Patterns in Heredity & Selection--Mendelian Genetics (Part 1 of 2)

This 5E model for instruction may be useful in connecting the concepts of meiosis with chromosomal mutations due to errors in meiosis before transitioning to Mendel's Law of Independent Assortment and dihybrid crosses.

Student Science Performance

Grade: 9-12 Biology	**Title:**
Topic: Mendel's Law of Segregation and Punnett Squares	Different Strokes for Different Folks

Performance Expectations for GSE:

SB3. Obtain, evaluate, and communicate information to analyze how biological traits are passed on to successive generations.

a. Use Mendel's laws (segregation and independent assortment) to ask questions and define problems that explain the role of meiosis in reproductive variability.
b. Use mathematical models to predict and explain patterns of inheritance. (*Clarification statement:* Students should be able to use Punnett squares (monohybrid and dihybrid crosses) and/or rules of probability, to analyze the following inheritance patterns: dominance, codominance, incomplete dominance.)
c. Construct an argument to support a claim about the relative advantages and disadvantages of sexual and asexual reproduction.

Standard notes:

- *Meiosis is a prerequisite lesson; however, this lesson may be adapted to embed the learning of the process of meiosis concerning Mendel's Law of Segregation. Mendel's Law of Independent Assortment is not addressed in this lesson.*
- *The focus is on the use of monohybrid Punnett squares to analyze dominance. Codominance, incomplete dominance, multiple alleles, and polygenic traits are not addressed in this lesson but may be included in the Elaboration phase.*
- *Asexual reproduction is not addressed in this lesson; however, the focus is on genetic variations that give an advantage to sexual reproduction.*

Performance Expectations for Instruction:

Investigate the pattern and determine the probability of inheriting traits from parents.

Group Performance: (Engage and Explore)

- Obtain information from patterns of inherited genetic traits.
- Ask questions to create a model and construct an explanation for the cause of genetic variations seen between parents and offspring and among offspring.
- Carry out investigations of a given scenario to determine parent and offspring phenotypes and possible genotypes to obtain data for evidence.
- Analyze and interpret the data to develop a model that demonstrates how offspring inherit traits from parents and explain patterns (or lack of patterns) seen in inheritance.

Individual Performance: (Explore and Explain)

- Write an argument for your explanation supported by evidence from the investigation.
- Use prior knowledge to refine a model of the inheritance of traits from parents to offspring in sexual reproduction using gametes produced in meiosis.
- Use prior knowledge and evidence to explain how genetic variations increase in sexual reproduction.

Group Discussion: (Explore and Explain)

- Use the evidence and explanations shared from others to refine or confirm your model and argument.

Teacher Reflection: (Explain)

- Reflect on students' ability to develop an argument where evidence supports the explanation.
- Reflect on students' ability to conclude that gamete production in meiosis increases genetic variation of traits inherited by offspring, which the probability of inheritance can be predicted through Punnett squares, is supported by evidence in the scenarios, activity, discussions, and models.

Group Performance: (Elaborate)

- Obtain information from scenarios of family histories regarding the inheritance of a trait.
- Obtain information from scenarios of family histories regarding evolution of populations (reproductive isolation, founder effect, or bottleneck events).
- Ask questions to create a model (pedigree) and construct an explanation for the patterns observed in the passage of traits from parents to offspring.

Individual Performance: (Elaborate and Evaluate)

- Write an argument using the information you gathered to support the claim that the patterns are evidence of the passage of traits from parents to offspring.

Group Discussion: (Elaborate)

- Use the evidence and explanations shared from others to refine or confirm your model and argument.

Teacher Reflection: (Evaluate)

- Reflect on students' ability to develop an argument where the evidence supports the explanation.
- Reflect on students' ability to conclude that sexual reproduction increases genetic variation between parents and offspring and among offspring that can be influenced by reproductive isolation.
- Reflect on students' ability to develop models from scenarios that accurate depict the passage of autosomal or sex-linked traits from parents to offspring.

Additional notes on student support

Materials

Each group of 2 students will need:

- Electronic Device for researching
- 12 clear pony beads
- 12 pony beads of a single color

For a class of 30 with 15 groups of 2 students:

- 15 Electronic Devices for researching
- 180 clear pony beads
- 180 colored pony beads (colors may vary)

Students will continuously be obtaining, evaluating, and communicating information. This is not a linear process. Students should be communicating through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners	**Phenomenon** Non-identical twin siblings do not look exactly like each other or their parents. *Obtaining* Students ask questions to identify patterns about an image of a family picture that includes parents and multiple children. *Teacher Notes: A personal family portrait is more engaging if available. The image should include multiple children and two parents. Including individuals with Down Syndrome, sickle cell disease, or twins (identical and/or fraternal) in the image increase questions and discussions.* Students obtain information by collecting class data on inherited traits or by sorting printed pictures into groups based on physical characteristics. This survey chart can be used to poll class data.

	Teacher Notes: Students should collect data using characteristics such as attached earlobes, widow's peak, cleft in chin, bent pinky, tongue rolling, dominant hand, freckles, "Spock fingers", "Hitchhiker's thumb," etc. Incomplete and codominant traits are used in a later lesson. Record the number of students with each trait. Repeat for each characteristic. Students will determine trends among the number of individuals with different characteristics.
	Evaluating Students analyze and interpret data to find patterns of inherited genetic traits recorded during the sorting activity. *Teacher Notes: Include data from large populations and have students compare to the small class sample size.* Students construct explanations for causes of the patterns of inherited genetic traits. *Teacher Notes: Students will use knowledge of meiosis and the development of gametes from a prerequisite lesson. Assess prior knowledge by the students' use of terms like DNA, genes, traits, alleles, dominant and recessive during discussions.*
	Communicating Students develop a model to describe the pattern of inherited genetic traits. *Teacher Notes: Assess prior knowledge by students communicating their understanding of the passing of traits from parents to offspring and Mendel's Law of Dominance by producing a monohybrid Punnett square.* *Additional notes on topic, focus, and phenomena.*
Exploring Revising Model	*Obtaining* Students obtain information about Mendel's Law of Dominance and monohybrid Punnett squares through provided reading or online resources. *Teacher Notes: This can be performed in a differentiation activity or using explore stations. A variety of resources (article, video, interactive, and practice) can be found at Ck-12: Punnett Squares.* Students plan and carry out an investigation to explain a given scenario based on an inherited genetic trait from the ENGAGE activity (i.e. a mother and a father with freckles have one son with freckles and one son without freckles. How did they have a child without freckles?) *Teacher Notes: Students may use a free online interactive Punnett square to complete this activity. They may also use clear and colored pony beads to manipulate the Punnett square. A sample guide for each scenario is given here.* *Clear beads represent a recessive allele and colored beads represent a dominant allele.* *In pairs, students use two beads to represent a parent genotype.* *They model Mendel's Law of Segregation during meiosis to represent the 4 possible gametes.* *This is repeated for the other parent genotype.* *The gametes are joined in the 4 possible combination to produce offspring.* *Use Punnett squares templates to show how this process can be organized and analyzed.* *This same process can be modified and adapted for dihybrid crosses as well*

	Evaluating Students analyze and interpret data collected during the ENGAGE activity and use the resulting patterns to identify which inherited genetic characteristics are dominant and which are recessive. Students construct explanations to describe the mechanism of solving Punnett squares and how to determine the pattern of inheritance. *Teacher Notes: This may lead to a discussion on Mendel's Law of Segregation with references of meiosis and the development of gametes that will be expanded on in the EXPLAIN phase.*
	Communicating Students develop a model of a monohybrid Punnett square to determine the pattern of inheritance of the genetic trait from the scenario of their investigation. Students use evidence to explain the cause and pattern of inheriting dominant and recessive traits by offspring from their parents. *Teacher Notes: Assess for the students' use of terms like DNA, genes, traits, alleles, genotype, phenotype, dominant, recessive, homozygous (purebred), and heterozygous (hybrid).*
Explaining Finalizing Model	*Obtaining* Students obtain information on the proportion and probability of the inheritance of genetic traits by using the monohybrid Punnett square created in the EXPLORE activity. *Teacher Notes: Clarify, teach, and emphasize the use of necessary terms used when describing Punnett Squares: genes, trait, alleles, genotype, phenotype, dominant, recessive, homozygous (purebred), & heterozygous (hybrid).* Students ask questions to create additional scenarios of the inheritance of genetic traits.
	Evaluating Students analyze and interpret the collected data from ENGAGE activity and determine patterns in individuals and their inherited genetic traits (i.e. could all students that were right-handed roll their tongue, make Spock fingers, and have freckles). *Teacher Notes: Students should notice no true pattern based on individuals and traits represented and may lead to a discussion on the Law of Independent Assortment to preview dihybrid crosses.* Students construct an explanation of why an individual looks different from their parents and siblings and how meiosis contributes to genetic variation within a family.

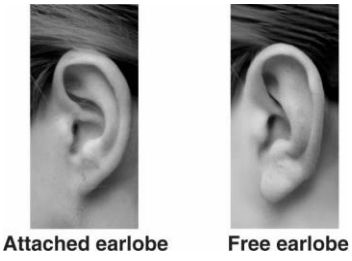
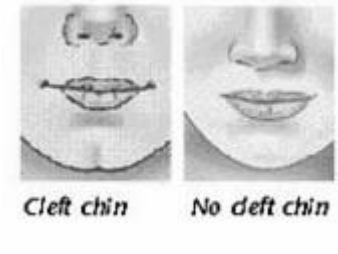
	Communicating Students develop a model of a monohybrid Punnett square that depicts the alleles that are crossed as a result of gamete formation during meiosis. Students construct an argument based on evidence from the ENGAGE and EXPLORE activities that meiosis supports Mendel's Law of Segregation in describing how genetic traits are passed to successive generations in sexual reproduction. *Teacher Notes: The following questions are useful in guiding class discussions:* ● *Where do our physical characteristics come from?* ● *Where do those genes come from?* ● *Are all those genes the same?* ● *What do we call the different versions of those genes?* ● *What evidence do we see that supports the Law of Segregation of the alleles?* ● *What is the role of meiosis in reproductive variability?* ● *What evidence do we see that supports differences between dominant and recessive alleles?* ● *How does this process repeat for additional siblings?* ***Formative Assessment of Student Learning*** *The following are assessed through discussions, writings, or analysis of images/models.* Students develop models to demonstrate the segregation and independent assortment of alleles into gametes produced through meiosis that are used in Punnett squares to determine probability of inheritance of traits. *Teacher Notes: Develop a scenario to provide students evidence to develop an argument, including scenarios regarding plants to demonstrate sexual reproduction occurs in plants as well.* Students use evidence from the ENGAGE scenarios and EXPLORE activities and any additional scenarios provided to argue the claim that sexual reproduction increases genetic variation between parents and offspring and among offspring. Arguments must clearly explain the role of meiosis and gamete formation in reproductive variability using the Law of Segregation to determine patterns of inheritance.
Elaborating Applying Model to Solve a Problems	**Phenomenon** A parent with sickle cell disease may produce offspring that may or may not have the disease (i.e. two parents without sickle cell disease may produce offspring who do have sickle cell disease). Other examples for students to use: The Amish have a high rate of polydactyly. The Fugates of Kentucky have blue-tinted skin. *Teacher Notes: Make a connection between the inheritance of traits shown through pedigrees with evolution of populations seen in reproductive isolation, founder effects, and bottleneck events. Additional traits may be addressed. It is beneficial to include a sex-linked trait such as hemophilia or colorblindness.*

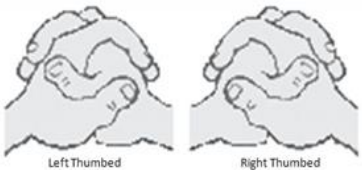
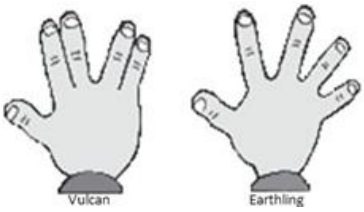
	Obtaining Students ask questions about the information regarding the inherited trait. *Teacher Notes: This may involve showing a family tree/history and having students if these traits are dominant or recessive and more prevalent in one sex versus the other.*
	Evaluating Students analyze and interpret data from the inheritance of traits from a family tree/history. Students use the data from the patterns of inheritance to support an explanation concerning a trait from a family tree/history.
	Communicating Students develop and use a model that demonstrates the patterns of inheriting traits. *Teacher Notes: A pedigree is a useful model to demonstrate the patterns of inheritance of traits.*
Evaluation	***Assessment of Student Learning***
	In models: Students develop models to demonstrate the segregation and independent assortment of alleles into gametes produced through meiosis using Punnett squares to determine probability of inheritance of traits. Students use evidence from models to argue the claim that sexual reproduction increases genetic variation between parents and offspring and among offspring. Students develop models (pedigrees) to demonstrate the inheritance of traits and use evidence from those models (pedigrees) to argue the claim that the trait is a dominant or recessive trait. Students use evidence from models (pedigrees) to argue the claim that the trait is an autosomal or sex-linked trait.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Using mathematics & computational thinking • Engaging in argument from evidence • Asking questions and defining problems
Crosscutting Concepts	• Patterns • Scale, Proportion, and Quantity • Cause and Effect
Disciplinary Core Ideas	From ***A Framework for K-12 Science Education:*** LS1.B Growth and Development of Organisms LS3.A Inheritance of Traits LS3.B Variations of Traits

Name_____Date_____

Human Traits Survey List

Use the chart below to collect class data on the presence of certain traits in humans. You will use this data to try to determine patterns in the population.

Trait	Example	Students with Trait	Students without Trait
Tongue Rolling			
Freckles			
Widow's Peak			
Earlobe			
Chin			

Dimples			
Interlocking Fingers			
Hitchhiker's Thumb			
Spock Fingers			

Return to Instructional Segment

Name_____Date_____

Modeling Mendelian Assortment

For this investigation, you will be using beads to represent alleles. You will cross two parents (each with two alleles) and determine the possible phenotypes and genotypes of their offspring. Colored beads will represent dominant alleles, and clear beads will represent recessive alleles.

Scenario 1

A mother and father both have freckles. They have a son with freckles and another son without freckles. How is this possible?

Use beads to represent the possible genotypes of the mother and father. Which gametes could be produced by the mother? The father?

Next, choose a letter to represent the dominant allele and a letter to represent the recessive allele. Show how the parents could have a child with no freckles in the Punnett Square below:

Alleles: _____ = dominant
_____ = recessive

	Mother's Gamete 1:_____	Mother's Gamete 2:_____
Father's Gamete 1:_____		
Father's Gamete 2:_____		

Return to Instructional Segment

Patterns of Heredity and Selection GSE: **SB3a, SB3b, SB3c, SB6d**			
Anchoring Phenomenon: Non-identical twin siblings do not look like each other or their parents.			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Sexual Reproduction	Overview of sexual reproduction; include advantages and disadvantages in comparison with asexual reproduction.	DNA fingerprints of a child and parent or non-identical sibling are not identical. Offspring have the same number of chromosomes as their parents.	SB1b/SB2c/SB3c/SB6c **Biotechnology Link:** Closely related organisms have similar DNA fingerprints. Discussions on why DNA fingerprints and physical appearance of offspring are different from parents and non-identical siblings are beneficial in connecting this instructional segment with Structure and Function of Molecular Genetics and biotechnology, emphasizing that DNA fingerprints are shared between family members but will not be identical DNA sequences. Make connections between the evolutionary benefits of having variations in DNA.
Meiosis	A parent diploid cell divides into four genetically different haploid gametes; emphasize the phases of mitosis and chromosome movement.		SB1b/SB3a Compare with mitosis to note similarities and differences. Emphasize gametes divide twice including discussion of phases (prophase, metaphase, anaphase, & telophase).

Karyotypes and Chromosomal Mutations	Nondisjunction may occur during anaphase I or II; several chromosomal abnormalities may occur during crossing over.	Trisomy 21 is known as Down Syndrome.	SB2a/SB2b Connect chromosomal errors in DNA to protein synthesis and discuss implications that may arise.
Mendel's Law of Segregation and Punnett Squares	The two alleles in a diploid cell separate to form a haploid gamete that contains only one allele during meiosis. The allele separation in the gametes is displayed in the Punnett square cross as the parent alleles. Emphasize the passage of X and Y chromosomes in determining the probability of the sex of offspring Pedigrees can be introduced to help students understand carriers of recessive diseases.	Non-identical twin siblings do not look like each other or their parents Inheritance of the sickle cell allele is a random event that can increase or decrease fitness of the offspring.	SB3a/SB3b/SB6b/SB6d **Different Strokes for Different Folks** Use phenomenon examples to make a connection to evolution (genetic drift). Alternative phenomenon addressed in lesson: The Amish have a high rate of polydactyly. The Fugates of Kentucky have blue-tinted skin. Emphasize patterns in monohybrid crosses and simple dominance Clarify that the processes of meiosis, the Law of Segregation, and Punnett squares for probability occurs with each offspring that is produced (i.e. families are not guaranteed to produce two male and two female offspring although the probability of each is 50%.).

Mendel's Law of Independent Assortment and Dihybrid Crosses	The two traits tend to be assorted independently of each other in different gametes during meiosis. The allele separation in the gametes is displayed in the Punnett square cross as the parent alleles and must be duplicated for each trait.	People with sickle cell anemia do not have the same blood type.	SB3a/SB3b Use phenomenon examples to make a connection to evolution (natural selection) and advantages of sexual reproduction with increased genetic variation. Emphasize patterns seen in probability results of dihybrid crosses.
Non-Mendelian Genetics	Incomplete Dominance	Pink snapdragon may produce red, pink, and white snapdragons.	SB3a/SB3b/SB6b/SB6d Revisit random genetic variations that may cause an increase in fitness.
	Codominance	Children of a parent with Type AB blood and a parent with Type O blood will not have the same blood type as either parent.	Multiple Alleles can be mentioned as an extension with codominance of blood types. A connection using the inheritance of the skin color to the evolution of different skin color resulting from adapting to different biomes may be beneficial in connecting this instructional segment with Stability and Change in Ecosystems Polygenic Traits can be included as an extension but are not explicit in the standards. Phenomenon: Skin color, eye color, hair color, and height are traits that have a wide variation of phenotypes.

Biodiversity and Patterns of Selection	Connect these random genetic mutations in offspring to an increase in biodiversity These mutations may increase or decrease fitness; it tends to decrease fitness and leads to a stabilized population	Some individuals do not contract malaria if bitten by an *Anopheles* mosquito whereas others do. Changes in traits in populations can result due to only a few surviving after a disturbance. The sickle cell trait, or heterozygote advantage, in the human population may increase fitness for a population over time.	SB6b/SB6d Revisit that analyzing DNA sequences are beneficial in determining relatedness between organisms (ancestry of the same species or of different species). Revisit random genetic variations that may cause a change (increase or decrease) in fitness. Lesson on Sickle Cell Inheritance: **Not the Weakest Link** Model stabilizing, directional, and disruptive selections noted in populations. Most speciation events occur due to reproductive isolation.

Anchoring Phenomenon:

Non-identical twin siblings do not look like each other or their parents.

Students should be able to explain the phenomenon using the following concepts:

- Parents produce haploid gametes through meiosis that join to produce an offspring through sexual reproduction.
- The gametes contain an allele for a trait that may be dominant or recessive.
- The combination of these alleles produces the genotype and phenotype of the offspring.
- Many alleles segregate and are assorted independently during the meiosis to produce variations in siblings.
- Punnett squares are useful in determining probability of inheriting traits from parents.
- Some alleles do not follow Mendelian genetics and may be codominant, or incompletely dominant.
- Errors may occur during meiosis and result in increased variation among offspring.

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. The teacher should model data collection in the activity 2. The teacher should model the graph on the board.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should try to connect this to something personal for the student (see notes in the engagement section).
2. The teacher should provide multiple formats that the student can use to express their knowledge.
3. At the end of the lesson the teacher should reflect on the following topics:

   -The teacher should reflect on grouping of students. Was it beneficial and were all students able to contribute? Why or Why not?
   -The teacher should reflect on supports for struggling learners. Were the supports enough for the student population? Why or why not? Then make a list of other supports that the teacher can try in the classroom.

Engaging Learners:

Obtaining

1. The teacher can link this back to the student's family by having the students think of 3 similarities and 3 differences in appearance between the student and their siblings. Then have the student determine which parent it came from.
2. Then use the image of a family to help students make connections to people outside of their family sharing traits.
3. The teacher should provide images of the traits that are being surveyed in the traits survey. Otherwise students may not make the connection with having the trait. The trait survey should be very visual for students.
4. The teacher should consider keeping up with the data from every class that does the survey to share the next day. This should allow students to see patterns on a larger scale.
5. The students should be given the opportunity to express their knowledge in various formats. This can include writing, drawing or explaining verbally.

Exploring:

1. Struggling students should be allowed to do both the online activity and the hands-on activity to reinforce the concept of Punnett squares.
2. Students may need additional support with setting up and interpreting Punnett squares.
3. The students should be given the opportunity to express their knowledge in various formats. This can include writing, drawing or explaining verbally.

Explaining:

1. The teacher should plan some videos, visuals and explanations of the vocabulary words for this unit. Many struggling students may not have been exposed to or recall this vocabulary.
2. The teacher should consider having a formative assessment here. The teacher can then provide additional support for those students that need it based on data. The additional supports may be re-teaching, card sorts, another investigation or any other format that works for the students in the class.
3. The students should be given the opportunity to express their knowledge in various formats. This can include writing, drawing or explaining verbally.

Elaborating:

1. Students may need additional assistance with connecting Punnett squares and inheritance. Giving the students a scenario to research and then create a Punnett square from would be an additional exposure. The teacher could use any of the scenarios mentioned in the phenomenon for this section.
2. The students should be given the opportunity to express their knowledge in various formats. This can include writing, drawing or explaining verbally.

Evaluating:

1. Students may need additional time to construct a model

2. Writing can be a major struggle for some students. Some choice as to how students express their knowledge may be warranted. Students could express their knowledge in the form of a picture, cartoon, slides presentation, or verbally.

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