Chapter 14

Mendel and the Gene Idea

Key Concepts

14.1 Mendel used the scientific approach to identify two laws of inheritance

14.2 The laws of probability govern Mendelian inheritance

14.3 Inheritance patterns are often more complex than predicted by simple Mendelian genetics

14.4 Many human traits follow Mendelian patterns of inheritance

Framework

Through his work with garden peas in the 1860s, Mendel developed the fundamental principles of inheritance and the laws of segregation and independent assortment. This chapter describes the basic monohybrid and dihybrid crosses that Mendel performed to establish that inheritance involves particulate genetic factors (genes) that segregate independently in the formation of gametes and recombine to form offspring. The laws of probability can be applied to predict the outcome of genetic crosses.

The phenotypic expression of genotype may be affected by such factors as incomplete dominance, codominance, multiple alleles, pleiotropy, epistasis, and polygenic inheritance, as well as the environment. Genetic screening and counseling for recessively inherited disorders use new technologies and Mendelian principles to analyze human pedigrees.

Chapter Review

The genetic material of two parents is not blended in offspring but is passed on to future generations as discrete heritable units, or genes. This "particulate" hypothesis of inheritance was developed by Gregor Mendel.

14.1 Mendel used the scientific approach to identify two laws of inheritance

Mendel's Experimental, Quantitative Approach Mendel worked with garden peas, a good choice of study organism because they are available in many varieties, their fertilization is easily controlled, and the characteristics of their offspring can be quantified.

Mendel studied seven **characters,** or heritable features, that occurred in alternative forms called **traits.** He used **true-breeding** varieties of pea plants, which means that self-fertilizing parents always produce offspring with the parental form of the character. To follow the transmission of these well-defined traits, Mendel performed **hybridizations** in which he cross-pollinated contrasting true-breeding varieties, and then allowed the next generation to self-pollinate. The true-breeding parental plants are the **P generation** (parental); the offspring of the first cross are the **F_1 generation** (first filial); and the next generation, from the self-cross of the F_1, is known as the **F_2 generation.**

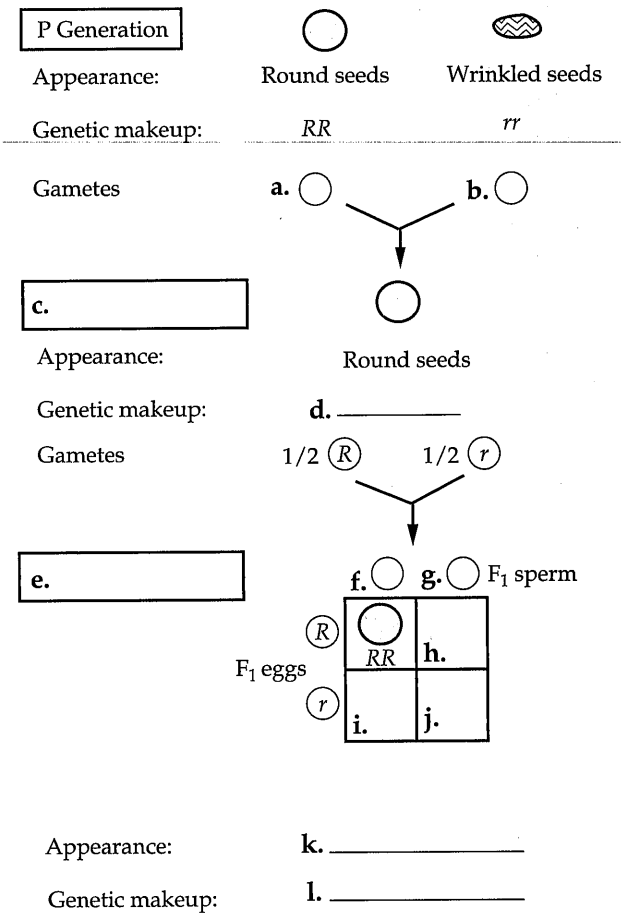
The Law of Segregation Mendel found that the F_1 offspring did not show a blending of the parental traits. Instead, only one of the parental traits of the character was found in the hybrid offspring. In the F_2 generation, however, the missing parental trait reappeared in the ratio of 3:1—three offspring with the *dominant* trait shown by the F_1 to one offspring with the reappearing *recessive* trait.

Mendel's explanation for this phenomenon contains four parts: (1) alternate forms of genes, now called **alleles,** account for variations in characters; (2) an organism has two alleles for each inherited trait, one received from each parent; (3) when two different alleles occur together, one of them, called the **dominant allele,** determines the organisms appearance while the other, the **recessive allele,** has no observable effect on the organism's appearance; and (4) allele pairs separate (segregate) during the formation of gametes (Mendel's **law of segregation**), so an egg or sperm carries only one allele for each inherited character. This explanation is consistent with the behavior of chromosomes during meiosis.

Mendel's law of segregation explains the 3:1 ratio observed in the F_2 plants. During the segregation of allele pairs in the formation of F_1 gametes, half the gametes receive one allele while the other half receive the alternate allele. Random fertilization of gametes results in one-fourth of the plants having two dominant alleles, half having one dominant and one recessive allele, and one-fourth receiving two recessive alleles, producing a ratio of plants showing the dominant to recessive trait of 3:1. A **Punnett square** can be used to predict the results of simple genetic crosses. Dominant alleles are often symbolized by a capital letter, recessive alleles by a small letter.

■ INTERACTIVE QUESTION 14.1

Fill in this diagram of a cross of round- and wrinkled-seeded pea plants. The round allele (*R*) is dominant and the wrinkled allele (*r*) is recessive.



An organism that has a pair of identical alleles is said to be **homozygous** for that gene. If the organism has two different alleles, it is said to be **heterozygous** for that gene. Homozygotes are true-breeding; heterozygotes are not, since they produce gametes with one or the other allele that can combine to produce offspring that are dominant homozygotes, heterozygotes, and recessive homozygotes. **Phenotype** is an organism's expressed traits; **genotype** is its genetic makeup.

In a **testcross,** an organism expressing the dominant phenotype is crossed with a recessive homozygote to determine the genotype of this phenotypically dominant organism.

■ INTERACTIVE QUESTION 14.2

A tall pea plant is crossed with a recessive dwarf pea plant. What will the phenotypic and genotypic ratio of offspring be

a. if the tall plant was *TT*?

b. if the tall plant was *Tt*?

The Law of Independent Assortment In a *monohybrid cross,* the inheritance of a single character is followed through the crossing of **monohybrids,** F_1 offspring that are heterozygous for one character. Mendel used *dihybrid crosses* between F_1 **dihybrids,** which are heterozygous for two characters, to determine whether the two characters were transmitted independently of each other from the parent plants.

If the two pairs of alleles segregate independently, then gametes from an F_1 hybrid generation (*AaBb*) should contain four combinations of alleles in equal quantities (*AB, Ab, aB, ab*). The random fertilization of these four classes of gametes should result in 16 (4×4) gamete combinations that produce four phenotypic categories in a ratio of 9:3:3:1 (nine offspring showing both dominant traits, three showing one dominant trait and one recessive, three showing the opposite dominant and recessive traits, and one showing both recessive traits). Mendel obtained these ratios when he categorized the F_2 progeny of dihybrid crosses, providing evidence for his **law of independent assortment.** This principle states that pairs of alleles for each character segregate independently in the formation of gametes. This law applies to genes located on different chromosomes.

■ INTERACTIVE QUESTION 14.3

A true-breeding tall, purple-flowered pea plant (*TTPP*) is crossed with a true-breeding dwarf, white-flowered plant (*ttpp*).

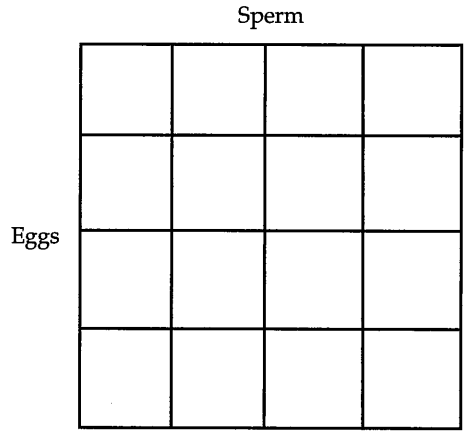
a. What is the phenotype of the F_1 generation?

b. What is the genotype of the F_1 generation?

c. What four types of gametes are formed by F_1 plants?

_____ _____ _____ _____

d. Fill in the following Punnett square to show the offspring of the F_2 generation. Shade each phenotype a different color so you can see the ratio of offspring.



e. List the phenotypes and ratios found in the F_2 generation.

_____ _____

_____ _____

f. What is the ratio of tall to dwarf plants? _____
Of purple- to white-flowered plants? _____
(Note that the alleles for each individual character segregate as in a monohybrid cross.)

14.2 The laws of probability govern Mendelian inheritance

General rules of probability apply to the laws of segregation and independent assortment. The probability scale goes from 0 to 1; the probabilities of all possible outcomes must add up to 1. The probability of an event occurring is the number of times that event could occur over all the possible events; for example, the probability of drawing an ace from a deck of cards is $\frac{4}{52}$. The outcome of independent events is not affected by previous or simultaneous trials.

The Multiplication and Addition Rules Applied to Monohybrid Crosses The rule of multiplication states that the probability that a certain combination of independent events will occur together is equal to the product of the separate probabilities of the independent events. The probability of a particular genotype being formed by fertilization is equal to the product of the probabilities of forming each type of gamete needed to produce that genotype.

If a genotype can be formed in more than one way, then the rule of addition states that its probability is equal to the sum of the separate probabilities of the different, mutually exclusive ways the event can occur. For example, a heterozygote offspring can occur if the egg contains the dominant allele and the sperm the recessive ($\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ probability) or vice versa ($\frac{1}{4}$). Therefore, the heterozygote offspring would be the predicted result from a monohybrid cross half of the time ($\frac{1}{4} + \frac{1}{4} = \frac{1}{2}$).

■ INTERACTIVE QUESTION 14.4

Apply the rule of multiplication to a dihybrid cross. How would you determine the probability of getting an F_2 offspring that is homozygous recessive for both traits?

Solving Complex Genetics Problems with the Rules of Probability Fairly complex genetics problems can be solved by applying the rules of multiplication and addition. The probability of a particular genotype arising from a cross can be determined by considering each gene involved as a separate monohybrid cross and then multiplying the probabilities of all the independent events involved in the final genotype. When more than one outcome is involved, the rule of addition is also used.

The larger the sample size, the more closely the results will conform to statistical predictions.

■ INTERACTIVE QUESTION 14.5

a. In the following cross, what is the probability of obtaining offspring that show all three dominant traits, *A_B_C_* (_ indicates that the second allele can be either dominant or recessive without affecting the phenotype determined by the first dominant allele)?

AaBbcc × *AabbCC*

probability of offspring that are *A_B_C_* = _____

b. What is the probability that the offspring of this *AaBbcc* × *AabbCC* cross will show at least two dominant traits? _____

14.3 Inheritance patterns are often more complex than predicted by simple Mendelian genetics

Extending Mendelian Genetics for a Single Gene Alleles may show varying degrees of dominance and recessiveness along a *spectrum of dominance*. In the case of an allele showing **complete dominance,** the phenotype of the heterozygote is indistinguishable from that of the dominant homozygote. At the other end of the continuum, alleles that exhibit **codominance** will both affect the phenotype in separate, distinguishable ways, as in the case of the MN blood group.

Intermediate phenotypes are characteristic of alleles showing **incomplete dominance.** The F_1 hybrids have a phenotype intermediate between that of the parents. The F_2 show a 1:2:1 phenotypic and genotypic ratio.

Even when alleles exhibit dominance or incomplete dominance at the phenotypic level, both alleles may be expressed at the molecular level. **Tay-Sachs disease** is a lethal disorder in which brain cells lack a critical enzyme and are unable to metabolize a type of lipid that then accumulates and damages the brain. In a heterozygote, the Tay-Sachs allele is recessive at the organismal level; at the biochemical level, the enzyme activity level is intermediate between both homozygotes; at the molecular level, the alleles are codominant in that each produces its enzyme product, either normal or dysfunctional.

Whether or not an allele is dominant or recessive has no relation to how common it is in a population.

Most genes exist in more than two allelic forms. The gene that determines human blood groups has three alleles. The alleles I^A and I^B are codominant with each other; each codes for an enzyme that attaches a carbohydrate to the surface of red blood cells. The allele i codes for an enzyme that attaches neither the A nor B carbohydrate, and is thus recessive to I^A and I^B. Blood type is critical in transfusions because, if the carbohydrate attached to the donor's blood cells is foreign to the recipient, the recipient's immune system will cause clumping of the donated blood cells.

■ INTERACTIVE QUESTION 14.6

List the possible genotypes for the following blood groups.

a. A _____

b. B _____

c. AB _____

d. O _____

Pleiotropy is the characteristic of a single gene having multiple phenotypic effects in an individual. Certain hereditary diseases with complex sets of symptoms are caused by a single allele.

Extending Mendelian Genetics for Two or More Genes In **epistasis,** a gene at one locus may affect the expression of another gene. F_2 ratios that differ from the typical 9:3:3:1 often indicate epistasis.

■ INTERACTIVE QUESTION 14.7

A dominant allele *M* is necessary for the production of the black pigment melanin; mm individuals are white. A dominant allele *B* results in the deposition of a lot of pigment in an animal's hair, producing a black color. The genotype *bb* results in brown hair. Two black animals heterozygous for both genes are bred. Fill in the following table for the offspring of this *MmBb* × *MmBb* cross.

Phenotype	Genotype	Ratio
Black		
	M_bb	

Quantitative characters, such as height or skin color, vary along a continuum in a population. Such phenotypic gradations are usually due to **polygenic inheritance,** in which two or more genes have an

additive effect on one character. Each dominant allele contributes one "unit" to the phenotype. A polygenic character may result in a normal distribution (forming a bell-shaped curve) of the character within a population.

■ INTERACTIVE QUESTION 14.8

The height of spike weed is a result of polygenic inheritance involving three genes, each of which can contribute an additional 5 cm to the base height of the plant, which is 10 cm. The tallest plant (*AABBCC*) can reach a height of 40 cm.

a. If a tall plant (*AABBCC*) is crossed with a base-height plant (*aabbcc*), what is the height of the F_1 plants?

b. How many phenotypic classes will there be in the F_2?

Nature and Nurture: the Environmental Impact on Phenotype The phenotype of an individual is the result of complex interactions between its genotype and the environment. Genotypes have a phenotypic range called a **norm of reaction** within which the environment influences phenotypic expression. Polygenic characters are often **multifactorial,** meaning that a combination of genetic and environmental factors influences phenotype.

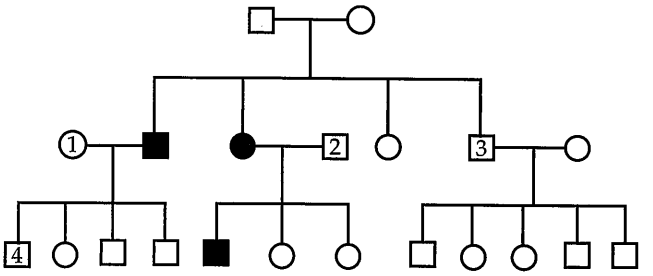
Integrating a Mendelian View of Heredity and Variation The phenotypic expression of most genes is influenced by other genes and by the environment. The theory of particulate inheritance and Mendel's principles of segregation and independent assortment, however, still form the basis for modern genetics.

14.4 Many human traits follow Mendelian patterns of inheritance

Pedigree Analysis A family **pedigree** is a family tree with the history of a particular trait shown across the generations. By convention, circles represent females, squares are used for males, and solid symbols indicate individuals that express the trait in question. Parents are joined by a horizontal line, and offspring are listed below parents from left to right in order of birth. The genotype of individuals in the pedigree can often be deduced by following the patterns of inheritance.

■ INTERACTIVE QUESTION 14.9

Consider this pedigree for the trait albinism (lack of skin pigmentation) in three generations of a family. (Solid symbols represent individuals who are albinos.) From your knowledge of Mendelian inheritance, answer the questions that follow.



a. Is this trait caused by a dominant or recessive allele? How can you tell?

b. Determine the genotypes of the parents in the first generation. (Let *AA* and *Aa* represent normal pigmentation and *aa* be the albino genotype.) Genotype of father _____; of mother _____.

c. Determine the probable genotypes of the mates of the albino offspring in the second generation and the grandson 4 in the third generation. Genotypes: mate 1 _____ mate 2 _____ grandson 4 _____.

d. Can you determine the genotype of son 3 in the second generation? Why or why not?

Recessively Inherited Disorders Only homozygous recessive individuals express the phenotype for the thousands of genetic disorders that are inherited as simple recessive traits. **Carriers** of the disorder are heterozygotes who are phenotypically normal but may transmit the recessive allele to their offspring.

Cystic fibrosis is the most common lethal genetic disease in the United States; it is found more frequently in people of European descent than in other groups. This recessive allele results in defective chloride channels in certain cell membranes. Accumulating extracellular chloride leads to the buildup of thickened mucus in various organs and a predisposition to bacterial infections.

Sickle-cell disease is the most common inherited disease among African Americans. Due to a single amino acid substitution in the hemoglobin protein, red blood cells deform into a sickle shape when blood-oxygen concentration is low, triggering blood clumping and other pleiotropic effects. Heterozygous individuals are said to have sickle-cell trait but are usually healthy. The resistance to malaria that accompanies the sickle-cell trait may explain why this lethal recessive allele remains in relatively high frequency in areas where malaria is common.

The likelihood of two mating individuals carrying the same rare deleterious allele increases when the individuals have common ancestors. Consanguineous matings, between siblings or close relatives, are indicated on pedigrees by double lines.

■ INTERACTIVE QUESTION 14.10

a. What is the probability that a mating between two carriers will produce an offspring with a recessively inherited disorder? _____

b. What is the probability that a phenotypically normal child produced by a mating of two heterozygotes will be a carrier? _____

Dominantly Inherited Disorders A few human disorders are due to dominant genes. In achondroplasia, dwarfism is due to a single copy of a mutant allele.

Dominant lethal alleles are more rare than recessive lethals because the harmful allele cannot be masked in the heterozygote. A late-acting lethal dominant allele can be passed on if the symptoms do not develop until after reproductive age. Molecular geneticists have developed a method to detect the lethal gene for **Huntington's disease,** a degenerative disease of the nervous system that does not develop until later in life.

Multifactorial Disorders Many diseases have genetic (usually polygenic) and environmental components. These multifactorial disorders include heart disease, diabetes, cancer, and others.

Genetic Testing and Counseling The risk of a genetic disorder being transmitted to offspring can sometimes be determined through genetic counseling and testing before a child is conceived or in the early stages of pregnancy. The probability of a child having a genetic defect may be determined by considering the family history of the disease.

■ INTERACTIVE QUESTION 14.11

If two prospective parents both have siblings who had a recessive genetic disorder, what is the chance that they would have a child who inherits the disorder?

Determining whether parents are carriers can determine the risk of passing on a genetic disorder. Tests that permit carrier recognition have been developed for a number of heritable disorders.

Amniocentesis is a procedure that extracts a small amount of amniotic fluid from the sac surrounding the fetus. The fluid is analyzed biochemically, and fetal cells present in the fluid are cultured for several weeks and then tested for certain genetic disorders and karyotyped to check for chromosomal defects.

Chorionic villus sampling (CVS) is a technique in which a small amount of fetal tissue is suctioned from the placenta. These rapidly growing cells can be karyotyped immediately, and this procedure can be performed at only 8 to 10 weeks of pregnancy, earlier than an amniocentesis can be performed. A new technique isolates fetal cells from maternal blood, which can then be cultured and tested.

Ultrasound is a simple, noninvasive procedure that can reveal major abnormalities. Fetoscopy, the insertion of a needle-thin viewing scope and light into the uterus, allows the fetus to be checked for anatomical problems.

Some genetic disorders can be detected at birth. Routine screening is now used to test for the recessively inherited disorder phenylketonuria (PKU) in newborns. If detected, dietary adjustments can lead to normal development.

Word Roots

co- = together (*codominance:* phenotype in which both dominant alleles are expressed in the heterozygote)

-centesis = a puncture (*amniocentesis:* a technique for determining genetic abnormalities in a fetus by the presence of certain chemicals or defective fetal cells in the amniotic fluid, obtained by aspiration from a needle inserted into the uterus)

di- = two (*dihybrid cross:* a breeding experiment in which offspring of a cross of parental varieties differing in two traits are mated)

epi- = beside; **-stasis** = standing (*epistasis:* a phenomenon in which one gene alters the expression of another gene that is independently inherited)

geno- = offspring (*genotype:* the genetic makeup of an organism)
hetero- = different (*heterozygous:* having two different alleles for a trait)
homo- = alike (*homozygous:* having two identical alleles for a trait)
mono- = one (*monohybrid cross:* a breeding experiment that crosses offspring of a cross of parental varieties differing in a single character)
pedi- = a child (*pedigree:* a family tree describing the occurrence of heritable characters in parents and offspring across as many generations as possible)
pheno- = appear (*phenotype:* the physical and physiological traits of an organism)
pleio- = more (*pleiotropy:* when a single gene impacts more than one characteristic)
poly- = many; **gene-** = produce (*polygenic:* an additive effect of two or more gene loci on a single phenotypic character)

Structure Your Knowledge

1. Relate Mendel's two laws of inheritance to the behavior of chromosomes in meiosis that you studied in Chapter 13.
2. Mendel worked with characters that exhibited two alternate forms: smooth or wrinkled, green or yellow, tall or short. In his F1 generation, the dominant allele was always expressed, with the recessive trait reappearing in the F2 offspring. But not all allele pairs operate by complete dominance; some show incomplete dominance or codominance. And some that show dominance on the phenotypic level are actually incompletely dominant or codominant when observed at the microscopic or molecular level. Taking into account the mechanisms by which genotype becomes expressed as phenotype, explain this spectrum in dominance.

Genetics Problems

One of the best ways to learn genetics is to work problems. You can't memorize genetic knowledge; you have to practice using it. Work through the problems presented below, methodically setting down the information you are given and what you are to determine. Write down the symbols used for the alleles and genotypes, and the phenotypes resulting from those genotypes. Avoid using Punnett squares; while useful for learning basic concepts, they are much too laborious and mistake-prone. Instead, break complex crosses into their monohybrid components and rely on the rules of multiplication and addition. Always *look at the answers you get to see if they make logical sense. And remember that study groups are great for going over your problems and helping each other "see the light." Answers and explanations are provided at the end of the book.*

1. Summer squash are either white or yellow. To get white squash, at least one of the parental plants must be white. The allele for which color is dominant?
2. For the following crosses, determine the probability of obtaining the indicated genotype in an offspring.

Cross	Offspring	Probability
AAbb × *AaBb*	*AAbb*	**a.**
AaBB × *AaBb*	*aaBB*	**b.**
AABbcc × *aabbCC*	*AaBbCc*	**c.**
AaBbCc × *AaBbcc*	*aabbcc*	**d.**

3. True-breeding tall red-flowered plants are crossed with dwarf white-flowered plants. The resulting F_1 generation consists of all tall pink-flowered plants. Assuming that height and flower color are each determined by a single gene locus on different chromosomes, predict the results of an F_1 cross of dihybrid plants. Choose appropriate symbols for the alleles of the height and flower color genes. List the phenotypes and predicted ratios for the F_2 generation.
4. Blood typing has been used as evidence in paternity cases, when the blood type of the mother and child may indicate that a man alleged to be the father could not possibly have fathered the child. For the following mother and child combinations, indicate which blood groups of potential fathers would be exonerated.

Blood Group of Mother	Blood Group of Child	Man Exonerated if He Belongs to Blood Group(s)
AB	A	**a.**
O	B	**b.**
A	AB	**c.**
O	O	**d.**
B	A	**e.**

5. In rabbits, the homozygous *CC* is normal, *Cc* results in rabbits with deformed legs, and *cc* is lethal. For a gene for coat color, the genotype *BB* produces black, *Bb* brown, and *bb* a white coat. Give the phenotypic ratio of offspring from a cross of a deformed-leg, brown rabbit with a deformed-leg, white rabbit.

6. Polydactyly (extra fingers and toes) is due to a dominant gene. A father is polydactyl, the mother has the normal phenotype, and they have had one normal child. What is the genotype of the father? Of the mother? What is the probability that a second child will have the normal number of digits?

7. In dogs, black (*B*) is dominant to chestnut (*b*), and solid color (*S*) is dominant to spotted (*s*). What are the genotypes of the parents in a mating that produced ⅜ black solid, ⅜ black spotted, ⅛ chestnut solid, and ⅛ chestnut spotted puppies? (*Hint:* First determine what genotypes the offspring must have before you deal with the fractions.)

8. When hairless hamsters are mated with normal-haired hamsters, about one-half the offspring are hairless and one-half are normal. When hairless hamsters are crossed with each other, the ratio of normal-haired to hairless is 1:2. How do you account for the results of the first cross? How would you explain the unusual ratio obtained in the second cross?

9. Two pigs whose tails are exactly 25 cm in length are bred over 10 years and they produce 96 piglets with the following tail lengths: 6 piglets at 15 cm, 25 at 20 cm, 37 at 25 cm, 23 at 30 cm, and 5 at 35 cm.
   a. How many pairs of genes are regulating the tail length character? *Hint:* Count the number of phenotypic classes, or determine the sum of the ratios of the classes. In a monohybrid cross, the F_2 ratios add up to 4 (3:1 or 1:2:1). In a dihybrid cross, the F_2 ratios add up to 16 (9:3:3:1 or some variation if the genes are epistatic or quantitative).
   b. What offspring phenotypes would you expect from a mating between a 15-cm and a 30-cm pig?

10. Fur color in rabbits is determined by a single gene locus for which there are four alleles. Four phenotypes are possible: black, Chinchilla (gray color caused by white hairs with black tips), Himalayan (white with black patches on extremities), and white. The black allele (*C*) is dominant over all other alleles, the Chinchilla allele (C^{ch}) is dominant over Himalayan (C^h), and the white allele (*c*) is recessive to all others.
    a. A black rabbit is crossed with a Himalayan, and the F_1 consists of a ratio of 2 black to 2 Chinchilla. Can you determine the genotypes of the parents?
    b. A second cross was done between a black rabbit and a Chinchilla. The F_1 contained a ratio of 2 black to 1 Chinchilla to 1 Himalayan. Can you determine the genotypes of the parents of this cross?

11. In Labrador retriever dogs, the dominant gene *B* determines black coat color and *bb* produces brown. A separate gene *E*, however, shows dominant epistasis over the *B* and *b* alleles, resulting in a golden coat color. The recessive *e* allows expression of *B* and *b*. A breeder wants to know the genotypes of her three dogs, so she breeds them and makes note of the offspring of several litters. Determine the genotypes of the three dogs.
    a. golden female (Dog 1) × golden male (Dog 2) offspring: 7 golden, 1 black, 1 brown
    b. black female (Dog 3) × golden male (Dog 2) offspring: 8 golden, 5 black, 2 brown

12. The ability to taste phenylthiocarbamide (PTC) is controlled in humans by a single dominant allele (*T*). A woman nontaster married a man taster, and they had three children, two boy tasters and a girl nontaster. All the grandparents were tasters. Create a pedigree for this family for this trait. (Solid symbols should signify nontasters (*tt*).) Where possible, indicate whether tasters are *TT* or *Tt*.

13. Two true-breeding varieties of garden peas are crossed. One parent had red, axial flowers, and the other had white, terminal flowers. All F_1 individuals had red, terminal flowers. If 100 F_2 offspring were counted, how many of them would you expect to have red, axial flowers?

14. You cross true-breeding red-flowered plants with true-breeding white-flowered plants, and the F_1 are all red-flowered plants. The F_2, however, occur in a ratio of 9 red : 6 pale purple : 1 white. How many genes are involved in the inheritance of this color character? Explain why the F_1 are all red and how the 9:6:1 ratio of phenotypes in the F_2 occurred.

Test Your Knowledge

MATCHING: *Match the definition with the correct term.*

_____ **1.** codominance
_____ **2.** homozygote
_____ **3.** heterozygote
_____ **4.** phenotype
_____ **5.** polygenic (quantitative)
_____ **6.** pleiotropy
_____ **7.** epistasis
_____ **8.** testcross
_____ **9.** dihybrid cross
_____ **10.** incomplete dominance

A. true-breeding variety
B. cross between two hybrids
C. cross between hybrids that are heterozygous for two genes
D. cross with recessive homozygote to determine genotype of unknown
E. the physical characteristics of an individual
F. genotype with two different alleles
G. genotype with multiple alleles for same locus
H. one gene influences the expression of another gene
I. both alleles are fully expressed in heterozygote
J. single gene with multiple phenotypic effects
K. heterozygote intermediate between phenotypes of homozygotes
L. two or more genes with additive effect on phenotype

MULTIPLE CHOICE: *Choose the one best answer.*

1. According to Mendel's law of segregation,
a. there is a 50% probability that a gamete will get a dominant allele.
b. gene pairs segregate independently of other genes in gamete formation.
c. allele pairs separate in gamete formation.
d. the laws of probability determine gamete formation.
e. there is a 3:1 ratio in the F_2 generation.

2. After obtaining two heads from two tosses of a coin, the probability of tossing the coin and obtaining a head is
a. ½. **c.** ⅙. **e.** 1/16.
b. ¼. **d.** ⅛.

3. The probability of tossing three coins simultaneously and obtaining two heads and one tail is
a. ½. **c.** ⅛. **e.** ⅜.
b. ¾. **d.** 1/16.

4. A multifactorial disorder
a. can usually be traced to consanguineous matings.
b. is caused by recessively inherited lethal genes.
c. has both genetic and environmental causes.
d. has a collection of symptoms traceable to an epistatic gene.
e. is usually associated with quantitative traits.

5. The F_2 generation
a. has a phenotypic ratio of 3:1.
b. is the result of the self-fertilization or crossing of F_1 individuals.
c. can be used to determine the genotype of individuals with the dominant phenotype.
d. has a phenotypic ratio that equals its genotypic ratio.
e. has 16 different genotypic possibilities.

6. The base height of the dingdong plant is 10 cm. Four genes contribute to the height of the plant, and each dominant allele contributes 3 cm to height. If you cross a 10-cm plant (quadruply homozygous recessive) with a 34-cm plant, how many phenotypic classes will there be in the F_2?
a. 4 **d.** 9
b. 5 **e.** 64
c. 8

7. A 1:1 phenotypic ratio in a testcross indicates that
a. the alleles are dominant.
b. one parent must have been homozygous dominant.
c. the dominant phenotype parent was a heterozygote.
d. the alleles segregated independently.
e. the alleles are codominant.

8. Carriers of a genetic disorder
a. are indicated by solid symbols on a family pedigree.
b. are involved in consanguineous matings.
c. will produce children with the disease.
d. are heterozygotes for the gene that can cause the disorder.
e. have a homozygous recessive genotype.

9. If both parents are carriers of a lethal recessive gene, the probability that their child will inherit and express the disorder is
   a. 1/8.
   b. 1/4.
   c. 1/2.
   d. 1/2 × 1/2 × 1/4, or 1/16.
   e. 2/3 × 2/3 × 1/4, or 1/9.

10. Which phase of meiosis is most directly related to the law of independent assortment?
    a. prophase I
    b. prophase II
    c. metaphase I
    d. metaphase II
    e. anaphase II

11. You think that two alleles for coat color in mice show incomplete dominance. What is the best and simplest cross to perform in order to support your hypothesis?
    a. a testcross of a homozygous recessive mouse with a mouse of unknown genotype
    b. a cross of F_1 mice to look for a 1:2:1 ratio in the offspring
    c. a reciprocal cross in which the sex of the mice of each coat color is reversed
    d. a cross of two true-breeding mice of different colors to look for an intermediate phenotype in the F_1
    e. a cross of F_1 mice to look for a 9:7 ratio in the offspring

12. Which of the following human diseases is inherited as a simple recessive trait?
    a. Tay-Sachs disease
    b. cancer
    c. diabetes
    d. Alzheimer's disease
    e. cardiovascular disease

13. In a dihybrid cross of heterozygotes, what proportion of the offspring will be phenotypically dominant for both traits?
    a. 1/16
    b. 3/16
    c. 1/4
    d. 9/16
    e. 3/4

14. A mother with type B blood has two children, one with type A blood and one with type O blood. Her husband has type O blood. Which of the following could you conclude from this information?
    a. The husband could not have fathered either child.
    b. The husband could have fathered both children.
    c. The husband must be the father of the child with type O blood and could be the father of the type A child.
    d. The husband could be the father of the child with type O blood, but not the type A child.
    e. Neither the mother nor the husband could be the biological parent of the type A child.

15. In guinea pigs, the brown coat color allele (*B*) is dominant over red (*b*), and the solid color allele (*S*) is dominant over spotted (*s*). The F_1 offspring of a cross between true-breeding brown, solid-colored guinea pigs and red, spotted pigs are crossed. What proportion of their offspring (F_2) would be expected to be red and solid colored?
    a. 1/9
    b. 1/16
    c. 3/16
    d. 9/16
    e. 3/4

16. A dominant allele *P* causes the production of purple pigment; *pp* individuals are white. A dominant allele *C* is also required for color production; *cc* individuals are white. What proportion of offspring will be purple from a *ppCc* × *PpCc* cross?
    a. 1/8
    b. 3/8
    c. 1/2
    d. 3/4
    e. None