GENETICS PROBLEMS

Introduction:

One of the facts of life involves the different types of offspring that can be produced as a result of sexual reproduction. Offspring may have traits of one parent, both parents or neither parent. This depends upon the genes the offspring receive from the parents. The types of traits possible in an offspring have long been of interest to mankind. Gregor Mendel, the Austrian monk who is the father of modern genetics, was interested in the inheritance of garden pea plants. In general, people can be interested in genetics for a variety of reasons: a new baby due in the family or the need to breed for certain characteristics in cows. In either case, they want to know the probability of having a given type of offspring.

In order to determine the probable appearance of an offspring, we must first know something about the parents. What do they look like? What **genes** do they possess? The **phenotype** is what an individual looks like (i.e. a tall male with attached ear lobes). The **genotype** is the genes an individual has (the two genes for tallness and the two genes for attached ear lobes). We must know what possible genes can be found in the gametes of each parent and the possible ways these genes may combine during fertilization.

Another important factor in genetics is the influence of chance on the inheritance of traits. Chance alone determines which genes will be passed from each parent to their offspring. The influence of chance is explained by Mendel's Laws: the **Law of Segregation** and the **Law of Independent Assortment**.

The Law of Segregation states that when gametes are formed, the two alleles for each gene separate from one another and each gamete receives **one** allele. In other words, there is equal chance of receiving either allele.

The Law of Independent Assortment states that traits located on **different** chromosomes will be inherited **independently** of each other. In other words, one trait has no influence on how another trait will be inherited, it is a chance occurrence.
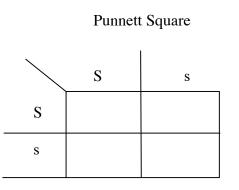
In today's lab, your goal will be to understand how chance influences inheritance and to learn how to solve genetics problems. First, here are some terms for easy reference:

> **Phenotype** - The physical appearance of an organism.
> **Genotype** - The genes of an organism.
> **Allele** - One of two or more forms of the same gene.
> **Locus** - A specific location on a chromosome where a gene is found.
> **Heterozygote** - An organism having two different alleles for a trait.
> **Homozygote** - An organism having two of the same alleles for a trait.
> **Homologous Chromosomes** - Chromosomes having genes for the same kinds of characteristics that pair during meiosis.

Exercise #1 — Applying the Laws of Chance to Genetics Report Sheets

The science of genetics uses chance to explain how traits are inherited. Chance happens whenever you toss a coin. There is a 50:50 chance or 1 chance out of 2 that the coin will land as "heads" or as "tails". This same principle operates in genetics since most traits will be either present or absent. The laws of chance can help you determine approximately how many times a result is expected to occur. In this activity, you will compare the results you expect from a monohybrid cross to the actual results of a monohybrid cross.

1. Complete the Punnett square of the monohybrid cross Ss x Ss to show how often each genotype is expected to appear in four offspring.

Punnett Square

2. In the monohybrid cross diagrammed by the Punnett square, how many offspring with the genotype (SS) are expected? What percentage of the possible genotypes is this?

3. How many offspring with the genotype (ss) are expected? What percentage of the possible genotypes is this?

4. How many offspring with the genotype (Ss) are expected? What percentage of the possible genotypes is this?

Materials Needed:
      Two small paper cups or other opaque container
      Two shiny pennies
      Two dull pennies

Procedure & Discussion:
Check to see if your expected results are the same as the actual results of a monohybrid cross.

5. Place one shiny and one dull penny in each container. One container represents the female gametes that have undergone meiosis and the other container represents the male gametes that have undergone meiosis.

   What are the four possible combinations of these gametes when they recombine during fertilization?

   Which two combinations are the same and therefore will be more likely to appear?

6. Fill out the blanks below by picking, without looking, one penny representing a gamete out of each container. Check off the genotype produced by the combination of the two gametes. Return the pennies to their original containers and repeat this step for a total of 40 tries.

   Monohybrid Cross:

   SS   Ss or sS   ss

   _____   _____   _____

7. Calculate the percentage of each genotype by adding the totals for each genotype and dividing each total by 40.

8. What factor determines whether a shiny or dull coin is picked?

9. How does your percentage of each genotype compare to the percentage of genotypes expected based on the Punnett square?

10. How can you explain the fact that your percentages are not exactly the same as the expected percentages based on the Punnett square?

11. What basic principle of Mendel's genetics is illustrated in this activity?

Exercise #2 — Solving Genetics Problems Report Sheets

In this activity, the class will be divided into groups. Each group will be assigned a set of problems to solve. It may help to solve the problems using the following guidelines:

1. Assign letters (alleles) to the various characteristics.

2. Determine the phenotype and genotype of each parent and indicate a mating.

3. Determine all the possible kinds of gametes each parent can produce.

4. Determine all the possible allele combinations that can result when these gametes combine to form the offspring, Punnett square.

5. Determine the phenotype of each allele combination, genotype, in the offspring.

Genetics Problems:

1. For each of the following genotypes, give all possible gametes. A gamete would be haploid for each trait (a single letter like G or t) while the genotype of an individual will be diploid (two letters like Gg or tt).

    a. BB
    b. Bb
    c. Tt
    d. TT

2. For each of the following, state whether a genotype or a gamete is represented.

    a. D
    b. GG
    c. P
    d. ee

3. For each of the following genotypes, give all possible gametes. Dihybrids will have letters representing alleles of two or more genes so will have two or more different letters. Gametes would still be haploid for each trait (gT for example) while genotypes of individuals are diploid for each trait (GGTt for example).

    a. ttGG
    b. TtGG
    c. TtGg
    d. TTGg

4. For each of the following, state whether a genotype or a gamete is represented.

    a. TT
    b. Tg
    c. IiCC
    d. TW

5. In rabbits, B is the dominant black allele and b is the recessive white allele, which of these genotypes could a white rabbit have?

    a. Bb
    b. BB
    c. bb
    d. WW

6. Let's say in humans, six fingers (F) is the dominant trait and five fingers (f) is the recessive trait. Both parents are heterozygous and have six fingers.
    What is the phenotype of the father and the mother? What is the genotype of each parent? What is the probability of them having a child with six fingers?
    A child with five fingers?

    a. Father's phenotype _____

        Mother's phenotype _____

    b. Father's genotype _____

        Mother's genotype _____

    c. Father's gametes _____ or _____

    d. Mother's gametes _____ or _____

    e. Probability of a child with six fingers _____

    f. Probability of a child with five fingers _____

7. If a father is heterozygous for six fingers and the mother has five fingers, what is the probability of having these characteristics in their offspring?

    Six Fingers _____   Five Fingers _____

    What is the expected phenotype ratio of their offspring?

8. In peas, yellow color (Y) is dominant to green color (y).

    a.   A heterozygous yellow is crossed with a green.
             What is the expected phenotype ratio of the offspring?

    b.   A heterozygous yellow is crossed with a heterozygous yellow.
             What is the expected phenotype ratio of the offspring?

9. White color (W) is dominant to yellow color (w) in squash.
A heterozygous white fruit plant is crossed with a yellow fruit plant.
What is the expected phenotype ratio of the offspring?

10. Two flies with long wings were mated and the offspring included 77 with long wings and 24 with short wings.

What is the phenotype ratio of the offspring?

    a.   Is the short winged condition dominant or recessive?

    b.   What are the genotypes of the parents?

11. A man with attached earlobes marries a woman with unattached ear lobes, whose father had attached ear lobes.
Unattached earlobes (U) is dominant over attached earlobes (u). What are the genotypes of all individuals mentioned?

    a.   Man with attached ear lobes: _____ _____

    b.   Woman with unattached ear lobes: _____ _____

    c.   Father: _____ _____

12. In certain flowers, color is inherited by genes that have incomplete dominance. In such flowers, a cross between homozygous red and a homozygous white will always result in a pink flower. A cross is made between two pink flowers.

What is the predicted phenotype ratio of the colors red, pink and white appearing in the offspring?

13. In humans, the condition for normal blood clotting dominates the condition for non-clotting or hemophilia. Both alleles are linked to the X chromosome. A male hemophiliac marries a woman who is a carrier for this condition. In this respect, a carrier is a woman who has an allele for normal blood clotting and an allele for hemophilia. What are the chances that if they have a male child he will be normal for blood clotting?

14. For this problem use the information given in problem 13. A male who has normal blood clotting marries a woman who is a carrier for this condition. What are the chances that if they have a male child he will be normal for blood clotting?

15. In humans, the allele for A type blood and the allele for B type blood show codominance. A person with both alleles has blood type AB. Both A and B dominate type O.

    A person with an allele for type A blood and type O blood marries someone with an allele for type B blood and type O blood. List the types of offspring they could have and the probability for each blood type in the offspring.

    (A allele = I^A, B allele = I^B, O allele = i)

16. For this problem use the information given in problem 15. A young lady with type O blood gave birth to a baby with type O blood. In a court case she claims that a certain young man is the father of her child. The man has type A blood. Could he be the father? Can it be proven on this evidence alone that he is the father?

17. In horses, black color (B) dominates chestnut color (b). The trotting gait (T) dominates the pacing gait (t). A cross is made between a horse homozygous for black color and the pacing gait and a horse homozygous for chestnut color and the trotting gait. List the probable genotype and phenotype of offspring resulting from such a cross.

18. For this problem use the information in problem 17. A cross is made between two horses, both of who are heterozygous black trotters.

   a.   Give the genotype of each parent horse.

   _____   _____

   b.   Determine all the possible kinds of gametes each parent can produce.

   _____   _____   _____   _____

   _____   _____   _____   _____

   c.   Construct a Punnett square and show all the possible gene combinations that result.

   d.   What is the expected phenotype ratio of the offspring?

19. Skin color in humans becomes darker by the number of dominant alleles; AABBCC have the darkest skin and aabbcc have the lightest skin. Place these genotypes in sequence according to the color of skin expected for each. Place the darkest skin first. Genotypes: AaBbCc, AAbbcc, aabbCc, AaBBCc and AaBBCC.

_____

_____

_____

_____

_____

You may need to refer back to previous problems to get some background information to solve the following problems.

20. In humans, A = normal amount of melanin produced and a = no melanin produced. If B = brown eyes and b = blue eyes, which of the genotypes below would have brown eyes? blue eyes? albino?

    a.   BBAA   _____
    b.   Bbaa   _____
    c.   bbAa   _____
    d.   BbAa   _____

21. A cross is made between parents with genotypes AABB and aabb. If there were sixteen offspring, how many of them would be expected to exhibit both dominant characteristics?

    a.   25%.
    b.   50%.
    c.   75%.
    d.   100%.

22. When two plants are crossed and three quarters of the offspring are tall. Which of the following describes the cross of the parents?

    a.   TT x tt.
    b.   Ty x Ty.
    c.   Tt x Tt.
    d.   TT x TT.

23. What would a green pea plant crossed with another of the same type produce?

    a. 3/4 yellow, 1/4 green peas.
    b. 1/2 yellow, 1/2 green peas.
    c. 100% green peas.
    d. 100% yellow peas.

24. Two parents produce children, three quarters of whom have unattached earlobes. Which of the following describes the genotype of the parents?

    a. Hybrids.
    b. Homozygous Dominant.
    c. Homozygous Recessive.
    d. Heterozygous.
    e. Both a and d.

25. Which of the following could produce a child with attached earlobes?

    a. UU X uu.
    b. Uu X Uu.
    c. uu X Uu.
    d. Both b and c.

26. In guinea pigs, B = black, b = brown, S = short hair and s = long hair. A homozygous black, heterozygous short hair is mated to a homozygous brown, heterozygous short hair. Which of the following describes the probability of offspring?

    a. Three black short hair, one black long hair.
    b. One black short hair, one black long hair.
    c. All black short hair.
    d. All of the above.

27. Which of the following offspring phenotypes could a homozygous black, homozygous short hair guinea pig produce?

    a. Brown long hair guinea pig.
    b. Black long hair guinea pig.
    c. Black short hair guinea pig.
    d. Brown short hair guinea pig.

28. In horses, T = trotter, t = pacer, B = black and b = chestnut. If a heterozygous dihybrid in both traits is mated with a chestnut pacer, which of the following describes the probability of offspring phenotypes?

    a.   One black trotter, one chestnut pacer.
    b.   Three black trotters, one chestnut pacer.
    c.   All black trotters.
    d.   One black trotter, one chestnut pacer, one black pacer, one chestnut trotter.

29. Which children could not occur if two parents were type A blood?

    a.   Type A.
    b.   Type O.
    c.   Type AB.
    d.   Both b and c.

30. Which children could not have a parent who is type AB?

    a.   Type A.
    b.   Type B.
    c.   Type AB.
    d.   Type O.