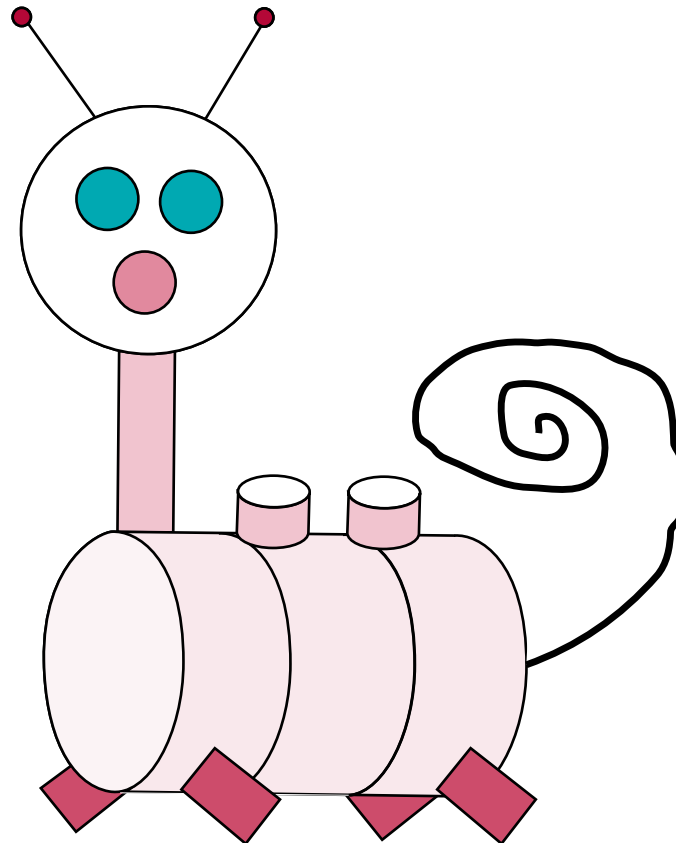


Reebops

A "Model" Organism for Teaching Genetic Concepts



The *Reebops* activity helps to demonstrate how genetics is responsible both for similarities and variation among members of the same species. Reebops are imaginary organisms made out of marshmallows and other inexpensive materials. The organisms tend to live in discarded shopping bags, and are rarely seen in the wild as they are extremely fast. If a male and a female Reebop are held together in captivity, your room quickly will become filled with Reebops. These creatures require minimal care, and can live comfortably in a covered shoebox with small ventilation holes punched in the sides.

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Revised 2012. Adapted for use in elementary school classrooms by the Center for Educational Outreach, Baylor College of Medicine (from Soderberg, 1991).

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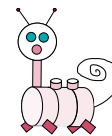
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Reebops was developed by Patti Soderberg, with support from a grant to the Center for Biology Education, University of Wisconsin-Madison, from the Howard Hughes Medical Institute. Graphic design by Tracy Saffran. For copies of the original Reebops exercise, please contact:

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Reebops



Notes for the Teacher

OVERVIEW

In this activity, students create imaginary creatures, referred to as “Reebops,” to explore the relationships between genes and inherited traits. Using Reebops as a model, students learn how hereditary information is passed from one generation to the next, and how the physical appearance of offspring is determined from the combinations of genes received from parents. By the end of this activity, students will be able to demonstrate why two parents can produce offspring whose characteristics resemble those of the parents but also demonstrate individual variation. There are several models of inheritance; this exercise will focus on one model of single-gene inheritance.

Time Required

Two 45-minute class periods

BACKGROUND

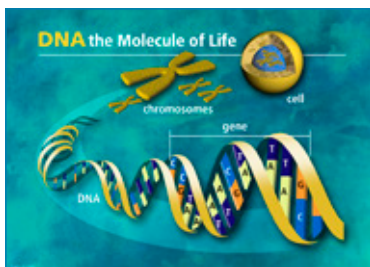
This background information is for teachers who would like to use the *Reebop* activity in their classrooms, but feel a little unsure about their genetics knowledge. Many elementary teachers are able to use Reebops to teach a variety of lessons to younger students.

Think about the students in your classroom. They have certain common characteristics, or observable **traits**, that identify them as members of the same species. While these similar traits set all of the students apart from other species, students also have traits that make them all unique from each other. Differences in

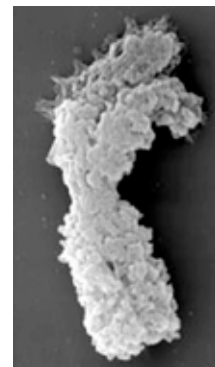


appearance and other unique traits are called **variations**. Usually, we observe less variation among close relatives than among individuals who are not closely related. For example, members of the same family may share visible traits, such as similar eye color, height, hair color and body type. They also may share similar, less visible traits, such as high blood pressure, diabetes or allergies. These similarities occur because we inherit our traits from our parents (**inherited traits**).

Although offspring share certain traits with their parents, they also usually display differences or variations from their parents. This activity will help students to understand how each parent contributes genetic information to an offspring, and why each offspring is similar to his/her parents, but unique in his or her appearance or traits.



Every cell in your body contains a complete set of your genetic information (your **genome**) in its nucleus.¹ This information consists of spiraled strands of **DNA (deoxyribonucleic acid)**. Each DNA strand is an extremely long molecule. When cells are not dividing (splitting into two new cells), the DNA will be uncoiled and spread over the entire cell nucleus. But when a cell is preparing to divide, each long DNA strand will coil tightly to form a **chromosome**. When this happens, the chromosomes can be seen using a microscope.



Chromosome

Since there are 46 strands of DNA in the nucleus of most human cells, it is logical that we also have 46 chromosomes. Our chromosomes can be arranged by length and physical appearance into 22 matching pairs, referred to as **homologous chromosomes**. Because these 44 chromosomes are not involved in determining sex or gender, they are called **autosomes** (from the Latin words for “self” and “body”). An individual inherits one chromosome in each homologous pair from his/her mother, and the other from his/her father. The remaining two chromosomes (the X and Y chromosome) are **sex chromosomes**. They determine gender. As with autosomes, individuals inherit one sex chromosome from each parent.

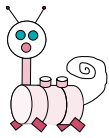


Twenty-two homologous pairs of chromosomes and two sex chromosomes

Sometimes, a medical procedure known as **amniocentesis** is used to see if a developing baby has the correct number of chromosomes. The chromosomes of fetal cells taken from the amniotic fluid are photographed using a microscope,

Continued

¹ There are a few exceptions to this rule; mature red blood cells of mammals, for example, do not have a nucleus.



and the different chromosomes then are manually matched into pairs using sections from the photo. Since each pair of chromosomes differs in length, the chromosomes can be arranged into pairs, from longest to the shortest. This visual arrangement of chromosomes is called a **karyotype**. (Note:



Karyotype: Twenty-two homologous pairs of chromosomes and two sex chromosomes

White blood cells or other body cells also can be used to obtain DNA and determine an individual's karyotype.) The human karyotype shown here has 22 homologous pairs of chromosomes, an X sex chromosome and a Y sex chromosome. Because the individual represented has

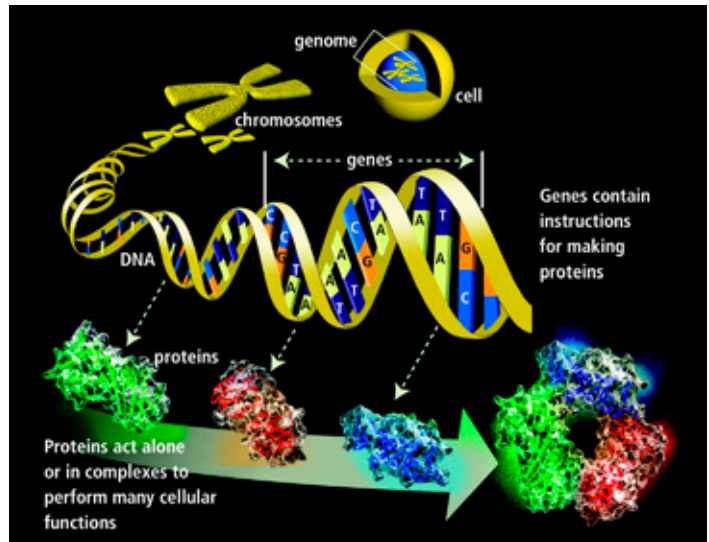
both X and Y sex chromosomes, we know it is a male. Human females have two X chromosomes (XX).

Now, let's think about what happens during reproduction. If both the mother's and father's cells have 46 chromosomes, the joining of two cells during **fertilization** should produce 92 chromosomes in each cell of the offspring! But this does not happen, because reproductive cells, or **gametes** (the female egg and the male sperm) are special.

Gametes are formed through a special process, known as **meiosis**. Meiosis reduces, by half, the number of chromosomes in each cell that is finally produced. For this reason, meiosis also is known as reduction division. (It should be noted that meiosis differs from the normal process of cell division, called **mitosis**, which creates two identical daughter cells, each with the same number of chromosomes as the parent cell.) The process of meiosis randomly selects a single chromosome from each of the 22 homologous pairs in the female parent, and another single chromosome from each homologous pair in the male. Meiosis also selects one sex chromosome from each parent. The 23 total chromosomes from each parent form the gametes: the **egg** in the female and the **sperm** in the male. When a female egg (23 chromosomes) joins with a male sperm (23 chromosomes) during **fertilization**, the resulting egg has a total of 46 chromosomes, half of which came from each parent.

Now, let's look closer at the chromosome. A **gene** is a section of DNA along a chromosome. Different genes may be different lengths. Genes contain instructions (designated by specific sequences of the chemical letters, A, C, G and T) that determine our characteristics, or traits. In other words, they hold the directions for building body parts and running chemical reactions required by the body. A separate class of molecule, referred to as **RNA (ribonucleic acid)**, copies the DNA instructions from a gene and uses this information to

manufacture **proteins**, the "workhorses" that make up many structural components of the body and carry out chemical reactions inside the body. Each gene contains the instructions to build one specific protein.

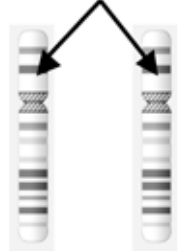


The location of a gene on a particular chromosome is called the **gene locus**. Since chromosomes come in pairs, genes do, too. A gene on one homologous chromosome has a companion gene in the same location on the other chromosome of the pair. Thus, every individual has two forms of each gene: one form that was inherited from the mother and another inherited from the father. *The two forms of a gene may be identical or different.* The matching forms of genes on homologous chromosomes are called **alleles**.

So, every individual has two alleles for each gene. The specific combination of alleles for a particular gene is referred to as **genotype**: the actual genetic makeup of the individual for that particular trait. An individual's particular combination of gene alleles determines his/her traits or characteristics; and his/her collective set of traits (e.g., hair color, body build, the presence or absence of a disease, etc.) is referred to as his/her **phenotype**.

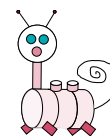
Let's use the inherited trait of freckles to demonstrate the **dominant-recessive model of inheritance**. (This is one of several models of single-gene inheritance.) To grasp how freckles are inherited, we must understand that an allele can be **dominant**—meaning that only one copy of the allele must be present for its associated trait to be expressed. An individual will have freckles if he or she receives an allele for freckles from his or her mother,

GENE ALLELES



Homologous pair of chromosomes showing gene alleles at a specific locus (location) on each chromosome.

Continued



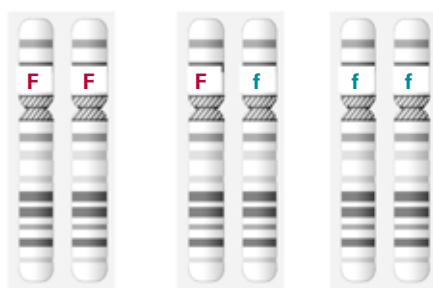
father, or both. Dominant alleles usually are represented by an upper-case letter, so in our example, we will use an “F.” A non-dominant allele is called **recessive** (usually shown with a lower-case letter; in this example, we will use “f”). A recessive allele will be expressed **only if** it is paired with a second recessive allele on the other chromosome of the homologous pair. In other words, in order to have the trait, a person would have to inherit



two copies of the recessive form of the gene—one copy from each parent.

The genotype, or combination of alleles, allows us to predict the phenotype for a given trait in an individual. One possibility is a **homozygous** combination of alleles—two alleles of the same form.

In our example, this combination would be either “FF” or “ff.” The “FF” combination, called **homozygous dominant**, produces freckles, while the “ff” combination, called **homozygous recessive**, results in



Possible combinations of allele forms: Homozygous dominant (left); heterozygous (center); homozygous recessive (right).

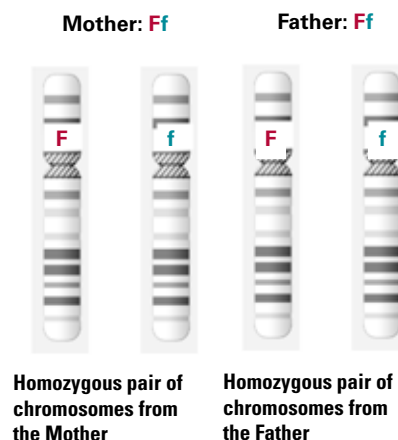
the absence of freckles. A second possible allele combination, **heterozygous**, would include two different alleles. In our freckle example, the heterozygous version would be written as “Ff.” Due to the presence of one dominant allele, this genotype would result in a phenotype with freckles.

Look at the “Key to Reebop Traits” on page 11. Notice that two “T’s” (TT) or a “T” and a “t” (Tt) code for the same thing, a curly tail. A Reebop with an allele identified with a small “t” on each chromosome (tt) will have a straight tail. Because both the heterozygous (Tt) and one of the homozygous (TT) forms code for the same trait of tail shape, curly tail is said to be the dominant form and straight tail is the recessive.

Now that we understand the dominant-recessive model of inheritance, let’s see if we can answer a question regarding the inheritance of freckles. Remember, offspring are similar to their parents (share many of the same traits), because each parent contributes half of the chromosomes to their progeny. The question is, *How can offspring possess traits that are unique from either parent?*

Let’s say both the mother’s and father’s genotype is “Ff.” That means that the alleles on the homologous chromosomes containing the freckle gene are heterozygous for both the

mother and father. When the gametes are formed in each parent, the process of meiosis randomly selects only one of these homologous chromosomes for the egg and another for the sperm. Because this is a random process, the mother will contribute either an “F” or an “f,” and the father will do the same. For the sake of simplicity, let’s keep only the freckle alleles for each parent and remove the rest of the chromosome.



Next, let’s place the possible gamete choices on the outside edges of a table containing two rows and two columns. Align the possible female allele choices for the egg in two rows along the left side of the table and the possible male allele choices for the sperm in two columns along the top of the table. You may recognize this table as a **Punnett square**. It

		Possible Male Alleles	
		F	f
Possible Female Alleles	F	FF	Ff
	f	Ff	ff

		Possible Male Alleles	
		F	f
Possible Female Alleles	F	FF	Ff
	f	Ff	ff

provides a visual representation of the possible offspring genotypes resulting from fertilization. When fertilization occurs, one of the mother’s two possible alleles for freckles joins with one of the father’s two possible alleles for freckles, resulting in the freckle genotype for the offspring. If both the female egg and the male sperm contain an “F” allele, the resulting offspring

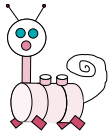
would have the genotype combination, “FF.”

Given the three possible genotypes for the offspring resulting from this mating (“FF,” “Ff,” and “ff”), there is a 75% chance that the progeny will have freckles, and 25% chance that he/she will not. Even though both

parents in this mating possess the freckles phenotype, there is the possibility of an offspring without freckles, “ff,” who exhibits traits different from either parent.

		Possible Male Alleles	
		F	f
Possible Female Alleles	F	FF	Ff
	f	Ff	ff

Continued



OVERVIEW OF ACTIVITY

For this activity, students will work with the fictitious “Reebop” organisms, and will have the opportunity to observe all of the offspring produced by one set of Reebop parents. Your students will sort Mom and Dad Reebops’ chromosomes, randomly select the new baby Reebop’s chromosomes, decode the “secret genetic code” found on the baby’s chromosomes, and construct the baby Reebop according to that code. In other words, your students will be modeling the life cycle processes of meiosis, fertilization, development and birth. After all of the babies are “born,” the Reebop family will be assembled so all family members can be compared and discussed.

Students will have an opportunity to examine a set of Reebop chromosomes and will observe that these organisms have 8 pairs of matching non-sex-chromosomes and 2 sex chromosomes, for a total of 18 total chromosomes.

Note: In the activity, the 18 chromosomes of the Reebop are described as 9 homologous (matching) pairs. This was done for the sake of simplicity and will not affect the outcome of the lesson activity. In humans, the two sex chromosomes are not considered homologous pairs.

Students will receive envelopes containing colored sets (red and green) of 18 chromosomes. Two of these chromosomes are sex chromosomes (the combination, XX produces females and XY produces males). Each parental set of chromosomes consists of pairs of 9 different lengths. The 18 red chromosomes are Mom’s and the 18 green ones are Dad’s. Remember, each parent has 8 homologous pairs of chromosomes and 2 sex chromosomes. The “genetic code” symbols (gene forms or alleles) are marked on each chromosome with upper-case or lower-case letters. The parents demonstrate a different trait on each non-sex chromosome (eight traits, eight pairs of chromosomes). Offspring gender is determined by the two sex chromosomes.

Materials

Per class of 30 students (includes materials to create a “Mom” and “Dad” Reebop for demonstration)

- 120 large white marshmallows (2 bags)
- 300 “mini” colored marshmallows (pastel colors: pink, green, orange, yellow) (1 bag)
- 34 fancy toothpicks with fringe (same color)
- 140 (approx.) plain round toothpicks
- 32 red flat thumb tacks
- 32 green flat thumb tacks
- 60 clear push pins
- 68 red push pins
- 17 brown pipe cleaners (each cut in half)
- 45 legal size envelopes

- Roll of black yarn
- Roll of yellow yarn
- 15 sheets of white “Karyotype” chromosomes
- 15 sheets of red “Mom” Reebop chromosomes
- 15 sheets of green “Dad” Reebop chromosomes

Per team of two students

- 4 large white marshmallows
- 6–8 “mini” colored marshmallows (pastel colors: pink, green, orange, yellow)
- 2 fancy toothpicks with fringe (all same color)
- 6–8 round plain toothpicks
- 2 red flat thumb tacks
- 2 green flat thumb tacks
- 4 clear push pins
- 4 red push pins
- 1/2 of a brown pipe cleaner
- Pair of scissors
- 12 inches of black yarn
- 12 inches of yellow yarn
- Set of white “Karyotype” chromosomes in an envelope
- Set of red “Mom” Reebop chromosomes in an envelope
- Set of green “Dad” Reebop chromosomes in an envelope
- Copy of student sheets (“Reebop Observations,” “Baby Reebop” and “Key to Reebop Traits”)

For class demonstration

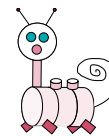
- 8 large white marshmallows
- 6 “mini” colored marshmallows (2, 2 green, 1 orange, 1 yellow)
- 4 fancy toothpicks with fringe (all same color)
- 12–16 round plain toothpicks
- 2 red flat thumb tacks
- 2 green flat thumb tacks
- 8 red push pins
- 2 pieces of brown pipe cleaner (1 pipe cleaner cut in half)
- Pair of scissors
- 24 inches of black yarn

Setup

Prior to the activity, allow the marshmallows to dry and harden (spread marshmallows on a flat surface to dry for several days). Fresh marshmallows may be used but the Reebops will be a little more “floppy.” One-and-one-half inch styrofoam balls may be substituted for marshmallows in this activity.

Prepare envelopes containing envelopes containing chromosomes for students by tearing out the chromosomes on the perforated white, green and red sheets. OR, have

Continued



students tear out the chromosomes before beginning the activity. Crease the sheets along the perforated lines so that the strips tear apart cleanly. Keep each set of colored strips separate. Place the white chromosomes in an envelope labeled “Karyotype;” the red chromosomes in an envelope labeled “Mom, or Female ReeBop;” and the green chromosomes in an envelope labeled “Dad, or Male ReeBop.”

Prior to class, assemble Mom and Dad demonstration ReeBops. Follow the guidelines below to create each “parent.”

- **Mom:** 2 antennae (fringe toothpicks), 1 head (white large marshmallow), neck (two round toothpicks), 2 green eyes (green flat thumb tacks), 1 yellow nose (colored miniature marshmallow attached with toothpick pieces), 3 body segments (white large marshmallows joined by round toothpicks), 2 pink humps (pink miniature marshmallows attached with toothpick pieces), 4 red legs (push pins), a straight tail (a pipe cleaner), black hair (black yarn attached with toothpick pieces), and no beard.
- **Dad:** 2 antennae (fringe toothpicks), 1 head (large white marshmallow), a neck (two round toothpicks), 2 red eyes (red flat thumb tacks), 1 orange nose (colored miniature marshmallow attached with toothpick pieces), 3 body segments (white large marshmallows joined by round toothpicks), 2 green humps (green miniature marshmallows attached with toothpick pieces), 4 red legs (push pins), a curly tail (a pipe cleaner), black hair (black yarn), and a beard (black yarn attached with toothpick pieces).

Place all materials for each team of two students on a tray. Set up trays with materials in a central supply center.

Safety

Have students wash their hands after the activity. Follow all district and school science safety rules.

ACTIVITY PROCEDURE

Day 1. ReeBop Traits and Chromosomes

For an illustration of a chromosome to share with your students visit this site.

<http://rex.nci.nih.gov/RESEARCH/basic/lrbge/Chromosome.jpg>

1. Show the class the Mom and Dad ReeBops, and briefly present the “natural history” of ReeBops, provided below.

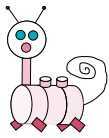
Reebops are imaginary organisms. They tend to live in discarded shopping bags. They are rarely seen in the wild,

as they are extremely fast. Reebops produce large families very quickly. They require minimal care, and can live comfortably in a covered shoebox with small ventilation holes punched in the sides

2. Ask students to observe the ReeBop parents. Ask, *What are some unique characteristics of ReeBops as organisms?* Help students to identify common features of both ReeBop parents. You may want to start a list on the board. The list might include antennae, head, neck, body made of marshmallows, tail, four legs, two humps, two eyes, hair, etc. Students also may begin to notice differences between the two ReeBop parents, such as nose color and the “Dad” ReeBop’s beard. List and discuss differences between the parents. Use this discussion as an opportunity to introduce the concept of variation.
3. Give each pair of students a copy of the handout, “ReeBop Observations.” Instruct students to observe the parent ReeBops and fill in the “appearance” column for each parent. Complete the first example, antennae, with the entire class. Ask, *How many antennae does the Mom ReeBop have?* [two] Have students write “2” in the box corresponding to number of antennae for the Mom. Follow the same procedure for the Dad ReeBop’s antennae, and give students time to complete the remaining ReeBop appearance observations within their teams.
4. Once students have completed their observations of the parents’ appearance, ask, *Do you think there might be other kinds of differences between the two ReeBops that are harder to observe?* [Mention that disease tendencies, personality traits, etc. also can be inherited.] Also ask students if they have ever thought about where the instructions for “how to build” an organism come from. Follow by asking students if they ever have heard the term, “gene.” Students may have a number of ideas about genes. Explain that the visible “features,” or traits they listed for the ReeBops are determined by different genes found in the organism. For example, the ReeBop has a gene for the number of antennae, the color of its eyes, the shape of its tail and so on. Ask students if they have ideas about where genes might be found. Explain that genes are located on chromosomes (inside our cell nuclei), much like beads on a string. Depending on your students’ prior knowledge, you may want to use the diagram that can be found at the link below to show genes on chromosomes inside a cell.

http://genomics.energy.gov/gallery/basic_genomics/detail.np/detail-17.html

Continued



5. Have each student work with a partner. Tell students that they are going to look more closely at examples of the chromosomes from a Reebop cell. Give each team a packet of white chromosomes labeled “Karyotype.” Have students open the envelope and remove the chromosome strips. (If you have not separated the chromosome strips in advance, have students carefully crease the sheets along the perforations before separating the set of strips. Keep each set together.)
6. Ask, *What do you notice about the chromosomes strips?* Students might report that the chromosomes have different lengths and different labels, and that some chromosomes seem to match. Discuss students’ observations. There are two of each kind of chromosome, called partner (homologous) chromosomes, which have the same genes. For example, one set of chromosomes has the gene for leg color, while another set has the gene for number of body segments.

Note: This activity uses a very simple model, in which only one gene, coding for a single trait (e.g., eye color), is marked on each “chromosome” that students examine. In advanced classes, you might tell students that partner chromosomes are called homologous chromosomes and that each chromosome actually has many genes.

7. Ask, *How might these chromosomes be sorted?* Students may suggest sorting by length or trait. Ask, *Do chromosomes of the same length have the same trait?* [Yes. For example, the longest pair of chromosomes has the gene that codes for the presence of antennae.] Ask students to lay out the chromosomes from longest to shortest—making sure to keep “partner chromosomes” (or homologous pairs) together.
8. Ask, *How many pairs of chromosomes does a Reebop have?* [9 pairs, making a total of 18 chromosomes] If students ask, tell them that humans have 23 pairs, or a total of 46 chromosomes.

Note: For simplicity, in this exercise, the sex chromosomes are treated as a homologous pair. In humans, they are not paired. Human chromosomes are described as 22 homologous pairs and 2 sex chromosomes.

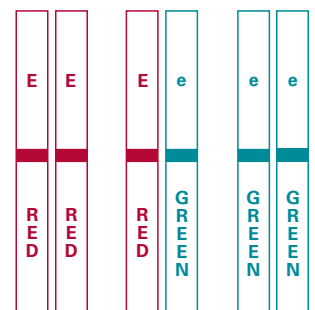
9. Explain that one method scientists use to study chromosomes is to lay out images (drawings or photographs) of chromosomes in order of size. The resulting arrangement is called a karyotype. Ask students, *What kinds of information could you obtain by observing a karyotype?* [relative sizes and shapes of chromosomes, number of chromosomes, number of chromosome pairs] *If a piece of a chromosome, or perhaps a whole chromosome were missing, would a scientist be able to see that defect by looking at a karyotype?* [yes]

Optional: If there are four students at a table, have one pair of students randomly hand one chromosome from their set to the other pair. Let them compare sets of chromosomes and decide the outcome for the two karyotypes. It should be easily visible that one set has three of one of the chromosomes, while the other set only has one of the same chromosome. Explain that this is one way to utilize a karyotype: to locate extra or missing chromosomes. Be sure the students hand back the chromosome to the original owners before placing the white chromosomes back in the appropriate envelope.

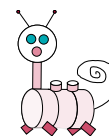
At this point, you may wish to show a PowerPoint slide of an actual karyotype, or find photos of karyotypes on the Internet to share with your students. You also may want to have one or more students demonstrate how to lay out their karyotype from the envelope to the rest of the class using an “Elmo” document camera or other projector. This URL leads to a good diagram of a human male karyotype.

http://upload.wikimedia.org/wikipedia/commons/5/53/NHGRI_human_male_karyotype.png

10. Ask students to return their Reebop chromosomes to the envelopes and collect the envelopes.
11. Next, refer back to the discussion of variation between the Mom and Dad Reebops. Ask, *Can a trait appear different within the same kind of organism?* [Yes. For example, eye color and nose color are different in each parent Reebop.] Tell students that the gene determines the appearance of a trait and can have several forms. (If you have advanced students, tell them these multiple forms are called alleles.) For example, the Reebop gene for eye color can have a red form and a green form. Similarly, the gene for antenna can have a form for 1 antenna or for 2 antennae (both Reebop parents, however, have two antennae). Ask students, *How many of a Reebop’s chromosomes have a gene that affects the number of antenna it will have?* [two] *How about eye color?* [two]
12. A Reebop’s eye color trait depends on the form (allele) of the gene that the Reebop has on each of the chromosomes that determine that (eye color) trait. Draw the following eye color example on the board (right).
13. Ask students to think about and predict what eye



Continued



ANSWER KEY: REEBOP OBSERVATIONS

TRAIT	MOM		DAD	
	Appearance (phenotype: expression)	Gene Forms (letter pairs or genotype)	Appearance (phenotype: expression)	Gene Forms (letter pairs or genotype)
Number of Antennae	2 antennae	Aa	2 antennae	Aa
Nose color	yellow	nn	orange	Nn
Eye color	green	ee	red	Ee
Number of Body Segments	3 segments	Dd	3 segments	Dd
Hump color	2 pink	gg	2 green	Gg
Tail shape	straight	tt	curly	Tt
Leg color	red	Rr	red	Rr
Hair color	black	Bb	black	Bb
Gender	female	XX	male	XY

color each combination of gene forms would produce. For example, if a Reebop has partner chromosomes with the “red-eye” form of the gene, it is reasonable to assume the Reebop will have red eyes. A Reebop with two “green-eye” forms of the gene will most likely have green eyes. Ask students, *What do you think will happen if a Reebop has a red-eye form of the gene on one chromosome and a green-eye form on the other?* Students may suggest that the Reebop would have one green eye and one red eye, or spots of both colors in each eye, etc. Explain that the gene form for red eyes is called dominant, and that it will, therefore, always show or be expressed if it is present. The gene form for green eyes is recessive will show or be expressed only if it is paired with another “green-eye” gene form on the partner chromosome. In the example above, the combination of the “red-eye” and “green-eye” gene forms will result in a Reebop with two red eyes, because red is dominant for eye color in Reebops.

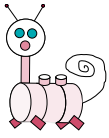
- Describe for students how scientists often represent genetic traits with letter symbols. Upper-case (capital) letters are used for dominant forms, and lower-case letters are used for recessive forms. In this case, we might assign the dominant red-eye form the capital letter “E,” and the recessive green-eye form a lower-case letter “e.”
- Ask students, *Can we tell by the appearance of the Dad Reebop if he has one or two red forms (alleles) of the gene for eye color (EE or Ee)?* [No, because the presence of just one “E” allele will produce red eyes.]

Optional: Ask, *How many form (allele) combinations of the gene will result in red eyes?* [two]. Ask, *Can you tell which allele combinations (genotypes) result in red eyes?* [EE and Ee]. Ask, *But can you tell which red eye*

allele combination (genotype) the dad Reebop really possesses by looking at his eyes? [no] In other words, we can predict the appearance of a trait if we know which gene forms are present. But it is not always possible to tell which gene forms are present just from appearance.

- Distribute one “Mom Reebop” (red) and one “Dad Reebop” (green) packet or sheet of chromosomes to each pair of students. (If necessary, have students separate chromosome strips as before.)
- Tell students that they now will examine the karyotypes of the Mom and Dad Reebops. Ask, *Do you predict that the two parents will have similar or different karyotypes?* (You may wish to have students look at the mom and dad Reebops.) Instruct students to sort the chromosomes for each parent separately, by trait and size (just like they did with the packet of white chromosomes at the beginning of the activity). Ask, *What similarities do you notice between these two chromosome sets and the karyotype of the set you sorted at the beginning of the activity?* [number of chromosome pairs, size, types of traits—such as color of eyes, kind of tail, etc.] *What is different?* [Paper colors are different; letter symbols are used on chromosome strips, in addition to the trait description; the members of each chromosome pair do not always have the same upper-case or lower-case designations.]
- Now, have students examine the two letters on each pair of chromosomes for each parent karyotype, and then fill in those letter pairs in the appropriate places on the Reebop Observations student sheet. Fill in the first row (Number of Antennae) as a class. Be sure and emphasize the importance of case sensitivity. Ask

Continued



students to locate the two chromosomes from the mother and the two from the father associated with antennae. Fill in the letter pairs in the appropriate space on the table for each parent (both parents have Aa).

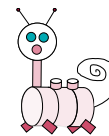
19. Students should work together in pairs to complete their tables. After everyone has finished, check students' work, then conduct a class discussion of students' observations. Ask, *For which traits do the Mom and Dad have the same forms of the gene?* [antenna number, body segment number, leg color, hair color] *For which traits do they have different forms of the gene?* [nose color, eye color, hump color, tail shape, gender] *Which trait is represented by two different letters—both in upper case?* [gender: male, XY, or female XX] *Do you think you could use this table to predict which combinations of gene forms produce certain traits? Why or why not?*
20. Have students return the chromosomes to the proper envelope and collect. Tell them that during the next session, they will observe how the baby Reebop inherits its genes from the parent Reebops.

Day 2. Reebop Offspring

1. Once again, show the Mom and Dad Reebops to the class. Ask, *Are the parents exactly the same?* Remind students that we call the differences between individuals "variation." Explain that students will have an opportunity to observe offspring that might be produced by these Reebop parents. Ask, *Do you think all of the offspring will look exactly like the parents?*
2. Have students work in pairs. One partner should receive a female envelope (red) containing a full set of Mom Reebop's chromosomes, and the other partner should receive a male envelope (green) containing a full set of Dad Reebop's chromosomes.
3. Ask each student to take out his or her set of chromosomes and turn them face down on the table, so that no letters are visible. Students should keep their chromosomes separate from their partners' chromosomes.
4. Next, have students sort chromosomes by length (from largest to smallest), just as they did in the karyotype exercise. Monitor the class to make sure each student has 9 pairs of chromosomes, sorted and matched correctly.
5. Ask students, *How many chromosomes does each parent have?* [18 chromosomes, or 9 pairs/partners]. Ask, *If you combined all of the Mom's chromosomes and all of the Dad's chromosomes, how many chromosomes would there be?* (36, or 4 of each type of chromosome). Ask the students if they see a mathematical relationship between 36 and 18. Their response should indicate that one is half of the other. Explain that for a Reebop to develop and grow normally, its cells must have 9 partner pairs, just like each parents's cells do. Ask students for ideas about the best way to reduce the number of chromosomes from 36 to 18.
6. After students have discussed their ideas, explain that in real organisms (and Reebops) each parent randomly contributes only one partner of each chromosome pair to their offspring. Have students with the Mom Reebop chromosomes randomly choose one member from each pair of partner chromosomes and place the selected chromosomes in one pile (this is like the female egg). Then, have students with the Dad Reebop chromosomes randomly choose one member from each pair of chromosomes and place the selected chromosomes in a separate pile (this is like the male sperm).
7. Chromosomes that were not selected should be returned to the appropriate envelopes before proceeding.
8. Next, direct students to join the two piles (egg and sperm) to make a new baby Reebop (this represents fertilization). Leaving the chromosomes face-down (no peeking!), students should sort the chromosomes so that those of equal length are together (in partner pairs). Ask, *What percentage of chromosomes came from each parent?* [50%, or half] Ask, *How many chromosomes are now present in the new baby Reebop?* [18 chromosomes, or 9 pairs]
9. It's time to see what traits each Reebop baby has inherited. Each group can discover what its baby will look like by turning over the baby's paired chromosomes. Students should record the letters from each pair (genetic forms, or genotype) in the "Baby Reebop" data table. Next, using the "Key to Reebop Traits," students should fill in what each trait will look like (for example, "red eyes").

At this point, if you have not done so, you also may want to introduce some new terminology: "genotype" and "phenotype." Tell students that genotype refers to the two-letter forms of the gene that a Reebop has for a particular trait. The term, phenotype, refers to the Reebop's physical appearance, determined by its genotype.
10. Once students have completed their table for gene forms (genotype) and appearance (phenotype), instruct each team to pick up materials from a central location, and make a baby Reebop with the traits listed in its table. Ask each group to name its baby Reebop and write the name on a note card or sticky note. Provide a place for the new baby Reebops and their name cards in a Reebop "nursery" next to the parents.

Continued



11. Discuss the outcomes of the activity as a class. Ask, *Do any of the Reebop babies look exactly like their parents?* [possibly] *Do any of the Reebop babies look exactly like each other?* [possibly] *Are any Reebop offspring completely different from all of their siblings?* [possibly] *What do we call the differences in appearance among the Reebop babies?* [variation] *Which processes lead to the variation we can see among the Reebop*

babies? [Each parent contributes only one set of 9 chromosomes each containing one gene form or allele to the offspring. Therefore each offspring receives a random combination of gene forms or genotype for each trait from his or her parents.]

12. Have students write in their notebooks to explain the relationship between genes and inherited traits.

GLOSSARY

Allele - Alternate forms of a gene. A gene actually consists of two forms, one on the chromosome that came from the father, the other on the chromosome given by the mother.

Amniocentesis - Removal of fluid from the womb containing a developing fetus. This is usually done to look at the karyotype but can be used for other tests.

Autosomal - A chromosome not involved in determining the gender of an organism.

Chromosome - Long strands of tightly coiled DNA wrapped around histone proteins. Each chromosome is a separate strand of DNA.

DNA - A long molecule of deoxyribonucleic acid that contains the genetic code for the organism. DNA is double-stranded and tightly coiled into compact structures called chromosomes.

Dominant trait - An allele that is fully expressed in the phenotype whether the genotype is homozygous or heterozygous. An example is curly tail (for either TT or Tt).

Egg - The female gamete formed by the process of meiosis and containing half the number of chromosomes as a body cell and is therefore haploid. Used in fertilization.

Fertilization - The union of the sperm and the egg to form a zygote that will develop into a full-grown organism. Fertilization results in the normal number of chromosomes for that species.

Gametes - The sex cells (sperm or egg). These cells have half the number of chromosomes as a body cell and are therefore haploid.

Gene - A section of DNA on a chromosome that contains instructions for the inheritance of a particular characteristic or trait. The protein it codes for will result in a particular trait. Different genes have different lengths.

Gene locus - The location of a gene on a chromosome. The locus is the same on the other chromosome of the pair.

Genotype - The actual genetic makeup of an organism.

Heterozygous - Having two alleles (forms of the gene) that are different (Aa).

Homologous pairs of chromosomes - Chromosome pairs of the same length that possess the same genes at the same loci. One homologous chromosome is inherited from the mother and the other from the father.

Homozygous - Having two alleles (forms of the gene) that are the same (TT or tt).

Inherited traits - The passing of traits from the parents to the offspring by receiving half of the chromosomes from the mother and half from the father. Traits are based on specific, inherited genes.

Karyotype - A chromosomal picture of an organism where the homologous pairs of chromosomes are aligned from the largest to the smallest.

Locus - The location on the chromosome where the gene can be found. The plural of locus is loci.

Meiosis - Cell division that produces daughter cells with half the number of chromosomes than were present in the original parent cell (reduction division). This is the process that creates the gametes or sperm and egg cells.

Phenotype - The physical traits or appearance of an organism.

Protein - A molecule consisting of a series of amino acids linked together. Proteins run chemical reactions (enzymes) in your body or make up the structural components of your body.

Recessive trait - An allele of a gene that demonstrates lack of dominance and will only be expressed if it is paired with a second recessive allele on the other homologous chromosome.

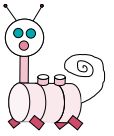
Species - Group of living organisms that possess similar characteristics and possess the ability to interbreed and produce live offspring.

Sperm - The male gamete formed by the process of meiosis and containing half the number of chromosomes as a body cell and is therefore haploid. Used in fertilization.

Trait - The characteristics of an organism or how it physically looks. Traits are based on the specific expression of inherited genes.

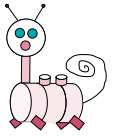
Variation - Differences in appearances or traits among organisms.

Reebop Observations



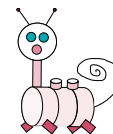
≡ TRAIT ≡	≡ MOM ≡		≡ DAD ≡	
	Appearance (phenotype: expression)	Gene Forms (letter pairs or genotype)	Appearance (phenotype: expression)	Gene Forms (letter pairs or genotype)
Number of Antennae				
Nose color				
Eye color				
Number of Body Segments				
Hump color				
Tail shape				
Leg color				
Hair color				
Gender				

Key to Reebop Traits



NUMBER OF ANTENNAE	NUMBER OF BODY SEGMENTS	LEG COLOR
AA = 2 antennae Aa = 2 antennae aa = 1 antenna	DD = 3 body segments Dd = 3 body segments dd = 2 body segments	RR = red legs Rr = red legs rr = clear legs
NOSE COLOR	HUMP COLOR	HAIR COLOR
NN = orange nose Nn = orange nose nn = yellow nose	GG = 2 green humps Gg = 2 green humps gg = 2 pink humps	BB = black hair Bb = black hair bb = yellow hair
EYE COLOR	TAIL SHAPE	SEX CHROMOSOMES (X AND Y)
EE = red eyes Ee = red eyes ee = green eyes	TT = curly tail Tt = curly tail tt = straight tail	XX = female (no beard) XY = male (black beard)

Baby Reebop



≡ TRAIT ≡ ≡	BABY REEBOP ≡	
	Appearance (phenotype)	Gene Forms (letter pairs or genotype)
Number of Antennae		
Nose color		
Eye color		
Number of Body Segments		
Hump color		
Tail shape		
Leg color		
Hair color		
Gender		

Antennae

A

Nose Color

n

Eye Color

e

Number of Body Segments

D

Hump Color

g

Tail Shape

t

Leg Color

R

Hair Color

B

dotted = cut

X

Antennae

a

Nose Color

n

Eye Color

e

Number of Body Segments

d

Hump Color

g

Tail Shape

t

Leg Color

r

Hair Color

b

X

Antennae

A

Nose Color

N

Eye Color

E

Number of Body Segments

D

Hump Color

G

Tail Shape

T

Leg Color

R

Hair Color

B

dotted = cut

X

Antennae

a

Nose Color

n

Eye Color

e

Number of Body Segments

d

Hump Color

g

Tail Shape

t

Leg Color

r

Hair Color

b

Y

