

# Genetics – Mutations 2

## Teacher's Guide

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### 1.0 Summary

**Mutations II** is an extension activity, which reviews and enhances the previous Core activities. We recommend that it follow **Mutations** and **X-Linkage**. This activity should take approximately 35-45 minutes.

### 2.0 Learning Goals

**Driving Question:** How are mutations inherited? Are all mutations harmful?

**Mutations II** builds on **Mutations** and **Monohybrid**. In Mutations students changed the DNA bases of the dragon genome and saw the resulting alterations in their traits. In this activity, students continue their investigations of mutations, distinguishing between dominant vs. recessive and somatic vs. germline mutations and how they are inherited. **Mutations II** guides students as they explore lethal mutations and x-linked mutations and gives the students more practice in using Punnett squares to determine the probability of inheriting a mutated trait.

#### Learning Goals

Students will understand that

- Mutations are changes in the DNA that may produce new alleles.
- There can be more than 2 alleles per gene in a population.
- An organism can carry and pass on a mutated gene without displaying the mutated trait.
- A mutated allele has a dominance relationship with every other existing allele for that gene.
- The inheritance of two recessive mutated genes can be lethal.
- Somatic mutations can occur in body cells and may result in abnormal growths or cancer, but are not inherited.

#### Additional Teacher Background

In this activity, students can come to understand that mutations, when occurring in humans, can possibly have profound effects. For example, in the *Horns Dilemma*, we found that Cystic Fibrosis is an autosomal recessive disorder. This genetic illness, usually caused by the deletion of three bases in the DNA of a single gene on chromosome 7, is a serious degenerative disease.

In the course of this activity, students are reminded that mutations are changes in the DNA, which may produce new alleles. The effects of mutated alleles can range from insignificant to fatal and everything in between. For example, a mutation does not always affect a gene, an organism's, ability to survive, its phenotype or its behavior. However, other, more serious mutations cause devastating illness such as, Huntington's disease and Achondroplasia, which are dominant and Tay-Sach's and

Polycystic Kidney disease which are recessive. Mutations that create new alleles are a main source of genetic variation within a population.

Students should be aware that mutations also are caused by environmental factors such as radiation and toxins but will be inherited only if they occur in the germline of an organism.

#### 4.0 Activity Sections

This activity deals with four interrelated ideas: dominant and recessive mutations, lethal alleles, the distinction between somatic and germline mutations, and the parallel between mutated dragon genes and mutated human genes.

#### 4.1 Double wings: When too much of a good thing is lethal!

Step 1: Determine if double wings result from a germline or somatic mutation.

1. So, what are wing phenotypes of their children? Click all that apply.  
 no wings  single wings  double wings

2. What does this tell you about where the mutation for double wings happened? Are double wings the result of a somatic mutation or a germline mutation?  
 somatic  germline

3. Why do you think so?  
because offspring with double wings appeared when I crossed the double-winged dragon with another dragon.

Submit Answer

Cross double-winged dragon with wingless dragon.

Step 2: Determine which genotypes create double-winged dragons.

You determined that:

- the  $Ww$  genotype produces no wings,
- the  $ww$  and  $Wwd$  genotypes produce single wings,
- and the  $wwd$  genotype produces double wings.

There is something here that is new to BioLogica. Two different genotypes ( $Wwd$  and  $ww$ ) produce dragons with the same phenotype (single wings). That happens in nature too.

Step 3: Determine whether mutated allele is dominant or recessive when paired with existing Wings alleles.

Wings Number of Offspring: 40

No Wings  Single Wings  Double Wings

For the existing Wings alleles, WW and Ww allele pairs produce dragons with no wings and ww produces dragons with wings because the w allele is recessive to the W allele.

Use the Chromosome tool and the pedigree above to answer the following questions:

7. Is wd dominant or recessive to W?  dominant  recessive

8. Is wd dominant or recessive to w?  dominant  recessive

9. Why do you think so?  
 Dragons with Wwd don't have double wings so it's recessive to W, while dragons with wwd allele have double wings so wd is dominant to w allele.

Submit Answer

Step 4: Examine recessive lethal pattern in pedigree.

Wings Number of Offspring: 80

No Wings  Single Wings  Double Wings

Interesting! Use the Chromosome tool to determine the genotype(s) of the dead dragons.

WW  Ww  ww  Wwd  wwd  wdwd

Submit Answer

Step 5: Complete a Punnett Square to determine probability of offspring inheriting two alleles for double wings.

11. What is the probability of producing dead offspring for this pair of dragons?

- 0 boxes out of 4 or none
- 1 box out of 4 or 1/4
- 2 boxes out of 4 or 2/4
- 3 boxes out of 4 or 3/4
- 4 boxes out of 4 or 4/4

Submit Answer

#### 4.2 Tracking down X-linked mutations

After a review of the inheritance of fire-breathing as an x-linked recessive trait, students are guided as they investigate a dragon that breathes blue fire.

Step 1: Cross new dragon with another dragon to see if offspring breathe blue fire.

Number of Offspring: 40

Legend:  No Fire,  Fire,  Blue Fire

Interesting! There are no blue-fire-breathers among these offspring.

Cross	Phenotype	Male	Female
1	Fire-breathing	10	4
	Non-firebreathing	13	13
	Blue fire-breathing	0	0

Lack of blue-fire-breathing offspring in the F1 generation keeps the question open.

Step 2: Examine pedigree, plan and test their model.

Fire Number of Offspring: 40

No Fire  Fire  Blue Fire

13. What does that suggest to you about whether blue fire is a germline or somatic mutation?

I can't tell yet. Maybe blue fire is a recessive trait or it might be a somatic mutation.

14. How would you test that idea?

I'd cross two offspring or a daughter with the blue-fire breathing father.

Submit Answer

Fire Number of Offspring: 120

No Fire  Fire  Blue Fire

15. Breathing blue fire results from a mutation in the Fire gene in which kind of cell?

somatic  germline

16. Why do you think so?

because offspring with blue fire appeared in the F2 generation.

Submit Answer

Look at your pedigree. Are there any female dragons that breathe blue fire?

Yes  No

22. Why is that so?

Blue - fire is definitely recessive to both Fire alleles, which means that a female needs 2 of the alleles to be blue-fire breathing.

Submit Answer

23. Can you produce a female dragon that breathes blue fire? How would you do it?

I'd look for a female with a blue-fire allele and cross her with a blue-fire-breathing male.

Submit Answer

Step 3: Breed for a blue-fire-breathing female.

Fire

Number of Offspring: 160

No Fire    Fire    Blue Fire

Excellent job! You were able to produce a female who breathes blue fire with just one cross. Was it luck? How did you choose which dragons to cross?

I looked for a female with the blue fire allele and crossed it with a blue fire breathing male.

Submit Answer

Step 4: Report on dominance relationship.

Now, do you think the mutated Fire allele fb is dominant or recessive to the existing Fire alleles F and f?

fb is dominant to f    fb is recessive to f

fb is dominant to F    fb is recessive to F

19. Why do you think so?

because dragons that have only fb alleles are the only ones that breathe blue fire.

Submit Answer

Step 5: Work through the probability that offspring of a blue-fire-breathing female and a fire-breathing male will breathe blue fire.

Dominique   Damian

Meet Damian and Dominique. Damian is your typical male fire-breathing dragon. Dominique, on the other hand, is special - she breathes blue fire. If you were to cross Damian and Dominique, what is the probability of Damian and Dominique having a female dragon that breathes blue fire?

Use a Punnett square to figure this out -->   Punnett Square

Damian

f   -

fb   ffb   fb-

fb   ffb   fb-

Dominique

Check   Help

Damian

f      -

fb      ffb      fb-

fb      ffb      fb-

Dominique

27. What is the probability that a female offspring will breathe blue fire?

0 chances out of 4 or none

1 chances out of 4 or 1/4

2 chances out of 4 or 2/4

3 chances out of 4 or 3/4

4 chances out of 4 or all

Submit Answer

Step 6: Test prediction by crossing Dominique and Damian.

Dominique

Fire

Number of Offspring: 0

No Fire     Fire     Blue Fire

You are correct. None of the female dragons will breathe blue fire. Here is the next question.

28. Do you think you could get a female dragon that breathes blue fire if you were to cross dragons from the F1 generation?

Yes     No

29. Why do you think so?

since dominique has 2 fb alleles, each of the offspring will have an fb allele. crossing any two offspring should produce a female who breathes blue fire.

Submit Answer

Students must make both an F1 and an F2 generation to produce females who breathe blue fire.

Fire

Number of Offspring: 80

No Fire    Fire    Blue Fire

You said, **Yes**, and there they are! Blue fire breathing females! Because all the males of the F1 generation breathe blue fire, their daughters get one fb allele from Dad. All the females of the F1 generation breathe fire because they are heterozygous with one mutated Fire allele and one normal allele, so their daughters might receive either a normal or mutated Fire allele. So half of the daughters will breathe blue fire!

Done

### 4.3 Mutations Quiz

Mutations II concludes with a mutations quiz about another novel trait – the arrow tail.

Step 1: Cross the parents using the Cross tool to create the F1 generation.

Tail

Number of Offspring: 120

Plain Tail    Fancy Tail    Arrow Tail

Punnett Square

There is a mutant allele for the Tail gene too. The allele is labeled "ta" and stands for arrow tail. Here is a pair of dragons, one with an arrow tail. Make the crosses you need to figure out whether the mutant allele is dominant or recessive to the existing Tail alleles.

When you have it figured out click Next.



Step 2: Answer a series of questions about which genotypes produce which phenotypes and justify their answers.

30. Click the genotype(s) that produce dragons with a fancy tail.

TT  Tt  tt  tta  Tta  tata

31. Using this pedigree, explain your answer.

Since the ta allele is recessive to the T allele, any combination with the T allele will produce a fancy tail.

Submit Answer

32. Click the genotype(s) that produce dragons with a plain tail.

TT  Tt  tt  tta  Tta  tata

33. Using this pedigree, explain your answer.

Since the ta allele is also recessive to the t allele, genotypes containing the only the t and ta allele produce plain tails on dragons.

Submit Answer

34. Click the genotype(s) that produce dragons with an arrow tail.

TT  Tt  tt  tta  Tta  tata

35. Using this pedigree, explain your answer.

Since the ta allele is recessive when paired with any other Tail allele, only genotypes with 2 ta alleles produce dragons with the arrow tail.

Submit Answer

After students answer the questions, a summary reinforces the dominance and recessive relationships among alleles.

A mutant allele can be dominant, recessive, incompletely dominant or co-dominant to each existing allele or it can have a different dominance relationship with each existing allele, for example, dominant to one but recessive to another. Remember that dominance relationships are defined for allele pairs in terms of what the heterozygous phenotype looks like compared with each homozygous phenotype.

Step 3: Reflect on the effects of mutations they have seen.

A mutation may be helpful, harmful or neutral. Which of the mutations you have explored in dragons (unicorn, white skin, blue fire, double wings, arrow tail) fit in each category?

36. Unicorn:

helpful  harmful  neutral

37. White skin:

helpful  harmful  neutral

38. Double wings:

helpful  harmful  neutral

39. Blue fire:

helpful  harmful  neutral

40. Arrow tail:

helpful  harmful  neutral

41. Explain your thinking.

Double wings alleles are potentially fatal, a lethal recessive. the others may be helpful or neutral depending on whether they enable the dragons with those traits to survive or compete in their current environments.

Submit Answer

42. How do mutations help produce variations among the individuals in a family or population?

Germline mutations produce new alleles that introduce new traits into a family and into a population. |



Submit Answer

Melanocytes, the cells of the skin that produce the melanin pigment that gives your skin color, can be damaged by extensive exposure to UV radiation in sunlight. If that damage is done to the DNA of the cells, would the resulting mutation be considered a somatic or germline mutation?

germline  somatic

44. Explain your answer.

Mutations in skin cells and non-germline cells cannot be inherited and are therefore somatic mutations.

You are correct that this is an example of a somatic mutation, meaning that it occurs in body cells (in this case, skin cells).

If the mutation occurs in a tumor suppressor gene, skin cancer can result.

If a mutation occurs in a germline cell or gamete of an individual it can be passed on to their offspring.

When offspring inherit a mutated tumor suppressor gene, it is present in all their cells and increases the risk of tumors throughout their bodies.

#### Step 4: Read the summaries.

Let's take a few minutes to review what you have learned:

- Mutation (change in the DNA) creates new alleles (mutant alleles).
- There can be more than two alleles per gene in a population.
- Mutation is rare and can be hidden through generations.
- A mutant allele will have a dominance relationship with every other existing allele.
- A mutant allele can be lethal.
- Somatic mutations can also occur in body cells and may result in abnormal growths or cancer, but are not inherited.

Why is this important?

Germline mutations are one of the factors that bring about change in a population. They are random. The effect of a mutation depends on how the mutation changes the structure, function, or behavior of an organism in relation to its environment. A mutant organism may be better or less well adapted to its environment than its normal counterpart. When a mutation helps an organism survive in its environment, it is considered helpful.

Somatic mutations occur in the body cells of an individual and cannot be inherited.

## 5.0 Student Reports

Your students' work with *Mutations 2* is logged and viewable on the MAC Project Web Portal at <http://mac.concord.org>. For each student, you can view a report containing questions and answers.

Students should now work through the *Dihybrid* activity. It guides students as they examine the different patterns that emerge when the genes for two traits are on the same chromosome versus different chromosomes.