Inheritance Teacher Guide

Print

Unit

Inheritance

Subject

Life Science

Grade Level

MS

Activity Names

Genes and Appearance

Meiosis

Thinking about the Discovery Questions

This lesson module will address the following essential questions:

1. How does the process of meiosis transfer genetic information to offspring?
2. How do genes determine appearance?

Meiosis is a special type of cell division necessary for reproduction in plants and animals. In this lesson, students will use models of baby dragons to explore how chromosomes from each parent recombine during meiosis to produce up to four genetically unique haploid cells called gametes. Each gamete contains genetic material from both parents. 21st Century national science standards have significantly expanded the topic of genetics and recommend its introduction earlier in the learning progression of life science. But it can be tricky for middle school students to form an accurate understanding of meiosis and the mechanism of how traits are inherited. Gene expression can also be confusing to students because it calls for a deeper understanding of dominant/recessive alleles, plus consideration of randomness. The baby dragon models animate the process of meiosis and allow students to select specific alleles and watch how this affects the infant dragon's appearance (phenotype).

Misconceptions

One stubborn misconception among secondary students is that in sexually reproducing organisms, each parent contributes genetic information only for certain characteristics and not others (i.e., a child has "his father's nose" and "his mother's eyes"). This erroneous idea has been well documented by educational researchers in a significant percentage (45%) of students from Grade 4 to Grade 12. To dispel this misconception, students need to use models that show simple chromosomal information from each parent, then combine these alleles to see how traits are inherited through random chance and probability. Understanding will deepen if the model designates each allele as recessive or dominant. Although most students in Grades 5-8 know that babies result from the fusion of sperm and egg, they often misunderstand how the process brings new life. It will help them to see the process of meiosis animated to visualize how haploid cells are produced.

Suggested Timeline

Allow three 45-minute class periods. The Meiosis model can be introduced and likely completed in the first class period. The Genes and Appearance model will take one entire class period and possibly part of a 3rd. Allow 20 minutes at the end of the third class period for follow-up discussion.

Learning Objectives

NGSS

- **Performance Expectations**
  - MS-LS3-2. Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
  - HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
  - HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

- **Disciplinary Core Ideas**
  - Growth and Development of Organisms
    - Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.
  - Inheritance of Traits
    - Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.
    - Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.
  - Variation of Traits
    - In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

- **Practices**
  - Constructing Explanations and Designing Solutions
    - Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.
  - Developing and Using Models
    - Develop a model to describe unobservable mechanisms.

- **Crosscutting Concepts**
  - Patterns
    - Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
    - Patterns can be used to identify cause and effect relationships.

- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
  - Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.
- Structure and Function
  - Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

NSES

- NSES Life Science
  - Reproduction and Heredity. Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait.
  - Reproduction and Heredity. The characteristics of an organism can be described in terms of a combination of traits.
  - Reproduction and Heredity. Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.

Being Prepared

It would be optimal for students to work individually to complete the modeling activities. The activities are inquiry-based -- students are expected to spend time figuring out allele arrangements through trial and error. After several trials, they will begin to figure out the pattern underlying a simple dominant/recessive combination. Discussion of the formative questions can be done as a full-class activity or in learning groups of 4-5.

Getting Started

This lesson requires Java-enabled computers. In most cases, your browser will automatically open and display Concord Consortium models. Some school districts have implemented very high security settings for Java applications. Teachers may want to check student computers to ensure that the models will run. If you get an error response, you probably need to contact your IT representative to redo the settings.

Discussion: Setting the Stage

For both activities, all you need is internet access and, ideally, one computer per student. HTML 5 versions of the models are slated for rollout in 2016. Prior to that time, teachers will need to be sure Java is enabled on each computer.

What Students Need to Know

It will be helpful to provide the given definition of meiosis on your whiteboard: Meiosis -- The process by which a diploid cell (with two complete sets of chromosomes) transforms into four haploid gametes (with only one set of chromosomes each).

Students will need to know the abbreviation system for identifying a genotype. In the dragon activities, there are several alleles (traits): type of tail, color, wings or no wings, horns or no horns, fire breathing. Each trait has a single-letter abbreviation given by the model. Dominance in a trait is designated by using the capital letter. The recessive trait is designated by using the lower case letter. *Example: In dragons, horns are dominant traits with abbreviation "H". If a dragon has the upper-case "H" in its allele for horns, it WILL have horns. The recessive trait (no horns) is designated by lower case "h".* For a dragon to have no horns, it must have lower-case recessive "h" genes from each parent to give "hh". Tell students to be careful! Sometimes a dominant gene means the trait will NOT exist. Example: In dragons, fire-breathing is a recessive trait whose abbreviation is the letter "f". If a dragon has one dominant allele (upper-case "F"), the dragon will NOT be a fire-breather. To inherit fire-breathing, the dragon must receive one recessive "f" gene from each

parent to produce a genotype of "ff". This means only 1 in 4 dragons will be fire-breathers. By contrast, 3 out of 4 will have horns (because horns are a dominant trait).

Questions to Elicit Understanding:

If two parents are both contributing genetic material to their offspring, why don't the genes and chromosomes double in each generation?

Students are not expected to know the answer to this question. Let their ideas be a springboard. They may need guidance to introduce the concept that chromosomes are inherited by both parents in a process called meiosis that occurs in plants and animals. Explain that they will discover a great deal about this question when they create baby dragons in the Meiosis model. *Teachers: In animals, all cells in the body EXCEPT reproductive cells are diploid cells, meaning they each contain two paired sets of chromosomes (one set from each parent for a total of 46 chromosomes). Germ cells (an egg or sperm) are haploid cells, which have only a single set of unpaired chromosomes. In the process of meiosis, cell division happens in two phases. The model animates the process clearly to show how a parent haploid cell divides once to create two daughter cells, then divides again to create four "gametes", each of which has half the genetic content of the original parent cell (23 chromosomes). Both male and female contribute parent cells in this process, which is why offspring can inherit traits from both parents without doubling the number of chromosomes.*

If each parent has two sets of genes and chromosomes, why do their offspring receive only one set from each parent?

This is the way that sexually reproducing organisms have evolved so that their chromosomal structure remains stable. When the egg or sperm divides to produce 4 gametes, each gamete has only a half set of chromosomes. In fertilization, the chromosomal material in one egg and one sperm fuse to produce a new life -- with the full number of chromosomes for that species.

What factors cause traits to be inherited?

Ask students to brainstorm their ideas in groups or as a class discussion and record answers for later analysis. Expect students to respond that offspring will look similar to, but not exactly like, their parents. They may also point out variations in traits among siblings. Some students may bring up the concept of dominance in traits.

This lesson introduces two ways for students to think about this question: 1) In the haploid division process into four gametes, there are many possibilities for how chromosomes can be contributed by the two parents. This part of the process is based on random chance. The other important factor is that alleles can be dominant or recessive, which affects the probability of how a trait will be expressed. In the simplest dominant/recessive pattern, the probability is 75% that the dominant trait will express itself in the offspring's appearance. The dragon model deals mostly with simple dominant/recessive patterns except for two instances: incomplete dominance in leg inheritance and a more complex pattern for inheritance of color of dragon scales.

Discussion: Formative Questions

Meiosis

How did the offspring differ from the parents? How were the offspring similar to the parents?

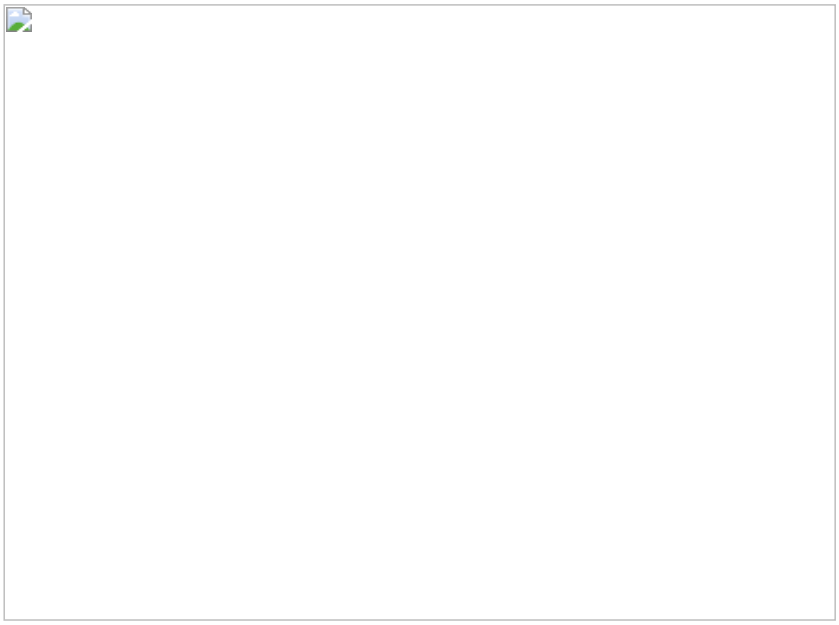
Before answering the question, ask students to run the meiosis model several times and record 2-3 allele patterns. Doing this will help them see that the haploid cell division can produce many, many variations of traits at random. Acceptable responses will discuss how meiosis recombines genetic material into four gametes, which will almost always be different, but all the traits had to originally exist in the parent's genes. When the gametes are fused into zygotes, genetic material is a blend of both mother and father's contributing gamete. Acceptable responses will document how offspring differed from one trial run to another, but they all basically resemble the parents.

Is it possible for these two dragons to have an offspring with wings?

This will take some experimentation with the model, which is part of the fun! Students should discover (with some effort) that wings are a recessive trait that will require contribution of a ww combination.

Can they have an offspring with no wings?

If a Ww combination or a WW combination is selected from among the gametes, the dragon will have no wings. Students should notice that Landar, the male dragon, has only lower case w's in his gametes. He has wings because he is carrying only recessive w genes from his parents. On the other hand, Tanada, the female dragon, has both a dominant W and a recessive w in her genes. She has no wings because wings are recessive.



Genes and Appearance

What do you think causes the different phenotypes of these dragons? How does the phenotype depend on its genes?

The phenotypes are caused by how chromosomes for a particular trait pair together from both parents. Some genes have simple recessive/dominant patterns in the dragons, so the dominant gene will express itself unless two recessive alleles are matched up. Some genes are more complex, like the dragon color gene. Regardless of complexity, a trait has to be present in the genetic information passed down by at least one of the parents to be passed on to the offspring and expressed as a phenotype. Dominant traits (such as horns) can be passed by only one parent, even if the other parent passes on a recessive gene. For a recessive gene to be expressed in appearance, it must be passed on by both parents.

How do you think the color of the dragon is controlled?

Female dragons can end up with four possible colors: red, brown, blue, or purple. Each requires a specific genetic pattern, for example -- a purple dragon is only produced with an aaBB combination. Encourage students to spend time playing with the model to test for different possibilities. On the other hand, male dragons can only be yellow or green because the B color is contributed only via chromosome X. Males, having an XY chromosome, have fewer color possibilities. Students will probably notice that the recessive bb combination is lethal to both genders.

How do the phenotypes of the female dragons differ from the male dragons?

The difference is that females have a second Chromosome X, which gives them additional alleles for color and fire-breathing. The female genotype allows for four colors: red, purple, blue, and brown. (See explanation above) Male dragons will only end up yellow or green. Male dragons have a 50% probability of being fire-breathing, while females have a 25% probability.

Which dragons -- males or females -- have more possible colors? Why?

As previously mentioned,females have more possible colors. This is because the color genes are located in the X chromosomes in these dragons. Females have two X chromosomes; males have an X and a Y chromosome. Thus, males will have fewer color possibilities for color inheritance.

How many different allelic combinations result in dragons with horns?

Horns are a dominant trait, so the possible combinations to produce a dragon with horns are: HH, Hh, and hH. (The other possible combination of this allele is hh, which produces a dragon with no horns.)

How did you change the Horns gene on Chromosome 1 to figure out which allelic combinations produced horns? List all of the allelic combinations that produce horns.

Students should easily be able to explain the drop-down selection that lets them choose dominant "H" or recessive "h". The possible allelic combinations that produce horns are: HH, Hh, and hH.

Discussion: Wrapping Up

How does trait inheritance occur as the result of both random chance and genetic probability?

After completing both modeling activities, students should have some understanding that trait inheritance is determined both by chance and by probabilities that result from gene dominance or recession. It would be a good time to explain that in human genetics, trait dominance is much more complex than we see in the baby dragon models. In humans, eye color (for example) is determined by multiple genes. Years ago, people thought blue eye color was a simple Mendelian recessive trait. More recent research shows that there are many more allele combinations for eye color, which explains why there are hazel and green eyes. Still, brown eyes exert more influence than the other colors. This would be a good way to explore why models help us build understanding, but can never be perfect.

2. Why are some alleles identical while some are different from each other?

Understanding this concept is foundational to an understanding of genetics. In sexually reproducing organisms, each parent contributes half of all the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene -- one acquired from each parent. The alleles may be identical (for example, both dragons contributed a dominant gene for Horns). Or, the alleles may be different (one parent contributed a dominant H gene for horns, while the other contributed a recessive h gene).

Additional Background

The dragon modeling activities present students with very simple dominant/recessive allele patterns. Most human genotypes are more complex and involve multiple genes. The activities are simple to promote understanding of basic concepts in genetic inheritance. For the simple genotypes presented in this lesson, there are 3 fundamental genotypes:

1. Homozygous Dominant (two dominant genes) HH
2. Heterozygous (one dominant and one recessive gene) Hh
3. Homozygous Recessive (two recessive genes) hh

Teacher Content Support

BioEd Online is a comprehensive collection of resources for science teachers from the Baylor College of Medicine. All the resources are free, which includes lessons, tutorials, courses, videos and images, and related news stories. The project is funded by the National Science Foundation and published by the Baylor College of Medicine. It's easy to navigate and user-friendly for a broad range of audiences. Find it at: bioedonline.org

Analysis

Meiosis Model

1. How does meiosis increase the diversity of potential offspring?

Acceptable responses should discuss how four daughter gametes contribute only a half set of chromosomes. When fertilization happens, traits are combined between father and mother in a random way. A parent can have both a dominant or recessive gene for one trait (for example, a dragon can have the dominant gene H for horns, but also possess a recessive h gene. There's no way of knowing whether this parent will be contributing the dominant gene or the recessive gene for horns. Either one could be sorted out during meiosis.

2. What do you think causes the different phenotypes of these dragons? How does the phenotype depend on its genes (genotype)?

Students should be able to express that the phenotype is determined by the genetic make-up of the parents. Two parents could produce offspring with different appearance (phenotypes) because of the random combination of genes in the germ cells (gametes). Don't expect too much sophistication. Responses could go something like this, "The dragons look different because you never know what you'll get when meiosis mixes up the genes to give you half a set. Then you still don't know which female gamete will combine with which male gamete."

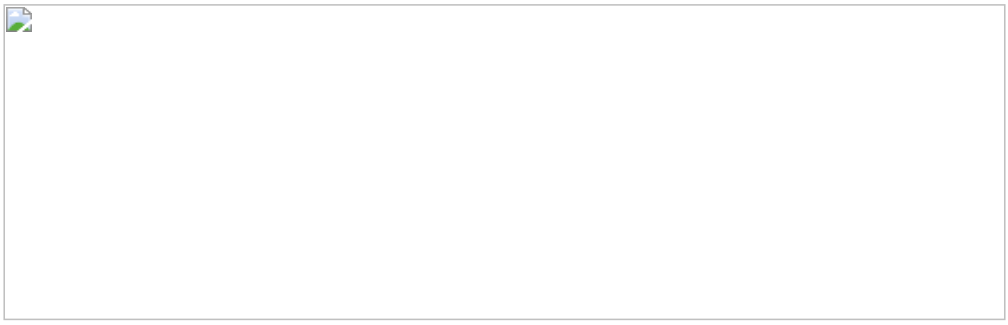
3. Why does the lethal "b" allele affect more males than females?

This could be tough for some students. The answer is because the male dragons do not possess the B allele in their Y chromosomes. This means that their offsprings' expression of a B color will depend entirely on what the mother contributes. If the mother contributes a dominant B, the baby dragon will be fine regardless of whether it is male or female. Female dragons will inherit the B or b in two chromosomes. Their odds are greater of avoiding the lethal bb combination. For the female, there are 8 possible allele combinations for color. 3 will produce a bb pattern, giving a 37.5% chance of getting the lethal gene. For males, there are 4 possible allele combinations for color. Two will produce a bb pattern, giving 50% odds of getting the lethal gene.

4. How does the genetic code of the offspring differ from its parents? What process makes children different than their parents?

Each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These alleles may be identical (i.e., both parents contributed a dominant trait for horns) or may differ from each other. The process of meiosis makes children different from parents.

Genes and Appearance



1. Can you make a purple male dragon? Why or why not?

No, because the genetic information to produce this combination doesn't exist in males.

2. Describe the allele combinations that resulted in the dragon shown below. Explain why these allele combinations resulted in this phenotype.

To result in no horns, you must have an hh combination because horns are a dominant trait. To produce no wings, you can have a WW, Ww, or wW combination (wings are a recessive trait). To result in fire-breathing, you must have an ff combination because fire-breathing is a recessive trait. To result in four legs, you must have LL (both dominant genes). Legs are an example of incomplete dominance. An Ll or lL combination produces two legs, while the ll combination produces zero legs. The dragon's plain tail is a recessive trait produced by tt. The orange color is produced by these combinations: AABb, AaBb, aABb, AAbB. The orange color can occur ONLY in female dragons.

Further Investigation

Meiosis Extension Activity

Is it possible for the dragons (featured in the image) to have offspring that breathe fire? Why or why not?

Acceptable response: No, these two dragons can't produce a fire-breathing baby because the father carries only the dominant F gene and fire breathing is a recessive trait. Teachers: this can be a tough concept for some students, who may believe that if a trait shows up as a phenotype, it must be dominant. In this case, the baby dragon would have to have the genotype "ff", with recessive fire-breathing alleles contributed by both father and mother.

Genes and Appearance Extension Activity

Is it possible to make a dead dragon? If so, how?

Yes, by clicking on the lethal bb combination on the color gene.