WEEK 14

Genetics Problems

Objectives

Be able to do the following:

1. Define these terms in writing.
    a. Alleles
    b. Homozygous
    c. Heterozygous
    d. Recessive
    e. Dominant
    f. Lack of dominance (incomplete)
    g. Multiple alleles
    h. Sex-linked genes
    i. Polygenic inheritance
    j. Carrier
    k. Genotype
    l. Phenotype
    m. Probability
    n. Punnett square
    o. Double-factor cross
    p. Single-factor cross
2. Interpret genetic data used in a single-factor cross, and use these data to preduct the phenotypes of the next generation.
3. Interpret genetic data used in a double-factor cross, and use these data to predict the phenotypes of the next generation.
4. Solve genetic problems that involve recessive, dominant, lack of dominance, sex-linked, multiple allele, and polygenic traits.

Introduction

One of the curiosities of life is the variety of offspring ·that can be produced as a result of sexual reproduction. The various offspring may show 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 humans. Some people are interested for personal reasons-a new baby due in the family; some people are interested for business reasons-the desire to breed a new variety of plant. They want to know the probability of having a given type of offspring.

To determine the probable appearance of an offspring, we must first know something about the parents. What do they look like? What alleles do they possess? The phenotype is what an individual looks like (i.e., a tall male with "attached" earlobes). The genotype is the genes an individual has (two genes for tallness and two genes for "attached" earlobes). We must know the genes possible and the probability of their being in the gametes (sperm or egg) of each parent. We must also know the possible ways these may combine during fertilization.

Preview

In this exercise, you are asked to determine the probable type of offspring when given the necessary genetic information. You are also asked to arrive at the genotype of the parents and their offspring.

During this lab exercise you will:

1. work a probability problem;
2. work single-factor inheritance problems;
3. work double-factor inheritance problems;
4. determine genotypes of parents and offspring.

Probability versus Possibility

To solve heredity problems, you must have an understanding of probability. Probability is the chance that an event will happen and is often expressed as a percent or a fraction. *Probability* is not the same as *possibility.* It is possible to toss a coin and have it come up heads. But the probability of getting a head is more precise than just saying it is possible to get heads. The probability of getting heads is one out of two (1/2 or 0.5 or 50%) because a coin has two sides, only one of which is a head. Probability can be expressed as a fraction.

$$\text{Probability} = \frac{\text{\# of events that can produce a given outcome}}{\text{total \# of possible outcomes}}$$

What is. the probability of cutting a deck of cards and getting the ace of hearts? The number of times that the ace of hearts can occur is one. The total number of possible outcomes, the number of cards in the deck, is fifty-two. Therefore, the probability of cutting an ace of hearts is 1/52.

What is the probability of cutting an ace? The total number of aces in the deck is four, and the total number of cards is fifty-two. Therefore, the probability of cutting an ace is 4/52 or 1/13.

It is also possible to determine the probability of two independent events occurring together.

The probability of two or more events occurring simultaneously is the product of their individual probabilities.

If you throw a pair of dice, it is possible that both will be a four. What is the probability that they both will be a four? The probability of one die being a four is 1/6. The probability of the other die being a four is also 1/6. Therefore, the probability of throwing two fours is

$$1/6 \times 1/6 = 1/36.$$

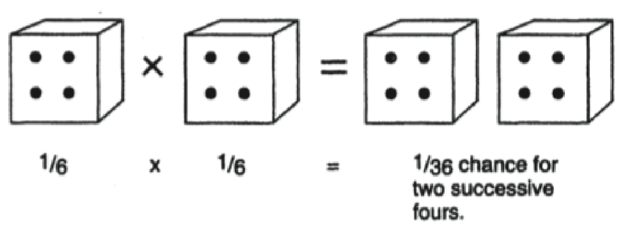


Figure 14-1

Exercise 1: Probability Problem

Work in pairs. One student shuffles and cuts a standard deck of cards. The other student records the suit. Repeat this one hundred times; shuffling, cutting, and recording. Record the information in the table.

Table 14.1 Probability Problem Results

Suit	Actual	Expected	Difference
Hearts		25	
Clubs		25	
Diamonds		25	
Spades		25	

Your instructor will tell you how to record this information for the whole class. Record the actual number of each suit cut. Compute the difference for each suit. Why is there a difference between the results you got and the results of the whole class?

Exercise 2: Single-Factor Inheritance Problems

Solving a heredity problem requires five basic steps.

Step 1: Assign a symbol for each allele Usually, a capital letter is used for a dominant allele and a small letter for a recessive allele.

For example, use the symbol *E* for free earlobes and *e* for attached earlobes.

E = free earlobes

e = attached earlobes

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

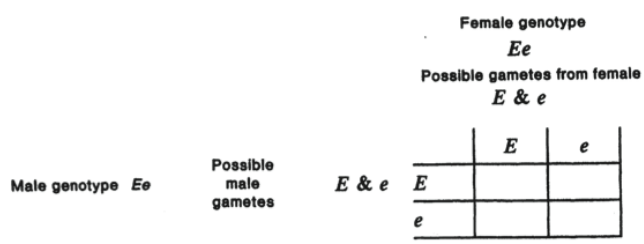
Suppose both parents are heterozygous; the male genotype is *Ee* and the female genotype is also *Ee*. The x between them is used to indicate a mating.

Ee x *Ee*

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

Remember that gametes are haploid; therefore, they can only have one allele instead of the two present in the diploid cell. Since the male has both the free earlobe allele and the attached earlobe allele, half of his gametes contain the free earlobe allele and the other half contain the attached earlobe allele. Since the female has the same genotype, her gametes are the same as his.

For solving genetics problems, a Punnett square is used. A Punnett square is .a box figure that allows you to determine the probability of genotypes and phenotypes of the offspring of a particular cross. Remember, because of the process of meiosis, each gamete receives only one allele for each characteristic listed. Therefore, the male gives either an *E* or *e;* the female also gives either an *E* or *e.* The possible gametes produced by the male parent are listed on the left side of the square, while the female gametes are listed on the top. In our example, the Punnett square would show a single dominant allele and a single recessive allele from the male on the left side. The alleles from the female would appear on the top.



Step 4: Determine all the allele combinations that can result when these gametes unite.

To determine the possible combinations of alleles that could occur as a result of this mating, simply fill in each of the empty squares with the alleles that can be donated from each parent. Determine all the allele combinations that can result when these gametes unite.

	E	*e*
E	*EE*	*Ee*
e	*Ee*	*ee*

Step 5: Determine the phenotype of each possible allele combination.

In this instance, three of the offspring, *EE, Ee,* and *Ee*, have free earlobes. One offspring, *ee*, has attached earlobes. Therefore, the probability of having offspring with free earlobes is ¾ and with attached earlobes is ¼.

Additional Single-Factor Inheritance Problems

(one trait followed from one generation to the next)

1. In humans, six fingers *(F)* is the **dominant trait**; five fingers *(f)* is the **recessive trait**. Both parents are **heterozygous** for 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 six-fingered children? Five-fingered children?

   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 six-fingered child__________________________________

   f. Probability of a six-fingered child__________________________________

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

   Six fingers __________________ Five fingers ________________

3. In certain flowers, color is inherited by alleles that show **lack of dominance (incomplete)**. In such flowers, a cross between a **homozygous** red and homozygous white always results in a pink flower. A cross in made between two pink flowers. What is the probability of these colors (red, pink, and white) appearing in the offspring?

Hint: Assign some letter to represent the red allele and a letter to represent the white allele. A pink flower contains an allele for red color and an allele for white color.

4. Use the information given in the previous problem. A cross is made between a red flower and a pink flower. What is the expected probability for the various colors?

Double-Factor Inheritance Problems

A double-factor cross is a genetic study in which two pairs of alleles are followed from the parental generation to the offspring. These problems are basically worked the same as a single-factor cross. The main differences are that in a double-factor cross you work with two different characteristics from each parent.

It is necessary to use Mendel's law of independent assortment when working double-factor inheritance problems. This law states that members of one allelic pair separate from each other independently of the members of other pairs of alleles. This happens during meiosis when the chromosomes segregate. (Mendel's law of independent assortment only applies if the two pairs of alleles are located on separate chromosomes. This is an assumption we will use in double-factor crosses.)

In humans, the allele for free earlobes dominates the allele for attached earlobes.

The allele for dark hair dominates the allele for light hair. If both parents are heterozygous for earlobe shape and hair color, what types of offspring can they produce and what is the probability for each type?

Step 1: Use the symbol *E* for free earlobes and *e* for attached earlobes. Use the symbol *D* for dark hair and *d* for light hair.

E = free earlobes

e = attached earlobes

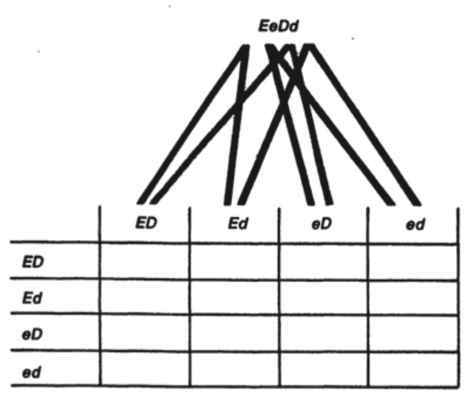
D = dark hair

d = light hair

Step 2: Determine the genotype for each parent and show a mating. In this example, the male genotype is *EeDd*, the female genotype is *EeDd*, and the X between them indicates a mating.

EeDd X *EeDd*

Step 3: Determine all the possible gametes each parent can produce and write the symbols for the alleles in a Punnett square. Since there are two pairs of alleles in a double-factor cross, each gamete must contain one allele from each pair, one of the *E* pair (either *E* or *e*) and one from the *D* pair (either *D* or *d*). In this example each parent can produce four different kinds of gametes. The four squares on the left indicate the gametes produced by the male; the four n the top indicate the gametes produced by the female. To determine the possible allele combinations in the gametes, select one allele from one of the pairs of alleles and match it with one allele from the other pair of alleles. Then match the second allele from the first pair of alleles with each of the alleles from the second pair. This may be done as follows:

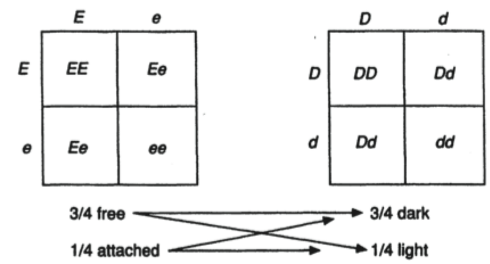


Step 4: Determine all the gene combinations that can result when these gamete unite. Fill in the Punnett squares.

Method 1

	ED	Ed	eD	ed
ED	EEDD	EEDd	EeDD	EeDd
Ed	EEDd	EEdd	EeDd	Eedd
eD	EeDD	EeDd	eeDD	eeDd
ed	EeDd	Eedd	eeDd	eedd

Method 2



Step 5: Determine the phenotype of each possible allele combination. In this double-factor problem, there are sixteen possible ways in which gametes could combine to produce offspring. There are four possible phenotypes in this cross. They are represented as:

Genotypes	Phenotype	Symbol
EEDD or *EEDd* or *EeDD* or EeDd	Free earlobes and dark hair	*
EEdd or *Eedd*	Free earlobes and light hair	^
eeDD or *eeDd*	Attached earlobes and dark hair	“
Eedd	Attached earlobes and light hair	+

	ED	Ed	eD	ed
ED	EEDD *	EEDd *	EeDD *	EeDd *
Ed	EEDd *	EEdd ^	EeDd *	Eedd ^
eD	EeDD *	EeDd *	eeDD “	eeDd “
ed	EeDd *	Eedd ^	eeDd “	eedd +

The probability of having a given phenotype is:

9/16 free earlobes, dark hair

3/16 free earlobes, light hair

3/16 attached earlobes, dark hair

1/16 attached earlobes, light hair

Additional Double-Factor Inheritance Problems

(two traits followed from one generation to the next)

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

Genotype_________; phenotype ______

6. Humans may have Rh^+ blood or Rh^- blood. A person with Rh^+ *(R)* has a certain type of protein on the red blood cell. A person with Rh- *(r)* does not have this particular protein. In humans, Rh^+ dominates Rh^-. Normal insulin *(I)* production dominates abnormal insulin *(I)* production (diabetes). If both parents are heterozygous for Rh^+ and normal insulin production, what probable phenotypes would they produce in their offspring? .

7. For this problem, use the information concerning the traits given in problem 6. The father is homozygous for Rh^+ and has diabetes. The mother is Rh^- and homozygous for normal insulin production. What phenotype would their offspring show?

8. In certain breeds of dogs, black color is dominant and red color is recessive; solid color is dominant and white spotting is recessive. A homozygous black-and-white spotted male is crossed with a red-and-white spotted female. What is the probability of them producing a solid black puppy?

9. In humans, a type of blindness is due to a dominant allele; normal vision is the result of a recessive allele. Migraine headaches are due to a dominant allele, and normal (no headaches) is recessive. A male who is heterozygous for blindness and does not suffer from headaches marries a woman who has normal

vision and does not suffer from migraines. Could they produce a child with normal vision who does not suffer from headaches? If yes, can the probability of such a child be determined?

10. *Challenge Question:* In the radish plant, the long and round traits are incompletely dominant and heterozygote& have an oval shape. The red and white color traits are incompletely dominant and heterozygote& have a purple color. Two oval-shaped, purple plants are crossed. What would be the phenotypic ratio in their offspring?

Sex-Linked Problems

(alleles located on the X chromosome)

11. In humans, the condition for normal blood clotting (X^H) dominates the condition for nonclotting (X^h) (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?

12. For this problem, use the information given in problem 11. A male who has normal blood clotting marries a woman who is a carrier for this condition. What are the chances that they will have a son who is normal for blood clotting?

13. In humans, the condition for normal vision dominates color blindness. Both alleles are linked to the X chromosome. A color-blind male marries a color-blind female. If they have a daughter, what are the chances that she will have normal vision?

14. For this problem, use the information given in problem 13. A male with normal vision marries a woman who is color blind. She gives birth to a daughter who is also color blind. The husband claims the child is not his. The wife claims the child is his. Can you support the argument of either parent? If yes, which one? Why?

Multiple Allele Problems

(characteristics that have more than two possible forms of the same gene)

15. In humans, the allele for blood type A and the allele for blood type B show incomplete dominance. A person with both alleles has blood type AB. Both A and B dominate type O. A person with an allele for blood type A and type O marries someone with an allele for blood type B and type O. List the types of blood their offspring could have and the probability for each blood type in

the offspring.

16. For this problem, use the information given in problem 15. A young woman with blood type O gave birth to a baby with blood type O. 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 humans, kinky hair *(H^{++})*, curly hair *(H^{+})*, wavy hair *(H)*, and straight hair *(h)* are dominant, in that order. Dark hair dominates red hair. A wavy, red-haired male who has a straight, dark-haired mother marries a straight, dark-haired female who has a curly, red-haired father. What type of children can they produce, and what is the probability of producing these types of offspring?

Epistasis Problems

(genes interact to determine phenotype)

Note: All of the epistasis problems in this exercise involve two different traits; therefore, they are all similar to double-factor problems.

18. Normal pigmentation dominates no pigmentation (albino). For an organism to exhibit color, it must have an allele for normal pigment production as well as alleles for a specific color. In cattle, red color dominates black. An albino bull that has a heterozygous genotype for red is crossed with a red cow. The cow is heterozygous for normal pigment production and for red coloring. What types of offspring will they produce and what is the probability for producing these types of offspring?

19. In some types of wheat, color is caused by two sets of alleles. To produce a red color, both dominant alleles, *R* and *B,* are needed. White results from both recessive alleles in the homozygous state, *rrbb.* Any other combination produces brown wheat grains. A strain with a genotype of *Rrbb* is crossed with a strain of wheat with a genotype of *rrBb.* What is the color of each of the parent strains? What colors of wheat result from this cross, and what is the probability for each color?

    Rrbb color _______*rrBb* color ___

20. In humans, normal pigmentation dominates no pigmentation (albino). Black hair dominates blonde hair. An albino person will have white hair even though he or she may also have the alleles for black or blonde hair. An albino male who is homozygous for black hair marries a woman who is heterozygous for normal pigmentation and who has blonde hair. What colors of hair can their children have, and what is the probability for each hair color?

Determination of Genotypes

(what you see and what you get)

Not all heredity problems deal with determining the phenotype of the offspring. There is a type of problem where the phenotype of both parents and the offspring are known and you then determine the genotype of each individual.

In humans, brown eyes are dominant and blue eyes are recessive. Two brown-eyed people marry and produce one brown-eyed child and two blue-eyed children. What is the genotype of the parents and each of the children?

Since both parents have brown eyes, they must have at least one allele for brown eyes, so their genotypes would be *B* _ (the _ means the allele could be either the dominant allele or the recessive allele). The genotype for the blue-eyed children must be *bb.* Since each parent contributed one allele to each blue-eyed off spring, you know that each brown-eyed parent has an allele for blue eyes. Therefore, the _ must be a *b* and the genotype for each parent is *Bb.* All you know about the brown-eyed offspring is that the child has one allele for brown eyes. The genotype could be either *BB* or *Bb.*

In the remaining problems, try to determine the genotypes of the individuals. Take it slowly; only put down an allele when you are certain the individual has that allele. If you are not certain, merely show that you don't know by leaving a blank.

21. Normal pigmentation *(A)* dominates no pigmentation (albino = *aa).* Brown-eyed coloring *(B)* dominates blue-eyed coloring *(bb).* Two people with normal pigmentation produce one brown-eyed, two blue-eyed, and two albino children. What are the possible genotypes tor the parents?
22. A red bull, when crossed with white cows, always produces roan-colored offspring. Explain how the colors for red, white, and roan are inherited.
23. In rabbits, short hair is due to a dominant allele, *S;* long hair to its recessive allele, *s.* Black hair is due to a dominant allele, *B,* and white hair to its recessive allele, *b.* When two rabbits were crossed, they produced 2,518 short-haired, black and 817 long-haired, black offspring. What are the probable genotypes of the parents?
24. In humans, the condition for normal blood clotting dominates hemophilia. Both alleles are sex-linked to the X chromosome. Two parents produced daughters who are all carriers and sons who are all normal. What are the probable genotypes of the parents?
25. In humans, deafness is due to a homozygous condition of either or both recessive alleles *d* and *e.* Both dominant alleles *D* and *E* are needed for normal hearing. Two deaf people marry and produce offspring who all have normal hearing. What are the probable genotypes of the children and parents?