely buy tomatoes in the market, because you don't think they are as good as your homegrown tomatoes, and you don't want pesticides sprayed on your tomatoes. You have heard about the genetically engineered tomatoes, but don't think you would buy them in the store. If you can't find good regular tomatoes in the winter, you would rather do without. You want all genetically engineered foods to be labelled, so you can avoid buying them.

Farmer 1

• You grow tomatoes. You would be willing to grow this new, genetically engineered tomato. You are willing because, if the consumers like the tomatoes, you could make more money by being one of the first to supply them. You have heard they last better during shipping, so more of them make it safely to market. You expect to increase your profit. You oppose labelling of genetically engineered tomatoes, because of the extra cost.

Farmer 2

• You grow conventional tomatoes organically on your farm, and have been asked if you would grow this new tomato. You have decided not to because you're afraid you will have to return to using chemical fertilizers and pesticides to get a good yield. You are worried that you won't be able to compete with farmers who grow the new tomato and may go bankrupt if it is approved. You also worry that some consumers prefer this tomato.

Genetic engineer

• You have been working with genetic engineering for years, and believe this new tomato is perfectly safe. The FDA has studied it extensively, and found no reason that it should not be approved. You love tomatoes and wouldn't hesitate to buy these for your family.

Environmentalist

• You feel there are safer ways to get good tomatoes than with genetic engineering. You worry that if this tomato is successful, farmers will grow this tomato with chemical fertilizers and pesticides. You also think it is possible that the genes in this tomato could be transferred to other plants.

Reporter

• You have been reporting on the development and testing of this tomato for several years. You see both sides of the issue. Even though you see no evidence the tomato is dangerous, you are not sure if you would buy one in the market.

FDA official

You have been on the review board for approval of this tomato since it was first developed. You don't feel genetic engineering is anything more than a more precise way to do selective breeding, which can be an unpredictable and lengthy process. You are convinced the tomato is safe and see no reason why it should not be grown commercially.

Consumer advocate

• More than anything, you want consumers to have a choice when it comes to buying genetically engineered produce. You worry that if the tomato is successful, farmers will only grow the new tomato, and consumers won't have a choice in the market. You also worry that the increased shelf life of this tomato will provide an opportunity for vitamin loss. You think the technology raises many questions and that consumers need to know more before the tomato is sold.

Restaurant chef

• You are a member of the San Francisco Chefs Association. This group is opposed to the use of all genetically engineered foods. You demonstrated against the RediRipe™ tomato. You want all genetically engineered foods to be labelled.

6

Last Things Last

☞ *Ask these questions*

- Some people think genetic engineers should not change the genes of organisms. What do you think? List some reasons why we should or should not use genetic engineering.
- How much of a genome does a new organism get from each parent with selective breeding? *One half of the genome.*
- How much of a genome does a new organism get with genetic engineering? *One gene at a time, 1/100,000.*

Hungry for More?

Some people worry about the risks of genetically engineered foods. One concern people have is that the protein from the gene that has been moved may cause an allergy in some people. For example, if a peanut gene was moved into another species to improve the protein quality, what would happen to people who are allergic to peanuts? To avoid problems like this, the Food and Drug Administration (FDA) is suggesting that some genetically engineered foods have labels so people can make informed decisions about buying them. The FDA has other strict rules for testing genetically engineered foods to make sure our food supply stays one of the safest in the world. As scientists learn more about the proteins that cause allergies, genetic engineers can cut and paste DNA to produce crops that are less allergenic. Genetic engineers in China have already produced hypoallergenic rice.

We Will Learn...

1 DARE TO BE DIFFERENT

- All living things are organisms.
- The huge variety of organisms is called diversity.
- Diversity results from the different genes each organism possesses.
- Organisms with similar characteristics and thus similar genes, may be related.

2 SECRET CODES

- An organism's genes are collectively called a genome.
- Some of the genome information of every organism is the same, while some is different, but the code symbols are the same.
- This code used to record the genome is called the genetic code.
- Information in the genome is recorded in code on DNA.

3 DNA FOR DINNER

- Every organism is made up of tiny compartments called cells.
- Every cell in all organisms contains a set of genes called a genome.
- An organism's genome in each cell is recorded on a chemical called DNA.
- The message coded on DNA determines what characteristics are present in each organism.
- DNA is a chemical as are water, sugar, proteins, and vitamins.
- DNA can be isolated from any organism, including the foods we eat.
- Genome cookbooks are recorded in volumes called chromosomes.
- An organism gets one of each pair of chromosomes from its mother and the other from its father.

4 LET'S BUILD AN ORGANISM

- Genes contain information for making proteins.
- Different proteins do different jobs in our bodies.

5 CUT AND PASTE

- Scientists can isolate a gene from the genome of an organism.
- The isolated gene can be put back in the same or different organism.
- Scientists use special proteins to cut DNA apart and glue it back together.
- These scientists are called genetic engineers.
- Biotechnology began when people started using yeast to make bread, beer or wine.

6 IT'S MY DECISION

- Genetic engineering is the newest tool of biotechnology.
- All technologies carry risks and benefits.

Word Rap

		NEW WORDS
1	**DARE TO BE DIFFERENT**	characteristic diversity genes organism
2	**SECRET CODES**	code DNA genetic code genome symbol mutation
3	**DNA FOR DINNER**	chemical cell chromosome
4	**LET'S BUILD AN ORGANISM**	amino acid amylase carbohydrate digest protein starch
5	**CUT AND PASTE**	biotechnology genetic engineering genetic engineers selective breeding
6	**IT'S MY DECISION**	risk benefit