Solutions for Concepts of Genetics 4th Edition by Brooker

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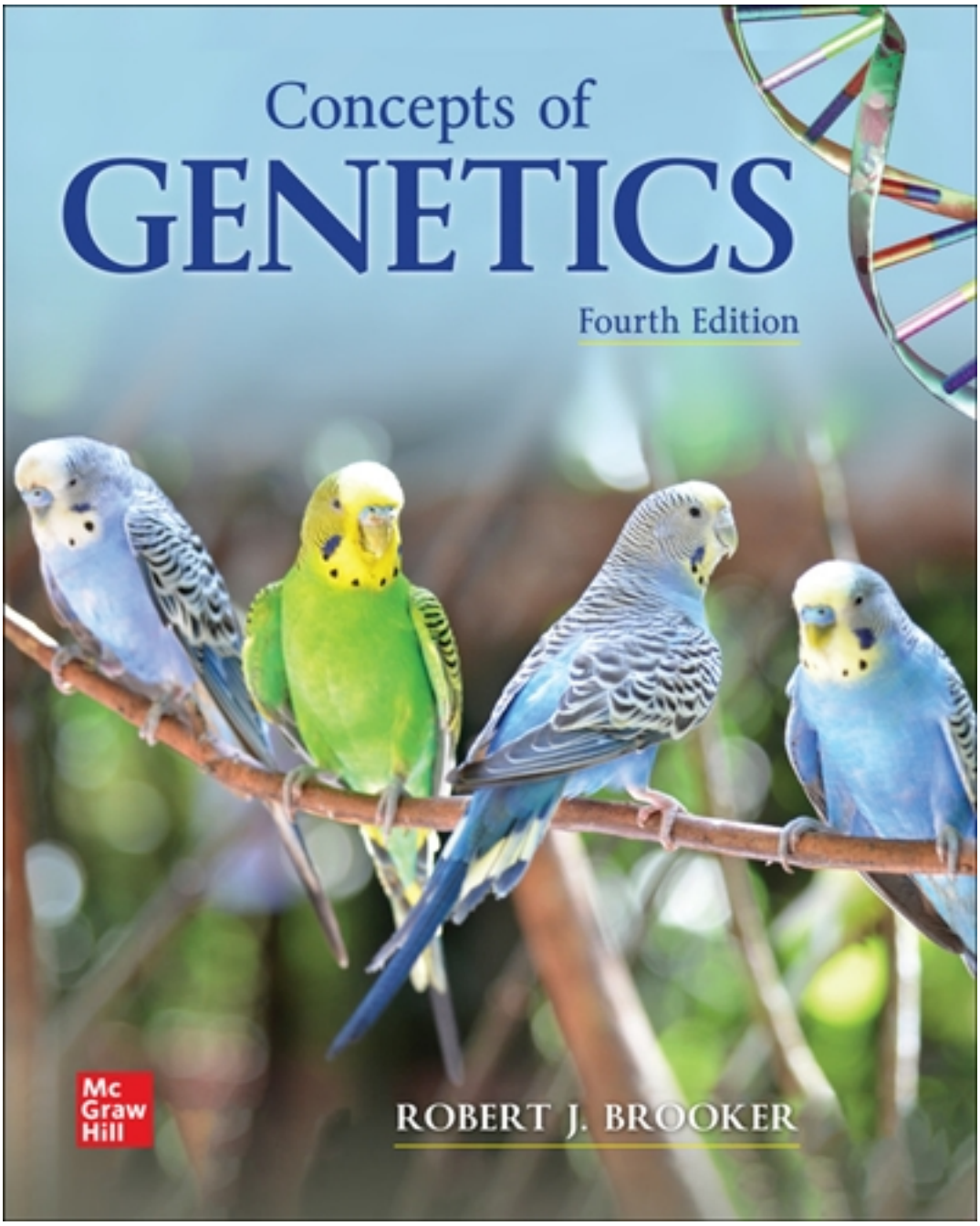


Solutions

Chapter 1: Overview of Genetics

Key Terms

Alleles
Amino acid
Behavioral traits
Biological evolution / Evolution
Carbohydrates
Cellular level
Chromosomes
Codon
Deoxyribonucleic acid (DNA)
Diploid
Discovery-based science
Environment
Enzymes
Gametes
Gene
Gene expression
Gene mutations
Genome
Genetic approach
Genetic code
Genetic cross
Genetics
Genetic variation
Haploid
Homologs
Hypothesis testing
Lipids
Loss-of-function allele
Loss-of-function mutation
Macromolecules
Messenger RNA (mRNA)
Model organisms
Molecular level
Morphological traits
Morphs
Natural selection
Norm of reaction
Nucleic acids
Nucleotides
Organelle
Organism level
Phenylketonuria (PKU)
Physiological traits
Polypeptides
Proteins
Proteome
Population level
Ribonucleic acid (RNA)
Scientific method
Somatic Cells
Species
Traits
Transcription
Translation

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 nucleotides
   b. project is 99.99% accurate (1 in 10,000 nucleotides)
2. Human Genome Project enables scientists to:
   a. determine the number of genes in humans
   b. examine the relationship between genes and living cells
   c. study the evolution of 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 are a result of developments associated with the Human Genome Project.
   a. The development of new medicines, such human insulin manufactured by *E. coli* bacteria.
   b. Cloning of mammals, such as Dolly the sheep by Ian Wilmut and associates (1997).
   c. production of transgenic organisms, such as those that contain an introduced GFP gene from jellyfish

1.1 The Molecular Expression of Genes

Learning Outcomes:

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

1. Genes are the basic units of heredity, while traits are the characteristics of an organism. Genes provide the blueprint for an organism's traits.

Living Cells Are Composed of Biochemicals

1. Organic molecules provide energy for cellular functions as well as the building blocks for larger molecules.
2. Categories of biologically important organic molecules:
   a. nucleic acids
   b. proteins
   c. carbohydrates
   d. lipids
3. Molecules that are made of repetitive subunits are called macromolecules.
4. Larger cellular structures, such as chromosomes, are built from combinations of micromolecules and macromolecules.

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

1. Cellular characteristics are determined primarily by proteins.
2. All of the proteins that a cell or organism makes at a given time is called the proteome.
3. General roles of proteins include: cellular support, transport across the cell membrane, biological motors, cell-to-cell recognition, and cell signaling.
4. Enzymes are primarily proteins that accelerate a chemical reaction.

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 nitrogen-containing base, which is either adenine (A), thymine (T), cytosine (C), or guanine (G).
3. The information in the DNA encodes the sequence of amino acids in a protein.
   a. the genetic code relates the genetic information to the correct amino acid.
4. In cells, DNA is found in chromosomes. The information on a chromosome is organized as genes.
   a. on average, a human chromosome contains about 1,000 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 synthesize a cellular protein.
2. Process includes two steps:
   a. information in the DNA is copied into RNA by transcription
   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, traits, and the environment.
4. Describe how genes are transmitted in sexually reproducing species.
5. Describe the process of evolution.

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.).
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.

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

1. Genetics spans four levels of biological organization:
   a. molecular level – the processes of transcription and translation
   b. cellular level – the function of a protein within the cell

   c. organism level – the observed traits of an organism
   d. population level – the occurrence of the trait in a population
2. Forms of a gene are called alleles.
   a. Different alleles of a gene have different DNA sequences.
   b. An example is eye color in humans. The gene is for eye pigmentation, the alleles of the gene determine the color, and different eye colors are produced by different alleles.

Inherited Differences in Traits Are Due to Genetic Variation

1. Genetic variation is the differences in inherited traits among individuals of a population.
2. For species that occupy wide geographic ranges, these differences may be drastic enough so that scientists may consider the organisms to be different species. These 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

Traits Are Governed by Genes and by the Environment

1. The external environment may influence an organism's traits.
2. The 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 hydroxylase. This gene allows for the metabolism of the amino acid phenylalanine.
   a. mutations causing a defect in this gene mean that toxic levels of phenylalanine accumulate in the blood, causing mental retardation
   b. defective gene present in 1 in 8,000 births in the U.S.
   c. By eating a diet free of phenylalanine, an individual with a defective PKU allele can avoid the symptoms of the disease.

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.
4. Gametes are haploid (one copy of each chromosome, also known as the n number).
5. Sexual reproduction increases genetic variation in a population.
6. Somatic cells, also known as body cells, are diploid.

The Genetic Composition of a Species Evolves from Generation to Generations

1. The change in the genetic composition of a species over time is called biological evolution.

2. Charles Darwin proposed the theory of natural selection as the mechanism for biological evolution.

1.3 Fields of Genetics

Learning Outcome:

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

1. Genetics is a broad discipline encompassing molecular, cellular, organism, and population biology.
2. The study of 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) have led to our understanding of genes in all species.

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 the genetic cross to examine how traits are passed from parents to offspring.

Molecular Genetics Focuses on a Biochemical Understanding of the Hereditary Material

1. The goal is to understand 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.
   a. Loss-of-function alleles (mutations) help geneticists understand the 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 to 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.

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. Students' learning will involve two general goals:
   a. Foundational knowledge – Learn to describe core concepts in genetics.
   b. Problem-solving skills – Be able to apply that knowledge in different ways.
2. The boxed feature in the textbook chapters called Genetics TIPS will help students develop these skills
   a. Topic, Information, and Problem-solving Strategy

List of Key Investigators

Chalfie, Martin – received Nobel Prize for the discovery and development of GFP.

Crisanti, Andrea – altered mosquitoes to express GFP only in the gonads of males, to allow them to sort males from females.

Darwin, Charles – Proposed the theory of natural selection as the mechanism for biological evolution.

Mendel, Gregor – Determined that genetic information was from generation to generation in discrete units.

Shimomura, Osamu – received Nobel Prize for the discovery and development of GFP.

Tsien, Roger – received Nobel Prize for the discovery and development of GFP.

Wilmut, Ian – Created Dolly, the first mammalian clone from an adult animal.

CONCEPTS OF GENETICS, 4/e

ANSWERS TO PROBLEM SETS
Chapters 1-24

CHAPTER 1

Note: the answers to the Comprehension Questions are at the end of the chapter.

Concept Check Questions (in figure legends)

FIGURE 1.1

Understanding our genes may help with diagnoses of 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 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 18, 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-producing enzyme.

FIGURE 1.8

Genetic variation is the reason the frogs look different.

FIGURE 1.9

These are examples of variation in chromosome number.

FIGURE 1.10

If this girl had been given a standard diet, she would have developed the harmful symptoms of PKU, which include mental impairment and foul-smelling urine.

FIGURE 1.11

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

FIGURE 1.12

The horse populations have become adapted to their environment, which has changed over the course of many years.
FIGURE 1.13
There are several possible examples of other model organisms, including rats and frogs.

End-of-chapter Questions:
Conceptual Questions

C1. A chromosome is a very long polymer of DNA. A gene is a specific sequence of DNA within that polymer; the sequence of bases creates a gene and distinguishes it from other genes. Genes are located in chromosomes, which are found within living cells.

C2. At the molecular level, a gene (a sequence of DNA) is first transcribed into RNA. The genetic code within the RNA is used to synthesize a protein with a particular amino acid sequence. This second process is called translation.

C3. 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.

C4. Genetic variation is the occurrence of genetic differences within members of the same species or 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. Examples include differences in coat color among mammals or flower color in plants. At the molecular level, this type of genetic variation is caused by changes in the DNA sequences of genes. There may also be variation in chromosome structure and number.

C5. An extra chromosome (specifically an extra copy of chromosome 21) causes Down syndrome.

C6. 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 in a flower color gene that affect this trait in petunias. In addition, the amount of sunlight, fertilizer, and water also affects the intensity of flower color.

C7. The term *diploid* means that a cell has two copies of each type of chromosome. In humans, nearly all of the cells are diploid except for gametes (i.e., sperm and egg cells). Gametes usually have only one set of chromosomes.

C8. 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 speaking of a DNA sequence, the focus is on the sequence of those bases.

C9. The genetic code is the way in which the sequence of bases in RNA is read to produce a sequence of amino acids within a protein.

C10. A. A gene is a segment of DNA. For most genes, the expression of the gene results in the production of a polypeptide, which is a unit of a protein. The functioning of proteins within living cells largely determines the traits of an organism.
B. A gene is a segment of DNA that usually encodes the information for the production of a specific polypeptide. 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 a plant has a flower color gene. One allele could produce a white flower, while a different allele could produce an orange flower. The white allele and orange allele are alleles of the flower color gene.
D. A DNA sequence is a sequence of bases, which are found within nucleotides. The information within a DNA sequence (which is transcribed into an RNA sequence) specifies the amino acid sequence within a polypeptide.

C11. 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.

C12. 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.

Application and Experimental Questions

E1. 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.

E2. A genetic cross involves breeding two different individuals.

E3. This would be used to a great extent by molecular geneticists. The sequence of DNA is a molecular characteristic of DNA. In addition, the sequence of DNA is interesting to transmission and population geneticists as well.

E4. You would see 47 chromosomes instead of 46. There would be three copies of chromosome 21 instead of two copies.

E5. A. Transmission geneticists. Dog breeders are interested in how genetic crosses affect the traits of dogs.
B. Molecular geneticists. This is a good model organism to study genetics at the molecular level.
C. Both transmission geneticists and molecular geneticists. Fruit flies are easy to cross and study 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 the subject of population geneticists. In the wild, you cannot make controlled crosses. But you can study genetic variation within populations 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.

E6. 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 at the end of the chapter.

Concept Check Questions (in figure legends)

FIGURE 2.1

Compartmentalization means that 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, banding pattern, and carry the same types of genes. However, the alleles of a given gene may be different.

FIGURE 2.4

FtsZ assembles into a ring at the future site of the septum and recruits to that site other proteins that produce a cell wall between the two daughter cells.

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 a phase in which a cell is either not advancing through the cell cycle or has committed to never divide again.

FIGURE 2.6

Homologs are genetically similar; one is inherited from the mother and the other from the father. 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 motor proteins shorten the contractile ring, which is formed from actin proteins.

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 that are produced during oogenesis and then degenerate.

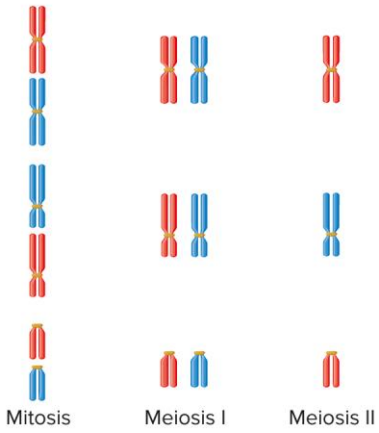
FIGURE 2.14

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

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 and order of genes. 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 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. G_1, there should be six linear chromosomes. In G_2, there should be 12 chromatids that are attached to each other in 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 the attachment is lost, a chromosome will not migrate to a pole and may 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.



C10. It means that the maternally derived and paternally derived chromosomes are randomly aligned along the metaphase plate during metaphase of meiosis I.
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 alignments equals 2^n, where *n* equals 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 would be much lower because pieces of maternal chromosomes would be incorporated into the paternal chromosomes. Therefore, a gamete would be unlikely to carry a chromosome that was completely paternally derived.

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 condensation process probably occurs so that the chromosomes easily align along the equatorial 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 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 of meiosis I and their separation during anaphase of meiosis 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 the 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.

Prophase/Prometaphase	Telophase
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 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. Male gametes are usually small and mobile. Animal and some plant male gametes have flagella, which make them motile. The mobility of the male gamete makes it likely that it will 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.

C25. 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.

C26. During oogenesis in humans, the cells are arrested in prophase of meiosis I for many years until selected primary oocytes advance through the rest of meiosis I and begin meiosis II. If fertilization occurs, meiosis II is completed.

C27. There is a 1/2 chance that the mother will transmit her abnormal chromosome and a 1/2 chance that the father will. You use the product rule to calculate the chances of both outcomes 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.

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

E3. You could karyotype other members of the family and see if affected members always carry the abnormal chromosome.

Questions for Student Discussion/Collaboration

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