**BIO1.LS3.3 Through pedigree analysis, identify patterns of trait inheritance to predict family member genotypes. Use mathematical thinking to predict the likelihood of various types of trait transmission. Modes of inheritance should include autosomal and sex-linked genes that are dominant/recessive, codominant, or incompletely dominant. Students can practice deductive reasoning using a basic set of criteria (including successive generation transmission and male/female ratio) in order to predict a mode of inheritance for a trait, define alleles for the trait, and assign genotypes to the family members of a given pedigree. Students can also practice using probability-based mathematics to predict offspring genotypes and phenotypes based on a given parental set.**

**(Numbers refer to page numbers in the student edition of Miler & Levine Biology)**

Pages: 383-389, 479, 498-499

**CCC: Pattern-Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.**

**SEP: CEDS-Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.**

**Probability** (383, 385) **(SEP: MATH)**

Points to emphasize:

Probability is the likelihood that a particular even will occur

Probabilities predict **averages**

The more times “sample” something, the more accurate your average will be

Bigger samples are better!

<https://www.mathsisfun.com/data/probability.html> Quick and easy questions to establish an understanding of probability

**Genetic trait overview**

Points to emphasize:

All living things or are built from the same “parts” (cells and proteins)

When these parts assembled in a particular order, you end up with specific organisms

-Cat, rat, earthworm, human, Aye aye

But you will notice that even though humans are essentially the same, we have slight differences between us

Even very close relatives like our parents or siblings may look very similar to us, everyone is unique!

Since we are kind of a blend of both of our parents, scientists 150 years ago thought that there was *blending concept of inheritance*

 *-*A plant with a white flower mated with a red flower would produce a pink flower

But sometimes mating two red flowers, a plant would suddenly have white offspring!

Something is wrong with the model **(SEP: MOD)**

**IS THERE A BETTER WAY TO PREDICT HOW AN OFFSPRING MIGHT INHERIT THEIR TRAITS? (SEP: AQDP)**

**Genotype vs. Phenotype (385)**

Points to emphasize:

Phenotype-Physical traits that an organism has

Genotype-Genetic makeup of an organism

Sometimes you cannot tell the genotype (the genes) from just the phenotype (physical appearance

**Homozygous vs. Heterozygous (384)**

Points to emphasize:

A gene is a particular section of your DNA that “codes” for a trait

There are almost always different types of genes that code for the same trait (think ice cream flavors, it’s all ice cream but they may come in different varieties

 -Hair and eye color are excellent examples

We call these different “flavors” or varieties of traits **alleles (know this word!)**

Since you have two parents, you could have gotten the same alleles from mom and dad...

Or they could be two different types of alleles

If you have the same type of allele from each parent, you would be homozygous

If you have different types of alleles from each parent, you would be heterozygous

 - (homo meaning same, hetero meaning different)

**Dominant vs. Recessive alleles (380)**

Points to emphasize:

Some alleles are “stronger” or more dominant than others. This is the **principle of dominance**

Let’s say that a cat has received allele for long fur from mom (We can call this allele F), short fur from dad (lowercase f)

In this type of cat, the long fur allele is more dominant than short

Since it received a F from mom and f from dad, this cat is heterozygous (Ff), the long fur is more dominant so that will be the phenotype of the kitty

 -This cat would have long fur, but still have a “hidden” allele for short hair

What would happen a cat’s offspring if we were to mate a cat that was homozygous recessive (ff) with a homozygous dominant (FF)? **(CCC: CE)**

 **This parent cats are called the parental generation**

**Punnett squares (385, 386)**

Points to emphasize:

We use diagrams called Punnett squares to determine the probability of and offspring inheriting a trait

Let’s take the cats from before, then combine the traits on the square:

|  |  |  |
| --- | --- | --- |
|  | **F** | **F** |
| **f** | **F f** | **F f** |
| **f** | **F f** | **F f** |

The result is all possible offspring will have long fur (remember F is dominant, it “blocks” or “overrides” the recessive trait (f).

If trait blending were true, then we would end up with all cats with medium-length fur

But they all had long fur! (they will all be heterozygous).

Each parent passed on only one allele, this concept is known as the **Law of Segregation**

This resulting generation is the **F1 generation**

**Now let’s mate the heterozygous cats (let’s pretend they aren't related!)**

|  |  |  |
| --- | --- | --- |
|  | **F** | **f** |
| **F** | **F F** | **F f** |
| **f** | **F f** | **f f** |

**(SEP: AQDP, MATH, DATA)**

From this table, what is the probability that a cat will have long fur? Remember F is dominant, it “blocks” or “overrides” the recessive trait (f) (3/4)

The probability that the cat will have short hair? (1/4)

The probability that the cat will be homozygous? (1/2)

The probability that the cat will be heterozygous? (1/2)

This generation is referred to as the **F2 generation**

**Independent assortment (387)**

Now say these types of cats also have a gene that gives them beautiful eye colors. Yellow is the dominant allele for this gene (Y), green is the recessive allele for this gene (y).

If the genes for eye color and fur length are not connected, take parent cats that are both homozygous dominant and recessive (**the parental generation)** and give them both the phenotype for dominant and recessive eye colors. Mate them and see what happens:

|  |  |  |
| --- | --- | --- |
|  | **F Y** | **F Y** |
| **f y** | **Ff Yy** | **Ff Yy** |
| **f y** | **Ff Yy** | **Ff Yy** |

We end up with the same result: All offspring are heterozygous for fur length and eye color. This generation is the **F1 generation**

Now let’s take two of these heterozygous cats (heterozygous for both traits) and mate

them:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **F Y** | **F y** | **f Y** | **f y** |
| **F Y** | **FF YY** | **FF Yy** | **Ff YY** | **Ff Yy** |
| **F y** | **FF Yy** | **FF yy** | **Ff Yy** | **Ff yy** |
| **f Y** | **Ff YY** | **Ff Yy** | **ff YY** | **ff Yy** |
| **f y** | **Ff Yy** | **Ff yy** | **ff Yy** | **ff yy** |

This generation is referred to as the **F2 generation**

Now we can ask the same questions we did earlier, now with more traits:

From this table, what is the probability that a cat will have long fur? Remember F is dominant, it “blocks” or “overrides” the recessive trait (f) (3/4)

The probability that the cat will have short hair? (1/4)

The probability that the cat will have green eyes? (1/4)

The probability that the cat will be homozygous for long hair? (1/4)

The probability that the cat will have heterozygous for long hair? (1/2)

The probability that the cat will be homozygous for yellow eyes? (1/4)

As you can see, the probability the genes were sorted in were not affected by each other, they were **independent.** This phenomenon is called **independent assortment**

**Big Question: The probability that the cat will have both short hair and green eyes? (1/16)**

As long as these genes are not linked, this will always be the probability. It’s math!

Try it for yourself

**Activity A: Single factor cross (F1 and F2)** (Bags of chips, paper to write results)

**Activity B: Two-factor cross (F1 and F2)** (Bags of chips, bags of playdough, paper to write results)

**Gregor Mendel (378-382)**

Points to emphasize:

Gregor Mendel was an Austrian monk who was well educated in science and math but at the time of his experiments he was substitute biology teacher! (Be nice to your teachers)

By using his knowledge of math and biology, he was able to successfully predict and study the patterns of how living things inherited their traits

 -Most well-known for studying the pea plant *Pisum sativum*

Mendel developed a theory known as ***Particulate theory of inheritance***

Based on his research, he discovered that inheritance was controlled by some type of tiny particles or units (We now know that these are genes!)

This theory was supported by 2 laws we discussed above:

**The law of segregation (only one allele from each parent)**

**The law of independent assortment (genes for different traits are passed down without affecting each other)**

**Incomplete dominance (389)**

Points to emphasize:

Of course nature is more complicated than what we have just described. There are always exceptions to the rule

What if two alleles were not dominant or recessive to each other, but were exactly as powerful? In this case the heterozygous offspring would be a blend between the two competing alleles.

**Codominance (390)**

Points to emphasize:

Some alleles don’t compete for dominance, but instead they will just team up and both show in the phenotype. Blood type in humans are a good example.

Blood type: There are three “flavors” or alleles that code for antigens on the surface of red blood cells. IA, IB, i or the O allele

The recessive allele is i, it can be overridden by IA, IB

IA, IB however are codominant, if each allele is inherited from each parent, then both alleles will show as identification markers for the red blood cell (type AB)

**(SEP: AQDP-what is the difference between incomplete dominance and codominance?)**

**Multiple Alleles (390)**

Points to emphasize:

Like different flavors of ice cream, there aren’t just two options like long vs. short fur, many genes have several different varieties. Some may be more dominant than others

The rule still stands that you only inherit one from one father, one from mother

**Polygenetic**

Points to emphasize:

Many traits in humans are polygenetic, meaning more than one allele contributes to that trait. Because many genes are involved in producing a trait, there will be many phenotypes. An example in humans is more than one gene codes for your eye color, but instead depends on several genes to give the iris pigmentation

**Gene linkage (398)**

Points to emphasize:

Mendel was lucky because the traits that he studies were all found on different chromosomes. We know today that may genes are linked together and seem to violate the law of independent assortment. Thomas Hunt Morgan found that orange-red eyed flies with small wings were always inherited together. Independent assortment still holds true; it is only the chromosomes that independently assort not the specific genes themselves. **Alleles of different genes tend to be inherited together if they are on the same chromosome.** Genes that lie next to each other are much more likely to be linked. The further the genes are separated along the chromosome, the more likely they are to be swapped during crossing over (see Prophase I p. 394)

**Sex-linked traits**

Points to emphasize:

The X and Y are the chromosomes that determine sex, but there are areas on the X that code for traits not linked to determining sex (the Y chromosomes is so small, almost all genes are dedicated to producing male traits). Females are XX and males are XY so if a trait is x-linked, then the male only needs one copy of the chromosome to express the trait. Colorblindness is an x-linked trait in humans that tends to affect male (usually red-green colorblindness because all they need is one copy of the colorblind X, while a female would need to have both paternal and maternal colorblind X to be affected**. X+ represent the normal allele while Xc represents the trait for colorblindness. Females can be silent carries of a trait with no phenotypical expression because of their XX chromosomes (hidden!)**

|  |  |  |
| --- | --- | --- |
|  | X+ | Xc |
|  X+ | X+ X+Normal female | X+ X+Silent carrier female |
| Y | X+ YUnaffected male | Xc YColorblind male |

**Pedigrees**

Khan academy has great resources for many science subjects. This would be something to work on as a class or assign as practices. **HINT: Squares are males, Circles are female, alleles that are irregular are almost always shown as lowercase!**

[**https://www.khanacademy.org/science/high-school-biology/hs-classical-genetics/hs-pedigrees/e/hs-pedigrees**](https://www.khanacademy.org/science/high-school-biology/hs-classical-genetics/hs-pedigrees/e/hs-pedigrees)