# *Genetics - Analysis and Principles 8th edition Brooker Solutions Manual*

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# Genetics, Analysis & Principles/8e

# Solutions Manual

## CHAPTER 1

**Note: The answers to the Comprehension questions are in Appendix B.**

**Concept check questions (following figure legends)**

FIGURE 1.1
Understanding our genes may help to diagnose inherited diseases. It may also lead to the development of drugs to combat diseases. Other answers are possible.

FIGURE 1.2
Many ethical issues are associated with human cloning. Is it the wrong thing to do? Does it conflict with an individual's religious views? And so on.

FIGURE 1.3
Because females mate only once, sorting out the male mosquitoes and releasing sterile males into the environment can limit mosquito reproduction.

FIGURE 1.4
DNA is a macromolecule.

FIGURE 1.5
DNA and proteins are found in chromosomes. A small amount of RNA may also be associated with chromosomes when transcription is occurring, and, as discussed in Chapter 17, some non-coding RNAs may bind to chromosomes.

FIGURE 1.6
The information to make a polypeptide is stored in DNA.

FIGURE 1.7
The dark-colored butterfly has a more active pigment-synthesizing enzyme.

FIGURE 1.8
Genetic variation is the reason these frogs look different.

FIGURE 1.9
These are examples of variation in chromosome number.

FIGURE 1.10

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A corn gamete contains 10 chromosomes. (The leaf cells are diploid.)

FIGURE 1.11
The horse populations adapted to their environment, which has gradually changed over the course of many years.

FIGURE 1.12
There are several possible examples of other model organisms, including rats and frogs.

**End-of-chapter Questions:**

**Conceptual Questions**

C1. There are many possible answers. Some common areas to discuss might involve the impact of genetics in the production of new medicines, the diagnosis of diseases, the production of new kinds of food, and the use of DNA fingerprinting to solve crimes.

C2. A chromosome is a very long polymer of DNA. A gene is a specific sequence of bases within that polymer; the sequence of bases distinguishes a gene from other genes. Genes are located in chromosomes, which are found within living cells.

C3. The structure and function of proteins govern the structure and function of living cells. The cells of the body determine an organism's traits.

C4. At the molecular level, a gene (a sequence of bases in DNA) is first transcribed into RNA. Most genes are transcribed into an mRNA, which codes a polypeptide. The genetic code within the mRNA is used to synthesize a polypeptide with a particular amino acid sequence. This second process is called translation.

C5.
A. Molecular level. This is a description of a how an allele affects protein function.
B. Cellular level. This is a description of how protein function affects cell structure.
C. Population level. This is a description of how the two alleles affect members of a population.
D. Organism level. This is a description of how the alleles affect the traits of an individual.

C6. Genetic variation is the occurrence of genetic differences in members of the same species or among different species. Within any population, variation may occur in the genetic material. Variation may occur in particular genes, so some individuals carry one allele and other individuals carry a different allele. An example would be alleles that cause differences in coat color among mammals. Variation may also occur in chromosome structure and number. In plants, differences in chromosome number can affect disease resistance.

C7. An extra chromosome (specifically an extra copy of chromosome 21) causes Down syndrome.

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C8. You can pick almost any trait. For example, flower color in petunias would be an interesting choice. Some petunias are red and others are purple. There must be different alleles of a flower color gene that affect this trait in petunias. In addition, the amounts of sunlight, fertilizer, and water also affect the intensity of flower color.

C9. The term *diploid* means that a cell has two copies of each type of chromosome. In humans, most cells are diploid; an exception are gametes (i.e., sperm and egg cells). Gametes usually have only one set of chromosomes.

C10. A DNA sequence is a sequence of nucleotides. Each nucleotide may have one of four different bases (i.e., A, T, G, or C). When we speak of a DNA sequence, we focus on the sequence of bases.

C11. The genetic code is the way in which the sequence of bases in mRNA is read to produce a sequence of amino acids within a protein.

C12.

A. A gene is a segment of DNA. For most genes, the expression of the gene results in the production of a functional protein. The functioning of proteins within living cells affects the traits of an organism.
B. A gene is a segment of DNA that usually codes the information for the production of a specific protein. Genes are found within chromosomes. Many genes are found within a single chromosome.
C. An allele is an alternative version of a particular gene. For example, suppose that a plant has a flower color gene. One allele of this gene may produce a white flower, and a different allele may produce an orange flower. The white allele and the orange allele are two versions of the flower color gene.
D. A DNA sequence is a sequence of nucleotides. The information within a DNA sequence (which is transcribed into an RNA sequence) specifies the amino acid sequence within a polypeptide.

C13. The statement in part A is not correct. Individuals do not evolve. Populations evolve because certain individuals are more likely to survive and reproduce and pass their genes to succeeding generations.

C14.

A. How genes and traits are transmitted from parents to offspring
B. How the genetic material functions at the molecular and cellular levels
C. Why genetic variation exists in populations, and how it changes over the course of many generations

**Experimental Questions**

E1. A genetic cross involves breeding two different individuals.

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E2. DNA sequencing is used primarily by molecular geneticists. The sequence of DNA is a molecular characteristic of DNA. However, as you will learn throughout this textbook, the sequence of DNA is also of interest to transmission and population geneticists.

E3. You would see 47 chromosomes instead of 46. There would be three copies of chromosome 21 instead of two copies.

E4.

A. Transmission geneticists. Dog breeders are interested in how genetic crosses affect the traits of dogs.
B. Molecular geneticists. *E. coli* is a good model organism for studying genetics at the molecular level.
C. Both transmission geneticists and molecular geneticists. Fruit flies are easy to cross for studying the transmission of genes and traits from parents to offspring. Molecular geneticists have also studied many genes in fruit flies to see how they function at the molecular level.
D. Population geneticists. Most wild animals and plants would be of interest to population geneticists. In the wild, you cannot make controlled crosses. But you can study genetic variation within a population and try to understand its relationship to the environment.
E. Transmission geneticists. Agricultural breeders are interested in how genetic crosses affect the outcome of traits.

E5. You need to follow the scientific method. You can take a look at an experiment in another chapter to see how the scientific method is followed.

## CHAPTER 2

**Note: The answers to Comprehension questions are in Appendix B.**

**Concept check questions (following figure legends)**

FIGURE 2.1
*Compartmentalization* means that the cells have membrane-bound compartments.

FIGURE 2.2
The chromosomes would not be spread out very well and would probably be overlapping. It would be difficult to see individual chromosomes.

FIGURE 2.3
Homologs are similar in size and banding pattern, and they carry the same types of genes. However, the alleles of a given gene may be different on two homologs.

FIGURE 2.4
Filaments of FtsZ assemble into a ring at the future site of the septum and recruits other proteins to this site to produce a cell wall between the two daughter cells.

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FIGURE 2.5
In the $G_1$ phase of the cell cycle, a cell may be preparing to divide. By comparison, the $G_0$ phase is the phase in which a cell is either temporarily not advancing through the cell cycle or never dividing again.

FIGURE 2.6
Homologs are genetically similar; one is inherited from the female parent and the other from the male parent. By comparison, chromatids are the product of DNA replication. The chromatids within a pair of sister chromatids are genetically identical.

FIGURE 2.7
One end of a kinetochore microtubule is attached to a kinetochore on a chromosome. The other end is within the centrosome.

FIGURE 2.8
Anaphase.

FIGURE 2.9
Ingression occurs because myosin shortens the contractile ring, which is formed from myosin proteins and actin filaments.

FIGURE 2.10
The end result of crossing over is that homologous chromosomes have exchanged pieces.

FIGURE 2.11
The cells at the end of meiosis are haploid, whereas the mother cell is diploid.

FIGURE 2.12
In metaphase of mitosis, each pair of sister chromatids is attached to both poles, whereas in metaphase of meiosis I, each pair of sister chromatids is attached to just one pole.

FIGURE 2.13
Polar bodies are small cells produced during oogenesis and then degenerate.

FIGURE 2.14
All cell nuclei in the embryo sac are haploid. The central cell has two haploid nuclei and the other cells, including the egg, have just one.

FIGURE 2.15
In the X-Y system, the presence of the Y chromosome causes maleness, whereas in the X-0 system, it is the ratio between the number of X chromosomes and number of sets of autosomes that determines sex. A ratio of 0.5 results in a male and a ratio of 1.0 produces a female.

FIGURE 2.16

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A higher average temperature would favor a high percentage of male alligators. This might limit population size by decreasing the number of females, which are the egg producers.

**End-of-chapter Questions:**

**Conceptual Questions**

C1. They are genetically identical, barring rare mutations, because they receive identical copies of the genetic material from the mother cell.

C2. A homolog is one of the members of a chromosome pair. Homologs are usually the same size and carry the same types of genes in the same order. They may differ in that the genes they carry may be different alleles.

C3. Sister chromatids are identical copies derived from the replication of a parental chromosome. They remain attached to each other at the centromere. They are genetically identical, barring rare mutations and crossing over with homologous chromosomes.

C4. Metaphase is the organization phase and anaphase is the separation phase.

C5. In $G_1$, there should be six linear chromosomes. In $G_2$, there should be 12 chromatids that are attached to each other as 6 pairs of sister chromatids.

C6. In metaphase of meiosis I, each pair of chromatids is attached to only one pole via the kinetochore microtubules. In metaphase of mitosis, there are two attachments (i.e., to both poles). If a chromatid did not attach to a kinetochore microtubule, that chromosome would not migrate to a pole and might not become enclosed in a nuclear membrane after telophase. If left out in the cytosol, it would eventually be degraded.

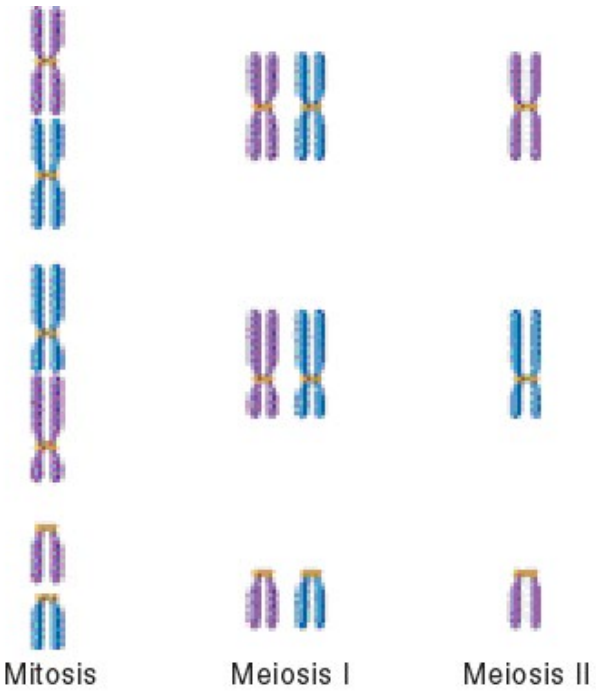
C7.
A. During mitosis and meiosis II
B. During meiosis I
C. During mitosis, meiosis I, and meiosis II
D. During mitosis and meiosis II

C8. The reduction occurs because there is a single DNA replication event but two cell divisions. Because of the nature of separation during anaphase of meiosis I, each cell receives one copy of each type of chromosome.

C9.

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C10. It means that the maternally derived and paternally derived chromosomes are randomly aligned along the metaphase plate during metaphase of meiosis I. Refer to Figures 2.11 and 3.13.

C11. Mitosis—two diploid cells containing 10 chromosomes each (two complete sets). Meiosis—four haploid cells containing 5 chromosomes each (one complete set)

C12. The number of different, random arrangments equals $2^n$, where $n$ is the number of chromosomes per set. In this case, there are three per set, so the possible number of arrangements equals $2^3$, which is 8.

C13. $(1/2)^n = (1/2)^4 = 1/16$ or 6.25%

C14. The probability of inheriting only paternal chromosomes would be much lower because pieces of maternal chromosomes would be mixed with the paternal chromosomes. Therefore, inheriting a chromosome that was completely paternally derived would be unlikely.

C15. Bacteria do not need to sort their chromosomes because they only have one type of chromosome. Though not discussed in the text, the attachment of the two copies of the chromosomes to the cell membrane prior to cell division also helps to ensure that each daughter cell receives one copy.

C16. During interphase, the chromosomes are greatly extended. In this conformation, they might get tangled up with each other and not sort properly during meiosis and mitosis. The

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condensation process probably occurs so that the chromosomes can align along the metaphase plate during metaphase without getting tangled up.

C17. To produce identical quadruplets, fertilization begins with one sperm and one egg cell. This fertilized egg then could divide twice by mitosis to produce four genetically identical cells. These four cells could then separate from each other to begin the lives of four distinct individuals. Another possibility is that mitosis could produce two cells that separate from each other. These two cells could then divide by mitosis to produce two pairs of cells, which also could separate to produce four individual cells.

C18. During prophase of meiosis II, your drawing should show four replicated chromosomes (i.e., four structures that look like Xs). Each chromosome is one replicated homolog. During prophase of mitosis, there should be eight replicated chromosomes (i.e., eight Xs). During prophase of mitosis, there are pairs of homologs. The main difference is that prophase of meiosis II has a single copy of each of the four chromosomes, whereas prophase of mitosis has four pairs of homologs. At the end of meiosis I, each daughter cell has received only one copy of a homologous pair, not both. This is due to the alignment of homologs during metaphase I and their separation during anaphase I.

C19. The products of meiosis have only one copy of each type of chromosome. For example, one human gamete may contain the paternally derived copy of chromosome 11, whereas a different gamete may contain the maternally derived copy of chromosome 11. These two homologs may carry different alleles of the same genes and therefore are not identical. In contrast, mitosis produces genetically identical daughter cells that have both copies of all pairs of homologous chromosomes.

C20. DNA replication does not take place during interphase II. The chromosomes at the end of telophase of meiosis I have already replicated (i.e., they are found in pairs of sister chromatids). During meiosis II, the sister chromatids separate from each other, yielding individual chromosomes.

C21.

<u>Prophase/Prometaphase versus Telophase</u>
Nuclear membrane dissociates. Nuclear membrane re-forms.
Mitotic spindle forms. Mitotic spindle disassembles.
Chromosomes condense. Chromosomes decondense.
Chromosomes attach to spindle. Chromosomes detach from the spindle.

C22.
A. 20
B. 10
C. 30
D. 20

C23. The hybrid offspring would have 44 chromosomes (i.e., 25 + 19). The reason for infertility is because each chromosome does not have a homologous partner. Therefore, the

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chromosomes cannot properly pair during metaphase of meiosis I, and the gametes do not receive one copy of each homolog. Gametes will be missing certain chromosomes, which makes them infertile.

C24.
A. Dark males and light females; reciprocal: all dark offspring
B. All dark offspring; reciprocal: dark females and light males
C. All dark offspring; reciprocal: dark females and light males
D. All dark offspring; reciprocal: dark females and light males

C25. Male gametes are usually small and mobile. Animal and some plant male gametes contain flagella, which make them motile. The mobility of the male gamete enables it to come in contact with the female gamete. Female gametes are usually much larger and contain nutrients to help the growth of the embryo after fertilization occurs.

C26. To produce sperm, a spermatogonial cell first goes through mitosis to produce two cells. One of these remains a spermatogonial cell and the other advances through meiosis. In this way, the testes continue to maintain a population of spermatogonial cells.

C27. During oogenesis in humans, meiosis begins before birth and the cells are arrested in prophase of meiosis I until puberty. At that time, selected primary oocytes advance through the rest of meiosis I and begin meiosis II. If fertilization occurs, meiosis II is completed.

C28.
A. *A B C, A B c, A b C, A b c, a B C, a b C, a B c, a b c*
B. *A B C, A b C*
C. *A B C, A B c, a B C, a B c*
D. *A b c, a b c*

C29. There is a 1/2 chance that the female parent will transmit an abnormal chromosome and a 1/2 chance that the male parent will. You use the product rule to calculate the chances of both events happening. So, the answer is 1/2 × 1/2 = 1/4, or 25%. The probability that such a child will pass both chromosomes to an offspring is also 25% because that child had a 1/2 chance of passing either chromosome.

C30.
A. The mosquito is a male because the ratio of X chromosomes to sets of autosomes is 1/2, or 0.5.
B. The mosquito is a female because the ratio of X chromosomes to sets of autosomes is 1.0.
C. The mosquito is a male because the ratio of X chromosomes to sets of autosomes is 0.5.
D. The mosquito is a female because the ratio of X chromosomes to sets of autosomes is 1.0.

C31.
A. Female; there are no Y chromosomes.
B. Female; there are no Y chromosomes.
C. Male; the Y chromosome determines maleness.

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D. Male; the Y chromosome determines maleness.

**Experimental Questions**

E1.
A. $G_2$ phase (it could not complete prophase)
B. Metaphase (it could not enter anaphase)
C. Telophase (it could not divide into two daughter cells)
D. $G_2$ phase (it could not enter prophase)

E2. The basic strategy is to set up a pair of reciprocal crosses. The phenotype of male offspring is usually the easiest way to discern the two patterns. If the gene is on the Y chromosome, the trait will be passed only from a male parent to a male offspring. If it is on the X chromosome, the trait will be passed from a female parent to a male offspring.

E3. During interphase, the chromosomes are longer, thinner, and much harder to see. In metaphase, they are highly condensed, which makes them thicker and shorter.

E4. You could karyotype other members of the family and see if affected members always carry the abnormal chromosome.

E5. Originally, individuals with abnormalities in their composition of sex chromosomes provided important information. In mammals, X0 individuals are females, while in flies, X0 individuals are males. In mammals, XXY individuals are males, whereas in flies, XXY individuals are females. These results indicate that the presence of the Y chromosome causes maleness in mammals, but it does not in flies. A further analysis of flies with abnormalities in the number of sets of autosomes revealed that it is the ratio between the number of X chromosomes and the number of sets of autosomes that determines sex in fruit flies.

E6.
A. 18 pg
B. 18 pg
C. 9 pg
D. 4.5 pg

**Questions for Student Discussion/Collaboration**

1. The wide variety of sex determination mechanisms suggests that such mechanisms may have arisen independently on multiple occasions. It would seem that it may have arisen relatively recently after the major groups of animals diverged from each other.

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2. It's not possible to give a direct answer, but the point is to be able to draw chromosomes in different configurations and understand the various phases. The chromosomes may or may not be the following:
   1. In homologous pairs
   2. Connected as sister chromatids
   3. Associated in bivalents
   4. Lined up in metaphase
   5. Moving toward the poles.

   and so on.

## CHAPTER 3

**Note: The answers to Comprehension questions are in Appendix B.**

**Concept check questions (following figure legends)**

FIGURE 3.2
The male gametes are found within pollen grains.

FIGURE 3.3
The white-flowered plant is providing the sperm, and the purple-flowered plant is providing the eggs.

FIGURE 3.4
A true-breeding strain maintains the same trait over the course of several generations of self-fertilization.

FIGURE 3.6
Segregation means that the *T* and *t* alleles separate from each other, and so a haploid cell receives one of them, but not both.

FIGURE 3.7
According to the hypothesis of linked assortment, two different genes are linked. The alleles of the same gene are not linked.

FIGURE 3.9
Independent assortment allows new combinations of alleles of different genes to be found in future generations of offspring.

FIGURE 3.10
Such a parent could make two types of gametes, *Ty* and *ty*, in equal proportions.

FIGURE 3.12
Homologous chromosomes separate at anaphase of meiosis I.

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FIGURE 3.13
If you view the left and right sides as being distinctly different, these chromosomes could line up in eight different ways.

FIGURE 3.15
Horizontal lines connect two individuals that have offspring together, and they connect all offspring produced by the same two parents.

**End-of-chapter Questions:**

**Conceptual Questions**

C1. Mendel's work showed that genetic determinants are inherited in a dominant/recessive manner. This was readily apparent in many crosses. For example, when Mendel crossed two true-breeding plants for a trait such as height (i.e., tall versus short), all $F_1$ plants were tall. This was not consistent with blending. Perhaps more striking was the result obtained in the $F_2$ generation: 3/4 of the offspring were tall and 1/4 were short. In other words, the $F_2$ generation displayed phenotypes that were like the parental generation. There did not appear to be a blending to create an intermediate phenotype. Instead, the genetic determinants did not seem to change from one generation to the next.

C2. In plants, cross-fertilization occurs when the pollen and eggs come from different plants, whereas in self-fertilization, they come from the same plant.

C3. The genotype is the type of genes that an individual inherits whereas the phenotype is the individual's observable traits. Tall pea plants, red hair in humans, and vestigial wings in fruit flies are phenotypes. Homozygous, *TT,* in pea plants; a heterozygous carrier of the cystic fibrosis allele; and homozygotes for the cystic fibrosis allele are descriptions of genotypes. It is possible to have different genotypes and the same phenotype. For example, a pea plant that is *TT* or *Tt* would both have a tall phenotype.

C4. A true-breeding organism is a homozygote that has two copies of the same allele.

C5. Conduct a cross in which the unknown individual is bred to an individual that carries only recessive alleles for the gene in question.

C6. Diploid organisms contain two copies of each type of gene. When they make gametes, only one copy of each gene is found in a gamete. Two alleles cannot stay together within the same gamete.

C7. B. This statement is not correct because these are alleles of different genes.

C8. Genotypes: 1 *Tt* :1 *tt*
Phenotypes: 1 tall : 1 short

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C9. The recessive phenotype must be a homozygote. The dominant phenotype could be either homozygous or heterozygous.

C10. Here, *c* is the recessive allele for constricted pods; *Y* is the dominant allele for yellow color. The cross is *ccYy* × *CcYy*. Follow the directions for setting up a Punnett square, as described in Section 3.3. The genotypic ratio is 2 *CcYY* : 4 *CcYy* : 2 *Ccyy* : 2 *ccYY* : 4 *ccYy* : 2 *ccyy*. This 2:4:2:2:4:2 ratio can be reduced to a 1:2:1:1:2:1 ratio.
The phenotypic ratio is 6 smooth pods, yellow seeds : 2 smooth pods, green seeds : 6 constricted pods, yellow seeds : 2 constricted pods, green seeds. This 6:2:6:2 ratio can be reduced to a 3:1:3:1 ratio.

C11. The genotypes are 1 *YY* : 2 *Yy* : 1 *yy*.
The phenotypes are 3 yellow : 1 green.

C12. Offspring with a nonparental phenotype are consistent with the law of independent assortment. If two different traits were always transmitted together as unit, it would not be possible to get nonparental combinations of traits. For example, if a true-breeding parent had two dominant traits and was crossed to a true-breeding parent having the two recessive traits, the $F_2$ offspring could not have one recessive and one dominant trait. However, because independent assortment can occur, it is possible for $F_2$ offspring to have one dominant and one recessive trait.

C13. (a) It behaves like a recessive trait because unaffected parents sometimes produce affected offspring. In such cases, the unaffected parents are heterozygous carriers.
(b) It behaves like a dominant trait. An affected offspring always has an affected parent. However, recessive inheritance cannot be ruled out.

C14.
A. Barring a new mutation during gamete formation, the probability is 100% because the parents must be heterozygotes in order to produce a child with a recessive disorder.
B. Construct a Punnett square. There is a 50% chance of heterozygous offspring.
C. Use the product rule. The chance of being phenotypically unaffected is 0.75 (i.e., 75%), so the answer is 0.75 × 0.75 × 0.75 = 0.422, which is 42.2%.
D. Use the binomial expansion equation where $n = 3$, $x = 2$, $p = 0.75$, $q = 0.25$. The answer is 0.422, or 42.2%.

C15.
A. 100% because they are genetically identical.
B. Construct a Punnett square. You know the parents are heterozygotes because they produced a blue-eyed child. The fraternal twin is not genetically identical, but this twin has the same parents as the other twin. The answer is 25%.
C. The probabilities for the possible genotypes of the fraternal twin are 0.25 for *BB*, 0.5 for *Bb*, and 0.25 for *bb*. The probability of this fraternal twin passing the *b* allele to their subsequent offspring is 0 for *BB*, 0.5 for *Bb*, and 1.0 for *bb*. You use the product rule for each genotype to determine the probability of the allele being passed from the fraternal twin to their offspring.

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*BB*: 0.25 x 0 = 0
*Bb*: 0.5 x 0.5 = 0.25
*bb*: 0.25 x 1.0 = 0.25
If you add the probabilities together, the summed probability is 0.5. There is a 50% chance that the fraternal twin's offspring will inherit the *b* allele.

D. Barring a new mutation during gamete formation, the chance is 100% because they must be heterozygotes in order to produce a child with blue eyes.

C16. First construct a Punnett square. The probabilities are 75% for solid coat and 25% for spotted coat.

A. Use the binomial expansion equation where $n = 5$, $x = 4$, $p = 0.75$, $q = 0.25$. The answer is 0.396, or 39.6% of the time.

B. You can use the binomial expansion equation for each litter. For the first litter, $n = 6$, $x = 4$, $p = 0.75$, $q = 0.25$; for the second litter, $n = 5$, $x = 5$, $p = 0.75$, $q = 0.25$. Because the litters are in a specified order, you use the product rule and multiply the probability of the first litter times the probability of the second litter. The answer is 0.070, or 7.0%.

C. To calculate the probability of the first litter, you use the product rule and multiply the probability of the first pup (0.75) times the probability of the remaining four. You use the binomial expansion equation to calculate the probability of the remaining four, where $n = 4$, $x = 3$, $p = 0.75$, $q = 0.25$. The probability of the first litter is 0.316. To calculate the probability of the second litter, you use the product rule and multiply the probability of the first pup (0.25) times the probability of the second pup (0.25) times the probability of the remaining five. To calculate the probability of the remaining five, you use the binomial expansion equation, where $n = 5$, $x = 4$, $p = 0.75$, $q = 0.25$. The probability of the second litter is 0.025. To get the probability of these two litters occurring in this order, you use the product rule and multiply the probability of the first litter (0.316) times the probability of the second litter (0.025). The answer is 0.008, or 0.8%.

D. Because the order of the first two is specified, you use the product rule and multiply the probability of the firstborn (0.75) times the probability of the second born (0.25) times the probability of the remaining four. You use the binomial expansion equation to calculate the probability of the remaining four pups, where $n = 4$, $x = 2$, $p = 0.75$, $q = 0.25$. The answer is 0.040, or 4.0%.

C17. If *B* is the black allele, and *b* is the white allele, the male is *bb,* the first female is probably *BB,* and the second female is *Bb*. You are uncertain of the genotype of the first female. This female could be *Bb,* although it is unlikely because no white pups were produced in a litter of eight.

C18.

A. Use the product rule:
(1/4)(1/4)=1/16

B. Use the binomial expansion equation, where
$n = 4$, $p = ¼$, $q = ¾$, $x = 2$:
$P = 0.21$, or 21%

C. Use the product rule:
(1/4)(3/4)(3/4) = 0.14, or 14%

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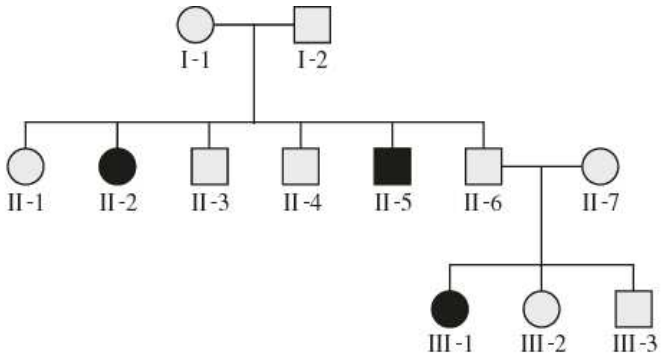
C19. The parents must be heterozygotes, so the probability is 1/4.

C20.
A. 1/4
B. 1, or 100%
C. (3/4)(3/4)(3/4) = 27/64 = 0.42, or 42%
D. Use the binomial expansion equation, where
$n = 7$, $p = 3/4$, $q = 1/4$, $x = 3$:
$P = 0.058$, or 5.8%
E. The probability that the first plant is tall is 3/4. To calculate the probability that among the next four, any two will be tall, use the binomial expansion equation, where $n = 4$, $p = 3/4$, $q = 1/4$, and $x = 2$:
$P = 0.21$
Then calculate the overall probability of these two events:
(3/4)(0.21) = 0.16, or 16%

C21.
A. *T Y R, T y R, T Y r, T y r*
B. *T Y r, t Y r*
C. *T Y R, T Y r, T y R, T y r, t Y R, t Y r, t y R, t y r*
D. *t Y r, t y r*

C22. The gamete violates the law of segregation because it has two copies of one gene. The two alleles for the *A* gene did not segregate from each other.

C23. It is recessive inheritance. The pedigree is shown here. Affected individuals are shown with filled symbols.




The mode of inheritance appears to be recessive. Unaffected parents (who must be heterozygous) produce affected children.

C24. Based on the pedigree provided, the disease is likely to be a dominant trait because a child with Marfan syndrome always has an affected parent. In fact, it is a dominant disorder.

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C25.
A. 3/16
B. (9/16)(9/16)(9/16) = 729/4096 = 0.18
C. (9/16)(9/16)(3/16)(1/16)(1/16) = 243/1,048,576 = 0.00023, or 0.023%
D. Another way of looking at this is that the probability it will have round, yellow seeds is 9/16. Therefore, the probability that it will not is 1 – 9/16 = 7/16.

C26. It is impossible for $F_1$ individuals to be true-breeding because they are all heterozygotes.

C27. This problem is a bit unwieldy, but you can solve it using the multiplication method.
For height, the ratio is 3 tall : 1 short.
For seed texture, the ratio is 1 round : 1 wrinkled.
For seed color, they are all yellow.
For flower location, the ratio is 3 axial : 1 terminal.
Thus, the product is
(3 tall + 1 short)(1 round + 1 wrinkled)(1 yellow)(3 axial + 1 terminal)
Multiplying this out, the answer is
9 tall, round, yellow, axial
9 tall, wrinkled, yellow, axial
3 tall, round, yellow, terminal
3 tall, wrinkled, yellow, terminal
3 short, round, yellow, axial
3 short, wrinkled, yellow, axial
1 short, round, yellow, terminal
1 short, wrinkled, yellow, terminal

C28. 2 *TY, tY,* 2 *Ty, ty, TTY, TTy,* 2 *TtY,* 2 *Tty*
This question is a bit tricky, but 2 *TY* and 2 *Ty* gametes are made because either of the two *T* alleles could combine with *Y* or *y.* Also, you get 2 *TtY* and 2 *Tty* because either of the two *T* alleles can combine with *t* and then combine with *Y* or *y.*

C29. The drone is *sB* and the queen is *SsBb.* According to the laws of segregation and independent assortment, the male can make only *sB* gametes, while the queen can make *SB, Sb, sB,* and *sb,* in equal proportions. Therefore, male offspring will be *SB, Sb, sB,* and *sb,* and female offspring will be *SsBB, SsBb, ssBB,* and *ssBb.* The phenotypic ratios, assuming an equal number of males and females, will be:

| *Males* | *Females* |
|---|---|
| 1 normal wings/black eyes | 2 normal wings, black eyes |
| 1 normal wings/white eyes | 2 short wings, black eyes |
| 1 short wings/black eyes | |
| 1 short wings/white eyes | |

C30. The genotype of the $F_1$ plants is *Tt Yy Rr.* According to the laws of segregation and independent assortment, the alleles of each gene will segregate from each other, and the alleles of different genes will randomly assort into gametes. A *Tt Yy Rr* individual could make eight types of gametes: *TYR, TyR, Tyr, TYr, tYR, tyR, tYr,* and *tyr,* in equal proportions

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(i.e., 1/8 of each type of gamete). To determine genotypes and phenotypes, you could make a large Punnett square that would contain 64 boxes. You would need to line up the eight possible gametes across the top and along the side, and then fill in the 64 boxes. Alternatively, you could use either the multiplication method or forked-line method described in Figure 3.11. The genotypes and phenotypes are as follows:
1 *TT YY RR*
2 *TT Yy RR*
2 *TT YY Rr*
2 *Tt YY RR*
4 *TT Yy Rr*
4 *Tt Yy RR*
4 *Tt YY Rr*
8 *Tt Yy Rr* = 27 tall, yellow, round

1 *TT yy RR*
2 *Tt yy RR*
2 *TT yy Rr*
4 *Tt yy Rr* = 9 tall, green, round

1 *TT YY rr*
2 *TT Yy rr*
2 *Tt YY rr*
4 *Tt Yy rr* = 9 tall, yellow, wrinkled

1 *tt YY RR*
2 *tt Yy RR*
2 *tt YY Rr*
4 *tt Yy Rr* = 9 short, yellow, round

1 *TT yy rr*
2 *Tt yy rr* = 3 tall, green, wrinkled

1 *tt yy RR*
2 *tt yy Rr* = 3 short, green, round

1 *tt YY rr*
2 *tt Yy rr* = 3 short, yellow, wrinkled

1 *tt yy rr* = 1 short, green, wrinkled

C31. Construct a Punnett square to determine the probability of these three phenotypes. The probabilities are 9/16 for round, yellow; 3/16 for round, green; and 1/16 for wrinkled, green. Use the multinomial expansion equation in Section 3.6, where $n = 5$, $a = 2$, $b = 1$, $c = 2$, $p = 9/16$, $q = 3/16$, $r = 1/16$. The answer is 0.007, or 0.7%.

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C32. Because this is a dominant trait, the wooly-haired male must carry at least one copy of wooly-hair allele. Because the female parent of the wooly-haired male does not have wooly hair, the wooly haired male must also have inherited one copy of the normal allele. Therefore, the wooly haired male is a heterozygote. The heterozygous wooly haired male has a 50% chance of passing the wooly hair allele to each offspring; each offspring has a 50% of passing the allele to their offspring; and those grandchildren have a 50% chance of passing the allele to their offspring (the wooly-haired male's great-grandchildren). Because this is an ordered sequence of independent events, you use the product rule: 0.5 x 0.5 x 0.5 = 0.125 , or 12.5%. If no other Scandinavians are on the island, the chance is 100% - 12.5% = 87.5% for the offspring to not have wooly hair. You use the binomial expansion equation to determine the probability that one out of eight great-grandchildren will have wooly hair, where n = 8 , x = 1 , p = 0.125 , q = 0.875 . The answer is 0.393, or 39.3%.

C33.

A. Construct a Punnett square. Because it is a rare disorder, you would assume that the one parent is a heterozygote and the other parent is homozygous for the normal allele. The chances are 50% that the Alonzo will have the allele.
B. Use the product rule: 0.5 (chance that Alonzo has the disease-causing allele) times 0.5 (chance that the disease-causing allele will be passed to each offspring), which equals 0.25, or 25%.
C. You use the binomial expansion equation. From part B, you calculated that the probability of an affected child is 0.25. Therefore, the probability of an unaffected child is 0.75. For the binomial expansion equation, $n = 3$, $x = 1$, $p = 0.25$, $q = 0.75$. The answer is 0.422 or 42.2%.

C34.

A. Use the product rule. If the brown-eyed parent is a heterozygote, there is a 50% chance of having an offspring with brown eyes at each birth: $(0.5)^7 = 0.0078$, or 0.78%. This is a pretty small probability.
B. However, the brown-eyed parent must be a heterozygote if an eighth child has blue eyes because brown eyes is a dominant trait. To have a child with blue eyes, the brown-eyed parent would have to pass a blue-eye allele to the offspring. In this case, the probability of being heterozygous is 100%.

**Experimental Questions**

E1. Pea plants are relatively small and hardy. They produce both pollen and eggs within the same flower. Because a keel covers the flower, self-fertilization is quite easy. In addition, cross-fertilization is possible by the simple manipulation of removing the anthers in an immature flower and later placing pollen from another plant. Finally, peas exist in several variants.

E2. The difference lies in where the pollen comes from. In self-fertilization, the pollen and eggs come from the same plant. In cross-fertilization, they come from different plants.

E3. Two generations would take two growing seasons. About 1 and 1/2 years.

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E4. According to Mendel's law of segregation, the genotypic ratio should be 1 homozygote dominant : 2 heterozygotes : 1 homozygote recessive. The data table considers only the plants with a dominant phenotype. The genotypic ratio should be 1 homozygote dominant : 2 heterozygotes. The homozygote dominants would be true-breeding while the heterozygotes would not be true-breeding. This 1:2 ratio is very close to what Mendel observed.

E5. In a single-factor cross, the experimenter is only concerned with the outcome of a single trait. In a two-factor cross, the experimenter follows the pattern of inheritance for two different traits.

E6. All three offspring had black fur. The ovaries from the albino female could produce eggs with only the dominant black allele (because they were obtained from a true-breeding black female). The actual phenotype of the albino female parent does not matter. Therefore, all offspring are heterozygotes (*Bb*) and have black fur.

E7. The data are consistent with two genes (let's call them gene 22 and gene 24) that exist in two alleles each, a susceptible allele and a resistant allele. The observed data approximate a 9:3:3:1 ratio. This is the expected ratio if two genes are involved, and if resistance is dominant to susceptibility.

E8. If you construct a Punnett square according to Mendel's laws, you expect a 9:3:3:1 ratio. Because a total of 556 offspring were observed, the expected numbers of offspring with different phenotypes are:
556 × 9/16 = 313 round, yellow
556 × 3/16 = 104 wrinkled, yellow
556 × 3/16 = 104 round, green
556 × 1/16 = 35 wrinkled, green
If you substitute the observed and expected values into the chi square equation, you get a value of 0.51. With four categories, the degrees of freedom equal $n - 1$, or 3. If you look up the value of 0.51 in the chi square table (see Table 3.1), you see that it falls between *P* values of 0.80 and 0.95. This means that the probability is between 80% and 95% that any deviation between observed results and expected results was caused by random sampling error. Therefore, you accept the hypothesis. In other words, the results are consistent with the law of independent assortment.

E9. No, the law of independent assortment applies to transmission patterns of two or more genes. In a single-factor cross, you are monitoring only the transmission pattern of a single gene.

E10.
A. Let $c^+$ represent normal wings and *c* represent curved wings and $e^+$ represent gray body and *e* represent ebony body.
Parental cross: $cce^+e^+ \times c^+c^+ee$.
$F_1$ generation is heterozygous: $c^+ce^+e$

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A cross of an $F_1$ offspring with a fly with curved wings and ebony body is represented as follows:

$c^+ce^+e \times ccee$

The $F_2$ offspring will have this 1:1:1:1 ratio of genotypes:

$c^+ce^+e : c^+cee : cc\ e^+e : ccee$

B. The phenotypic ratio of the $F_2$ flies will be 1:1:1:1:
normal wings, gray body : normal wings, ebony bodies : curved wings, gray bodies : curved wings, ebony bodies

C. From part B, the $F_2$ offspring consists of 1/4 of each phenotypic category. There are a total of 444 offspring. The expected number of each category is 1/4 × 444, which equals 111.

$$\chi^2 = \frac{(114-111)^2}{111} + \frac{(105-111)^2}{111} + \frac{(111-111)^2}{111} + \frac{(114-111)^2}{111}$$

$$\chi^2 = 0.49$$

With 3 degrees of freedom, a value of 0.49 or greater is likely to occur between 80% and 95% of the time. Therefore, the experimental data are consistent with the expected outcome.

E11. You would expect a ratio of 3 normal : 1 long neck. In other words, there should be 1/3 as many long-necked mice as normal mice. If you multiply 522 times 1/3, the expected value is 174. However, only 62 were observed. Therefore, it appears that 174 – 62, or 112, mice died during early embryonic development; 112 divided by 174 gives us the percentage that died, which equals 0.644, or 64.4%.

E12. Use the same basic chi square analysis. You expect a 3:1 ratio, or 3/4 of the dominant phenotype and 1/4 of the recessive phenotype.
The observed and expected values are as follows (rounded to the nearest whole number):

| Observed* | Expected | $\frac{(O-E)^2}{E}$ |
|---|---|---|
| 5,474 | 5,493 | 0.066 |
| 1,850 | 1,831 | 0.197 |
| 6,022 | 6,017 | 0.004 |
| 2,001 | 2,006 | 0.012 |
| 705 | 697 | 0.092 |
| 224 | 232 | 0.276 |
| 882 | 886 | 0.018 |
| 299 | 295 | 0.054 |
| 428 | 435 | 0.113 |
| 152 | 145 | 0.338 |
| 651 | 644 | 0.076 |
| 207 | 215 | 0.298 |
| 787 | 798 | 0.152 |
| 277 | 266 | 0.455 |
| | | $\chi^2 = 2.15$ |

*Due to rounding, the observed and expected values may not add up to precisely the same number.

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Because *n* = 14, there are 13 degrees of freedom. If you look up the value 2.15 in the chi square table, you have to look between 10 and 15 degrees of freedom. In either case, a value of 2.15 or greater is expected to occur more than 99% of the time. Therefore, the data are consistent with the law of segregation.

E13. This means that a deviation value of 1.005 or greater (between the observed and expected data) would occur 80% of the time. In other words, it is fairly likely to obtain this value due to random sampling error. Therefore, you accept the hypothesis.

E14. Perhaps the most convincing evidence was that all white-eyed flies of the $F_2$ generation were males. This suggests a link between sex determination and the inheritance of this trait. Because sex determination in fruit flies is determined by the number of X chromosomes, this outcome suggests a relationship between the inheritance of the X chromosome and the inheritance of this trait.

E15. Actually, the data are consistent with this hypothesis. To rule out a Y-linked allele, a cross could be made between an $F_1$ female and a true-breeding red-eyed male rather than an $F_1$ male. The same results would be obtained. Because the red-eyed male would not have a white allele, this would rule out Y-linkage.

E16. If you use the data from the $F_1$ mating (i.e., the $F_2$ results), there were 3,470 red-eyed flies. You would expect a 3:1 ratio between red- and white-eyed flies. Therefore, assuming that all red-eyed offspring survived, there should have been about 1,157 (i.e., 3470/3) white-eyed flies. However, there were only 782. If you divide 782 by 1,157, you get a value of 0.676, or a 67.6% survival rate.

E17. You need to make crosses to understand the pattern of inheritance of traits (determined by genes) from parents to offspring. And you need to microscopically examine cells to understand the pattern of transmission of chromosomes. The correlation between the pattern of transmission of chromosomes during meiosis, and Mendel's laws of segregation and independent assortment, is what led to the chromosome theory of inheritance.

**Questions for Student Discussion/Collaboration**

1. The methods for making a Punnett square and using the forked-line method are described in the chapter. Presumably, the forked-line method (or the multiplication method) will work a lot faster.

2. If you construct a Punnett square, the following probabilities will be obtained:
   tall with axial flowers 3/8
   short with terminal flowers 1/8
   The probability of being tall with axial flowers or short with terminal flowers is then:
   3/8 + 1/8 = 4/8 = 1/2

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You use the product rule to calculate the probability of the ordered events of the first three offspring being tall and axial or short and terminal, and the fourth offspring being tall and axial:
(1/2)(1/2)(1/2)(3/8) = 3/64 = 0.047 = 4.7%

3. The five principles are described in the text. The tenets involving chromosome transmission and individuality were determined via microscopy (2, 3 and 4). The tenets involving traits were determined from crosses (1 and 5), although some overlap occurs among these tenets. Modern techniques to verify this theory could involve a variety of cloning techniques that are described in Chapter 20.

## CHAPTER 4

**Note: The answers to the Comprehension questions are in Appendix B.**

**Concept check questions (following figure legends)**

FIGURE 4.1
Both of these colors are considered wild type because both of them are common in natural populations.

FIGURE 4.2
Yes. The *PP* homozygote probably makes twice as much of the protein than is needed for the purple color.

FIGURE 4.3
Individual III-2 shows the effect of incomplete penetrance.

FIGURE 4.4
Genes and the environment determine an organism's traits.

FIGURE 4.5
In a heterozygous four-o'clock plant, 50% of the functional protein is not enough to give a red color.

FIGURE 4.6
It is more likely to observe incomplete dominance at the molecular or cellular level.

FIGURE 4.7
In this case, the heterozygote is resistant to malaria.

FIGURE 4.8
The scenario in part (a) explains the heterozygote advantage for the sickle cell allele.

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FIGURE 4.9
The *i* allele is a loss-of-function allele.

FIGURE 4.10
The key feature of the pedigree that points to X-linked inheritance is that only males are affected with the disorder. Also, carrier females often have male siblings that are affected with the disorder.

FIGURE 4.11
The reciprocal cross yields a different result because females carry two copies of an X-linked gene, whereas males have only one.

FIGURE 4.12
Homologous regions of the X and Y chromosomes are important for chromosome pairing (synapsis) during meiosis.

FIGURE 4.13
A heterozygous female cow would not have scurs.

FIGURE 4.14
When a trait is expressed only in males or females, this is possibly due to differences in the levels of sex hormones or to developmental factors that differ between males and females.

FIGURE 4.15
The heterozygote has one copy of the wild-type allele (*m*), which allows for development to proceed in a way that is not too far from normal. Having two mutant copies of the gene (*MM*) probably adversely affects development to a degree that is incompatible with survival.

FIGURE 4.17
*Epistasis* means that the alleles of one gene mask the phenotypic effects of the alleles of a different gene. *Complementation* occurs when two strains exhibiting the same recessive trait produce offspring that show the dominant (wild-type) trait. This usually indicates that the alleles for the recessive trait are in two different genes.

FIGURE 4.18
In some cases, a single gene knockout does not have an effect due to gene redundancy. Other explanations are also possible.

FIGURE 4.19
The two genes determining seed capsule shape are redundant. Having one functional allele of either gene produces a triangular capsule. If both genes are inactive, an ovate capsule is produced.

**End-of-chapter Questions:**

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**Conceptual Questions**

C1. Dominance occurs when one allele completely exerts its phenotypic effects over another allele. Incomplete dominance is a situation in which two alleles in the heterozygote have an intermediate phenotype. In codominance, both alleles exert their effects independently in the heterozygote. Heterozygote advantage is a case in which the heterozygote has a phenotype that is superior to either homozygote with regard to reproductive success.

C2. Sex-influenced traits are influenced by the sex of the individual even though the gene that governs the trait is autosomally inherited. Scurs in certain breeds of cattle is an example. A sex-influenced trait is dominant in one sex and recessive in the other. The expression of a sex-limited trait is limited to one sex. For example, colorful plumage in certain species of birds is limited to the male sex. Sex-linked traits are traits whose genes are found on the sex chromosomes. Examples in humans include hemophilia and color blindness.

C3. The term *gene interaction* refers to the phenomenon that two or more different genes have an impact on the same trait. This can occur, for example, if two genes code enzymes in the same enzymatic pathway that is required for the synthesis of a pigment. If the pathway is disrupted by a mutation in either of these two genes, the same net result may occur.

C4. If the functional allele is dominant, it tells you that one copy of the gene produces a sufficient amount of the protein coded by the gene. Having twice as much of this protein, as in the dominant homozygote, does not alter the phenotype. If the functional allele is incompletely dominant, one copy of that allele does not produce the same trait as is observed in the homozygote with two functional alleles.

C5. The function of the tyrosinase enzyme is lower because less of the dark pigment is being synthesized. The underlying cause is a higher temperature; the mutant tyrosinase enzyme in Siamese cats functions poorly at higher temperature. One reason for the change in fur color might be that the cat was exposed to higher environmental temperatures; maybe it's summer and the cat has been outside more. Alternatively, maybe the cat has some kind of prolonged illness that is raising its body temperature, such as some kind of persistent infection.

C6. The ratio would be 1 normal : 2 star-eyed.

C7. The red and white seed packs should be from true-breeding (homozygous) strains. The pink pack should be seeds from a cross between white- and red-flowered plants.

C8. If individual 1 is *ii,* individual 2 could be $I^Ai$, $I^AI^A$, $I^Bi$, $I^BI^B$, or $I^AI^B$.
If individual 1 is $I^Ai$ or $I^AI^A$, individual 2 could be $I^Bi$, $I^BI^B$, or $I^AI^B$.
If individual 1 is $I^Bi$ or $I^BI^B$, individual 2 could be $I^Ai$, $I^AI^A$, or $I^AI^B$.

Assuming that individual 1 is the parent of individual 2:
If individual 1 is *ii*, individual 2 could be $I^Ai$ or $I^Bi$.
If individual 1 is $I^Ai$, individual 2 could be $I^Bi$ or $I^AI^B$.

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## Chapter 1: Overview of Genetics

### *Key Terms*

Key Terms are listed by section at the end of the chapter.

### *Chapter Outline*

*Introduction*

1. The Human Genome Project began in 1990 as a project between the National Institutes of Health (NIH) and the Department of Energy (DOE). The project was completed in 2003.
   a. human genome contains approximately 3 billion nucleotide base pairs (Figure 1.1)
   b. project is 99.99% accurate (1 error in 10,000 nucleotides)
2. Human Genome Project should enable scientists to:
   a. determine the number of genes in humans
   b. examine the relationship between genes and living cells
   c. study the evolution of the species
   d. understand developmental genetics
   e. explore the relationship between genetic mutations and disease
   f. develop new technologies for genetic studies
3. Modern genetic studies result in developments that affect our daily lives.
   a. The development of new medicines such as Humulin. Humulin is human insulin manufactured by *E. coli* bacteria.
   b. Cloning of mammals, such as Dolly the sheep by Ian Wilmut and associates (1997) (Figure 1.2)
   c. production of transgenic organisms (Figure 1.3)

*1.1 The Molecular Expression of Genes*

***Learning Outcomes:***

1. Describe the biochemical composition of cells.
2. Explain how proteins are largely responsible for cell structure and function.
3. Outline how DNA stores the information to make proteins.

1. Genes represent the basic unit of heredity, while a trait represents the characteristics of an organism. Genes provide the blueprint that determines an organism's traits.

Living Cells Are Composed of Biochemicals

1. Small organic molecules provide energy for cellular functions as well as the building blocks for larger molecules.
2. There are Four categories of biologically important organic molecules that are made of repetitive subunits. These organic molecules are called macromolecules.
   a. nucleic acids
   b. proteins
   c. carbohydrates
   d. lipids

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3. Larger cellular structures, such as chromosomes, are built from combinations of macromolecules and smaller molecules (Figure 1.4).

Each Cell Contains Many Different Proteins That Determine Cellular Structure and Function

1. Cellular characteristics are determined primarily by proteins.
2. A cell's proteome consists of all of the proteins that a cell makes at a given time.
3. General roles of proteins include: enzymatic functions, cellular support, transport across the cell membrane, biological motors, cell-to-cell recognition, and cell signaling.
4. Most enzymes are proteins that accelerate a chemical reaction (catalyst).
   a. catabolic enzymes break down molecules and release energy
   b. anabolic enzymes synthesize larger molecules

DNA Stores the Information for Protein Synthesis

1. DNA stores the information needed for synthesis of cellular proteins.
2. DNA is made of nucleotides. Each nucleotide includes a nitrogenous base, which is either adenine (A), thymine (T), cytosine (C), or guanine (G).
3. The information in the DNA contains the information the sequence of amino acids in a protein.
   a. the genetic code is used to relate the genetic information to the correct amino acid
4. In cells, DNA is found in chromosomes (Figure 1.5). The information on a chromosome is organized as genes.
   a. on average, a human chromosome contains approximately1000 genes

The Information in DNA is Accessed During the Process of Gene Expression

1. Gene expression refers to the use of the genetic information to affect the characteristics of cells.
2. Process includes two steps (Figure 1.6):
   a. information in the DNA is copied into RNA by transcription (genes that contain the information for the synthesis of proteins are copied into messenger RNA (mRNA)).
   b. the RNA is then translated into a functional protein.
3. The distinctive structure of a protein determines is cellular function.

*1.2 The Relationship Between Genes and Traits*

***Learning Outcomes:***

1. Outline how the expression of genes leads to an organism's traits.
2. Define genetic variation.
3. Discuss the relationship between genes and traits.
4. Describe how genes are transmitted in sexually reproducing species.
5. Explain the process of evolution.

The Molecular Expression of Genes Within Cells Leads to an Organism's Traits

1. A trait is the displayed characteristic of an organism.
2. Morphological traits are associated with the appearance of an organism (eye color, height, etc.).

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3. Physiological traits are associated with the ability of the organism to function, such as metabolic functions.
4. Behavioral traits are associated with how an organism responds to its environment.
5. Genetics spans four levels of biological organization (Figure 1.7):
    a. molecular level – the processes of transcription and translation
    b. cellular level – the function of a protein within the cell
    c. organismal level – the observed traits of an organism
    d. population level – the occurrence of the trait in a population under given conditions
6. Alternate forms of a gene are called alleles. Different alleles of a gene have different DNA sequences.

Inherited Differences in Traits Are Due to Genetic Variation

1. Genetic variation is the differences in inherited traits among individuals of a population (Figure 1.8).
2. For species that occupy wide geographic ranges, these differences may be drastic. These are very distinct forms of a single species are called morphs.
3. Genetic variation is due to changes in the nucleotide sequence of the DNA. These variations may be caused by:
    a. gene mutations at the nucleotide level
    b. major structural changes in a chromosome
    c. variation in the total number of chromosomes in an organism

Traits Are Governed by Genes and by the Environment

1. The external environment in which an organism exists may influence that organism's traits.
2. The term norm of reaction refers to the effects of environmental variation on an individual's traits.
3. Example is the human disease phenylketonuria (PKU), which encodes a gene called phenylalanine hydrolase. This gene allows for the metabolism of the phenylalanine amino acid.
    a. Mutations causing a defect in this gene mean that toxic levels of phenylalanine accumulate in the blood, causing mental impairment and developmental problems.
    b. The defective allele is present in 1 in 8,000 individuals in the U.S.

During Reproduction, Genes Are Passed from Parent to Offspring

1. Gregor Mendel first established that genetic information was passed from parent to offspring as discrete units (genes).
2. Sexually reproducing species are usually diploid (two copies of each chromosome, or 2n).
3. The copies of each chromosome are called homologs (Figure 1.10a).
4. Gametes are haploid (one copy of each chromosome, also known as the n number) (Figure 1.10b).
5. Sexual reproduction increases genetic variation in a population.
6. Somatic cells, also known as body cells, are diploid in a diploid organism.

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The Genetic Composition of a Species Evolves from Generation to Generation

1. The change in the genetic composition of a species over time is called biological evolution, or simply evolution.
2. Charles Darwin proposed the theory of natural selection as the mechanism for biological evolution.
3. Over a long period of time, the accumulation of many genetic changes may lead to rather striking modifications in a species' characteristics (Figure 1.11).

*1.3 Fields of Genetics*

***Learning Outcomes:***

1. Compare and contrast the three major fields of genetics: transmission, molecular, and population genetics.
2. Define model organism.

Model Organisms Are Species That Are Studied by Many Different Researchers

1. Genetics is a broad field encompassing molecular, cellular, organism, and population biology.
2. Experimentally, geneticists often focus their efforts on model organisms – organisms studied by many different researchers so they can compare their results and determine scientific principles that apply more broadly to other species.
3. Figure 1.12 shows some common model genetic organisms.

Transmission Genetics Explores the Inheritance Patterns of Traits as They Are Passed from Parents to Offspring

1. Framework provided by Gregor Mendel who suggested that genetic determinants (genes) were discrete units that were passed from generation to generation.
2. Studies of transmission genetics rely on controlled genetic crosses and pedigree analyses to examine how traits are passed from parents to offspring.

Molecular Genetics Focuses on a Biochemical Understanding of the Hereditary Material

1. The workings of the genetic material at the molecular level.
2. Molecular geneticists use a genetic approach to study mutant genes with an abnormal function. These loss of function mutations help geneticists understand the normal role of the gene in the organism.

Population Genetics Is Concerned with Genetic Variation and Its Role in Evolution

1. Involves the use of mathematical theories explain the prevalence of certain genes in a population.
2. Provides a link between the study of transmission genetics (Mendel) and natural selection (Darwin).
3. Population geneticists study the relationship between genetic variation and the environment that an organism inhabits.

*1.4 The Science of Genetics*

***Learning Outcomes:***

1. Describe what makes genetics an experimental science.
2. Outline different strategies for solving problems in genetics.

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Genetics is an Experimental Science
1. Uses hypothesis testing, also known as the scientific method, and discovery-based science.
2. Hypothesis testing involves gathering of data to support or refute a putative conclusion.
3. Discovery-based science involves gathering of data without a preconceived hypothesis.

Genetics TIPS Will Help You to Improve Your Problem-Solving Skills
1. Genetics TIPS are solved problems that walk students through the problem-solving process.
2. Genetics TIPs are presented throughout chapters 2 through 29, in the chapter and at the end of the chapter.
3. Many different problem-solving strategies are used in the Genetics TIPS: Define key terms, Make a drawing, Predict the outcome, Compare and contrast, Relate structure and function, Describe the steps, Propose a hypothesis, Design and experiment, Analyze data, and Make a calculation.
4. Genetics TIPS provides students with practice at applying these problem-solving skills.

*1.5 Gender Identity Versus Sex*

***Learning Outcomes:***

1. Compare and contrast gender identity and sex.
2. Define female and male, as the terms will be used in this textbook.

1. Inclusion, the practice that strives to include all types of people, involves including people from various backgrounds who might otherwise be excluded or marginalized.
2. To achieve inclusion, recognition needs to be given to the entire spectrum of gender identities.

Gender Identity Is a Person's Perception of Their Own Gender
1. Gender refers to socially constructed characteristics that differentiate women and men.
2. Gender identity is a person's inner feelings about whether they are a woman, man, both, or neither. The research and medical community now accepts gender identity as being more complex and is viewed as a spectrum.

Sex Is Rooted in Anatomical and Cellular Characteristics
1. The terms female and male refer to sex but not to gender and so these terms will be used in discussing genetics.
2. In humans, the characteristics of sex includes:
   - An assignment at birth based on external anatomy and internal structures associated with reproduction. A wide variation in internal sex characteristics is observed.
   - The type of gametes an individual has the potential to produce (oocytes and sperm).
   - Sex chromosome composition is typically XX for females and XY for males, but

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variations may appear in some individuals (XXX, XXY, X).

Different Relationships May Occur Between Gender Identity and Sex

1. The prefixes *cis* and *trans* are used to describe the relationship between a person's sex and their gender identity. A nonbinary person has a gender identity that is not solely that of a man or woman.
2. Avoiding the terms related to gender, such as woman, man, mother, father, allows the discussion to focus on sex, not gender.

Sexual Orientation Is a Person's Attraction to Someone Else

1. Gender identity refers to one's inner feelings about oneself. Sexual orientation is about the type of person someone is attracted to in terms of romantic, emotional, and/or sexual attraction.
2. As with gender identity, sexual orientation falls along a spectrum.

*1.6 The Meaning of Normal in Genetics*

***Learning Outcomes:***

1. With regards to genetics, define normal, abnormal, and wild type.

1. When considering inclusion, some terms used in genetics can be misunderstood.

In Genetics, *Normal* Means Common

1. The term *normal* has a positive connation in everyday language whereas *abnormal* may have a negative connotation.
2. In genetics, normal is meant to be a quantitative term, meaning common, displaying a characteristic that is commonly observed.
3. Abnormal means rare, or not very common among members of its species.
4. Wild type refers to any characteristic that is commonly found in members of a given species in nature.

Rare Genetic Variation May Be Beneficial, Neutral or Detrimental

1. Genetic variation can affect an individual's traits that may affect survival and reproductive success and thereby acted upon by natural selection. From this perspective, variation may be beneficial, neutral, or detrimental.

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