16

Meiosis and Sexual Reproduction

After you have finished reading this chapter, you should be able to:

Explain the importance of reduction division to sexual reproduction.

Describe what happens to chromosomes during Meiosis I and Meiosis II.

Discuss methods of sexual reproduction in plants and animals.

And here's the happy bounding flea,
You cannot tell the he from she.
The sexes look alike, you see;
But she can tell, and so can he.

Roland Young, *The Flea*

Introduction

For almost all animals, it takes two to reproduce—a male and a female. This is **sexual reproduction**. Even most plants use this method of reproduction to make more of their own kind. Sexual reproduction is very important in understanding living things. It also plays a significant role in the process of evolution. To understand why this is so, we must look, as always, at individual cells. Within cells, we must closely examine the chromosomes. (See Figure 16-1 on page 340.)

IT'S ALL ABOUT CHROMOSOMES

Each of our cells contains chromosomes. The word *chromosome* means "colored body." Chromosomes are microscopically small. They were discovered only in the late 1800s as microscope lenses were improved. With a microscope, chromosomes can be observed when the cell is stained with a dark dye. The chromosomes absorb the dye and appear to be colored, thus giving them their name.

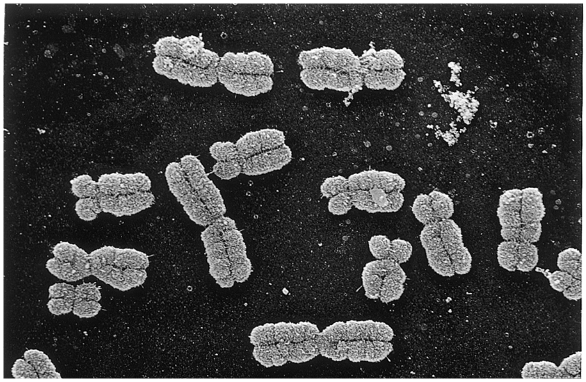


Figure 16-1 Human chromosomes.

Chromosomes have the two most important jobs in the world. They contain the inherited information that has been passed along from the beginning of life on Earth. It is this information that determines an individual's characteristics. In humans, this information makes us who we are. The chromosomes also contain the "know-how" that keeps our cells running correctly. This is what keeps us and all organisms alive.

Why is sexual reproduction all about chromosomes? About 105 years ago, it was observed—again with the newly improved microscopes—that when a sperm cell and an egg cell unite during sexual reproduction, it is the nucleus from each cell that joins. In particular, it is only after the nucleus from the sperm cell enters the egg cell and fuses with its nucleus that the development of a new organism begins. (See Figure 16-2.) What

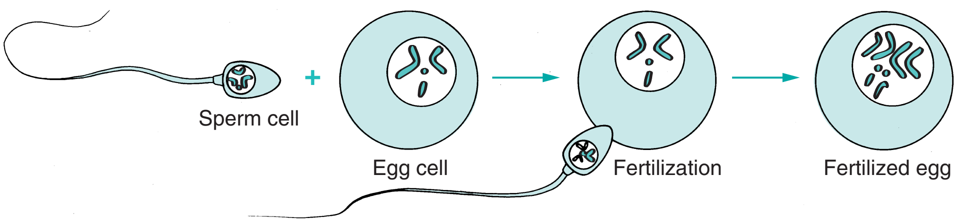


Figure 16-2 Sexual reproduction involves the joining of chromosomes from a sperm cell and an egg cell.

does the nucleus contain? The chromosomes, of course. So sexual reproduction is all about joining chromosomes from two individuals, usually those from a male individual (the father) with those from a female individual (the mother). Put this way, it does not sound very romantic, but that's biology.

How many chromosomes are found in a human body cell? In the past

100 years, guesses based on microscopic observation have varied from 8 to 50 chromosomes per cell. Finally, T. C. Hou, a young Ph.D. student at the University of Texas, accidentally found a way to separate the chromosomes and count them accurately. Hou found that human body cells each contain 46 chromosomes.

Right away, a problem becomes obvious. Your body cells require a chromosome number of 46. That means that the first cell from which each of us came, the cell resulting from the combination of a sperm and an egg, must have had 46 chromosomes. The fertilized egg divided by mitosis many, many times to become you. After each mitotic division, the number of chromosomes in each body cell is equal to that of the parent cell. Therefore, every body cell now in you still has 46 chromosomes. The problem is, how can a cell from each of your parents, a sperm and an egg, combine to make a new cell with 46 chromosomes?

Arithmetic tells us there is only one way. Both the sperm and the egg must have only 23 chromosomes—half the number of chromosomes from the normal number of 46. And indeed this is the case. In this chapter, you will study the type of cell division that produces sperm and egg cells, which have that reduced number of chromosomes. (See Figure 16-3.)

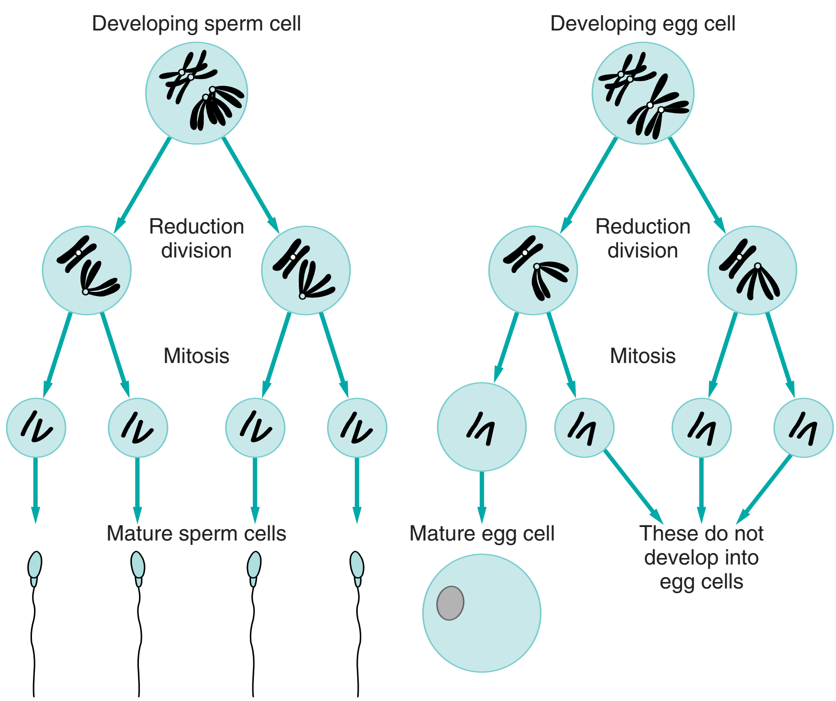


Figure 16-3 Sperm cells and egg cells have half the normal number of chromosomes for their species.

GAMETES

The sperm and egg cells, or sex cells, are called **gametes**. In the process of sexual reproduction, the nuclei of the gametes join together. This fusion of the nuclei is called **fertilization**. The resulting cell, a fertilized egg cell, is called a **zygote.**

Each gamete, as we have said, has exactly one-half the normal number of chromosomes. Cells that have half the normal number of chromosomes are said to be **haploid**. In humans, the haploid number is 23. The zygote and all body cells that come from the mitotic division of the zygote have two sets of chromosomes in them, one from each parent. These cells are **diploid**. In humans, the diploid number is 46.

Haploid gamete cells must be made by a special type of cell division that reduces the chromosome number by one-half; so, when fertilization occurs, the normal diploid number of chromosomes for the species is maintained. This type of cell division is called **meiosis**.

A CLOSER LOOK AT CHROMOSOMES

Grasshoppers played an important role in helping us understand the next step in the story of sexual reproduction. In 1903, Walter Sutton, a graduate student at Columbia University in New York City, observed grasshopper cells to study their chromosomes. (See Figure 16-4.) By looking closely at the diploid set of chromosomes in grasshopper cells, Sutton discovered something very interesting. Each chromosome in the set had a partner that matched it perfectly in shape and size. The chromosomes came in pairs. These pairs are known as **homologous chromosomes**.

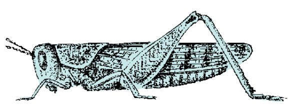


Figure 16-4 Walter Sutton studied the chromosomes of grasshoppers.

Our chromosomes therefore exist in homologous pairs. Essentially, we have two chromosomes of each type. And where does each of these two chromosomes come from? That question should be easy to answer: one from each parent. Now we have a clear idea of the job that must be performed by meiosis. Beginning with a normal diploid body cell, gametes must be produced through meiotic cell division. Each gamete contains a haploid set of chromosomes. And it must be an exact set, meaning one and only one of each of the homologous chromosomes.

Today it is a standard procedure to examine the chromosomes in human cells. White blood cells are used. Certain diseases can be detected in unusual patterns in chromosomes. While undergoing mitosis, white

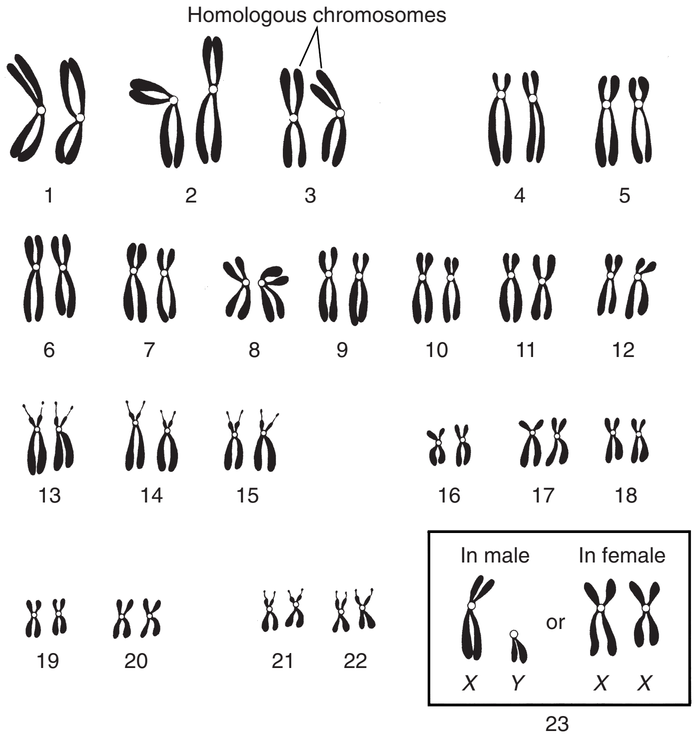


Figure 16-5 A karyotype is prepared by arranging pictures of matching chromosomes by size and shape.

blood cells are collected and their chromosomes are photographed under magnification. Pictures of the chromosomes are enlarged, cut out, and arranged by size and shape. This process of arranging pictures of chromosomes by their size and shape is called preparing a **karyotype**. In Chapter 22, you will see that it is often very important to study the karyotype of chromosomes in a developing fetus's cells. (See Figure 16-5.)

MEIOSIS: REDUCING THE CHROMOSOME NUMBER

Mitosis and meiosis take place during cell division, and in some ways these two processes are similar. Chromosomes replicate before either process begins. However, the results of mitosis and meiosis are very different. When mitosis is completed, the chromosome number remains the same as the original parent cells. When meiosis is completed, the chromosome number is half the original number. (See table on page 344.)

How does this happen? Meiosis actually involves two separate cell divisions that take place one after the other. Meiosis I is the first cell division in this process. It is called **reduction division** because it is during this

SOME DIFFERENCES BETWEEN MITOSIS AND MEIOSIS

Mitosis	Meiosis
Double-stranded chromosomes line up in middle of the cell in single file.	Double-stranded chromosomes line up in middle of the cell in double file (i.e., in tetrads).
Results in diploid number of chromosomes in daughter cells (i.e., the normal species number).	Results in haploid number of chromosomes in daughter cells (i.e., half the species number).
Process occurs in all cells of the body.	Process occurs only in certain cells of the sex organs.
Results in very few genetic variations because the chromosomes retain their identity.	Results in many genetic variations because the chromosomes break and exchange parts during synapsis.

process that the chromosome number is halved. At the beginning (Prophase I), we see the familiar double-stranded chromosomes not enclosed by a nuclear membrane. Just as in mitosis, each double-stranded chromosome consists of two chromatids. Unlike mitosis, however, we also begin to see the homologous chromosomes pairing up in a process called *synapsis*. Two double-stranded homologous chromosomes consist of four chromatids, two each. These are therefore called **tetrads** (*tetra* means "four"). (See Figure 16-6a.)

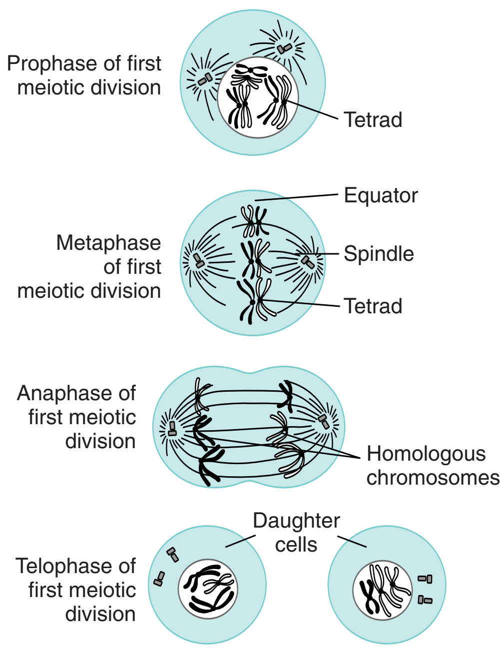


Figure 16-6a Meiosis I.

Now the chromosomes line up (Metaphase I). However, this time they are not in single file. They are in homologous pairs. In Anaphase I, the paired chromosomes separate, with the homologous chromosome (consisting of two chromatids) from each pair moving to opposite ends of the cell. Finally, in Telophase I, we have two new cells, each with only one of each homologous chromosome. For humans, if we began with the 46 double-stranded chromosomes, we now have two cells, each having 23 double-stranded chromosomes.

The second division, Meiosis II, also passes through four stages. In Meiosis II, the chromosome number is not being reduced. Rather, the chromatids from each double-stranded chromosome are being separated. Meiosis II in humans begins with two cells that have 23 double-stranded chromosomes each. It ends with four cells, each with 23 single-stranded chromosomes. (See Figure 16-6b.)

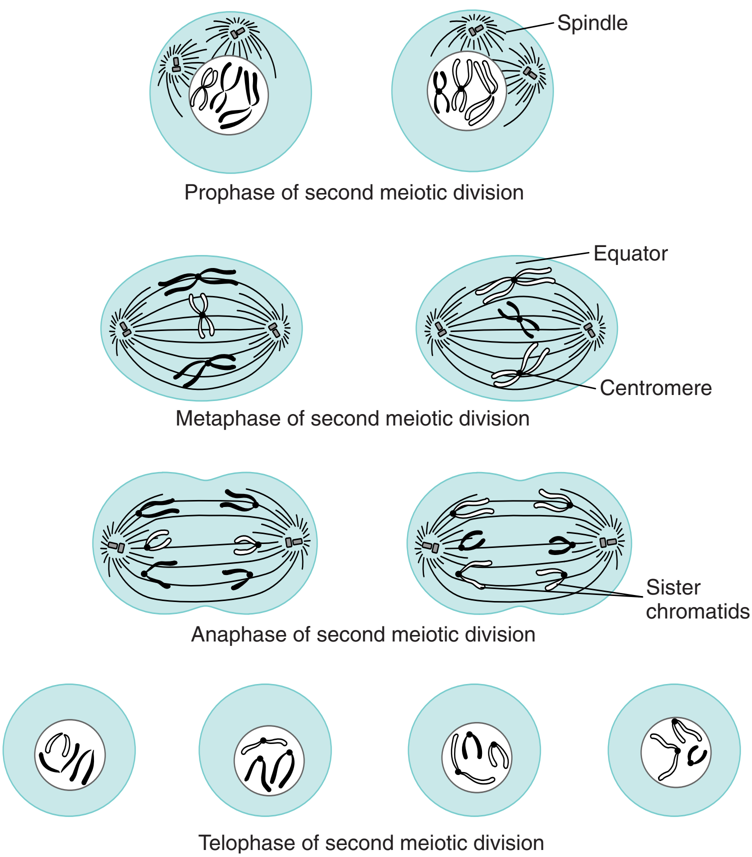


Figure 16-6b Meiosis II.

MEIOSIS I: THE SOURCE OF OUR DIFFERENCES

With the exception of identical twins, children in the same family are never exactly alike. Differences occur in eye color, hair color, hair texture, height, nose shape, ear size, and many other characteristics. Why is this so, if the children were born of the same parents? The explanation for these differences lies in the details of Meiosis I.

During Prophase I, tetrads are formed. The chromatids of homologous chromosomes are very close to each other. In fact, they often overlap and actually exchange pieces in a process called **crossing-over**. (See Figure 16-7.) Why is crossing-over important?

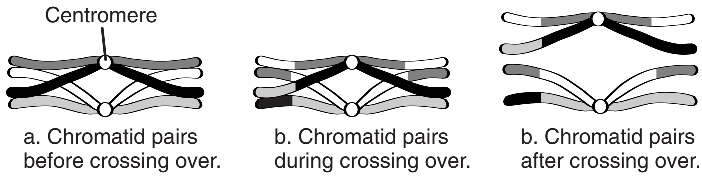


Figure 16-7 In crossing-over, the chromatids of homologous chromosomes overlap and exchange pieces.

Suppose we are looking at a pair of homologous chromosomes from a plant. The same genes are located at the same places on each chromosome. However, the version of the gene may be different on each chromosome. For example, both chromosomes have a gene for plant height and a gene for flower color. But chromosome A has the genes for tall plants and white flowers, while chromosome B has the genes for short plants and yellow flowers. After crossing-over, the positions of genes on a chromosome are altered. The new arrangement puts the genes for tall plants and yellow flowers on the same chromosome, and the genes for short plants and white flowers on the same chromosome. This is obviously a new combination of genes. As a result of crossing-over, genetic **recombination** has occurred. The offspring may have combinations of genetic traits that neither parent had. (See Figure 16-8.) This happens in all meiotic cell divisions. Imagine how many new combinations are possible in humans, when there are 23 pairs of homologous chromosomes, with about 30,000 to 50,000 different genes altogether. The potential number of gene recombinations is staggering!

However, there is yet another major source of our genetic and physical differences. This source of change occurs during Metaphase I. We get one of each homologous chromosome from each parent: the maternal chromosome from Mom and the paternal chromosome from Dad. Imagine the

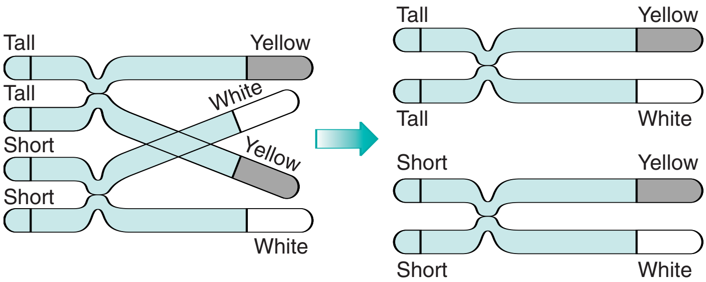


Figure 16-8 Genetic recombination is the result of crossing-over.

maternal chromosomes were green and the paternal ones yellow. (Of course, they have no color unless they are artificially stained.) Nevertheless, the green maternal chromosomes could all line up on the left side, the yellow paternal ones on the right side. This would put only green maternal chromosomes in one daughter cell and only yellow paternal chromosomes in the other daughter cell. However, there is no rule as to how they line up. Any number of maternals may be on one side; any number of paternals on the other. Each time meiosis occurs, the lining up can be different. This is known as **independent assortment**. The number of possible different assortments is huge. In fact, with 23 chromosome pairs in humans, there are more than eight million (2^{23}) different possible arrangements. Since this happens during meiosis in both parents, the chances of two identical children being born at different times within one family are one in 70 trillion ($2^{23} \times 2^{23}$). You have a much better chance of winning a lottery, and you know how small that chance is! (See Figure 16-9.)

In conclusion, meiosis has two all-important functions. First, meiosis maintains the normal species chromosome number by preparing haploid

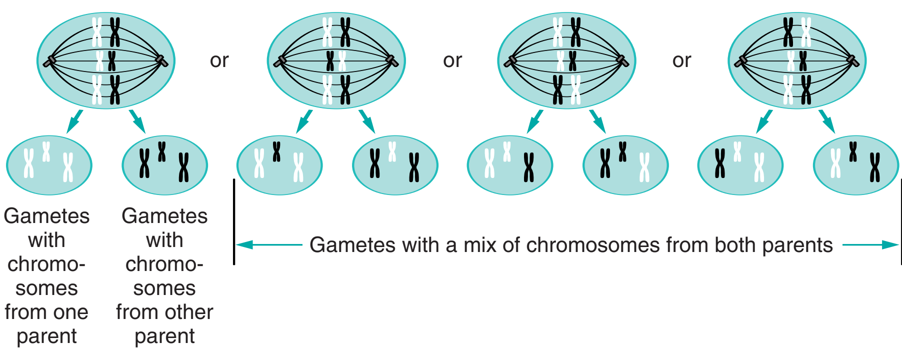


Figure 16-9 Each time meiosis occurs, the chromosomes line up in a different arrangement.

gametes. The two haploid gametes are able to fuse during sexual reproduction to make a diploid zygote, with the characteristic species chromosome number.

Second, meiosis increases genetic variability by recombining genes in eggs and sperm. Because of meiosis, sexual reproduction results in offspring that are different from each other and from their parents. This genetic variation is what natural selection acts on. A greater variety of characteristics in offspring increases the chances that some individuals will be better suited than others to survive in a particular place and time. As natural selection acts on the varied offspring, generation after generation, the species evolves.

Check Your Understanding

Why does crossing-over occur only between homologous chromosomes? How does this lead to genetic variation?

MEIOTIC MISTAKES

The dance of the chromosomes that occurs in cell division—especially during meiosis—is a wonderfully complex sequence of events. However, it does not always proceed correctly. For example, in Meiosis I, a pair of homologous chromosomes occasionally fails to separate; and in Meiosis II, sometimes a double-stranded chromosome does not separate. Either of these situations creates gametes with an incorrect number of chromosomes. A gamete may have an extra chromosome because it has both members of a homologous pair of chromosomes, instead of only one. Or a gamete may be one chromosome short, having neither member of a homologous pair. These differences are called **chromosomal abnormalities**. If a gamete with such an abnormality fuses with another gamete, problems occur. In most instances, the zygote fails to develop. However, in some cases, the zygote does develop into an individual with an abnormal chromosome number.

One of the best-known examples of this is the disorder known as Down syndrome. In this case, a person has an extra copy of chromosome 21, resulting in a total of 47 chromosomes instead of the normal 46. The serious problems that occur include mental and physical disabilities, greater risks of developing leukemia and heart disease, and often a shorter-than-normal life span.

At one time, Down syndrome children rarely lived beyond age 10. Today, there is significant potential for development in Down syndrome children. In fact, the popular 1990s television program *Life Goes On*

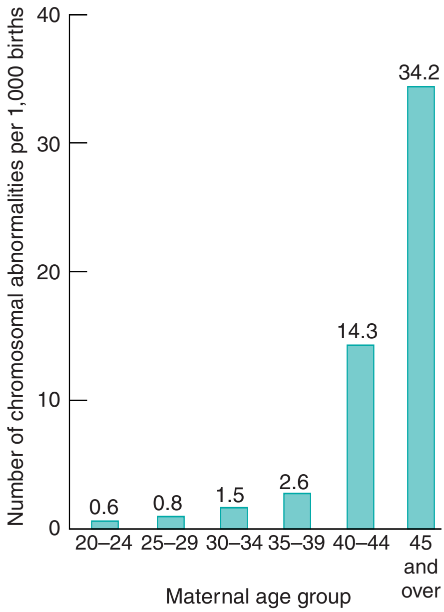


Figure 16-10 As maternal age increases, especially after 40, the possibility of giving birth to a child with a chromosomal abnormality increases.

starred Chris Burke, an actor with Down syndrome. By the year 2002, at age 37, Burke was recording music and making appearances in such shows as *The Commish* and *Touched by an Angel*.

The age of the mother affects the chances of having a child with Down syndrome. For a mother between the ages of 20 and 24, the chances are 6 in 10,000 births. For a mother who is 45 years old or over, the chances increase greatly, to 342 in 10,000 births. Early detection of a chromosomal abnormality such as this is one of the main reasons for preparing a karyotype of fetal cells early in a woman's pregnancy. (See Figure 16-10.)

THE SEX LIFE OF FLOWERING PLANTS

Of the many types of plants on Earth, flowering plants are the group that has evolved most recently. Most types of plants reproduce sexually. As in animals, the male gamete (sperm) joins together with the female gamete (egg) to produce a zygote. The zygote then begins to grow into the new plant. What is special about flowering plants is that the place where all this happens is very visible. The location is often brightly colored, beautifully shaped, and sweet smelling. Flowers are the parts of plants where sexual reproduction occurs. In fact, the parts that make up flowers include the sex organs of the plants. Let's take a closer look. (See Figure 16-11 on page 350.)

A typical flower contains a central structure called the **pistil**. The pistil consists of three parts. The base of the pistil is the **ovary**. The ovary

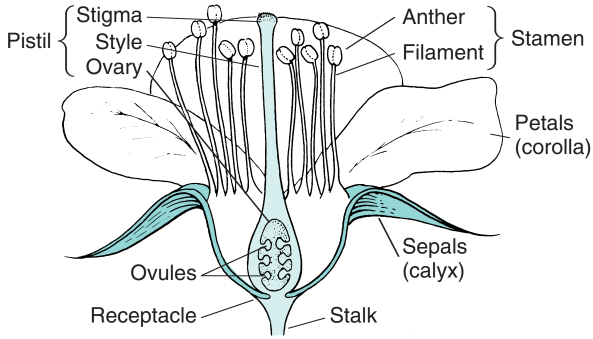


Figure 16-11 In plants, sexual reproduction takes place in the flowers.

contains eggs cells, as in animals. Above the ovary is the **style**. The style is usually long and thin. Located on top of the style is the "sticky" **stigma**. The pistil contains the female reproductive parts of the plant. Often seen arranged around the pistil are a number of **stamens**. Each stamen consists of an **anther** supported by a thin **filament**. The anther is the source of countless numbers of tiny pollen grains. Each pollen grain contains sperm cells. The stamens are the male reproductive structures of the plant.

Why is the stigma sticky? It must catch and hold the pollen grains that land on it. Each pollen grain begins to grow a tube down through the style. Eventually, a sperm nucleus from the pollen grain reaches and fertilizes an egg cell in the ovary. The sperm and egg cells fuse, fertilization occurs, and a zygote is the result. (See Figure 16-12.)

But why is the rest of the flower so showy? Anything that increases the chances of fertilization occurring—which involves getting pollen grains to the sticky stigma—is a survival advantage to the plant species. One of the best methods of getting pollen grains to the stigma is through the action of insects. Many flowers produce nectar, a nutrient-rich, sweet-smelling fluid. Insects such as bees are attracted by the nectar, since it is a good

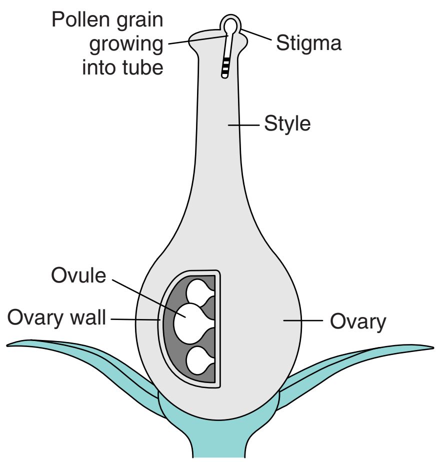


Figure 16-12 The pollen grain grows a tube down through the style until it reaches the ovary and fertilizes an egg cell.

source of energy. While gathering it, the bees carry pollen from the anther to the stigma. Other types of flowers have structures that allow wind to blow pollen from one flower to another. There are many different types of flowers and methods of **pollination**. In all cases, however, the same process, sexual reproduction, is about to occur after the transfer of pollen from an anther to a stigma. The next time you look at a flower, it may be of interest to remember that these are the reproductive organs of a plant. The ultimate purpose of a flower is to make more of its own kind.

SEXUAL REPRODUCTION: ON THE INSIDE OR THE OUTSIDE?

Various methods of sexual reproduction occur in plant and animal species. However, whatever the method, sexual reproduction always involves fertilization—the fusing of nuclei from gametes; and development—the growth of the zygote into a new individual. One of the main differences in the types of reproduction involves the location of the events. As strange as it may seem, both fertilization and development may occur either inside or outside the bodies of the reproducing organisms. Let's see how.

Single-celled algae and many plants live in water. Gametes, both sperm and eggs, meet in the open water. Fertilization occurs, and the zygote begins to develop. These events that occur in the environment, and not inside the organism, are known as external fertilization and external development. (See Figure 16-13.)

Although plants first evolved in water, many species eventually adapted

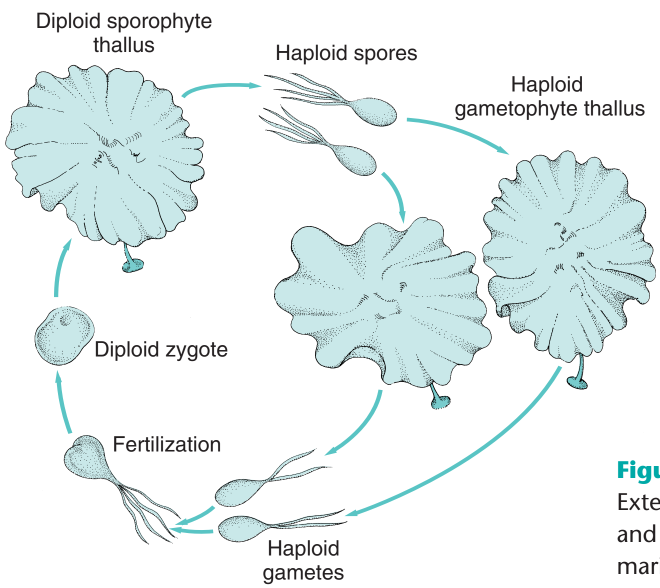


Figure 16-13 External fertilization and development in a marine alga.

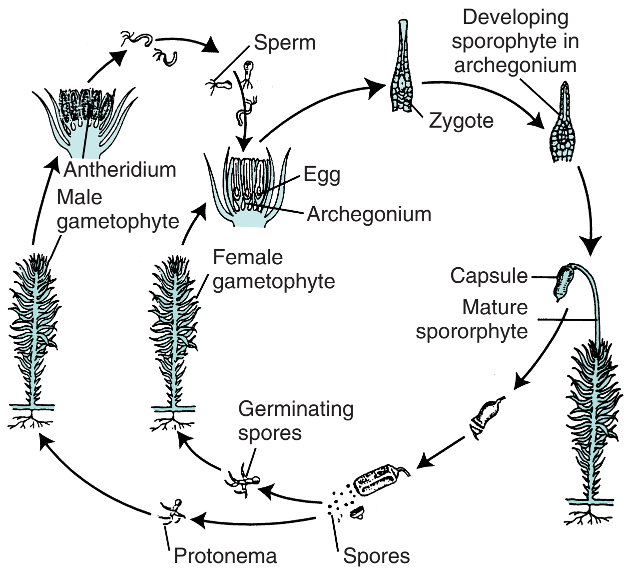


Figure 16-14 Internal fertilization and development in a moss plant.

to life on land. One of the important changes that occurred was the evolution of internal fertilization and development. For example, a moss plant consists of a small bundle of leaves that live on the moist forest floor. Egg cells develop inside a round structure on the plant. Sperm cells are attracted to this structure and swim to it. They enter it and fertilize the egg. The zygote develops into a new moss plant. (See Figure 16-14.)

External fertilization in animals requires a watery environment. Many invertebrates simply release their eggs and sperm into the water. This happens with the coral animals that make up the beautiful reefs around tropical islands. When a sperm and an egg unite, the zygote develops into an immature, free-swimming **larva**. The larva continues to grow and eventually settles down on the coral reef along with other adult coral animals.

Two groups of vertebrates, the fish and the amphibians, reproduce in water. In most species of fish, fertilization is external, with egg cells and sperm cells being released into the water by the female and male fish, respectively. The zygotes also begin their lives outside the body of the female. For this method of reproduction to be successful, large numbers of sperm and egg cells must be produced. Also, the female's eggs must be fertilized by the sperm of a male from the same species—preferably a strong, healthy one. Aquatic animals will often behave in amazing ways for these reasons at the time of spawning, or reproduction. For example, several male salmon will closely follow a female salmon to the place

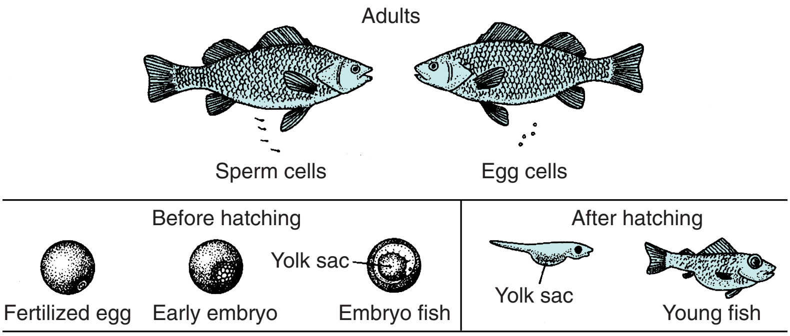


Figure 16-15 In most species of fish, fertilization and development are external.

where she prepares a nest in the river bottom. The males fight each other until the strongest one remains. The male is ready to release his sperm into the water the moment the female lays her eggs. On the river bottom, the fertilized eggs begin to develop. (See Figure 16-15.)

Amphibians also release their eggs into the water, where they are fertilized and develop into adults. Amphibians usually provide no parental care. However, there is one species of tropical frog in which the males carry the developing embryos as tadpoles in their stomachs. During this time, the male's stomach does not release digestive juices. Once the tadpoles have developed and are ready to live on their own, the male opens his mouth and out hop the young frogs!

Similarities and differences can be seen in the patterns of sexual reproduction in the vertebrates that reproduce on land. Gametes need moisture to meet and fuse. Reptiles and birds make use of the fluids inside their bodies for fertilization. Fertilization is internal, within the body of the female. The male and the female must mate for the sperm to be deposited in the female. Once fertilization occurs, the fertilized egg is prepared for development on land. A watertight membrane, the **amnion**, forms around the fertilized egg. (See Figure 16-16.) A protective shell also forms, the egg is laid, and the development of the new organism now occurs externally.

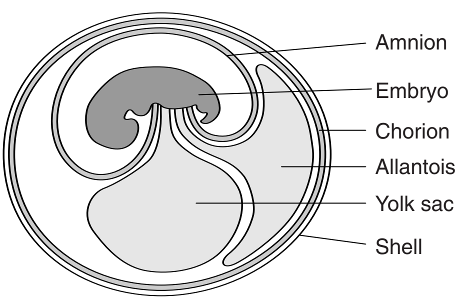


Figure 16-16 In birds, fertilization is internal. The amnion, a watertight membrane, forms around the fertilized egg, which is then covered with a shell. Development takes place externally.

Group Courtship Among the Corals

It seems impossible to imagine all organisms of a single species reproducing at the same time. But this is exactly what happens when all trees of a species simultaneously release pollen into the wind to fertilize the female flowers of that species. Still, in animal species, simultaneous reproduction of many individuals is a rare occurrence. However, one of the most spectacular underwater events involves the mass spawning of the millions of small organisms that make up a coral reef. A coral reef is a stony structure made of minerals removed from the water, over a long period of time, by tiny coral animals that live on the outer edges of the reef. Reefs are found only in the clear, warm, shallow waters of the tropics. During their lifetime, coral organisms remain in one place. They catch and remove food particles from the water that surrounds them. One good place to observe the mass spawning of coral animals is the Flower Gardens National Marine Sanctuary in the Gulf of Mexico.

One of the most amazing things about a mass spawning is its timing. It involves all coral animals in an area at the same time. The coral animals release packets of eggs and sperm simultaneously. This is called the *synchronous release of gametes*. Even more amazing is that this release of gametes happens only once a year, and at exactly the same time each year! At Flower Gardens, you must be diving on the eighth night after the full moon in August, between the hours of eight and eleven, to see this. What you see is the water teeming with brightly colored eggs intermixing with countless packets of sperm. To see this again, you need to come back one year later, again eight nights after the August full moon, and at the same time in the evening.

Scientists believe that mass spawning increases the chances of successful fertilization in three ways. First, with so many eggs and sperm in the water at the same time, fertilization is more likely to occur. Second, with gametes from different colonies of one species being released at the same time, cross-fertilization between different colonies is more likely. This increases the genetic variation among the offspring. Finally, with so many fertilized gametes in the water at once, the amount lost to predation is limited.

This is "love on the rocks," and it happens once every year.

(In Chapter 18, you will look more closely at the structure of the amniotic egg.) The eggs of some snakes develop within the female, and she gives "birth" to live young. Turtles simply bury their eggs in the ground, where they hatch several weeks later. Alligators prepare elaborate nests for their eggs. During incubation and after the eggs hatch, the alligator parents care for their offspring. Most birds prepare nests and provide careful supervision of the eggs by sitting on them, keeping the eggs warm until they hatch. The parents then care for the young, bringing food to and providing protection for the hatchlings.

One final pattern of sexual reproduction takes place only in mammals. Fertilization occurs internally. Males often fight with one another for the chance to mate with an available female or females. With many mammals, mating occurs only at a specific time of the year. What is the big difference between mammals and most other animal groups? It is that the development of the zygote occurs within the body of the female. The food for the developing embryo comes entirely from the body of the mother. A structure, the **placenta**, has evolved to bring nutrients to the developing baby and to remove wastes. After birth, continuing nourishment of the baby mammal occurs through its nursing on milk provided by the mother's mammary glands. Of course, there are exceptions even among the mammals. *Marsupials*, such as kangaroos, are mammals that do not have a placenta. Instead, they give birth to very undeveloped embryos, which continue to develop and receive nutrition from mammary glands within the mother's pouch. The platypus and the echidna are unusual mammals that lay eggs, which develop outside of the female's body. Yet they also nurse their offspring after they hatch.

Two ways to compare patterns of sexual reproduction are in terms of the number of eggs and the amount of parental care provided. External fertilization and development are risky. Eggs and sperm may not meet and, even if they do, the fertilized eggs may easily be destroyed before they can develop. Large numbers of eggs increase the chances of reproduction and the chance that some offspring will survive. Internal fertilization, while more complex, increases the chances of reproductive success and survival; so, fewer eggs are produced. Providing parental care also protects the developing embryo. The most complete form of protection, of course, is allowing the embryo to develop within the body of the female. (See table below.)

SEXUAL REPRODUCTION IN VERTEBRATES

Vertebrate	Fertilization	Development	Number of Eggs	Parental Care
Fish	Most external	Most external	Many	None, usually
Amphibians	External	External	Many	None, usually
Reptiles	Internal	Most external	Not very many	Little
Birds	Internal	External	Few	Much
Mammals	Internal	Most internal	Few	Much

LABORATORY INVESTIGATION 16

What Are the Relationships Among the Structures of Flowers, Fruits, and Seeds?

INTRODUCTION

Because a flower is the reproductive organ of higher plants, someone once suggested that a "flower is a plant's way of making more flowers." In this investigation, you will observe and compare the structures of flowers, fruits, and seeds.

MATERIALS

Gladiolus flowers, scalpels, hand lens, pea pods, presoaked lima beans

PROCEDURE

1. Observe the gladiolus flower. Describe the appearance of the sepals and the petals. Carefully remove the sepals and petals. Leave the rest of the flower intact and draw it in your notebook.
2. Use a scalpel to cut along the length of the ovary. Use a hand lens to observe the internal structures. Remove a stamen and rub the anther on your finger. Describe what you observe.
3. Carefully open the pea pod. Observe, draw, and label the contents.
4. Obtain a lima bean that has been soaked in water. Locate the tiny opening along the inner edge of the bean and the scar from the point of attachment to the pod. Draw what you observe.
5. Carefully remove the seed coat from the lima bean. Gently separate the halves of the bean to expose the embryo inside. Use a hand lens to observe the embryo. Draw and label what you see.

INTERPRETIVE QUESTIONS

1. Explain the relationship of a plant's fruit and seeds to the structure of its flower.
2. What is the purpose of a seed? How is a seed's structure related to this function? What are the functions of a fruit?
3. Why are tomatoes, peppers, and cucumbers actually fruits and not vegetables, as many people believe?

CHAPTER 16 REVIEW

Answer these questions on a separate sheet of paper.

VOCABULARY

The following list contains all of the boldfaced terms in this chapter. Define each of these terms in your own words.

amnion, anther, chromosomal abnormalities, crossing-over, diploid, fertilization, filament, gametes, haploid, homologous chromosomes, independent assortment, karyotype, larva, meiosis, ovary, pistil, placenta, pollination, recombination, reduction division, sexual reproduction, stamens, stigma, style, tetrads, zygote

PART A—MULTIPLE CHOICE

Choose the response that best completes the sentence or answers the question.

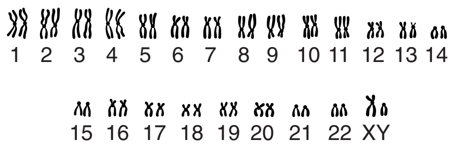
1. Reduction division is another term for *a.* mitosis *b.* Meiosis I *c.* Meiosis II *d.* Prophase II.
2. How many chromosomes are found in a normal human egg cell? *a.* 8 *b.* 16 *c.* 23 *d.* 46
3. Down syndrome results when an individual *a.* has an extra copy of chromosome 21 *b.* is exposed to harmful chemicals before birth *c.* is missing a chromosome *d.* has an extra piece of chromosome 17.
4. New combinations of genes result from *a.* budding *b.* mitosis *c.* asexual reproduction *d.* sexual reproduction.
5. An example of a gamete is a *a.* sperm cell *b.* zygote *c.* stigma *d.* maternal chromosome.
6. Which is a male reproductive structure in a flower? *a.* ovary *b.* stigma *c.* style *d.* stamen
7. Crossing-over may take place during *a.* Anaphase I *b.* Metaphase II *c.* Prophase I *d.* Telophase II.
8. Because of independent assortment, *a.* gametes can receive different mixes of maternal and paternal chromosomes *b.* maternal chromosomes are separated from paternal chromosomes during reduction division *c.* mothers over the age of 35 are at greater risk of having a child with Down syndrome *d.* organisms with fewer offspring are more likely to give more parental care to each offspring.

9. A multicellular, immature stage in the life cycle of an organism that is unlike the adult form is *a.* a zygote *b.* a gamete *c.* an anther *d.* a larva.
10. Which of these animals would you expect to have internal fertilization? *a.* goldfish *b.* butterfly *c.* coral *d.* frog
11. In humans, the diploid number is *a.* 8 *b.* 16 *c.* 23 *d.* 46.
12. Homologous chromosomes *a.* match in shape and size *b.* stay together during Anaphase I *c.* come from the mother only *d.* come from the father only.
13. In flowers, what structure produces pollen? *a.* ovary *b.* anther *c.* filament *d.* stigma
14. Which of these mammals nourishes the developing embryo through a placenta? *a.* kangaroo *b.* duckbill platypus *c.* echidna *d.* dog
15. Tetrads line up along the center of a cell during *a.* Meiosis II *b.* fertilization *c.* Metaphase I *d.* Prophase II.

PART B—CONSTRUCTED RESPONSE

Use the information in the chapter to respond to these items. (Note: Two X chromosomes indicate a female; an X and a Y indicate a male.)

16. What is shown in the diagram? How is it used to understand chromosomal abnormalities in humans?



17. Examination of the diagram shows a *a.* male with Down syndrome *b.* male without Down syndrome *c.* female with Down syndrome *d.* female without Down syndrome.
18. Compare and contrast mitosis and meiosis. Be sure to consider where in the body these processes occur as well as the steps and results of each process.
19. What is the significance of crossing-over?
20. Discuss the general evolutionary trends in vertebrates regarding fertilization, number of eggs, location of development, and amount of parental care.

PART C—READING COMPREHENSION

Base your answers to questions 21 through 23 on the information below and on your knowledge of biology. Source: *Science News* (December 21, 2002): vol. 162, pp. 189–190.

Novel Enzyme Provides Sperm's Spark of Life

Biologists may have finally found what they call the "spark of life," a molecule in sperm that triggers a fertilized egg to begin developing.

Immediately after a sperm penetrates an egg, several waves of calcium flow out of the egg's stores of the ion. These calcium surges set off development of the fertilized egg. For more than a century, biologists have speculated that sperm must contain something that liberates this calcium. Several egg-activating factors have been proposed, but none has withstood scrutiny.

Because of its calcium-releasing role in some other cells, an enzyme called phospholipase C (PLC) was among the suspects. None of the known versions of PLC fits the bill as an egg activator, however.

Now, in the Aug. 15 *Development*, F. Anthony Lai of the University of Wales College of Medicine in Cardiff and his colleagues report the discovery of a new form of PLC that's present only in sperm. Moreover, when injected into an unfertilized egg, the enzyme stimulates calcium surges identical to those caused by sperm. This enzyme may provide a seemingly natural means of activating eggs in cloning or other forms of artificial reproduction, the scientists suggest.

Given the history of this issue, the role of the new PLC must be verified "10 times over," cautions Sergio Oehninger of the Jones Institute for Reproductive Medicine in Norfolk, Va.

21. Explain where the molecule called "spark of life" is found and what it does.
22. Describe the events that occur as soon as a sperm enters into an egg cell.
23. State the discovery that may explain why a fertilized egg begins developing.