PowerUp Lesson 2: The Science of Diversity

PowerUp Lesson Plan Overview

This lesson is one of six lessons developed as a classroom companion to PowerUp, a free, online, educational video game that allows students to experience the excitement and the diversity of modern engineering.

The lessons are designed to be flexible and scalable to meet your students' needs. Facilitation tips, extension activities and resources for learning more can be found in the Teachers' Guide, which is available for download along with each of the lessons. For these resources, as well as to download and play PowerUp for free, go to http://powerupthegame.org.

PowerUp was created by IBM and TryScience/The New York Hall of Science with scientific content and expertise provided by the Tech Museum of Innovation, the Bakken Museum, Idaho National Laboratory and the National Renewable Energy Laboratory.

PowerUp Lesson 2:
The Science of Diversity

Student Objectives

To begin this lesson, students will look at a picture of a family with twin girls who have inherited very different physical traits from their parents. Students discuss whether or not this is truly possible and if so, how?

This discussion will serve as a review of genetic inheritance – students will understand that our traits are inherited from our parents (and their parents, and their parents) in discrete parcels, called genes. Students will discuss the ways everyone is made him- or herself by a combination of inherited biological traits and environmental factors. Students will understand that all humans are far more alike than different – 99% genetically identical – and that all of our genetic differences can be traced back to just 1% of our DNA.

Using the genotype/phenotype worksheet as a guide, students will perform a series of coin tosses to randomly determine the traits of a person's genotype. Next they will apply their knowledge of genetics to sketch a face that represents that person's phenotype. Students will take into account the multiple ways alleles can interact to influence the physical manifestation of a trait. Finally, students will toss coins again to create two different gametes through which that person can procreate and pass on genetic information.

Working with a partner, in class or for homework, students exchange gametes and draw two offspring based on inherited traits. Discuss the traits of the second generation – Are there higher instances of dominant traits or recessive traits? Why? Do siblings have similar traits?

Class Time

- One Period
- Look at family portrait – discuss inherited traits, review DNA and genetic inheritance (10 - 15 minutes)
- Genotype/Phenotype worksheet:
- Toss coins to determine genotype, sketch phenotype (10 minutes)
- Toss coins to create gametes (5 minutes)
- Sketch offspring, based on interaction between alleles (5 minutes)
- Discuss traits of offspring (5 minutes)

Materials (per student)

- 1 penny
- 1 phenotype worksheet
- colored pencils (optional)

Preparation

- Review background information
- Print and copy worksheet
- Gather materials

National Science Standards 9-12

NS.9-12.3 Life Science
As a result of activities in grades 9-12, all students should develop understanding of:

- Molecular basis of heredity
- Biological evolution

NS.9-12.7 History and Nature of Science
As a result of activities in grades 9-12, all students should develop understanding of:

- Science as a human endeavor

Classroom–Game Connections

When your students log in to PowerUp and enter the **Orientation Center** they will have many opportunities to further investigate concepts addressed in this lesson. You may choose to have your students play PowerUp before the lesson, or you may assign gameplay for homework after this lesson to reinforce lesson concepts in a highly motivating context.

Here are some examples of the classroom – game learning connections:

- **Engineering is a diverse field. Engineering is for people like me.**
  Your students will meet interact with the characters based on over a dozen real Engineers.

  The more time your students spend in conversation with these Engineers, the more examples they will learn of the types of diversity that exist within and strengthen the field of Engineering. They will learn that Engineers themselves come from diverse cultural, social, and ethnic backgrounds, and that these backgrounds prepared them differently and uniquely for the challenges of Engineering. They will learn that within Engineering there are diverse specializations, and that different kinds of Engineers do different kinds of work in a variety of settings.

When your students participate in the **Wind, Solar and Hydro Electric Missions** they will have further opportunity to experience concepts of diversity in Engineering.

Here are some examples of the classroom – game learning connections:

- **Diversity can strengthen a team.**
  In each mission your students will be working in groups to solve Engineering challenges. In class or for homework you may have them reflect on these in-game experiences and think about examples where teamwork was strengthened by having a variety of different approaches to a task, different ideas of how to solve a problem, different strengths and abilities of team members.

LESSON FACILITATION

A Remarkable Family: Discussion and Review of Genetic Inheritance (10 - 15 minutes)
Show your students the family portrait, below, of two parents with their twin girls. These two daughters are dizygote twins born in England, to these two parents, in April 2005. Kian, on the left, has dark brown hair, brown eyes and brown skin. Remee, on the right, has fair skin, blue eyes and blonde hair.

Kylie Hodgson and Remi Horder with twin daughters Kian and Remee**. © Gary Roberts**

Ask your students whether they believe that these two girls are, in fact, twin sisters. Why or why not? Encourage your students to discuss and debate the science behind the heredity of these traits. Ask your students to estimate the likelihood that these two parents would have twin girls with such different coloring.

Use this discussion to prime your students' prior knowledge of and review genetic inheritance.

Encourage your students to use the proper scientific terms throughout the discussion: DNA, chromosome, gene, trait, allele, homozygous, heterozygous, gamete, meiosis, genotype, phenotype, dominant/recessive, incomplete dominance, monogenetic, polygenetic.

Ask if any of your students is a twin, or if they have siblings or cousins who are twins. Ask what type of twins they are? (Students will likely use the colloquial “fraternal” or “identical”) Ask students to explain the distinctions between the two types of twins. Explain the terms “monozygous” and “dizygous.”

Ask your students to think of ways siblings are the same and ways they are different. Ask them to think about themselves and their friends – how are they the same, how are they different? Which of these are linked to genetic inheritance? What other factors can influence who we are? Do they have more in common with their friends or their parents? Biologically? Environmentally? Culturally?

Genotype/Phenotype worksheet (20 minutes) (attached)

Wrap up Discussion (5-10 minutes)

Use this key to sketch a person based on his or her genotype:

Worksheet Page 1

Sex chromosome (females are homozygous XX, therefore mom always contributes X)	Mom contributes **X**	Dad contributes **X or Y**	XX = female XY = male

Trait	Allele (physical manifestation of allele's expression)	
Monogenetic, Dominant/Recessive	**Dominant**	**Recessive**
freckles	F (yes)	f (no)
chin cleft	C (yes)	c (no)
free-hanging ear lobes	E (yes)	e (no)
widow's peak	W (yes)	w (no)
Monogenetic, Incomplete Dominance	**Dominant**	**Recessive**
Hair – dark pigment	D (yes)	d (no)
hair – curly texture	T (yes)	t (no)
lip color – dark pigment	L (yes)	l (no)
Polygenetic, Incomplete Dominance*	**Dominant**	**Recessive**
black melanin in iris	B (yes)	b (no)
yellow melanin in iris	Y (yes)	y (no)

* This is a simplified explanation of eye color inheritance. Current research shows that the gene most responsible for eye color is the *OCA2* gene which controls how much melanin is produced in the iris. The way OCA2 is expressed has a lot to do with three single nucleotide polymorphisms (SNPs) in a DNA sequence near the gene. Green eyes are likely the result of interaction between OCA2 and other genes. (http://discovermagazine.com/2007/mar/eye-color-explained)

Procedure: Use a coin toss to determine which alleles of a given gene are present on this person's DNA. If the coin comes up "Heads" that means the **dominant** allele is present. "Tails" means the **recessive** allele is present. Remember to toss the coin TWICE for EACH trait – each of us inherits two alleles for each gene, one inherited on a **chromosome** from our mother (through her egg cell) and one from a chromosome from our father (through his sperm cell). The interaction of the two alleles determines which is expressed physically.

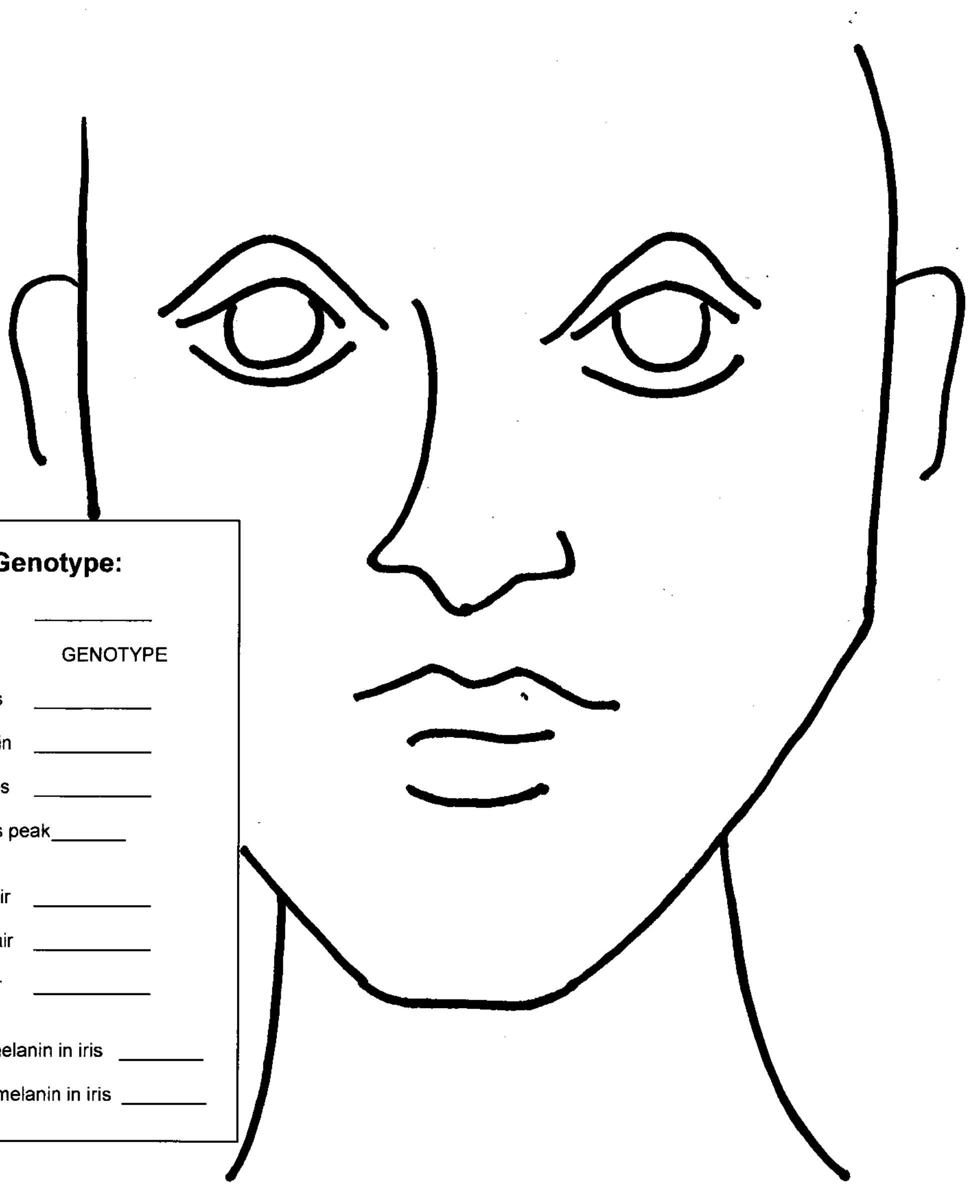
Example: If you are determining the genotype for the freckles gene, you would toss the coin...and if you get tails that symbolizes that the person has inherited at least one recessive allele, **f**, from one parent. Now toss the coin one more time to determine what the second allele is (from the other parent)... if you get heads, that represents that a dominant allele, **F**. was inherited. Make a note of the person's **genotype** (in this case, **fF**) for this trait in the chart on the other side of this page. Next determine, based on your knowledge of genetics and the key, above, how this combination of alleles will LOOK. Sketch the results on the face template. This outward, physical manifestation of a person's genetic material is called his or her **phenotype**.

As you draw the phenotype remember that certain alleles have a **dominant/recessive** relationship in which a heterozygous genotype results in the same phenotype as a homozygous genotype of the dominant allele. Other alleles display **incomplete dominance**. In these cases, a heterozygous genotype results in a phenotype that is somewhere between the two homozygous phenotypes. Also remember that while some traits are monogenetic, or decided by one single gene, others – like eye color -- are **polygenetic**, or the sum result of multiple genes and multiple alleles. For this activity, to determine eye color you must flip your coin four times.

To find the sex of the person, you need only toss the coin 1 time, to determine what is inherited from the father. Since women are **homozygous** XX, when a woman's chromosomes replicate and split she has a 100% probability to pass on an X chromosome to her child. Men, however, are **heterozygous** – XY– you will use a coin flip to symbolize whether this person's father passed on an X or a Y chromosome. Let “Heads” symbolize X and “Tails” symbolize Y.

Worksheet Page 2

Sketch Phenotype:



Write Genotype:

Sex ___________

TRAIT GENOTYPE

freckles ___________

cleft chin ___________

earlobes ___________

widow's peak_______

dark hair ___________

curly hair ___________

lip color ___________

black melanin in iris ________

yellow melanin in iris ________

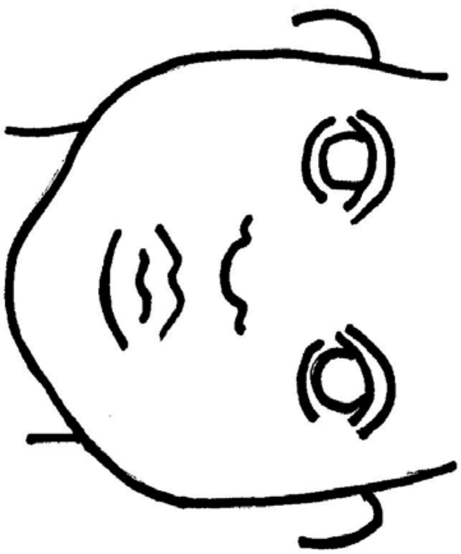
Worksheet Page 3

Gamete From Mother:
sex chromosome____

TRAIT/ allele
freckles____
cleft chin ____
earlobes____
window's peak____
dark hair____
curly hair____
lip color____
black melanin in iris____
yellow melanin in iris____

Gamete From Father:
sex chromosome____

TRAIT/ allele
freckles____
cleft chin ____
earlobes____
window's peak____
dark hair____
curly hair____
lip color____
black melanin in iris____
yellow melanin in iris____

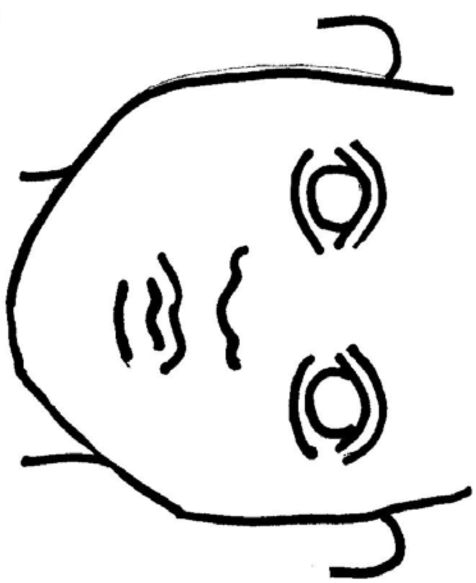


Gamete From Mother:
sex chromosome____

TRAIT/ allele
freckles____
cleft chin ____
earlobes____
window's peak____
dark hair____
curly hair____
lip color____
black melanin in iris____
yellow melanin in iris____

Gamete From Father:
sex chromosome____

TRAIT/ allele
freckles____
cleft chin ____
earlobes____
window's peak____
dark hair____
curly hair____
lip color____
black melanin in iris____
yellow melanin in iris____



Background Information

DNA, Chromosomes and Genes

Genetic information is passed on from parents to children via DNA (Deoxyribo Nucleic Acid). DNA is a long molecule that carries encoded information on how to build and maintain an organism that can be read and understood by cells. Almost every cell in your body contains a complete set of your DNA (exceptions are red blood cells that do not have a nucleus and gametes – egg and sperm cells which contain HALF a set of DNA, more on that later). Your DNA is divided into 23 pairs of chromosomes (thread-like pieces of DNA). Chromosomes are further divided into genes – which are tiny sections of DNA that contain information that translates into specific traits in an organism, for instance, whether or not you can roll your tongue. Each person has two separate genes that code for each trait – one inherited from each parent.

More alike than different

Every human being has practically the exact same DNA, which gave their cells precise instructions on how to form, system by system, from an embryo into a person, and continues to give cells instructions on how to keep those systems functioning. For all of our differences – physical, cultural, and otherwise – all humans are 99% biologically identical.

The differences that we do have are a result of random gene mutations and natural selection that favors some traits over others. Mutations can create an alternative form of any gene, called an allele. This allele can be passed on to offspring and expressed.

Environmental factors also play in role in shaping who we are. A person's DNA may contain a gene that predisposes him to develop type 2 Diabetes, but if that person eats a healthy diet and gets regular exercise the disease may never develop. Height is another trait that is affected by environmental factors. Scientists estimate that 10% of a person's height depends on his or her diet and overall health during their developmental years. Cultural factors influence further influence who we are and what we like to do. A person may have a gene that codes for the development of more taste buds on her tongue, which gives her a heightened sense of taste. She will be very sensitive to hot pepper and she may find certain vegetables taste very bitter. However, if these foods are part of the traditional dishes of her culture, she may, over time, become accustomed to these flavors and begin to enjoy them.

Inheriting Genes

Children resemble, but do not exactly match their parents or their siblings. Nor are they a simple average of their mother's and father's traits. In order to reproduce, women produce egg cells and men produce sperm cells. Each of these reproductive cells, called gametes, contains half of his or her DNA; 23 chromosomes, rather than 46, one gene for each trait instead of two. But which version of the parents' two genes, or alleles, for each trait end up in their gametes? It's completely random! When a sperm cell fertilizes an egg their genetic information is combined. Their offspring inherit 23 chromosomes from each parent – a total of 46 chromosomes containing 2 genes for each trait. The relationship between these alleles determines how a person's genotype (the two alleles present for a given trait) is manifest physically, also called his or her phenotype.

Heterozygous/Homozygous and Genotype/Phenotype
A person is considered heterozygous if his or her genotype has two different alleles for a given trait. If he or she has two of the same alleles for a given trait that person is considered homozygous for that trait. In those who are homozygous, their phenotype – what is expressed physically – always matches their genotype – the allele of which they have 2 copies. A person who is heterozygous for a certain trait can have different manifestations depending on the relationship of the alleles:

- **Dominant/Recessive:** Certain alleles have a simple dominant/recessive relationship. One allele dominates the other – a person who is heterozygous will always have a phenotype that matches the dominant allele, the only way to have a phenotype consistent with the recessive allele is if a person is homozygous (two recessive alleles) for that trait.

- **Incomplete Dominance:** Certain alleles exhibit incomplete dominance. A person who is heterozygous for such a trait will have a phenotype that is something in the middle between the homozygous phenotype for the dominant allele and the homozygous phenotype for the recessive allele.

- **Monogenetic Traits:** Certain traits are determined by one, single gene.

- **Polygenetic traits:** Certain traits are the combined result of instructions coded for by multiple genes and multiple alleles. Therefore, there is a greater range of variation in the phenotype of these traits.

Two types of twins
Some twins have the same exact DNA and some twins are no more genetically alike than any two siblings. The difference is how many eggs are fertilized, initially. In the case of monozygous twins, often called “identical twins,” one egg is fertilized by one sperm cell, creating one zygote. This cell then splits into two identical cells which each develop into genetically identical fetuses. In other cases two separate egg cells embed themselves in the mother's uterine lining and each is fertilized by a different sperm cell from the father, creating two zygotes (hence, dizygous) which develop into fetuses which likely have different combinations of their mother's and father's genetic traits. This type of twins is often called “fraternal” twins. This term is appropriate as these twins are no more genetically alike than any two siblings, they just happen to have been conceived at the exact same time and developed together in their mother's uterus.

No Single Gene for Eye Color, Researchers Prove
ScienceDaily (Feb. 25, 2007)

A study by researchers from The University of Queensland's Institute for Molecular Bioscience (IMB) and the Queensland Institute of Medical Research is the first to prove conclusively that there is no single gene for eye colour.

Instead, it found that several genes determine the colour of an individual's eyes, although some have more influence than others.

“Each individual has two versions of a gene, inheriting one from each parent, and these versions can be the same as each other or different,” Dr Rick Sturm, the IMB researcher who led the study, said.

“It used to be thought that eye colour was what we call a simple Mendelian recessive trait - in other words, brown eye colour was dominant over blue, so a person with two brown versions of the gene or a brown and a blue would have brown eyes, and only two blues with no brown could produce blue eyes.

“But the model of eye colour inheritance using a single gene is insufficient to explain the range of eye colours that appear in humans. We believe instead that there are two major genes - one that controls for brown or blue, and one that controls for green or hazel - and others that modify this trait.

“So contrary to what used to be thought, it is possible for two blue-eyed parents to have a brown-eyed child, although this is not common.”

Dr Sturm likens the system to a light bulb.

“The mechanism that determines whether an eye is brown or blue is like switching on a light, whereas an eye becoming green or hazel is more like someone unscrewing the light bulb and putting in a different one.”

The study was carried out to clarify the role of the OCA2 gene in the inheritance of eye colour and other pigmentary traits associated with skin cancer risk in white populations, and examined nearly 4000 adolescent twins, their siblings and their parents over five years.

The findings are published in this month's edition of the American Journal of Human Genetics, and were supported with grants from Australia's National Health and Medical Research Council and the United States of America's National Cancer Institute.

Adapted from materials provided by University of Queensland.

University of Queensland (2007, February 25). No Single Gene For Eye Color, Researchers Prove. *ScienceDaily*. **Retrieved December 10, 2007, from http://www.sciencedaily.com /releases/2007/02/070222180729.htm**