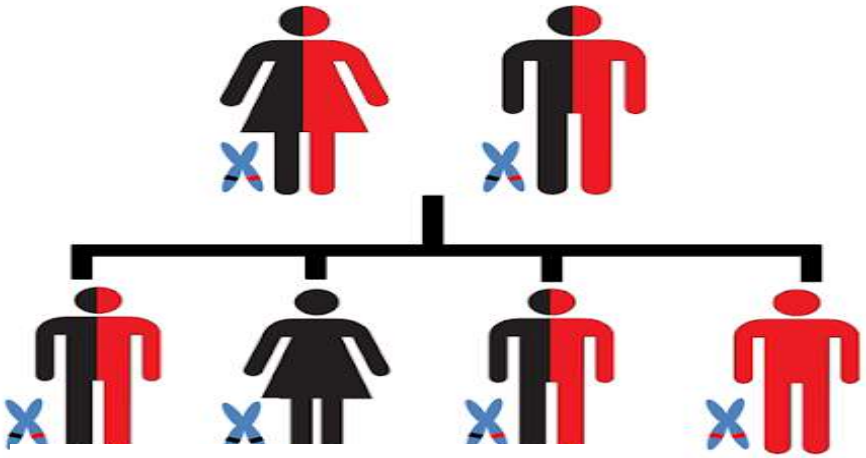
9

Science

Quarter 1 – Module 8

NON-MENDELIAN PATTERNS OF INHERITANCE:

Sex determination, Sex-Linked, Sex-Limited, Sex-Influenced Traits



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Science– Grade 9
Quarter 1 – Module 8: NON-MENDELIAN PATTERNS OF INHERITANCE:

Sex determination, Sex-Linked, Sex-Limited, Sex-Influenced Traits

Regional Director: Gilbert T. Sadsad
Assistant Regional Director: Jessie L. Amin

Development Team of the Module

Writer: Gracea M. Manjares

Editor: Benjie L. Cadag

Reviewer: Emily Esmabe

Illustrator

Layout Artist:

Regional Center Site, Rawis, Legazpi City 4500
0917 178 1288
region5@deped.gov.ph

MOST ESSENTIAL
LEARNING
COMPETENCY

Explain the different patterns of Non-Mendelian inheritance.

Supplementary Learning Module for Junior High School Learners

NON-MENDELIAN PATTERNS OF INHERITANCE:

Sex determination, Sex-Linked, Sex-Limited, Sex-Influenced Traits

The different patterns of inheritance discussed in the previous module deal with the traits controlled by genes found in autosomes, or chromosomes other than the sex chromosomes. The expression of these genes are not affected by the sex chromosomes.

What are sex chromosomes? These are the chromosomes that determine the sex of an individual. There is a pair in every somatic cell. In humans, they are the X and Y chromosomes while they are called differently in some animals.

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How is sex determined? how do they affect the expression of some genes? Read on and perform the activities prepared for you in this module.

At the end of the module, you should be able to:

- differentiate how the following are inherited and expressed:
  a. Sex-linked traits
  b. Sex Limited traits
  c. Sex Influenced traits
- solve some problems involving sex-linked traits;
- analyze sex-linked traits using a pedigree; and
- realize how sex chromosomes affect the expression of some genes in an individual

Directions: Identify what is asked or described in each item then write the letter of the correct answer.

1. In humans, males have:
   a. a pair of X chromosomes in their cells.
   b. an X and a Y chromosome in all their somatic cells.
   c. a pair of Y chromosomes in their sperm cells.
   d. 2 pairs of Y chromosomes in their cheek cells.

2. Traits that are found in the sex chromosomes are called
   a. sex-influenced traits.
   b. sex-limited traits.
   c. sex-linked traits.
   d. all of these

3. Baldness is commonly seen in males. Very few women exhibit this characteristic. If ever they do, their genotype for this trait is:
   a. homozygous dominant.
   b. homozygous recessive.
   c. Heterozygous.
   d. cannot be determined.

4. Both males and females have mammary glands. But only females have the capacity to produce milk. This is an example of:
   a. sex-influenced trait.
   b. sex-linked trait.
   c. sex-limited trait.
   d. any of these.

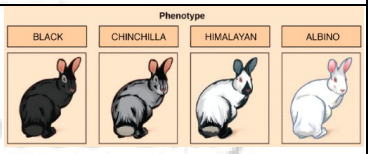
5. Color-blindness in humans is mostly manifested in
   a. Women.
   b. men.
   c. Adults.
   d. children.

Hi! How did you find the test?

I know these are new information for you. Just check your answers using the answer key section. But don't worry if you got a low score. This just means that there are more things that you can learn from this module. So, hop on!

Let's find out if you can remember the previous lesson by comparing the different non-Mendelian patterns of inheritance.

A. Match the pattern of inheritance with its description and example.

NON-MENDELIAN PATTERN	DESCRIPTION	EXAMPLE
1. Incomplete dominance	a. There are several genes that control a trait	A. 
2. codominance	b. Heterozygotes exhibit both phenotypes	B. 
3. Multiple allelism	c. Characteristics appear blended	C. 
4. polygenic	d. There are several alleles for a gene	D. 

In these four patterns of non-Mendelian inheritance, the genes are found in autosomes, or chromosomes other than the sex chromosomes. The expression of the traits or phenotypes differ from each other depending on the combination of alleles (multiple alleles) or the interactions of these genes with each other or with the environment (polygenes).

SEX DETERMINATION

What determines the sex of an individual? Which part of the genome determines the sex? How do sex chromosomes affect other traits found in other chromosomes?

To answer the first question, look at the karyotype of the human chromosomes. A **karyotype** is a visual presentation of the appearance and number of chromosomes of an individual.

Questions:

1. How many pairs are there? _____ How many chromosomes do we have? _____
2. What are the sex chromosomes? _____
3. A combination of X and Y chromosomes makes an individual a male. Two X chromosomes makes an individual a female. What is the sex of this individual? _____

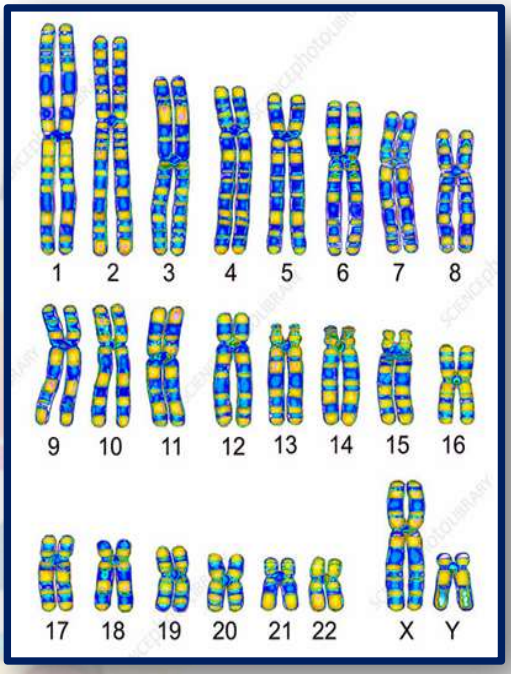


Figure 1. Human Karyotype

Look at the Punnet square at the right.

Answer the questions below by filling up the blanks.

4. A baby boy gets his X chromosome from his _____ while he gets his Y chromosome from his _____.
5. A baby girl gets her X chromosomes both from her _____
6. Suppose the mother is pregnant, what is the chance or percentage that her baby is a girl? _____

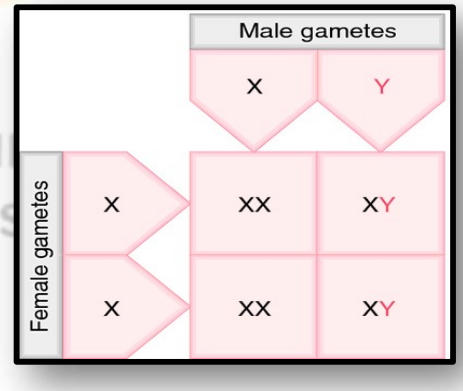
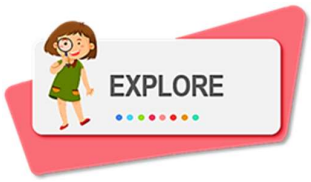


Figure 2. Punnet square showing inheritance of sex chromosomes



Other patterns of non-Mendelian inheritance involve the sex chromosomes. There are three types of inheritance of sex traits: **sex-linked**, **sex-influenced** and **sex-limited**.

A. Sex-linked traits

Genes located in the same chromosomes are said to be linked together so they are called **linked genes**. They go together during the seggregation process of meiosis unless they were separated during crossing over.

Traits that are carried or found in the sex chromosomes are called **sex-linked traits**. Genes on the X chromosomes are called **X-linked genes** and those in the Y chromosome are called **Y-linked genes**. X chromosome is a bit bigger and longer than the Y chromosome, therefore, has more genes found in it.

Examples of X-linked traits in humans include color-blindness and hemophilia. Color-blindness is the inability of a human to identify the correct color of an object while hemophilia is the inability of the blood to clot causing hemorrhage and death.

The table at the right shows the genotypes and phenotypes of individuals for color-blindness.

Genotype	Phenotype
$X^C X^C$	Normal female
$X^C X^c$	Normal female (carrier)
$X^c X^c$	Red-green color-blind female (homozygous)
$X^C Y$	Normal male
$X^c Y$	Red-green color-blind male

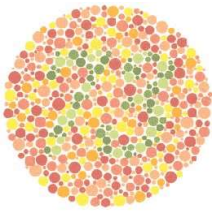
Figure 3. Genotype sand phenotypes for colorblindness

Questions: The terms inside the parenthesis are your choices.

1. Which is dominant, normal vision or colorblindness? _____
2. Why do you say so? _____
3. When there is only one chromosome with the gene for colorblindness, the female is only a _____ (*normal for color vision / carrier)*
4. A female only becomes colorblind when she has _____ *(one / two)* gene/s for colorblindness in her chromosome.
5. A male becomes _____ *(normal / colorblind)* when his only X chromosome has the gene for colorblindness.
6. There are no _____ *(male/ female)* heterozygote with respect to colorblindness.
7. There are more _____ *(male /female)* colorblinds in the population than with the opposite sex.

DO THIS!

Let us solve a sample problem involving linked genes like colorblindness using a Punnet square. The gene for colorblindness is linked to the X chromosome making it an **X-linked gene**.



Suppose a woman with normal vision marries a colorblind man, What would be the possible genotypes and phenotypes of their children if they will have any?

Genotype of woman = XX

Genotype of man = X^cY

♀ \ ♂	X^c	Y
X	XX^c	XY
X	XX^c	XY

	genotypes	phenotypes
	XX^c - 2	Female carrier - 2
	XY - 2	Normal male - 2
ratio	2:2	2:2

Q: Is there a chance of having a colorblind daughter? _____

Solve the following cross using the Punnet square:

1. **XX x X^cY**

♀ \ ♂		

	genotypes	phenotypes
ratio		

Q: What is the chance of having a colorblind son? _____

2. **X^cX^c x XY**

♀ \ ♂		

	genotypes	phenotypes
ratio		

Q: If the mother is colorblind, what is the chance that her son has normal vision? _____

KEEP THIS IN MIND

Key Concepts

X-linked genes are found in the X chromosomes. Because there is only one X chromosome in males, the trait is mostly observed in males because there is no gene in the Y chromosome that can suppress the expression of that gene. Females only become carriers if they have only one gene because the X chromosome can hinder the expression of the gene. They exhibit the trait only when they become homozygous.

What are holandric genes?

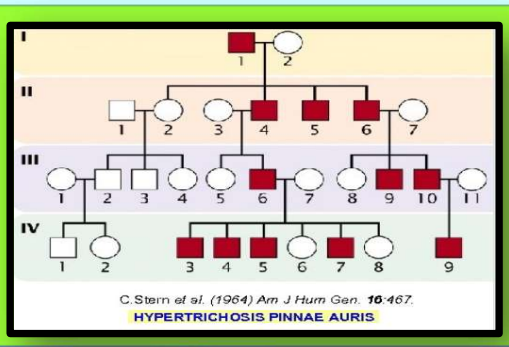
HOLANDRIC GENES

are genes found in the

Y chromosome

How can they be inherited?

Since they are found in the Y chromosome only, they can only be passed on from father to son.

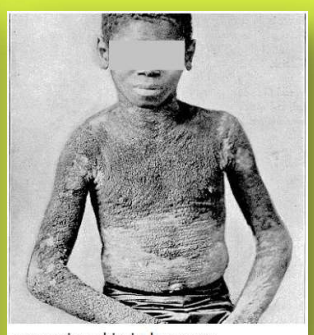


Are there dominant or recessive genes in holandric traits?

There are no dominant or recessive traits because there is only one copy of Y chromosome in a human male cell.

Some examples of Y-linked traits

hypertrichosis or excessive hair on ears



porcupine skin in humans

baldness

B. Sex-influenced traits

Sex-influenced traits are controlled by genes found in autosomes, not the sex chromosomes, but their expressions differ from male to female because they are affected by hormones.

Make a Punnet square of this cross:

B'B' x BB

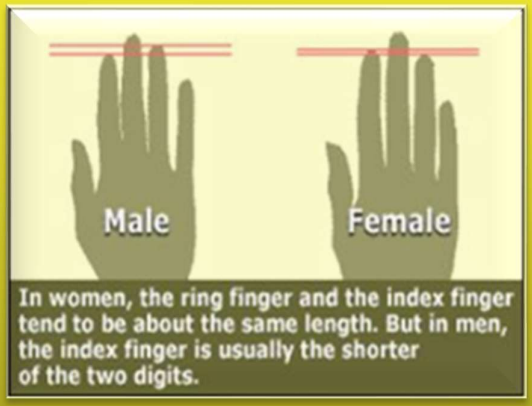
What is the chance of having a son who will become bald?

♀ \ ♂		

	genotypes	phenotypes
ratio		

A bit of TRIVIA

Another example of sex-influenced trait in human is the ratio of index and ring finger as shown below.



In women, the ring finger and the index finger tend to be about the same length. But in men, the index finger is usually the shorter of the two digits.

This trait is dominant in males and recessive in females.

FYI:
High amount of prenatal testosterone influences this trait.

Other examples in animals:

Horn size in mountain sheep

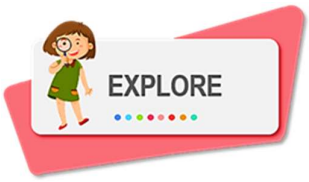
Feather color in peacock

Males have more colorful feathers than females!

KEEP THIS IN MIND

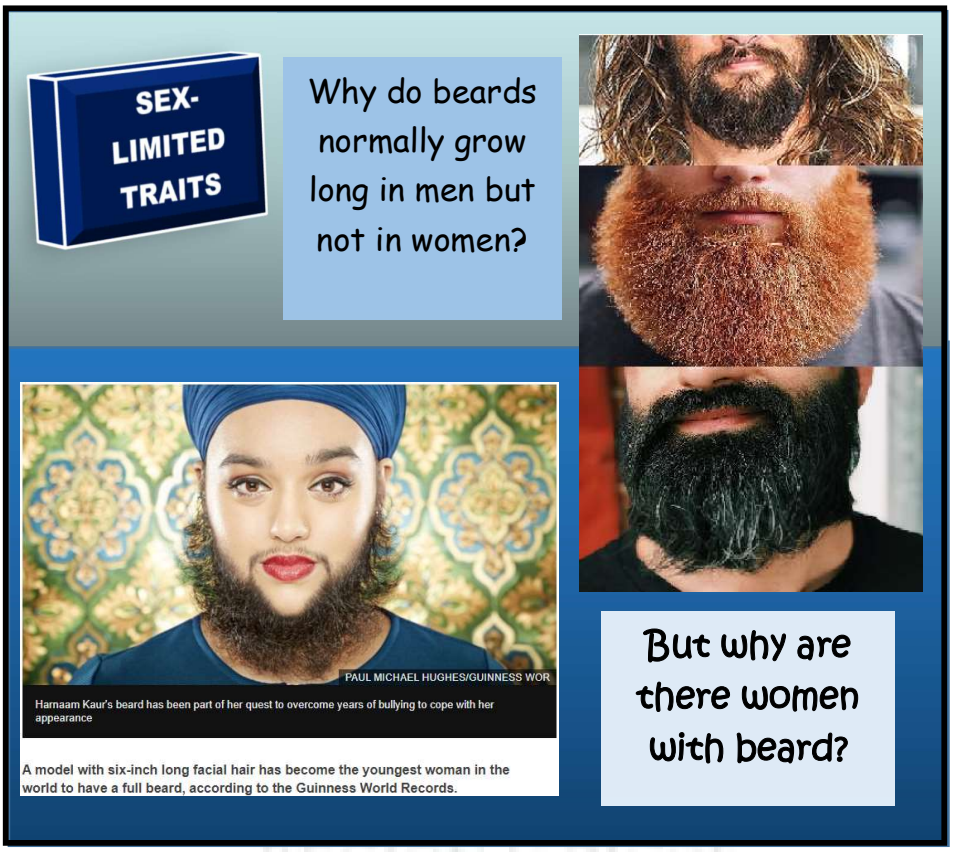
Key Concepts

The expression of sex-influenced traits is affected or influenced by sex hormones. If a male has one recessive trait, he will exhibit the trait. But females have to have two recessive genes to show the trait.



C. Sex-limited traits

Traits that are expressed only in one of the sexes are called **sex-limited traits**. They are controlled by genes found in autosomes.



Genes of sex-limited traits are found in both males and females but their expression is limited to one sex only.

Both men and women have the genes for growing beards but only men grow beards because of the effect of the male sex hormones. However, when women experience hormonal imbalance, they tend to grow beard too.

In the same manner, breasts are present to both sexes but development is limited to women only. However hormonal imbalance in males can also lead to the development of breast! But only females have the ability to produce milk because of the effects of female hormones.

The presence or absence of sex hormones generally affect the expression of sex-limited traits. In some animals, castration can lead males to produce high-pitch voice because of the absence of the male sex hormone.

Let's compare!

Direction: Check the pattern of sex related traits applicable to the indicated characteristics.

Characteristics	Sex-linked traits	Sex-influenced traits	Sex-limited traits
Genes are found in autosomes.			
Genes are found in sex chromosomes.			
There are dominant and recessive traits.			
Expression of trait is limited to one sex only.			
Expression of trait is influenced by hormones.			
Males only exhibit the trait in Y chromosome.			
Males show the trait when X chromosome has the gene.			

Direction: Use your knowledge of Punnet square to answer the following word problems below.

1. A bald woman (BB) marries a man who has normal hair (B'B'). What is the probability that:
   a) their daughter will be bald?
   b) their son will have normal hair?

2. A couple who are both normal as regards to color vision had a son who is colorblind. What are the genotypes of the persons mentioned?

3. A colorblind man marries a woman who is a carrier of the disorder. What are the possible genotypes of their sons and daughters if they have any?

4. In which of the following situations does the resulting male offspring have a higher chance of acquiring an X-linked recessive trait?
   a. A female carrier marrying a normal male

b. An affected male marrying a normal female

Direction: Write **TRUE** if the statement is correct or **FALSE** if the statement is not correct on the space provided before the number.

_____1. Development of the male and female sex characteristics is an example of sex-limited trait.

_____2. Males usually show the characteristics of X-linked traits.

_____3. Females may become bald if they have one copy of the gene for baldness.

_____4. In sex-influenced traits, genes are found in both sexes.

_____5. In sex-limited traits, genes are found in both sexes.

_____6. The ability to lactate is an example of sex-influenced trait.

_____7. Holandric traits are observed only in males.

_____8. X-linked traits are observed in both sexes.

_____9. Limited traits are usually observed in one sex only.

_____10. Difference in body and facial hair in male or female is an example of sex-influenced trait.

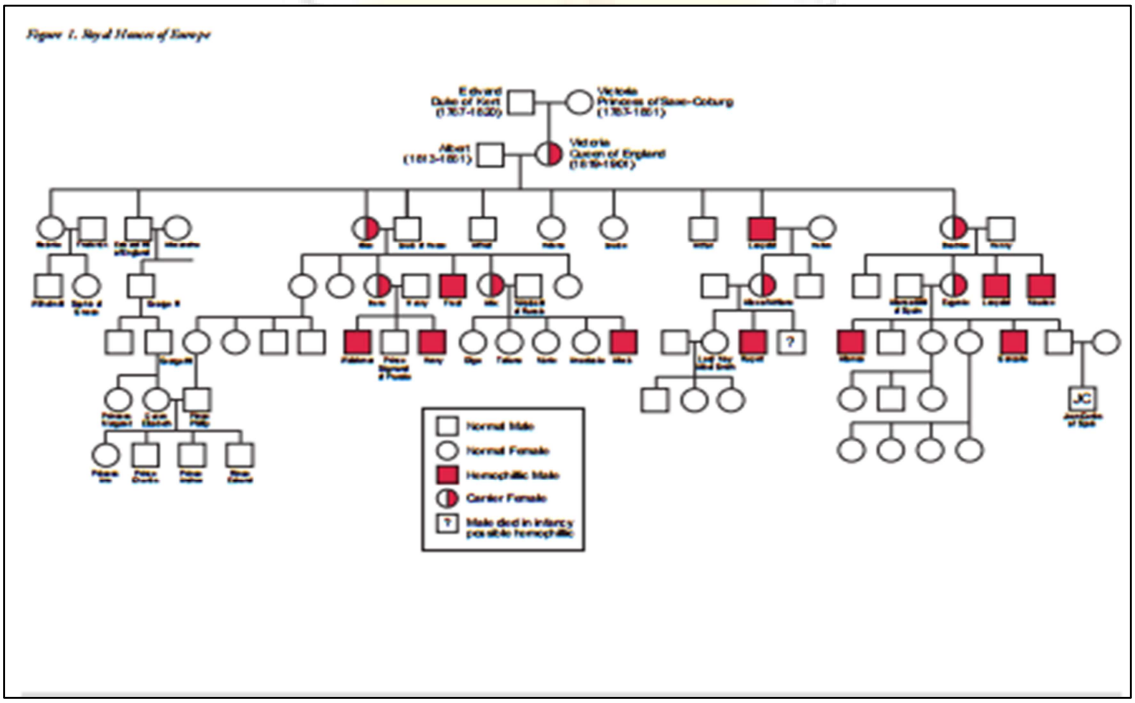
The following references and internet links can be accessed for a more detailed explanation of the topic.

1. Genetics! sex limited vs sex influenced vs sex linked inheritance
   https://www.youtube.com/watch?v=Eek0KpV8jUo
2. sex linked inheritance, Sex Influence inheritance and sex limited characters
   https://www.slideshare.net/AashishPatel14/sex-linked-inheritance-sex-influence-inheritance-and-sex-limited-characters
3. Sex Limited Genes and Sex Influenced Traits | Genetics | Biotechnology
   https://www.biotechnologynotes.com/genetics/inheritance/sex-limited-genes-and-sex-influenced-traits-genetics-biotechnology/13346

4. What is the difference between sex influenced/sex limited and sex linked inheritance? https://www.enotes.com/homework-help/what-difference-between-sex-influenced-dominance-247643

In order for you to practice how to determine the genotype based on the phenotype in a pedigree, write the genotype of each individual in Queen Victoria's pedigree.

Some of Queen Victoria's descendants were observed to have hemophilia, a rare X-linked trait. Hemophiliacs lack a certain protein needed to clot the blood.



QUEEN VICTORIA'S PEDIGREE

Source: Hemophilia: The Royal Diseases by:
Yelena Aronova-Tiuntseva and Clyde Freeman Herreid
University at Buffalo
State University of New York
http://sciencecases.lib.buffalo.edu/cs/files/hemo.pdf

I have learned that…

_____
_____
_____
_____

I wish to ask my teacher about…

_____
_____
_____
_____

CONGRATULATIONS!!!

You're done with lesson 3 of Module 2 for Quarter 1. To check your answer to the questions, refer to the answer key in the succeeding pages.

GOOD JOB!

ANSWER KEY

TRY THIS

6. B
7. C
8. B
9. C
10. B

A REVIEW

1. Incomplete dominance – c, B
2. Codominance – b, A
3. Multiple allelism – d, D
4. Polygenic – a, C

A. SEX DETERMINATION

1. How many pairs are there? 23 PAIRS
   How many chromosomes do we have? 46 CHROMOSOMES
2. What are the sex chromosomes? The sex chromosomes are the X and Y chromosomes
3. A combination of X and Y chromosomes makes an individual a male. Two X chromosomes makes an individual a female. What is the sex of this individual? MALE
4. A baby boy gets his X chromosome from his MOTHER while he gets his Y chromosome from his FATHER.
5. A baby girl gets her X chromosomes both from her PARENTS.
6. Suppose the mother is pregnant, what is the chance or percentage that her baby is a girl? 50% CHANCE.

X-LINKED GENES

8. Which is dominant, normal vision or colorblindness? NORMAL VISION

9. Why do you say so? THE PRESENCE OF ONLY ONE GENE IN FEMALE MAKES HER ONLY A CARRIER. THE OTHER GENE PREVENTS THE EXPRESSION OF THE X-LINKED TRAIT GENE.

10. When there is only one chromosome with the gene for colorblindness, the female is only a CARRIER.

11. A female only becomes colorblind when she has TWO gene/s for colorblindness in her chromosome.

12. A male becomes COLORBLIND when his only X chromosome has the gene for colorblindness

13. There are no MALE heterozygote with respect to colorblindness.

DO THIS

Q: Is there a chance of having a colorblind daughter? NO

Solve the following cross using the Punnet square:

3. XX x X^cY

♀ \ ♂	X^c	Y
X	X^cX	XY
X	X^cX	XY

	genotypes	phenotypes
	X^cX = 2	Normal female, carrier = 2
	XY = 2	Normal male = 2
ratio	2:2	2:2

Q: What is the chance of having a colorblind son? NONE

4. X^cX^c x XY

♀ \ ♂	X	Y
X^c	X^cX	X^cY
X^c	X^cX	X^cY

	genotypes	phenotypes
	X^cX = 2	normal female, carrier = 2
	X^cY = 2	Colorblind male = 2
ratio	2:2	2:2

Q: If the mother is colorblind, what is the chance that her son has normal vision? NONE

SEX-INFLUENCED TRAITS

Make a Punnet square of this cross:

B'B' x BB

♀ \ ♂	**B**	**B**
B'	B'B	B'B
B'	B'B	B'B

	genotypes	phenotypes
	B'B = 4	male will be bald female will be normal
ratio	4:0	Male = 100% Female = 0%

What is the chance of having a son who will become bald? 100%

LET'S COMPARE

Characteristics	Sex-linked traits	Sex-influenced traits	Sex-limited traits
Genes are found in autosomes		/	/
Genes are found in sex chromosomes	/		
There are dominant and recessive traits	/	/	
Expression of trait is limited to one sex only			/
Expression of trait is influenced by hormones		/	
Males only exhibit the trait in Y chromosome.	/		
Males show the trait when X chromosome has the gene	/		

APPLY WHAT YOU HAVE LEARNED

5. A bald woman (BB) marries a man who has normal hair (B'B'). What is the probability that:
   a) their daughter will be bald? ALL POSSIBLE DAUGHTERS WILL BE NORMAL
   b) their son will have normal hair? ALL POSSIBLE SONS WILL BE BALD

6. A couple who are both normal as regards to color vision had a son who is colorblind. What are the genotypes of the persons mentioned?

   FATHER – XY
   MOTHER X^cX
   SON - X^cY

7. A colorblind man marries a woman who is a carrier of the disorder. What are the possible genotypes of their sons and daughters if they have any?

   DAUGHTERS – 50% CHANCE NORMAL, 50% CHANCE CARRIER
   SONS – 50% CHANCE COLORBLIND, 50% CHANCE NORMAL

8. In which of the following situations does the resulting male offspring have a higher chance of acquiring an X-linked recessive trait?
   c. A female carrier marrying a normal male
   d. An affected male marrying a normal female

ASSESS WHAT YOU HAVE LEARNED

1. TRUE
2. TRUE
3. FALSE
4. TRUE
5. TRUE
6. FALSE
7. TRUE
8. TRUE
9. TRUE
10. TRUE

REFERENCES

Grade 9 Science Student Module

https://www.animalgenome.org/edu/blue_genes/sexlim.html

Genetics! sex limited vs sex influenced vs sex linked inheritance
https://www.youtube.com/watch?v=Eek0KpV8jUo

sex linked inheritance, Sex Influence inheritance and sex limited characters
https://www.slideshare.net/AashishPatel14/sex-linked-inheritance-sex-influence-inheritance-and-sex-limited-characters

Sex Limited Genes and Sex Influenced Traits | Genetics | Biotechnology
https://www.biotechnologynotes.com/genetics/inheritance/sex-limited-genes-and-sex-influenced-traits-genetics-biotechnology/13346

What is the difference between sex influenced/sex limited and sex linked inheritance?
https://www.enotes.com/homework-help/what-difference-between-sex-influenced-dominance-247643

Human karyotype https://www.sciencephoto.com/media/458364/view/human-karyotype

Punnet square showing inheritance of sex chromosomes https://medical-dictionary.thefreedictionary.com/Punnett+square

Genotype and phenotype for colorblindness trait https://www.easynotecards.com/print_list/58839

Holandric Genes: Traits & Inheritance https://study.com/academy/lesson/holandric-genes-traits-inheritance.html

Porcupine skin https://www.pinterest.ph/pin/565905509396980005/

Baldness https://www.medicalnewstoday.com/articles/317788#Existing-hair-loss-treatments

Mendelian Genetics Inheritance Lecture Notes Biol 100 https://present5.com/mendelian-genetics-inheritance-lecture-notes-biol-100/

Pattern hair loss https://en.wikipedia.org/wiki/Pattern_hair_loss

Trophy Hunting linked to Smaller Horns for Mountain Sheep http://canadianmountainnetwork.ca/trophy-hunting-linked-to-smaller-horns-for-mountain-sheep/

Big Horn Sheep - Ovis Canadensis https://nhpbs.org/natureworks/bighornsheep.htm

Unlocking color mechanism of peacock's feathers could lead to next-gen color displays https://newatlas.com/structural-color-reflective-color-displays/26128/

Psychology of a Bearded Man https://fashionispsychology.com/the-psychology-of-the-bearded-man/

Guinness World Record for bearded woman Harnaam Kaur https://www.bbc.com/news/uk-england-37305050