DNA FOR DINNER?

LESSON 2

Language of Life

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WHAT WE WILL DO

- Use code to figure out characteristics and guess the organism with those characteristics.
- Create a unique "M&M" code to describe a fruit or vegetable; let others guess the identity. *(optional).*
- Read a DNA sequencing gel to determine the order of A's, C's, G's and T's. *(optional).*

WHAT WE WILL LEARN

- All of an organism's genes are called a **genome.**
- Some genes from every organism are the same; some are different.
- The genome is written with a set of rules called the **genetic code**; that code is the same for all organisms.
- Genetic code is made up of different arrangements of four chemical units that together are arranged in a sequence called **DNA**.

TABLE OF CONTENTS

** optional*

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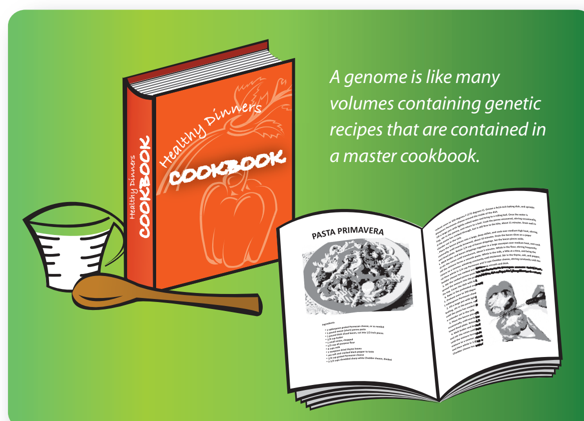
http://aspb.org

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

Appetizer

In Lesson 1 participants learned that diversity results from differences in the all of the genetic recipes or genes in the master cookbook of the organism, which is called the **genome.** You can think of the genome as many volumes in a master cookbook with each volume containing thousands of recipes.

The genome cookbook is written in combinations of four different chemical units that together comprise deoxyribonucleic acid, or **DNA** for short. The chemical units are arranged in a **code**, called the **genetic code**, which follows a specific set of rules. Some genomes are small; some are larger. Wheat, used to make bread and cookies, contains 32 billion chemical units; the human genome is 20% that size.



A genome is like many volumes containing genetic recipes that are contained in a master cookbook.

The genetic information specified by the code is like the recorded information in the cookbook recipes. The recipes and the DNA both serve to hold information. Just as the alphabet is used to communicate ideas in a recipe through words, the chemicals that make up DNA communicate information about the characteristics of an organism. Substituting one letter for another or inserting/deleting a letter in a word may have no effect on sentence's meaning or it can dramatically change its meaning. For example, inserting a letter in the following sentence can change its meaning. "I saw my friend eat her sandwich" is different from "I saw my friend **h**eat her sandwich". Substituting a letter in this sentence changes its meaning. "My best friend got an **A** on his math quiz" certainly differs from "My best friend got an **F** on his math quiz"! The same situation occurs with DNA. Changing a single chemical unit, referred to as causing a **mutation**, can have no effects or a profound effect depending on the change.

What's in a Word?

Words

Code • DNA • Genetic code • Genome • Mutation

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

Code is a system of symbols, letters, or words used for transmitting messages. The word *code* comes from French and Latin words meaning "set of laws".

DNA, short for deoxyribonucleic acid, is a series of chemical units, called nucleic acids, that contains information for specific characteristics of organisms. DNA is the long-term storage unit for the organism. It is like a cookbook of instructions to construct the parts of an organism.

Genetic code is the chemical code in which DNA is written. It specifies how information in the genome is read to give proteins that determine the organism's characteristics. The code is contained in a long chain of chemical units called nucleotides. From which word is *genetic* derived? (Look in Lesson 1.)

Genome is all of the genetic information in an organism that determines its characteristics. Physically it is a coiled string of DNA that, stretched out, is over five feet long. It is from the German, *gen*, meaning "to produce" and the Greek *ome*, meaning "body".

Mutation happens when a change occurs in the series of chemical units in DNA. These changes, or mutations, play a role in evolution and contribute to the different plant varieties we saw in Lesson 1. The word is from the Latin, *mutationem*, meaning "action of changing."

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

Remembering Last Lesson's Important Points

Remember these words?

Cell • Characteristic • Diversity • Genes • Organism • Protein

Ask These Review Questions

- Explain what you think determines an organism's characteristics.
- Tell me what you think it is about an apple tree that makes it produce apples and not tomatoes?
- Why do you think some fruits and vegetables have the same shape or color but are not related?
- Explain why you think it might be important to have a wide diversity of plants and animals in the world?

Main Course

- Activities will introduce participants to codes, particularly the genetic code.
- You will explore how DNA and the genetic code determine characteristics of the organism and how changes in the DNA can alter the characteristics.
- Three activities are offered in this lesson; two are optional
- There are also activities associated with the Dessert
- In these activities participants will make, use and decipher codes that relate to characteristics of organisms; some are fruits and vegetables from Lesson 1.

ACTIVITY 2.1 Mystery Decoder

In this activity pairs of participants are given "genome sequences" and a code. Teams work to figure out what organism has the characteristics they find in their sequences.

WHAT TO DO AHEAD OF TIME?

- Duplicate **Handouts 2.1** and **2.2**.
- Copy lists of characteristics and families developed in Lesson 1.

WHAT IS NEEDED?

- Copies of one genome sequence (**Handout 2.1**) and one decoder sheet (**Handout 2.2**) for each group.
- Sheets of paper, pens or pencils for each participant.

HOW MUCH TIME IS NEEDED?

20 minutes.

Directions

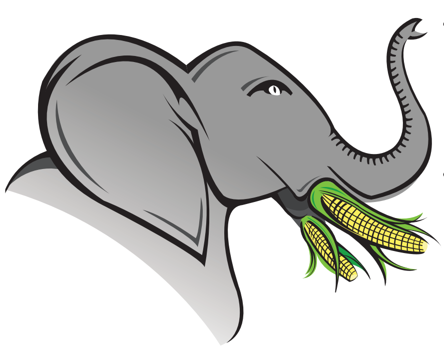
Form at least six groups of participants and have the groups form a circle. Each team receives any one of the genomes from **Handout 2.1** and any one of the Decoding Keys from **Handout 2.2**. Give teams five minutes to try to decode their genomes, write down the decoded characteristics and guess the identity of the organism. Suggest that they use the list of characteristics from Lesson 1. Then engage the group with the following.

- Can you share any difficulties you had in decoding your genome.
- Can you explain what additional information would have been helpful in figuring out the identity of your organism?

Remind participants that, to solve complex problems, scientists often share information with other scientists to find answers. If it does not come out in the discussion, point out that each team, as scientists, were given only part of the decoding key they needed.

In order to help the teams figure out the identity of their organism, ask them to trade their decoder with the next pair to their left in the circle and then try again to identify their organism. Teams continue to trade decoders with the group to their left until they can decode enough characteristics to determine their organism's identity. Then question the group.

- How did sharing decoders help you identify your organism.
- Discuss what would happen if only one team had decoders and the other did not?
- Explain why was it more difficult to identify your organism when you had only one characteristic?



- Explain what would happen if there was a mistake made in, for example, the second gene for the elephant – from 9%H!H to 5%H!H.
- Discuss why you might think that such a mutation would change the whole animal or only part of it?

ACTIVITY 2.2 M&M Codes (optional)

Using six colors of M&Ms, groups of participants will assign combinations of three colors to stand for each letter of the alphabet. Additional M&Ms will then be used to spell out characteristics of one of the vegetables or fruits from Lesson 1, using the lists of characteristics and families identified in that lesson. Groups will view coded messages from another group and, using the decoder sheet from that group, try to figure out what fruit or vegetable they are describing.

WHAT TO DO AHEAD OF TIME?

- Copy lists of characteristics and families from Lesson 1 for each group.
- Provide pictures or actual fruits and vegetables used in Lesson 1.
- Obtain ~ 250 M&Ms per group, approximately equal in color distribution.
- Obtain 3-4 sheets per group of light-colored, heavy construction paper and double-sided tape for each group.
- Obtain pens or pencils and scratch paper.

WHAT IS NEEDED?

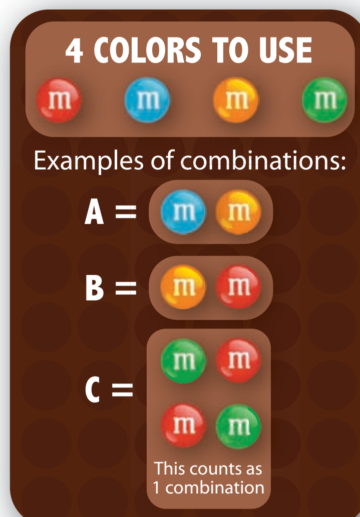
- Pens or pencils and scratch paper for each group.
- List of characteristics and families from Lesson 1.
- Pictures of or actual fruits and vegetables from Lesson 1.
- Approximately 250 M&Ms per group of approximately equal color distribution.
- Sheets of heavy construction paper and double-sided tape for each group.

HOW MUCH TIME IS NEEDED?

30 to 40 minutes.

Directions

- The code for each letter will be only made of three M&Ms but the colors for each alphabetic letter have to be unique.
- Participants in each group will work together to make their alphabet using construction paper and double-sided tape to hold the M&Ms on the paper.
- Once each group has a code, they choose a fruit or vegetable, find its characteristics from the Lesson 1 handout.
- Each group spells out in M&M code the first characteristic of their fruit or vegetable.
- Groups then trade codes and clues and see if the group with which they trade can decode the message and guess the fruit or vegetable.



- If the first clue does not lead to the right answer, the original group must describe a new trait with M&Ms and let the other group guess again.
- Continue trading clues until each group gets the right answer.

Challenge participants with these questions:

- Explain the challenges you might encounter when trying to determine genome characteristics without a decoder?
- Describe how you think keeping the decoder to yourself would affect the other group.
- Explain what would happen if your code did not use unique colors for each letter.

ACTIVITY 2.3 Sudoku Codes (optional)

In this activity participants work in pairs to solve the Sudoku puzzle and then use the code provided to discover the "genetic message" encoded in the puzzle.

WHAT TO DO AHEAD OF TIME?

- Duplicate **Handout 2.3** for each pair of participants.

WHAT IS NEEDED?

- Copies of **Handout 2.3** for each participant.
- Pencil for each pair of participants.

HOW MUCH TIME IS NEEDED?

20 minutes.

Directions

Leader asks participants to divide into groups of two and instructs participants that the Sudoku puzzle has a unique solution.

- Ask each group to read the directions on the handout.
- Explain that numbers from 1 to 9 are entered into each of the 3 X 3 squares.
- Point out to participants that each 9-box row and each 9-box column contains only one of each number. Suggest that they look at the example on the handout.
- Once the puzzle is solved, participants should use the code at the right of the puzzle to covert the numbers to letters and decode the message contained in the top line of the puzzle.

Challenge participants the following:

- Explain what you would think might happen if a mistake was made in the message while solving the puzzle?
- Describe what you think would happen if you did not have the code or had only part of it.
- Explain what you think might be the advantages of solving the Sudoku puzzle versus having the code to decode the message.

Instructions

The Soduku puzzle has a unique solution. Numbers from 1 to 9 are entered into each of the nine squares (left) in the large square.

6	5	4
8	1	3
2	7	9

Each 9-box row (below)

6	5	4	7	9	1	2	3	8

and each 9-box column (left) can contain only one of each number.

6
8
2
9
3
7
1
4
5

Final Course

What You Will Need

- Modern apple and crabapple; modern tomatoes and heirloom varieties; and colored Indian corn and yellow corn - or colored pictures of them.

Discussion with Participants

Invite participants to think about the activities they did with codes and to explain how important the codes were in these activities. How does this relate to the importance of the genetic code used for the genomes of organisms. Ask participants to talk about how their views of the importance of genomes have changed after these two lessons. Encourage them to compare differing thoughts and views. The goal is to have participants use the new terms introduced in the two lessons in their discussion and come to some conclusions about the concepts introduced. Try to bring out the important points of the lesson. If needed, use the targeted questions below to stimulate discussion. Give participants time to discuss each question.

- Can you explain how the genetic instructions in the genome are similar to and different from instructions contained in a computer folder created with a word processing system? (Encourage participants to use the terms introduced in this lesson.)
- Can you think the differences in genetic information in different organisms affect the genetic diversity that we talked about in Lesson 1?

Crabapples

Genetic diversity occurs in humans as well. Identical twins have exactly the same sets of genes and so their genomes are essentially identical. Immediate family members share most genes – about 99.5% or 199 out of 200 genes – since they were conceived from the same parents. Unrelated individuals share about 99% or 198 out of every 200 genes. Even humans and animals share many genes and, perhaps surprisingly, plants and humans share 40 to 60% of their genes.

Some diversity results from mutations in genomes. Sometimes this occurs from mistakes in decoding. Mutations can also result from, for example, radiation from the sun, which can cause changes in the chemical units in the DNA. Some different colors, tastes and shapes of apples are from mutations in the original wild apple variety, called a crabapple. Modern tomatoes also developed in part from mutations in the heirloom varieties sometimes found in the market.

Heirloom tomatoes

Indian corn

Genomes can also change because of what are called "jumping genes". These are small pieces of DNA that move around the genome. When they jump, they change the sequence of the genome and this can change characteristics. Different colors and stripes in the kernels of Indian corn are evidence of DNA jumping around in the color genes.

- Since plants and humans share 40 to 60% of their genes, can you think about any characteristics that plants might have in common with humans? Some that might be different?
- Please describe what you think might happen when the cellular machinery makes a mistake while decoding the genome?
- Explain how you think such a mistake might affect genetic diversity?

Dessert

Reading the Language of Life

This activity builds on the other things that have been done in this lesson. Explain to participants that scientists need to determine the precise order of the four chemical letters in DNA, called A's, G's, C's and T's, in the genome. They use that information to tell what characteristics a plant will have. This exercise stresses that there are only four chemical "letters" in DNA – not 26 as in the alphabet, or the 27 that are used in Activity 1 in this lesson or the 9 that are used in Activity 2.

WHAT TO DO AHEAD OF TIME?

- Duplicate **Handout 2.4** and **2.5** for each pair of participants.

WHAT IS NEEDED?

- Copies of **Handouts 2.4** and **2.5** for each pair of participants.
- Pencils or pens and scratch paper.
- Ruler or straight-edge.
- Scissors and double-sided tape.

HOW MUCH TIME IS NEEDED?

25 to 35 minutes.

Directions

Leader asks participants to form into groups of two.

- One individual reads the gel code in Handout 2.4, starting at the arrow and using the four letters listed at the end of the gel. Note that it might be helpful for the reader to use a ruler or straight-edge to follow the gel ladder more accurately.
- Bands are read in order from left to right, just like English writing.
- The second participant writes down the letters in order as their partner reads them. Suggest to participants that reading the bands on the gels might remind them of reading a scantron they might fill out for an exam at school.
- Once all chemical letters have been read, individuals change roles and the two versions of the reads are compared to see if they are the same or have differences.

Discussion with Participants

Explain that each dark band represents one of four chemical units that make up DNA. **Handout 2.4** has photographs of "sequencing gels" that were used by scientists to determine the DNA language in genomes of living organisms. The DNA language is "written" in the four chemical units or nucleotides, represented by the four symbols, G, C, A, T. Order of the symbols determines the genes and the genes are responsible for the organism's characteristics. Ask the following.

- If sequencing gels were made that contained the genetic information in each of the different fruits and vegetables from Lesson 1, explain whether you think the gels would be the same or different.
- Explain what you think the sequencing gels might look like if they contained DNA from identical twins.
- Explain what you think sequencing gels with your DNA and that from other people in the room would look like.
- If you were responsible for copying the DNA of a cell, discuss what you think the consequences of making a mistake might be.

Since in the tomato genome, for example, there are some 950,000,000 chemical units or bases, scientists just sequence small random DNA fragments and then match overlapping base pairs. It would be like reconstructing a sentence from its parts.

IT IS LIKE CTING A SENTENCE TS PARTS.
KE RECONSTRUCT NCE FROM ITS

Try your hand using overlapping DNA fragments to reconstruct a genome (**Handout 2.5**).

- Can you discuss what would happen if a sequencing error was made in the overlapping region of one fragment?
- Can you explain how generating more fragments might help this situation?

MATH MENU

1. Family members have in common about 199 out of 200 genes. If we have 30,000 genes, how many genes do you have in common with your mother or father?
2. Wheat, used to make bread and cookies, contains 32 billion chemical units or bases. The human genome is 20% that size. How many chemical units or bases does the human genome have?
3. How many different combinations of two M&M's can you make using the six different colors of M&M's? Will it be enough to have a unique combination for all letters of the alphabet?

See answers in Leader Supplements

Stuffed, but Hungry for More?

Even though it took people a long time to understand how the genetic code worked, people have been using other codes for thousands of years. Actually all languages are codes.

Test your ability to decode. What do you think the following sentences says?

Me encanta la ciencia
(Spanish)

Ja ich liebe Wissenschaft sehr
(German)

Я люблю науку
(Russian)

मैं विज्ञान प्यार
(Hindi)

- Can you explain how a "decoder" or a dictionary for Spanish, German , Russian or Hindi could help you understand what the speaker is trying to say?

Some people make codes so they can send information without other people knowing what they are saying. In war time, some armies use codes.

- Can you explain why armies might use such codes at such a time?

If it does not come out in the discussion explain that people are oten employed to decipher codes. For example, during World War II, the American army used Navajo Indian radio operators to transmit information in the Navajo language.[1] Other armies tried to "break" the code but were never able to figure it out.

- Why do you think that even today Word Monkey (in iGoogle at http://www.google.com/language_tools?hl=en) does not allow translations of this language?

See answers in Leader Supplements

[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.*

SET CONCEPTS ADDRESSED

Discovery-based research and scientific method

National Science Education Standards in Life Sciences Grades 5-8, Content Standard C: Structure and function in living systems

SET Process Skills Used: Build/construct; design solutions; use numbers; problem solve; interpret/analyze/reason

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

NEXT TIME WE MEET

In this lesson we learned that information in a gene is contained in a code in DNA, but what exactly is DNA? Next time, we will learn more about DNA. We will do an activity that will allow you to see and touch DNA. Just keep this thought in mind until we meet again: DNA is in every living organism – every plant, bacteria, virus, animal and human. This means we do eat "DNA for Dinner" in fruits, vegetables, grains, eggs and meat.

Leader Supplements for Lesson 2

Key for Activity 2.1
Mystery Decoder

Organism	Decoded Characteristics
#1 elephant	trunk, tusks, floppy gray ears
#2 rose bush	thorns, green leaves, fragrant flowers
#3 tiger	fangs, striped fur, claws, ears
#4 apple tree	tall, green leaves, branches, trunk, crisp fruits
#5 corn	yellow, ears, husks, silks
#6 tomato	red fruits, acidic, seeds, watery

Key for Handout 2.3
Sudoku Puzzle Solution

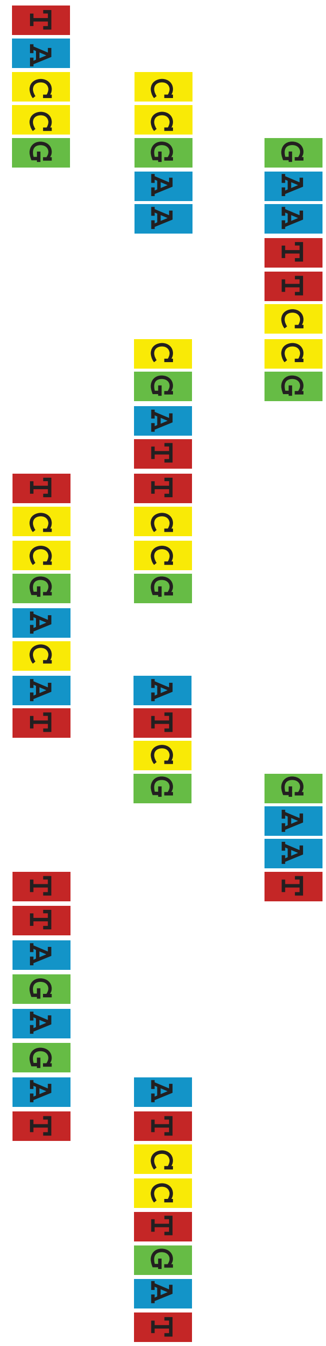
3	5	7	2	4	1	9	6	8
6	1	2	7	9	8	4	3	5
4	8	9	5	6	3	1	2	7
2	7	5	3	1	9	6	8	4
1	3	4	6	8	7	5	9	2
9	6	8	4	2	5	7	1	3
7	2	6	9	3	4	8	5	1
5	9	1	8	7	2	3	4	6
8	4	3	1	5	6	2	7	9

Message: CODES RULE

Key for Handout 2.4 DNA Sequencing Puzzle Solution

PUZZLE 1		PUZZLE 2	
1	A	1	A
2	G	2	A
3	A	3	T
4	C	4	A
5	G	5	A
6	C	6	G
7	C	7	C
8	C	8	C
9	C	9	T
10	C	10	C
11	T	11	G
12	C	12	C
13	C	13	C
14	G	14	T
15	C	15	T
16	C	16	A
17	G	17	T
18	C	18	G
19	C	19	T
20	T	20	C
21	A	21	A
22	G	22	A
23	C	23	C
24	C	24	G
25	G	25	C
26	C	26	C
27	C	27	G
28	C	28	A
29	C	29	A
30	C		

Key for Handout 2.5 Genomics Puzzle Solution



Answers to Math Menu

1. 29,850
2. 6.4 billion
3.

Answer to Stuffed, But Hungry for More?

The phrase is "I love science".

Genome Sequence Search

Clip out the 6 genomes and hand one out to each team.

Genome 1

9A%$!
9%H!H
T2GZZ?/WAX?/ &XAH

Genome 4

9X22/WA&&$/2&XR&H
@AX$Y5&H
9A%$!
YAQHZ/TA%Q9H

Genome 2

95GA$H
WA&&$/2&XR&H
TAXWAX$9/T2G8&AH

Genome 5

?&22G8
&XAH
5%H!H
HQ2!H

Genome 3

TX$WH
H9AQZ&K/T%A
Y2X8H
&XAH

Genome 6

A&K/TA%Q9H
XYQKQY
H&&KH
8X9&A?

Decoding Key

Clip out the 6 decoding keys and hand one out to each team.

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

DNA FOR DINNER?

LESSON 2
HANDOUT 2.3

Soduku Puzzle

Complete the Soduku puzzle to reveal the secret message!

	5		2		1	9		
6	1	2	7	9		4	3	5
4	8	9	5	6	3	1	2	7
	7	5	3		9		8	4
1		4	6	8		5	9	2
9	6	8	4	2	5	7	1	
7	2	6		3	4	8		1
5	9			7	2	3	4	6
8		3	1	5	6		7	9

Code

1 = R
2 = E
3 = C
4 = S
5 = O
6 = L
7 = D
8 = E
9 = U

MESSAGE: _ _ _ _ _ _   _ _ _ _ _

Instructions

The Soduku puzzle has a unique solution. Numbers from 1 to 9 are entered into each of the nine squares (left) in the large square.

6	5	4
8	1	3
2	7	9

Each 9-box row (below)

6	5	4	7	9	1	2	3	8

6
8
2
9
3
7
1
4
5

and each 9-box column (left) can contain only one of each number.

When the puzzle is solved, participants use the code at the right to convert the numbers in the top line of the puzzle to letters and discover the hidden message.

DNA FOR DINNER?

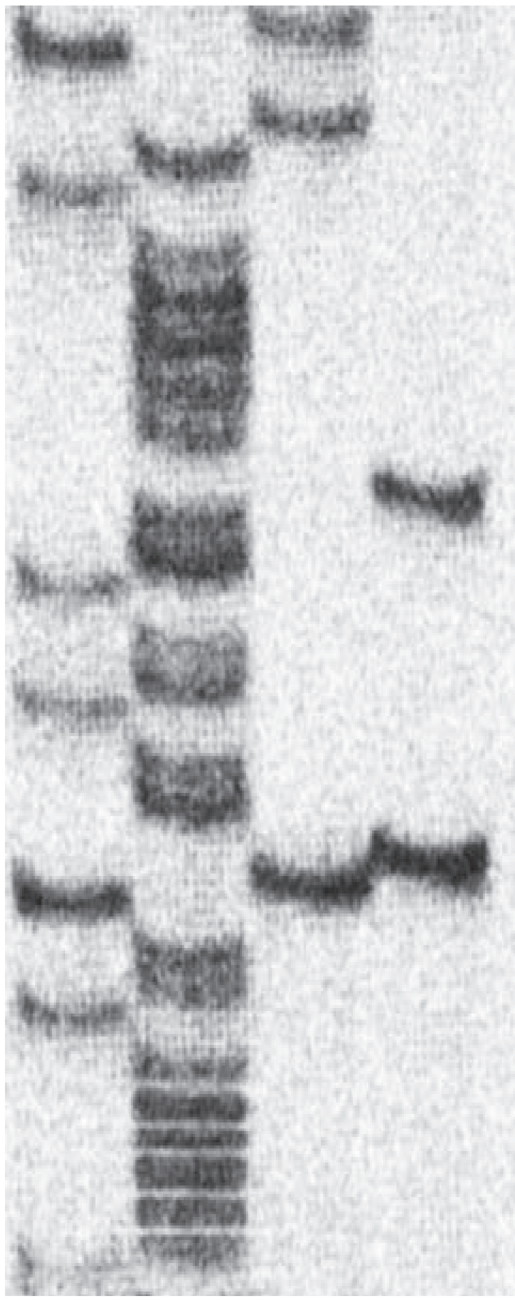
LESSON 2
HANDOUT 2.4

DNA Sequencing Puzzle

PUZZLE 1

Start reading here

Fill in the code letter



1	1	______
2	2	______
3	3	______
4	4	______
5	5	______
6	6	______
7	7	______
8	8	______
9	9	______
10	10	______
11	11	______
12	12	______
13	13	______
14	14	______
15	15	______
16	16	______
17	17	______
18	18	______
19	19	______
20	20	______
21	21	______
22	22	______
23	23	______
24	24	______
25	25	______
26	26	______
27	27	______
28	28	______
29	29	______
30	30	______

DNA FOR DINNER?

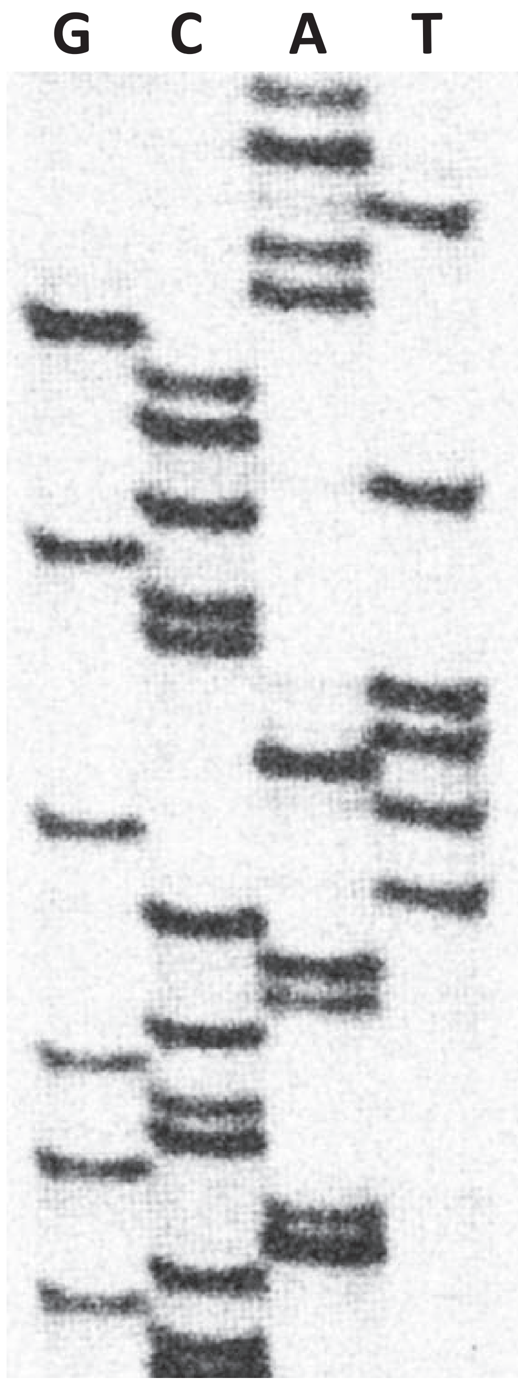
LESSON 2
HANDOUT 2.4

DNA Sequencing Puzzle

Start reading here

PUZZLE 2

Fill in the code letter



1 ______
2 ______
3 ______
4 ______
5 ______
6 ______
7 ______
8 ______
9 ______
10 ______
11 ______
12 ______
13 ______
14 ______
15 ______
16 ______
17 ______
18 ______
19 ______
20 ______
21 ______
22 ______
23 ______
24 ______
25 ______
26 ______
27 ______
28 ______
29 ______

DNA FOR DINNER?

LESSON 2
HANDOUT 2.5

Genomics Puzzle

Special thanks to the Boyce Thompson Institute for Plant Research for providing the idea for the "Genomics Puzzle" activity.

Sequence the DNA by cutting out each DNA fragment along the dotted lines, and placing them in the correct spaces on the left alongside the chromosome. The first fragment is already provided.

Remember that the colors and letters at the end of the fragments must match.

G A A T T C C G

C C G A A

A T C C T G A T

G A A T

T T A G A G A T

C G A T T C C G

A T C G

T C C G A C A T