

# CHAPTER 15

# Human Development

## Chapter Concepts

### 15.1 Fertilization and Embryonic Development

- Fertilization results in a zygote, which goes through several stages of development before implantation.
- An implanted embryo undergoes significant stages of development and differentiation in the first eight weeks after fertilization.
- Extra-embryonic membranes, some of which develop into the placenta and umbilical cord, provide support, protection, and nourishment for the developing life.

### 15.2 Fetal Development and Birth

- Fetal development occurs over about the last 30 weeks of pregnancy.
- Parturition is the process leading up to and including birth.
- Hormones play an important role during pregnancy, birth, and lactation following birth.
- Environmental factors, including teratogens, have an effect on embryonic and fetal development.

### 15.3 Development, Technology, and Society

- Reproductive technologies include technologies to enhance reproductive potential and technologies to restrict reproductive potential.
- The use of reproductive technologies leads to ethical, moral, legal, and personal issues.



**T**he process of human development and birth inspires awe and wonder in both scientists and non-scientists alike. Over a period of about 38 weeks—266 days—a single fertilized egg cell undergoes a staggeringly complex sequence of changes as it multiplies, modifies, develops, and grows to form the hundreds of billions of cells that make up the tissues, organs, and systems of the infant human body. In this chapter, you will follow the processes and events that lead to the development and birth of a human child. As well, you will consider the role that technology increasingly plays in these processes and events. In addition, you will examine some of the challenges that reproductive technology presents to individuals, families, and other segments of society.



Carrying on a tradition that is perhaps as old as the oldest human societies, a midwife (meaning literally “with woman”) provides care and advice to a woman during her pregnancy and the birth of her baby. The midwife also helps to provide care for the newborn child in the weeks, and sometimes months, that follow.

## Launch Lab

### Visualizing Early Human Development

The first 56 days (two months) are the most crucial period during human development. Among the many changes that occur during this time is an astonishing increase in size. What else might be changing during this time?

#### Procedure

1. Graph the data in the data table. Consider designing a three-dimensional bar-type graph, either with a computer or using concrete objects, to help you visualize the sizes.

Human Embryo Size (Length) during the first 56 Days of Development

Day	Approximate Length (mm)
1	0.1
7	0.1
14	0.2
21	1
28	3
35	8
42	13
49	20
56	30

#### Analysis

1. In terms of size, over what period of time is the *least* amount of change occurring?
2. How does the change in size in the first four weeks of development compare with the change in size during the second four weeks?
3. Sketch or describe what you think the developing human embryo looks like at four weeks. Then do the same for the embryo at eight weeks.
4. The first eight weeks is the most significant period of time during human development. What types of changes do you think occur during the remaining 30 weeks? List at least five and when you think they occur.
5. Substances consumed by or exposed to the mother during pregnancy can harm the baby as it develops.
  - a) List at least four substances that you think are harmful to the developing baby.
  - b) During which period of time do you think a baby is most sensitive to harm from these substances?

# Fertilization and Embryonic Development

## Section Outcomes

In this section, you will

- **trace** the processes and key events that occur during embryonic development (the first eight weeks of life)
- **describe** the significance of the primary germ layers and **identify** the tissues and organs that arise from them
- **compare** embryonic changes and extra-embryonic structures in humans and other animals

## Key Terms

fertilization  
zygote  
cleavage  
blastocyst  
inner cell mass  
implantation  
human chorionic gonadotropin (hCG)  
gastrulation  
primary germ layers  
morphogenesis  
differentiation  
neurulation  
extra-embryonic membranes  
allantois  
amnion  
chorion  
yolk sac  
placenta  
umbilical cord

Biologists commonly divide prenatal (prebirth) development into three three-month periods called *trimesters*. Biologists also use a complementary system to organize and describe developmental events before birth. This system uses two main periods of prenatal development:

- **The embryonic period of development:** This period of development takes place over the first eight weeks, or the first two thirds of the first trimester. During this time, tremendous change takes place. Cells divide and become redistributed. Tissues and organs form, as do structures that support and nourish the developing embryo.
- **The fetal period of development:** This period of development takes place from the start of the ninth week through to birth. It corresponds to the remaining third of the first trimester and all of the second and third trimesters. During the fetal period, the body grows rapidly and organs begin to function and coordinate to form organ systems.

In this section, you will learn about key developments that take place during the embryonic period. In Section 15.2, you will examine key developments that take place during the fetal period.

## Fertilization

Human development begins with fertilization. **Fertilization** involves the joining of male and female gametes (sperm and egg) to form a single cell that contains 23 chromosomes from each parent, for a total of 46 chromosomes.

Several events lead up to the moment of fertilization (also called conception). In the female body, an egg is released from an ovary and swept into an oviduct. The egg is carried toward the uterus by muscular contractions and the wavelike actions of cilia, which line the walls of the oviduct. The passage of the egg is slow—it takes about four days to reach the uterus. It must be fertilized, however,

within 12 to 24 h of its release, or it will lose its capacity to develop further. For a sperm and egg to join, the sperm must reach the egg during the early part of its movement through the oviduct.

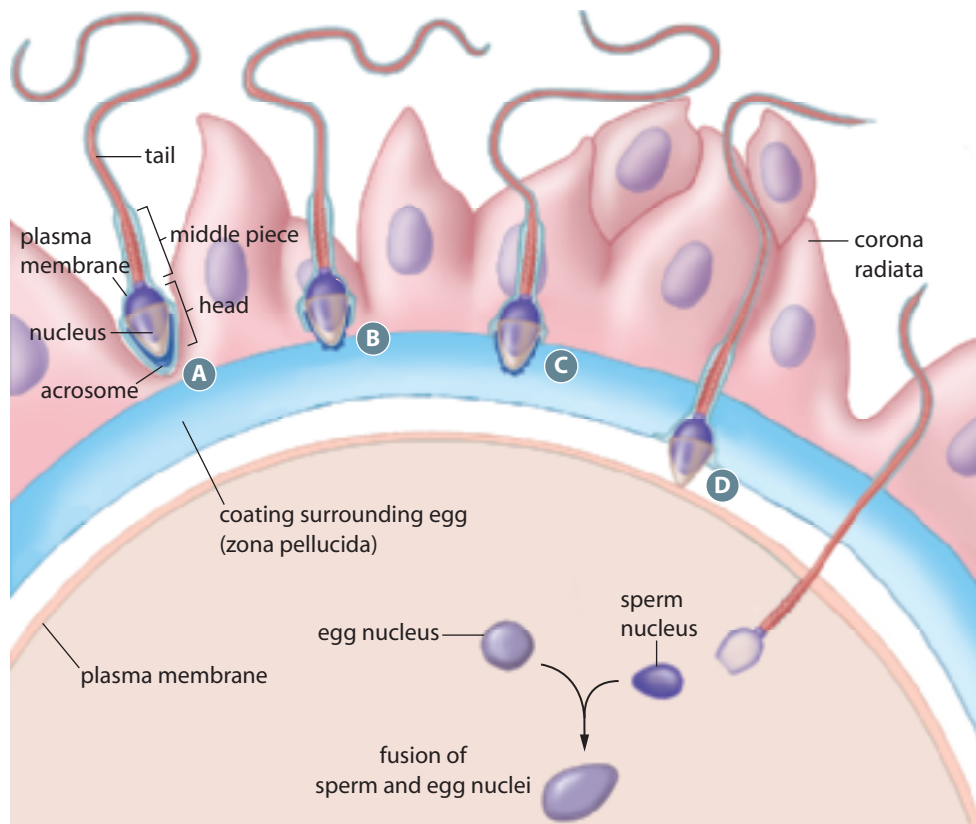
Several hundred million sperm cells exit the male's urethra during each ejaculation. Once they enter the female's vagina, they must make their way to the cervix, then through the uterus, and finally to the oviduct into which the egg was released. Most sperm do not survive this journey. Many are destroyed by the naturally acidic environment of the vagina. Other sperm go the “wrong way”—that is, they enter the oviduct that does not have the egg. From the millions of sperm released, only a few dozen to a few hundred survive to reach the egg.

The plasma membrane of the egg is surrounded by a thin, clear layer of protein and carbohydrates called the *zona pellucida*. This layer, in turn, is surrounded by several jelly-like layers of follicle cells that loosely adhere to one another, called the *corona radiata*. These cells were a source of nourishment for the egg when it was in an ovarian follicle.

When a sperm meets the corona radiata, the sperm's enzyme-containing acrosome (the “cap” surrounding the nucleus) releases its contents. The enzymes digest a path through the corona and zona pellucida. Meanwhile, the sperm advances farther by means of the lashing actions of its tail. As shown in Figure 15.1, many sperm are involved in this activity. The action of hundreds of sperm may be necessary to clear a path for the one sperm that is able to successfully enter the egg. Once a sperm enters the egg, the egg's plasma membrane depolarizes, preventing other sperm from binding with and entering it.

Within about 12 h of the sperm's nucleus entering the egg, the membranes of the sperm nucleus and the egg nucleus disappear. The 23 chromosomes in the





**Figure 15.1** During fertilization, sperm cells reach the jelly-like coating surrounding the egg (A) and release enzymes that digest a path through the coating. The path allows other sperm cells to go farther through the coating and move toward the plasma membrane of the egg (B, C, D). Eventually, the head of one sperm cell might successfully enter the egg. When this happens, the sperm nucleus and the egg nucleus fuse, completing fertilization.

ovum are joined with the 23 chromosomes in the sperm. Fertilization of the egg is now complete. The resulting single cell—the first cell of a new life—is called a **zygote** (from a Greek word that means “joined”). The zygote has 23 pairs of chromosomes—one chromosome from each pair in each parent for a total of 46 chromosomes.

- 1 How many chromosomes are there in a human egg once it has been fertilized?
- 2 Why must the egg be fertilized within 12 to 24 hours of its release?
- 3 Why do so few sperm arrive in the oviduct where the egg is?
- 4 Why is the first sperm that reaches the egg unlikely to be the sperm that enters and joins with it?

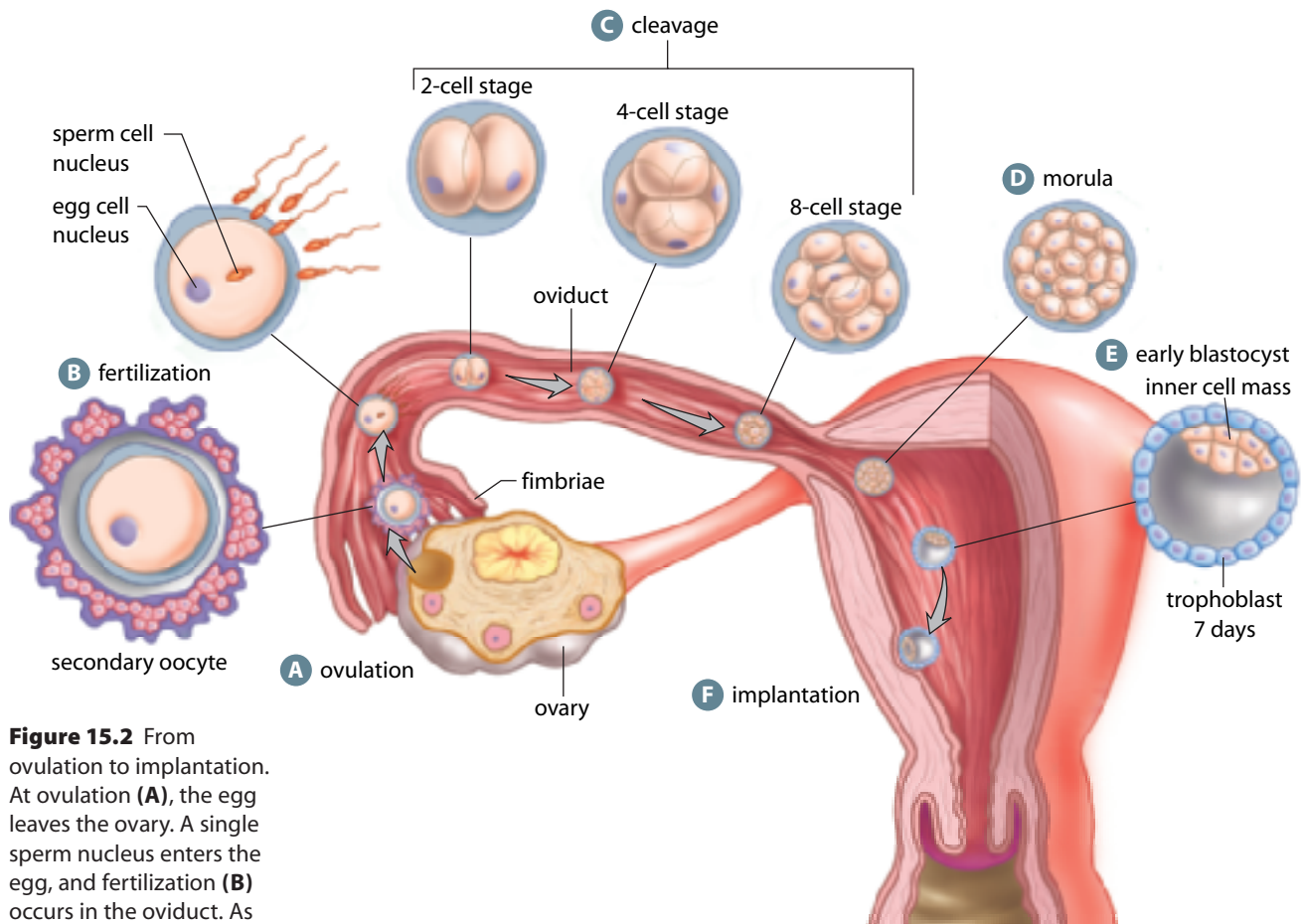
## Cleavage and Implantation

When the egg is fertilized, it is still moving through the oviduct and is several days away from entering the

uterus. During this journey, tremendous activity can be observed in the zygote, as shown in Figure 15.2 on page 510. (Unfamiliar terms in this diagram are explained in the paragraphs below.)

Within 30 h of being fertilized, the 0.1 mm zygote divides by mitosis for the first time, giving rise to two new cells. These cells also divide, forming four cells. The four cells, in turn, divide to form eight cells, and so on. This process of cell division occurs quickly, with little time for the individual cells to grow. As a result, the cells become smaller and smaller with each division. The overall size of the zygote, however, remains about 0.1 mm. This process of cell division without enlargement of the cells is called **cleavage**. Figure 15.3 shows the zygote during several stages of cleavage. By the time the zygote is a sphere of 16 cells, it is called a *morula*. (The term *morula* comes from a Latin word that means “mulberry.”)

The morula reaches the uterus within three to five days after fertilization. During this time, it begins to fill with fluid that diffuses from the uterus. As the fluid-filled space develops, two different



**Figure 15.2** From ovulation to implantation. At ovulation (**A**), the egg leaves the ovary. A single sperm nucleus enters the egg, and fertilization (**B**) occurs in the oviduct. As the zygote moves along, it undergoes cleavage (**C**) to produce a morula (**D**). The blastocyst forms (**E**) and implants in the lining of the uterus (**F**).

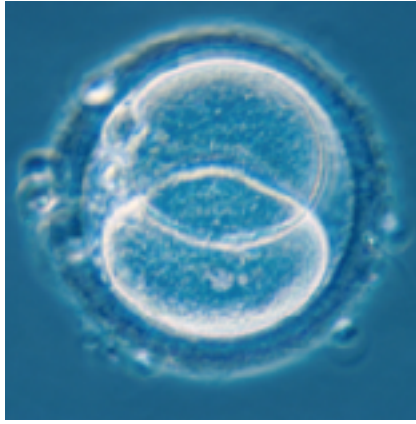
groups of cells form. The entire spherical structure is now called a **blastocyst** (Figure 15.4). The term *blastocyst* comes from two Greek words that mean “germ pouch.” Here, the word “germ” refers to cells from which new cells or tissues can develop. Thus, the blastocyst is a hollow structure—a “pouch”—from which new cellular structures can develop.

One group of cells, called the *trophoblast* (meaning “nourishment of the germ”), forms the outer layer of the blastocyst. The trophoblast will develop into a membrane called the chorion. (The term *chorion* comes from a Greek word that refers to the region surrounding a city. In more modern terms, *chorion* means “membrane.”) The chorion, in turn, will develop to form part of the placenta. The placenta is a structure that provides nutrients and oxygen to, and removes wastes from, the developing offspring. (You will learn more about the placenta on page 516.) The other group

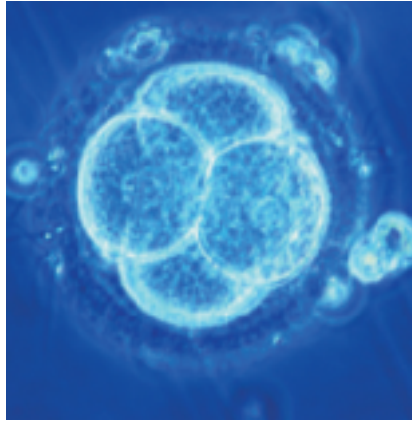
of cells come together within the blastocyst to form the **inner cell mass** (also called the embryoblast). The inner cell mass develops into the embryo itself.

Between the fifth and seventh day after fertilization, the blastocyst attaches to the endometrium (the outer lining of the uterus), with the inner cell mass positioned against the endometrium. The trophoblast cells secrete enzymes that digest some of the tissues and blood vessels of the endometrium, and the blastocyst slowly sinks into the uterine wall. This nestling of the blastocyst into the endometrium is called **implantation**. Implantation is complete by the tenth to fourteenth day. With successful implantation, the woman is now said to be pregnant.

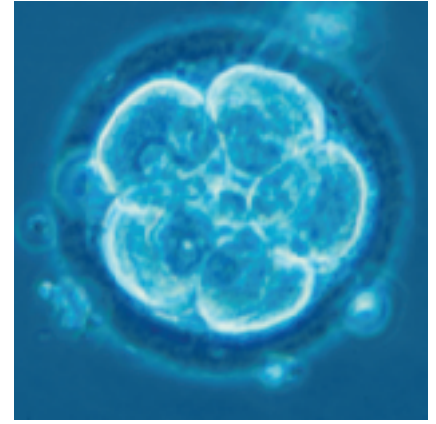
About the time that implantation begins, the trophoblast starts to secrete a hormone called **human chorionic gonadotropin (hCG)**. hCG has the same effects as luteinizing hormone (LH), so



**A** First division (two cells produced)



**B** Second division (four cells produced)



**C** Third division (eight cells produced)

it maintains the corpus luteum past the time when it would otherwise degenerate. As a result, the secretion of estrogen and progesterone continues, maintaining the endometrium and preventing menstruation. The secretion of hCG continues at a high level for about two months. Then it declines to a low level by the end of four months. Although the corpus luteum remains intact throughout pregnancy, its function as a source of hormones is less important after the first trimester. By this time, the placenta secretes sufficient estrogen and progesterone to maintain the endometrium (see Figure 15.5 on page 512).

- 5 Explain what the process of cleavage is.
- 6 How does a morula differ from a blastocyst?
- 7 From which group of cells, the trophoblast or the inner cell mass, does the embryo develop?
- 8 Explain what implantation is.
- 9 What is hCG, and how long is it secreted?

### Gastrulation and the Start of Tissue Formation

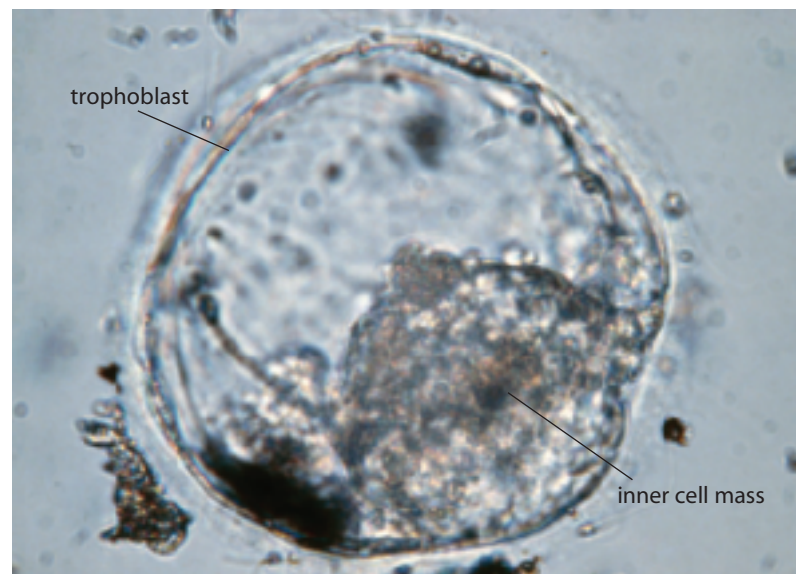
During the second week, as the blastocyst continues and completes the process of implantation, the inner cell mass

changes. A space begins to form between the inner cell mass and the trophoblast. This space, called the amniotic cavity, will soon fill with fluid and is the place where the baby will develop. (The amniotic cavity forms within a sac called the amnion. The amnion is one of several embryo-supporting structures that you will learn about later in this section.)

As the amniotic cavity forms, the inner cell mass flattens into a disk-shaped structure called the *embryonic disk* (see Figure 15.6). The embryonic disk is supported by a short stalk that connects the blastocyst with the endometrium. At first, the embryonic disk consists of two layers: an outer *ectoderm*, which is closer to the amniotic cavity, and an inner *endoderm*. Shortly after, a third layer, called the *mesoderm*,

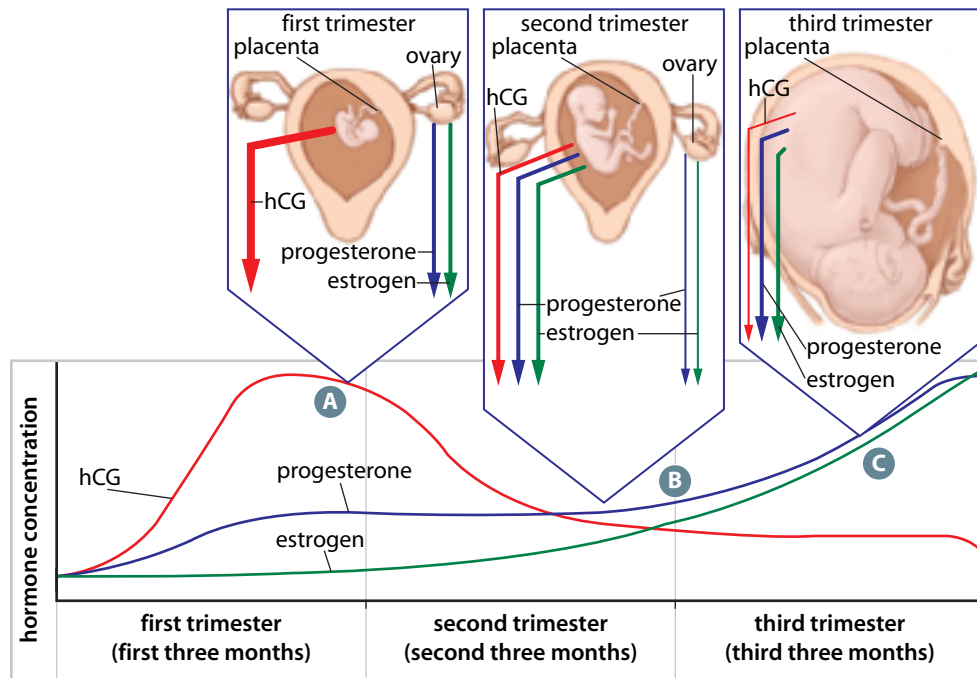
**Figure 15.3** The zygote at several stages of early cell division. Notice that the overall size (volume) of the zygote remains the same with each division.

**Figure 15.4** At the time of implantation, the blastocyst is about the size of the period at the end of this sentence.





**Figure 15.5** hCG, progesterone, and estrogen are secreted from various sources during pregnancy. Early in pregnancy, estrogen and progesterone are secreted by the corpus luteum. During mid-pregnancy, there is a shift toward secretion of these hormones by the placenta. Late in pregnancy, these hormones are secreted solely by the placenta. (The thickness of the arrows represents the relative concentrations of these hormones.)



**A** Human chorionic gonadotropin (hCG) increases until it reaches a maximum concentration near the end of the first trimester. Then it decreases to a low level for the remainder of the pregnancy.

**B** Progesterone continues to increase until it levels off near the end of the pregnancy. Early in the pregnancy, progesterone is produced by the corpus luteum in the ovary. By the second trimester, its production shifts to the placenta.

**C** Estrogen levels increase slowly throughout the pregnancy, but they increase more quickly as the end of the pregnancy approaches. Early in the pregnancy, estrogen is produced only in the ovary. By the second trimester, its production shifts to the placenta.

forms between the endoderm and the ectoderm. The process of forming these three layers is called **gastrulation**, and the three layers are called the **primary germ layers**. The developing embryo is now called the *gastrula*.

Gastrulation marks the start of **morphogenesis**—the series of events that form distinct structures of the developing organism. (*Morphogenesis* comes from two Greek words that mean “shape creator” or “producer of forms.”) Morphogenesis depends on the ability of early embryonic cells to become different types of cells—that is, to differentiate.

**Differentiation** is the cellular process that enables a cell to develop a particular shape and to perform specific functions that are different from the functions of other cells. The development of the three primary germ layers is especially important because all the cells, tissues, and organs of the body are derived from the primary germ layers through differentiation (see Figure 15.7).

- 10 What is the amniotic cavity, and where does it form?
- 11 Name each of the three layers of the embryonic disk.
- 12 Name the process that results in the formation of the primary germ layers.
- 13 What is morphogenesis?
- 14 Explain how the development of the primary germ layers is related to differentiation.

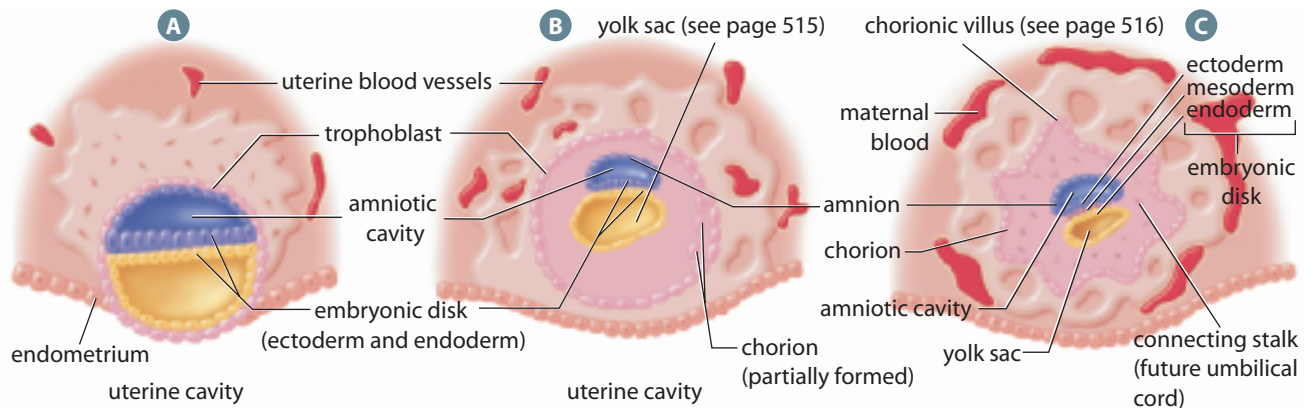
## BiologyFile

### FYI

The term *gastrulation* comes from Greek words that mean “stomach forming.” It refers to one of the early structures formed during the process, the archenteron (or gastrocoel), from which the digestive system will develop.

## Neurulation and Organ Formation

Between the third and eighth weeks, the organs form. With each passing day, different rates of cell division in the primary germ layers cause tissues to fold into distinct patterns. Gradually, the three-layered embryo is transformed



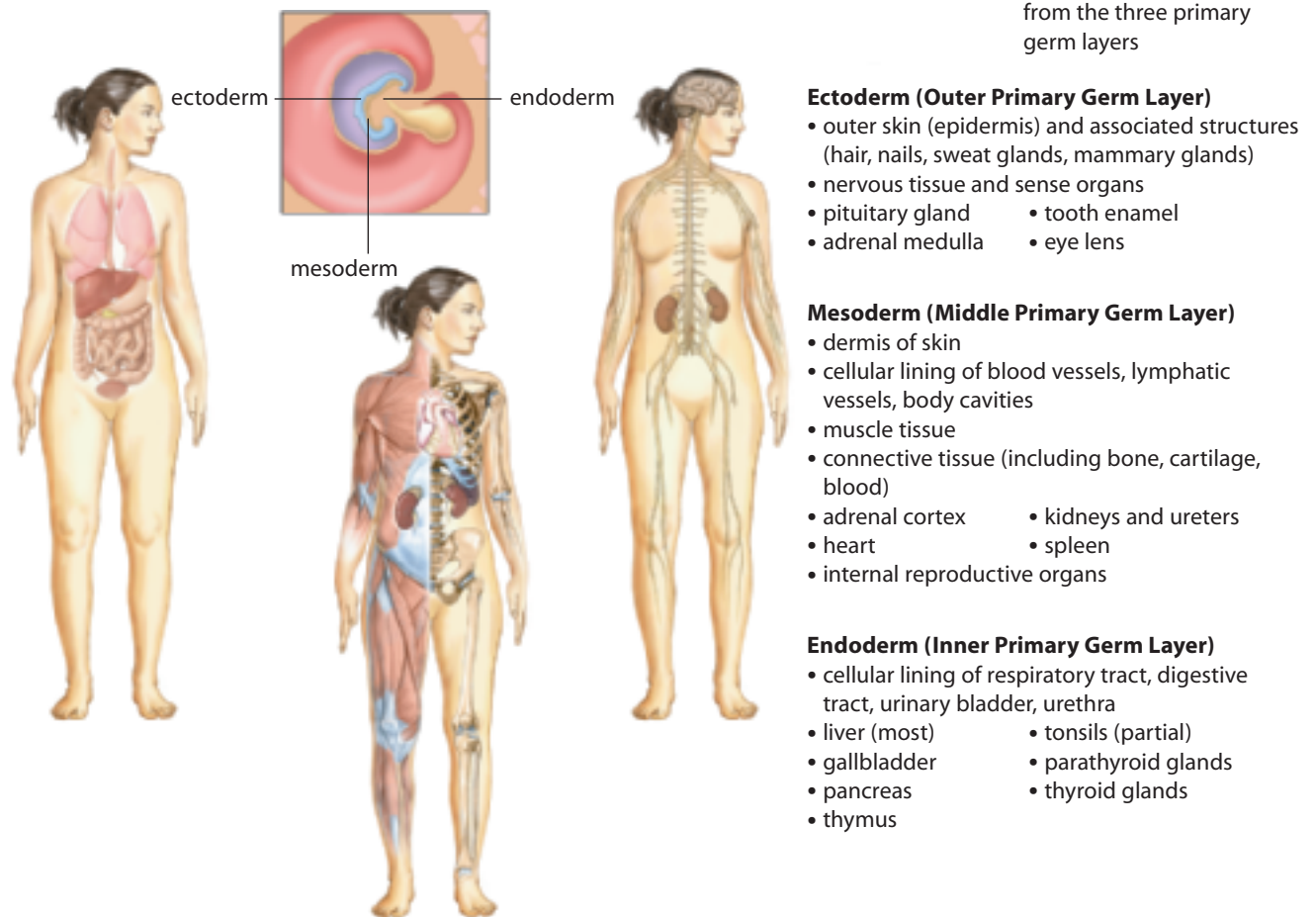
**Figure 15.6** The changes that are illustrated in these diagrams take place over a period of about one week. Gastrulation—the formation of the three primary germ layers—is a pivotal event in embryonic development. All future tissues, organs, and organ systems of the body will develop from the cells of the germ layers.

into a body with separate organs and, by about the eighth week, a shape that is recognizably human.

During the third week, a thickened band of mesoderm cells develops along the back of the embryonic disk. These cells lie along what will become the baby's back and come together to form

a rod-like structure called the notochord. (The *noto-* part of this term comes from a Greek word that means “back.”) The notochord will form the basic framework of the skeleton. The nervous system develops from ectoderm that is located just above the notochord (Figure 15.8). First, cells along the surface above the

**Figure 15.7** Organs and body systems that develop from the three primary germ layers



**Ectoderm (Outer Primary Germ Layer)**

- outer skin (epidermis) and associated structures (hair, nails, sweat glands, mammary glands)
- nervous tissue and sense organs
- pituitary gland      • tooth enamel
- adrenal medulla      • eye lens

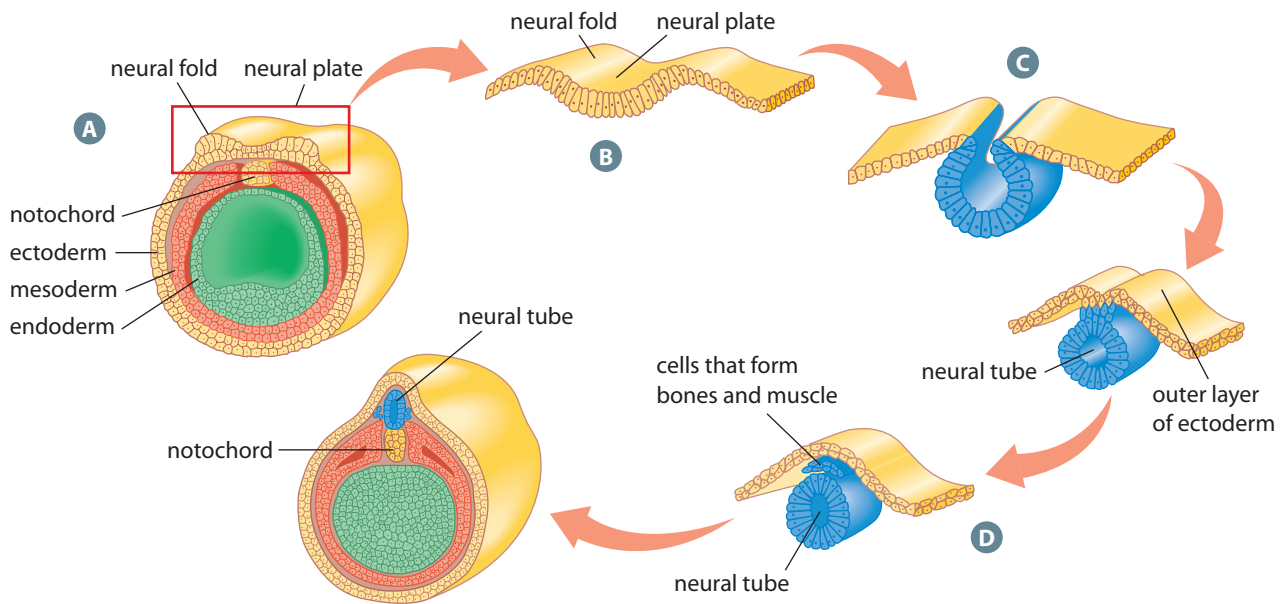
**Mesoderm (Middle Primary Germ Layer)**

- dermis of skin
- cellular lining of blood vessels, lymphatic vessels, body cavities
- muscle tissue
- connective tissue (including bone, cartilage, blood)
- adrenal cortex      • kidneys and ureters
- heart                  • spleen
- internal reproductive organs

**Endoderm (Inner Primary Germ Layer)**

- cellular lining of respiratory tract, digestive tract, urinary bladder, urethra
- liver (most)              • tonsils (partial)
- gallbladder              • parathyroid glands
- pancreas                  • thyroid glands
- thymus





**Figure 15.8** The process of neurulation. **(A)** The notochord forms from mesoderm on the dorsal (back) side of the embryo. **(B)** The neural tube starts as a plate of ectoderm just above the developing notochord. **(C)** The edges of this plate fold inward, meeting to form a hollow tube surrounded by cells. The neural tube pinches off from the ectoderm and develops into the spinal cord and brain. **(D)** Cells migrate from the meeting margins of the neural tube and eventually form other organs, bone, and muscles.

notochord begin to thicken. Folds develop on each side of a groove along this surface. When the folds fuse, they become a tube, called the neural tube, which develops into the brain and spinal cord. The process of forming this tube is called **neurulation** and marks the start of organ formation. Soon after neurulation begins, a reddish bulge that contains the heart forms. By about the eighteenth day, the heart starts beating.

The fourth week of prenatal development and on is a time of rapid growth and differentiation (Figure 15.9). Blood cells start to form and fill developing blood vessels. Lungs and kidneys take shape. Small buds, which will develop into arms and legs, appear. A distinct head is visible, as well as early evidence of eyes, ears, and nose. The embryo is about 0.6 cm long at this point. The mother might now suspect that she is pregnant, because her menstrual period is about two weeks late.

During the fifth week, the embryo's head is very large compared with its body. The eyes open, but they do not yet have eyelids or irises. Cells in the brain

are differentiating very quickly. The embryo is about 1.3 cm long now.

In the sixth week, the brain continues its rapid development. The limbs lengthen and flex slightly. The gonads are starting to produce hormones that will influence the development of the external genitalia.

During the seventh and eighth weeks, the embryo has distinct human characteristics. The organs are formed, and the nervous system is starting to coordinate body activity. A skeleton of cartilage has formed. (Bone will not begin to replace the cartilage until about the ninth week.) Eyes are well developed, but the lids are now closed, stuck together to protect them against random movements of fingers from the still-elongating arms. The nostrils are developed, but are plugged with mucus. (Breathing will not be required until the baby emerges from the uterus.) The external genitalia are still forming, but they are undifferentiated. That is, the physical sex of the embryo is not yet apparent, even though its genetic sex has already been determined.

## BiologyFile

### FYI

By the end of the second week of prenatal development, the woman has not yet missed her menstrual period and likely does not know that she is pregnant. Her urine does, however, contain enough hCG for an at-home pregnancy test to detect. Highly sensitive blood tests can detect hCG as early as three days after fertilization.

By the end of the eighth week of prenatal development, the embryo is about the size and mass of a paper clip. Approximately 90 percent of the organs and other structures that make up the adult human body are established. From this time on, as the organs enlarge and mature, until birth, the developing life is called a fetus (Latin for “offspring”).

- • •
- 15 What is neurulation?
  - 16 Other than neurulation, identify two events that occur during the third week of development.
  - 17 Identify three events that occur during the fourth week of development.
  - 18 Identify four events that occur between the fifth and eighth week and when they occur.
  - 19 At what point is the embryo termed a fetus?
- • •

## Structures That Support the Embryo

The internal organs of the embryo form between the third and eighth weeks. At the same time, an intricate system of membranes that are external to the embryo are also forming. Figure 15.10 shows these **extra-embryonic membranes**: the **allantois**, **amnion**, **chorion**, and **yolk sac**. The extra-embryonic membranes, along with the placenta and umbilical cord that develop from some of them, are responsible for the protection, nutrition, respiration, and excretion of the embryo (and, later, the fetus). During birth, these membranes—as well as the placenta and umbilical cord—are expelled from the uterus. The expelled membranes and structures are collectively and commonly referred to as the *afterbirth*.

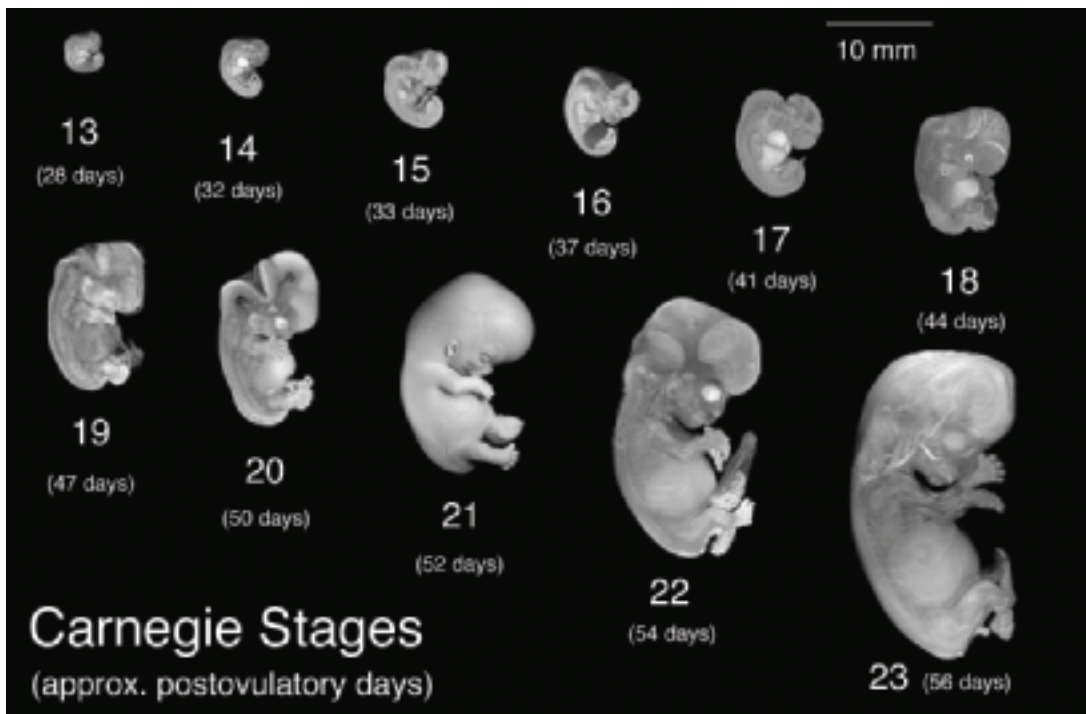
## The Placenta and Umbilical Cord

By the end of the second week after fertilization, finger-like projections from

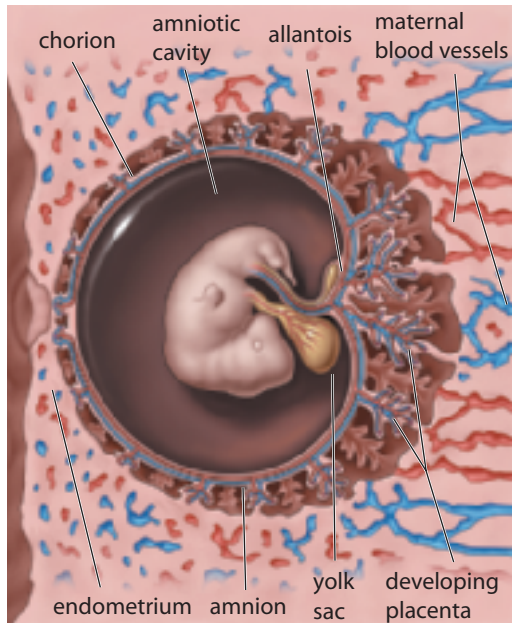
## BiologyFile

### FYI

The amniotic fluid initially forms by filtration of the mother’s blood plasma. By about the eighth or ninth week, the fetus urinates into the amniotic fluid about once an hour, adding to the volume of the fluid. The volume increases slowly because the fetus swallows amniotic fluid at nearly the same rate. By the time of birth, the amnion contains 700 mL to 1000 mL of fluid.



**Figure 15.9** During the first eight weeks (56 days) after ovulation, the appearance of various internal and external features may be used to describe the development of the embryo. The eight weeks are divided into 23 embryonic stages, also known as Carnegie stages. Embryologists use the Carnegie stages to make statements about development that are more specific than reference to size or age allow, since the moment of conception cannot be determined precisely.



**Amnion** (AM-knee-on): a transparent sac that develops from cells of the embryonic disk. It grows to enclose the embryo completely. It is penetrated only by the umbilical cord. The amnion becomes filled with fluid (amniotic fluid), which protects the embryo from trauma and temperature fluctuations, allows freedom of movement, and prevents limbs from sticking to the body. (The term *amnion* comes from a Greek word that means “lamb.” It refers to the membrane that is often observed clinging to the head of a lamb when it is born.)

**Yolk sac:** a small sac that is suspended from the abdominal area of the embryo. It contributes to the formation of the digestive tract and produces the first blood cells and the future egg or sperm cells. Unlike the yolk sac in many other vertebrates, the yolk sac in humans serves no nutritive function.

**Allantois** (uh-LAN-toe-iss): forms the foundation for the umbilical cord. During the second month, most of the allantois degenerates. The remainder becomes part of the urinary bladder. (The term *allantois* comes from a Greek word that means “sausage,” referring to the shape of this structure.)

**Chorion** (KOR-ee-on): the outermost membrane. It encloses all the other extra-embryonic membranes, as well as the embryo. The chorion forms the fetal portion of the placenta.

**Figure 15.10** The extra-embryonic membranes are structures that are external to (*extra-*) the embryo.

the chorion extend into the uterine lining. These projections, called chorionic villi, establish the beginnings of the placenta. The **placenta** is a disk-shaped organ that is rich in blood vessels. The embryo (or fetus) is attached to the uterine wall by the placenta, and metabolic exchange occurs through it (see Figure 15.11). The placenta is fully developed by about 10 weeks, with a mass of about 600 g. (The term *placenta* comes from a Greek word that means “flat cake.”)

One part of the placenta—the chorion tissue—comes from the embryo. The other part consists of blood pools from the mother’s circulatory system. The blood systems of the mother and embryo are separate, but they lie very close to each other. This proximity permits nutrients and oxygen to diffuse from the mother’s circulatory system to the developing baby and for wastes to leave the baby’s circulation and enter the mother’s for excretion. Table 15.1 outlines the functions of the placenta.

Note that the placenta does not filter out substances such as alcohol, drugs, and nicotine, which can diffuse across membranes. If these substances are present in the mother’s blood, they will diffuse into the developing baby’s blood. Exposure to these substances while pregnant can have severe negative effects on the embryo and fetus. (Refer to the section called “The Effects of Teratogens on Development” on page 521 for more information.)

Near the end of the eighth week, as the yolk sac shrinks and the amniotic sac enlarges, the umbilical cord forms. The **umbilical cord** is a rope-like structure that averages about 60 cm long and 2 cm in diameter. (It can, however, be as long as 300 cm or as short as a few millimetres.) It leads from the navel area of the fetus

**Table 15.1** Functions of the Placenta

<b>Nutritional functions</b>	<ul style="list-style-type: none"> <li>• transports nutrients (for example, glucose, amino acids, fatty acids, minerals, and vitamins) from the mother’s blood to the fetus’s blood</li> <li>• stores nutrients, such as carbohydrates, proteins, iron, and calcium, in early pregnancy and releases them to the fetus later, when fetal demand is greater than the mother can absorb from her diet</li> </ul>
<b>Excretory functions</b>	<ul style="list-style-type: none"> <li>• transports wastes (such as urea, ammonia, and creatinine) from the fetal blood to the mother’s blood</li> </ul>
<b>Respiratory functions</b>	<ul style="list-style-type: none"> <li>• transports oxygen from the mother to the fetus and carbon dioxide from the fetus to the mother</li> </ul>
<b>Endocrine functions</b>	<ul style="list-style-type: none"> <li>• secretes hormones, such as estrogen, progesterone, and human chorionic gonadotropin</li> <li>• allows hormones from the fetus to diffuse into the mother’s blood and hormones from the mother to diffuse into the fetus’s blood</li> </ul>
<b>Immune functions</b>	<ul style="list-style-type: none"> <li>• transports antibodies from the mother into the fetus’s blood to provide passive immunity</li> </ul>



to the centre of the placenta. (The term *umbilical* comes from a Latin word that means “navel.”) The umbilical cord contains two arteries, which transport oxygen-depleted blood from the fetus to the placenta. It also contains one vein, which brings oxygen-rich blood to the fetus.)

The umbilical cord has natural twists because the umbilical vein is longer than the arteries are. In about 20 percent of all deliveries, the umbilical cord is looped once around the baby’s neck. Usually, this poses no problem for the baby’s health or the delivery. The doctor or midwife can easily slide the umbilical cord over the baby’s head before delivery.

- 20 Name the extra-embryonic membranes.
- 21 From which extra-embryonic membranes do the placenta and umbilical cord develop?
- 22 Summarize the role of the placenta.
- 23 Summarize the role of the umbilical cord.

## BiologyFile

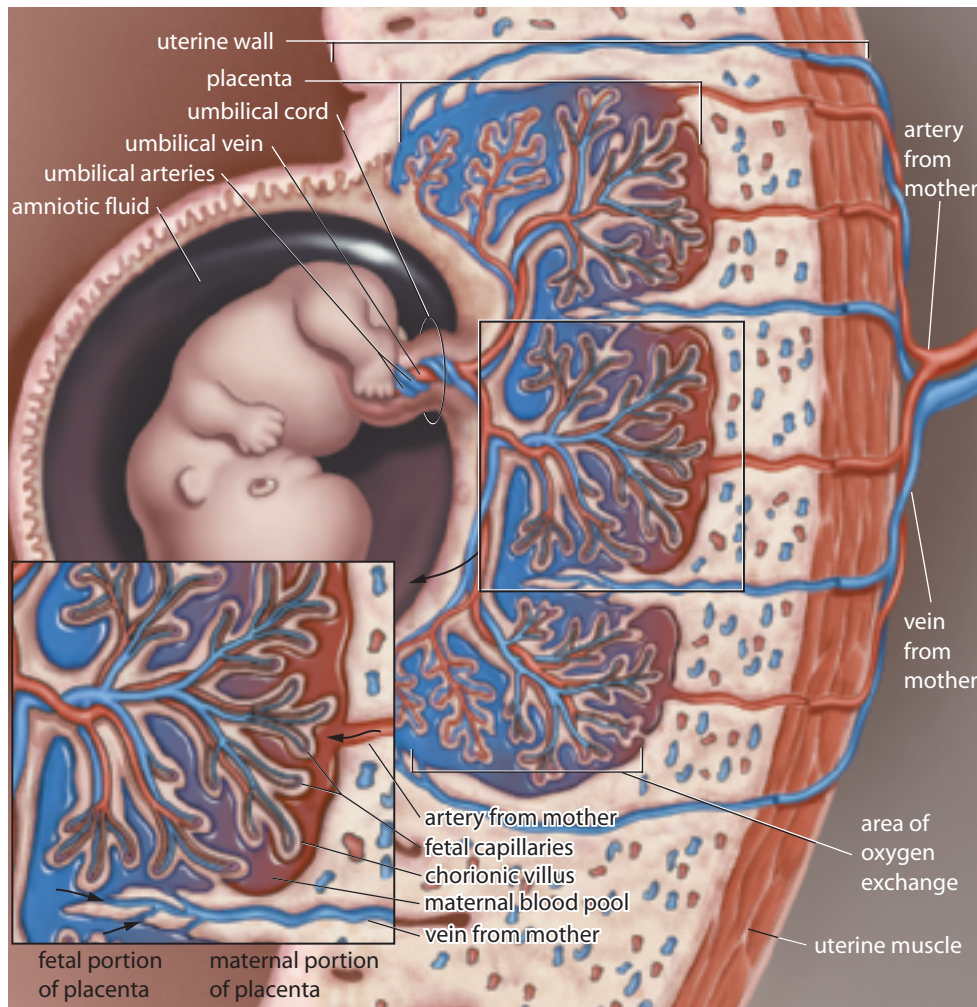
### Web Link

Potential complications that involve the umbilical cord are surprisingly numerous. What types of complications can occur? How serious are they? What percentage of babies are affected?

[www.albertabiology.ca](http://www.albertabiology.ca)  
WWW

## Section 15.1 Summary

- Fertilization occurs in the oviduct and results in a zygote.
- Cleavage of the fertilized egg occurs within 30 h and continues until a morula forms.
- The morula enters the uterus around the third day.



**Figure 15.11A** In the placenta, chorionic villi that extend from the embryo are in contact with pools of blood from the mother. Nutrients and oxygen pass by diffusion from the maternal blood to the embryo, and wastes diffuse in the opposite direction.

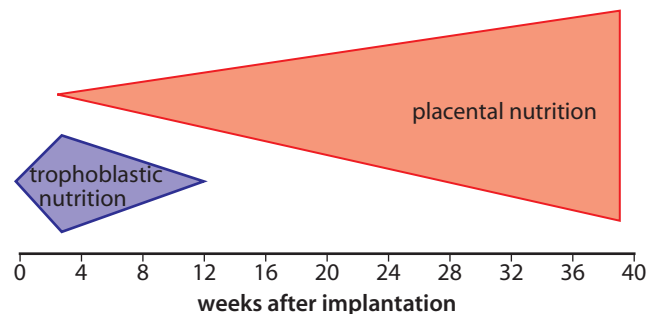
**Figure 15.11B** The pancake-like placenta



- The still-dividing morula begins to fill with a fluid and is now called a blastocyst.
- The blastocyst is bounded by a thin layer of cells, called the trophoblast, and has a group of cells, called the inner cell mass, within it.
- The inner cell mass develops into the embryo.
- The blastocyst implants in the uterine wall around the seventh day after fertilization.
- During the second week, cells begin to specialize.
- During gastrulation, which marks the start of morphogenesis, the embryo's cells become arranged into three distinct primary germ layers (ectoderm, mesoderm, and endoderm), which develop from the embryonic disk within the blastocyst.
- During neurulation, the embryo's nervous system begins to develop.
- By the third week, the extra-embryonic membranes begin to form. These membranes provide support, nourishment, and protection for the embryo. Some of them will become the placenta and umbilical cord, which continue to provide nourishment for the fetus until birth.
- By the fourth week, the embryonic heart is beating, the arm and leg buds are recognizable, and the tissues that will form the eyes, brain, spinal cord, lungs, and digestive organs are in place.
- By the eighth week, all the body organs are formed (although they will continue to develop) and the embryo's features are distinctly recognizable as human.

## Section 15.1 Review

- List at least three events that must occur for fertilization to take place.
- Describe three ways that a fertilized egg is different from the two cells that combined to form it.
- Describe what happens during implantation.
- Arrange the following in order, from youngest to oldest: morula, zygote, blastocyst, gastrula. Give reasons for your order.
- Identify the three primary germ layers, and explain their significance.
- Following implantation, the trophoblast begins to secrete hCG (human chorionic gonadotropin hormone).
  - Describe the effect of hCG secretion on the mother's reproductive system.
  - Pregnancy tests are designed to detect higher-than-normal concentrations of hCG in the mother's blood or urine. Explain why you would expect to be able to find hCG in these two body fluids.
- Using a table, concept map, or labelled diagram, outline the six structures that support the developing embryo (and, later, the fetus) and briefly describe the function of each. **ICT**
- The following diagram outlines the timetable of trophoblastic and placental nutrition.
  - Approximately when does trophoblastic nutrition reach its peak, and when does it end?
  - Approximately when does placental nutrition begin?
  - Infer the significance of the shape of the placental nutrition element in the diagram.
  - According to the diagram, at what times do the two modes contribute equally to prenatal nutrition?
- Developing human embryos do not have a significant amount of yolk as part of their supporting tissues, but chick embryos do. Explain why.
- Design a table to summarize the major events that occur from fertilization to the end of eight weeks of human prenatal development. Your table should include at least these headings: Time period, Place of occurrence, Major events. **ICT**



Observing changes during embryo development

Comparing extra-embryonic membranes of human and chicken embryos

## Comparing Embryonic Structures

### Question

How do embryonic structures of humans and other animals compare?

### Safety Precautions

Handle microscope equipment and slides carefully.

### Materials

- prepared slides showing stages of development of an animal from zygote to embryo (e.g., sea star or sea urchin)
- microscope or microviewer

### Procedure

#### Part 1: Observing Embryonic Structures

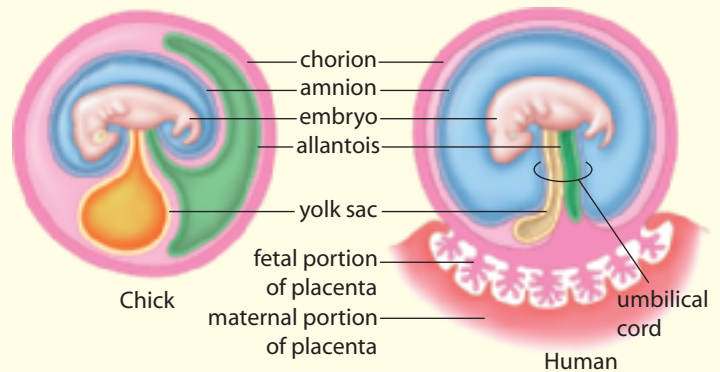
1. Obtain and set up a microscope or microviewer and the slides you will be viewing.
2. Sketch the main features that you observe in each slide. Add labels to identify all the features that you recognize.
3. Answer Analysis questions 1–4.

#### Part 2: Comparing Extra-embryonic Structures

1. Examine the diagrams of extra-embryonic membranes of an embryonic chick and an embryonic human.
2. **a)** In your notebook, identify the extra-embryonic membranes that human and chicken embryos have in common.
  - b)** What similarities and differences do you observe in the structure of these membranes? Describe or sketch your observations.
3. Answer Analysis questions 5 and 6.

### Analysis

1. On which slide or slides do you observe evidence that cleavage has occurred?
2. Identify changes in the embryo that indicate that a blastocyst has formed.
3. Identify changes that indicate a gastrula has formed.
4. Describe any recognizable tissues in the last phase of development that you observed.



5. In birds, the extra-embryonic membranes have the following functions:
  - allantois: transports, in combination with the chorion, oxygen to the embryo and removes carbon dioxide produced by the embryo; also stores nitrogenous wastes and absorbs calcium from the shell to make it available for bone formation
  - amnion: a fluid-filled sac that provides protection from physical shock and enables the embryo to move freely and safely
  - chorion: see allantois
  - yolk sac and yolk: stores nutrient-rich yolk and absorbs nutrients from it so that they are available for nourishing the embryo via blood vessels in the sac membrane

How do the functions of the extra-embryonic membranes in birds compare with their function in humans?
6. **a)** Think about the place (the environment or location) in which human development takes place. Based on the place (environment or location) in which the following animals develop, predict whether they would form a placenta, and give reasons to justify your prediction.
  - frog • turtle • sea star • pike • crow
- b)** Identify the extra-embryonic membranes from which the placenta forms and explain how their function, modified in humans, relates to their function for chicken embryos.



## SECTION 15.2

# Fetal Development and Birth

### Section Outcomes

In this section, you will

- **trace** the processes and key events that occur during fetal development (the last thirty weeks of prenatal life)
- **describe** and **investigate** the effect of teratogens and other environmental factors on the development of prenatal body structures and systems
- **trace** the processes of parturition and lactation, and **outline** their control mechanisms

### Key Terms

teratogen  
fetal alcohol spectrum disorder (FASD)  
parturition  
lactation

### BiologyFile

#### Try This

Plan, design, and create a multimedia presentation to show development through the embryonic and fetal periods. What images will you use? Will your information be text-only or can you include audio? What sources of information will you use for your images and script?

The fetal period of development starts during the ninth week and lasts until birth. During this period, the fetus looks obviously human. The main difference between the embryonic and the fetal periods relates to the organs. In the embryo, most of the organs are taking shape. In the fetus, the organs are present and continue to develop. The embryonic period is a time of morphogenesis. The fetal period, on the other hand, is a time of growth and “refinement” of the existing structures.

### First Trimester Developments (Weeks 1 to 12)

In Section 15.1, you examined the embryonic period of development, which takes place in the first eight weeks after fertilization. During the next four weeks—the last month of the first trimester—growth in the length of the body accelerates, but growth of the head slows. The cartilage-based skeleton begins to harden, with the development of bone. By the end of the twelfth week, the external reproductive organs are distinguishable as male or female.

### Second Trimester Developments (Weeks 13 to 24)

By the fourth month, the heartbeat of the fetus is strong enough to hear with a stethoscope. The bones of the skeleton begin to form. The brain grows rapidly, and the nervous system starts to function. As the fetal legs grow and develop, the mother begins to feel movement.

During the fifth month, the fetus becomes covered with fine, soft hair and an oily substance to protect the still-developing skin. The hair, called lanugo (from a Latin word that means “wool”) is usually shed before birth.

In the sixth month, the skin appears wrinkled because there is very little fat

beneath it. The skin becomes more pink as blood-filled capillaries extend into it. If the fetus is born at this stage, it is unlikely to survive. It certainly would not survive without medical intervention.

### Third Trimester Developments (Weeks 25 to 38)

In the third and final trimester, fetal brain cells form rapidly (by the tens of thousands per minute), connecting to form more and more intricate networks. The testes of males descend into the scrotum. A layer of fat develops beneath the skin. The digestive and respiratory systems are usually the last to mature, which is why infants that are born prematurely often have difficulty digesting milk and breathing.

Proper nutrition is important during all of pregnancy, for both the mother and the fetus. Nutrition is especially important during the third trimester. Poor nutrition damages the placenta, which can lead to low birth weight, short stature, delayed sexual development, and learning disabilities.

About 266 days (approximately 40 weeks) after the formation of a single fertilized cell, a multi-trillion-celled being is ready to be born. Table 15.2 lists major monthly events in the development of this new life.

24 What is the main difference between the embryonic and fetal periods of development?

25 Identify three events or characteristics of fetal development during the second trimester.

26 Identify three events or characteristics of fetal development during the third trimester.

## The Effects of Teratogens on Development

In addition to the nutrients and other beneficial substances that a mother transfers to the embryo and fetus, she can transfer harmful substances. Whatever the mother ingests or inhales can end up in her circulating blood. Some of these

substances pass through the placental system to the fetus's blood. This is especially significant during the first nine weeks, when developing organs are highly sensitive to environmental factors, as shown in Figure 15.12 on page 522.

Many substances and conditions can affect the normal development of the embryo and fetus. The term **teratogen**

**Table 15.2** Major Events, by Month, in Prenatal Development

Month	Length* at end of month (cm)	Mass at end of month (g)	Significant developmental events
1	0.4	less than 1	<ul style="list-style-type: none"> <li>• Spinal column and central nervous system start to form.</li> <li>• Appendages are represented by small limb buds.</li> <li>• Heart begins beating (around day 22).</li> </ul>
2	3	1	<ul style="list-style-type: none"> <li>• Eyes form, but eyelids are fused shut.</li> <li>• Nose is flat.</li> <li>• Head is nearly as large as rest of body.</li> <li>• Nostrils are evident, but plugged with mucus.</li> <li>• Limb buds form paddle-like hands and form ridges (which later separate into distinct fingers and toes).</li> <li>• Brain waves are detectable.</li> <li>• Bone growth begins.</li> <li>• Blood cells and major blood vessels form.</li> <li>• Genitals are present, but sexes are not yet distinguishable.</li> </ul>
3	9	30	<ul style="list-style-type: none"> <li>• Eyes are well developed, but eyelids are still fused.</li> <li>• Nose develops bridge.</li> <li>• Fetus swallows amniotic fluid and produces urine.</li> <li>• Sexes can be distinguished visually.</li> <li>• Limbs are well-formed, with nails on fingers and toes.</li> <li>• External ears are present.</li> <li>• Fetus moves but too weakly for mother to feel it.</li> </ul>
4	14	100	<ul style="list-style-type: none"> <li>• Face looks more distinctly human.</li> <li>• Body is larger in proportion to head.</li> <li>• Skin is bright pink.</li> <li>• Scalp has hair.</li> <li>• Joints are forming.</li> <li>• Lips exhibit sucking movements.</li> <li>• Heartbeat can be heard with a stethoscope.</li> </ul>
5	19	200–450	<ul style="list-style-type: none"> <li>• Body covered with fine hair (lanugo).</li> <li>• Skin has oily secretion to protect it from amniotic fluid.</li> <li>• Fetus is now bent forward into “fetal position” because it is beginning to outgrow the amniotic sac.</li> <li>• Mother can feel fetal movements.</li> <li>• Skin is bright pink.</li> </ul>
6	27–35	550–800	<ul style="list-style-type: none"> <li>• Eyes are open.</li> <li>• Eyelashes form.</li> <li>• Skin is wrinkled, pink, and translucent.</li> </ul>
7	32–42	1100–1350	<ul style="list-style-type: none"> <li>• Skin is wrinkled and red.</li> <li>• Fetus turns to an upside-down position.</li> <li>• Bone marrow is now the only site for red blood cell formation.</li> <li>• Testes descend into scrotum.</li> <li>• Fetus can usually survive if born prematurely.</li> </ul>
8	41–45	2000–2300	<ul style="list-style-type: none"> <li>• Fatty tissue deposition gives fetus a more plump, “babyish” appearance, with lighter, less wrinkled skin.</li> <li>• Twins are usually born now.</li> </ul>
9	50	3200–3500	<ul style="list-style-type: none"> <li>• More fat deposition occurs.</li> <li>• Lanugo is shed.</li> <li>• Nails extend to or beyond fingertips.</li> <li>• Birth is imminent.</li> </ul>

\* Length is measured from the top of the head to the bottom of the buttocks (often referred to as the crown-to-rump, or CR, length).

Severe congenital abnormalities						Less severe abnormalities and functional disorders			
Embryonic period (weeks)						Fetal period (weeks)			
3	4	5	6	7	8	9	16	32	38
abnormalities of the neural tube								CNS abnormalities	
heart abnormalities			heart abnormalities						
abnormalities of the extremities		upper extremities							
abnormalities of the extremities		lower extremities							
cleft lip		upper lip							
abnormalities of the ears (lower ear location, hearing impairment)							ears		
eye disorders (abnormally small eyes, glaucoma, cataracts)					eyes				
tooth enamel, discoloration					teeth				
cleft palate					gums				
genital abnormalities						external sex organs			

Legend:

- highly sensitive phase
- less sensitive phase

**Figure 15.12** This graph shows the critical phases of prenatal development. The darker portions correspond to periods when organs are most sensitive to teratogens.

refers to any agent that causes a structural abnormality due to exposure during pregnancy. Cigarette smoke, for example, can constrict the fetus's blood vessels, preventing the fetus from getting enough oxygen. Mothers who smoke or who are exposed to second-hand smoke during pregnancy tend to have babies that are underweight. Cigarette smoke during pregnancy also increases the risk of premature births, stillbirths, and miscarriages. As well, there is mounting evidence of behavioural problems and reduced intellectual ability in children of smoking mothers.

One of the most damaging teratogens is also the most avoidable: alcohol. Alcohol can affect the fetus's brain, central nervous system, and physical development (see Figure 15.13). Babies who are affected by alcohol consumption during pregnancy are likely to have decreased weight, height, and head size, as well as malformations of the face and head. In addition, these children show varying degrees of learning and memory difficulties and often exhibit unusual aggression or personality disorders. Because each woman metabolizes alcohol slightly differently, physicians advise that all women avoid alcohol when pregnant,

when trying to become pregnant, and when breast-feeding.

The term that is used to describe all the disorders related to alcohol consumption during pregnancy is **fetal alcohol spectrum disorder (FASD)**. This includes the more commonly known clinical disorder called fetal alcohol syndrome (FAS).

Many prescription and over-the-counter medications have teratogenic properties. Examples of medications that are known to have dangerous effects on a fetus include some antibiotics (such as tetracycline), some acne medications, anti-thyroid drugs (for treating hypothyroid and hyperthyroid conditions), and some anti-cancer drugs. The most notorious prescription drug with teratogenic effects is thalidomide, which was first prescribed in the 1950s to reduce morning sickness. Its use for pregnant women was discontinued when doctors discovered that an alarming number of babies were being born with missing and deformed limbs. Thalidomide is still available under tightly controlled regulations. In the United States, it is approved for treating skin conditions associated with leprosy. As well, it is being studied for its potential to treat cancers of the bone marrow (myeloma).



Certain nutrients ingested in large amounts, particularly vitamins, can have teratogenic effects. One example is vitamin C. The fetus becomes accustomed to the large doses and, when the supply drops after birth, the baby develops symptoms of vitamin C deficiency (scurvy), bruising easily and being prone to infection. Other teratogenic agents include radiation, such as X-rays, and pollutants, such as PCBs and organic mercury compounds.

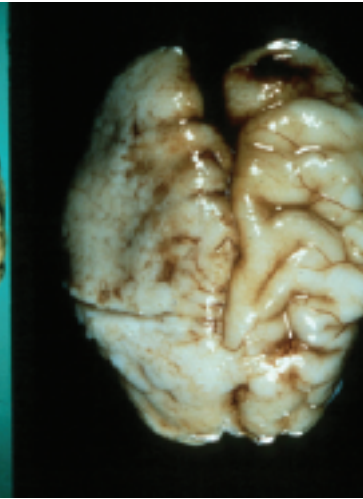
Good judgment and decision making play key roles during pregnancy. Sometimes, however, the mother cannot control her exposure to teratogens. For example, people in many northern Aboriginal communities rely heavily on fish and wildlife in their traditional diet. The presence of environmental contaminants in the food chain, due to industrial discharges and run-off from contaminated land, is a great concern for those who rely solely or partly on traditional foods. There is ongoing research, and much debate, about the effects of exposure to elevated levels of environmental contaminants (such as mercury, lead, cadmium, DDT, and PCBs) in fish and wildlife for pregnant and nursing women. Contaminants have been found in pregnant women, the umbilical cord, and the breast milk of nursing mothers in northern Aboriginal communities. Women with these contaminants in their blood are reported to have a higher number of miscarriages, lower birth-weight babies, babies who have difficulty fighting infections and disease, and children who are developmentally delayed, compared with women who have limited or no exposure to these contaminants.

- 27 What are teratogens?
- 28 Give three examples of dangers that teratogens pose to the developing baby.

**Normal brain of baby  
6 wks old**



**Brain of baby same age  
with FAS**



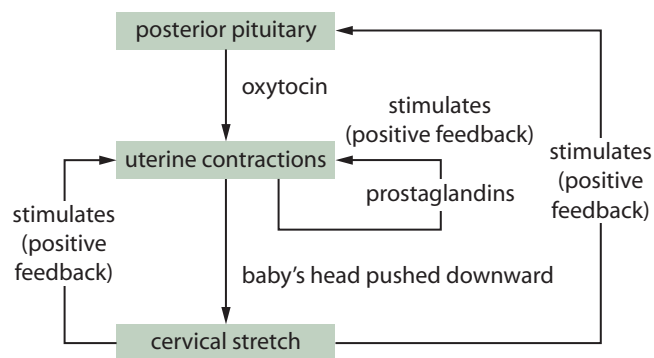
**Figure 15.13** This photograph provides dramatic evidence of the damaging effects of alcohol on brain development.

### Parturition: Delivery of the Baby

The birthing process is called **parturition**, and all the events associated with parturition are commonly referred to as *labour*. These events typically begin with uterine contractions.

The uterus experiences contractions throughout pregnancy. At first, these are light, lasting about 20 to 30 seconds and occurring every 15 to 20 minutes. Near the end of pregnancy, the contractions become stronger and more frequent. The onset of labour is marked by uterine contractions that occur every 15 to 20 minutes and last for 40 seconds or longer.

The onset of labour includes both hormonal and neural components (Figure 15.14). A positive feedback mechanism can explain the onset and



**Figure 15.14** This diagram outlines positive feedback mechanisms that are hypothesized to control parturition. In fact, despite advances in technology, our understanding of the factors that initiate and control parturition in humans remains incomplete.

**Investigating** the effects of folic acid on embryonic and fetal development

**Discussing** the societal impact of folic acid consumption on fetal development

Teratogens are agents that cause developmental or physical abnormalities through ingesting (or inhaling) them or through exposure to them. In some cases, however, not being exposed to a substance or receiving inadequate amounts of it can also result in physical or developmental abnormalities. This is certainly true of nutrition during (as well as before and after) prenatal development. Inadequate intake of one nutrient in particular, folic acid (vitamin B9, also called folate), can have devastating consequences for embryonic development. In this investigation, you will use an abstract from a medical journal as the starting point for further study on the impact of folic acid on neural tube defects. (Neural tube defects, or NTDs, result when the neural tube—refer to page 514—does not close by about the twenty-eighth day. This leaves open an area of the spine from which nervous tissue protrudes, usually causing paralysis from the site downward.)

### Procedure

1. Read the abstract below, which was published in *Clinical and Investigative Medicine* in 1996. You may need to look some words up in a print or electronic dictionary. Even if you do not understand every word or some of the sentences, you should still be able to “pick out” the general meaning or significance of what the authors of the journal article are saying. **ICT**
2. Using print or electronic resources, conduct further research on neural tube defects to find out the following. **ICT**

- what kind of defects can occur, how often they occur statistically in Alberta and/or Canada, their characteristics/symptoms, and what, if any, treatments are available for them
- why Canada’s health agency was reluctant to advise fortifying foods with folic acid, and the current status of folic-acid fortification
- actions taken on the part of Health Canada to inform the public about folic acid and NTDs

### Analysis

1. What is the recommended daily amount of folic acid for women who could become pregnant?
2. When should women who could become pregnant start taking folic acid?
3. Why is dietary (unsupplemented) intake of folic acid considered to be inadequate to prevent NTDs?
4. What other risk factors are involved in having a baby with an NTD?
5. In your opinion, based on what you have discovered through your research, should the Canadian government have acted more quickly when the link between folic acid and neural tube disorders was established and communicated in the scientific community? Give reasons to justify your opinion.

### Abstract

**Objectives:** To determine the diffusion of information about preventing neural tube defects (NTDs) through folic acid consumption by examining whether mothers of Canadian children born with spina bifida, who had become pregnant at least a year after evidence of the preventive effect of folic acid had been published, had taken sufficient amounts of folic acid in the periconceptional period [that is, the first few weeks of pregnancy] and were aware of this important new information.

**Design:** Validated food-frequency questionnaire to assess folate intake.

**Setting:** The Hospital for Sick Children in Toronto between Jan. 4 and Aug. 16, 1994.

**Participants:** Thirty mothers whose infants were being treated for spina bifida.

**Main outcome measures:** The mothers’ mean folate intake and knowledge about the protective effect of folic acid; demographic and health information.

**Results:** The mothers’ mean folate intake was 0.182 mg/d (standard deviation 0.076 mg/d, range 0.02 to 0.53 mg/d), less than half the protective dose. Only 4 (13%) of the mothers had been aware of the relation between nutritional folate and NTDs when they conceived, but even they did not supplement their diets with sufficient folic acid. The medical data showed that, in addition to the failure of primary prevention of NTDs, secondary prevention through diagnostic tests during pregnancy were also inadequate.

**Conclusions:** Our study, one of the first to be conducted after the role of folate in preventing NTDs was confirmed, reveals that, in one of the most advanced countries in the world, this new information has had no effect on patients’ folate intake. Unless food is fortified with folate, the estimated 400 to 800 annual cases of NTDs in Canada will not be prevented.

Source: *Clin Invest Med* 1996; 19 (3): 195–201

continuation of labour. Uterine contractions are induced by a stretching of the cervix, which also brings about the release of oxytocin from the posterior pituitary gland. Oxytocin stimulates the uterine muscles, both directly and through the action of prostaglandins. Uterine contractions push the fetus downward, and the cervix stretches even more. This cycle keeps repeating itself until birth occurs.

Figure 15.15 illustrates the three stages of parturition. Although the diagrams show the birthing mother in a horizontal position, some mothers may choose to give birth from a squatting or partially upright position so that gravity can help with the delivery. Other mothers prefer to give birth in water,

to lessen the shock of the baby's entry into an atmospheric environment.

For several reasons, it may not be safe or possible to deliver a baby in the usual way. For example, the baby may be in a rump-first position. It is difficult for the cervix to expand enough to accommodate this type of birth (called a breech birth), and the baby or mother could be harmed. Instead, the baby is usually delivered by a Caesarean section. In this procedure, a physician makes an incision in the mother's abdomen and uterus, and delivers the baby through the incision. A mother with a sexually transmitted infection, such as herpes, or a mother with a small pelvis may also have her baby delivered by Caesarean

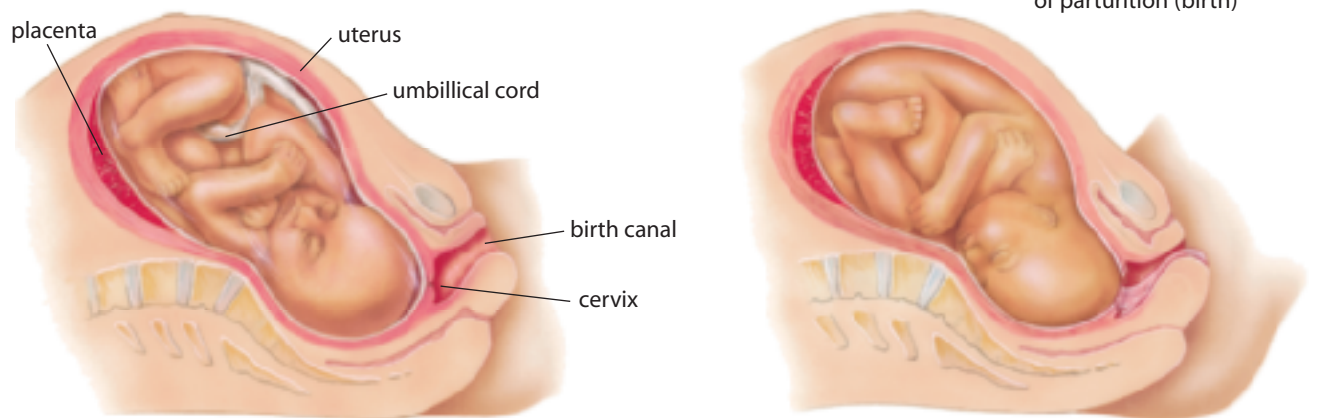
## BiologyFile

### Web Link

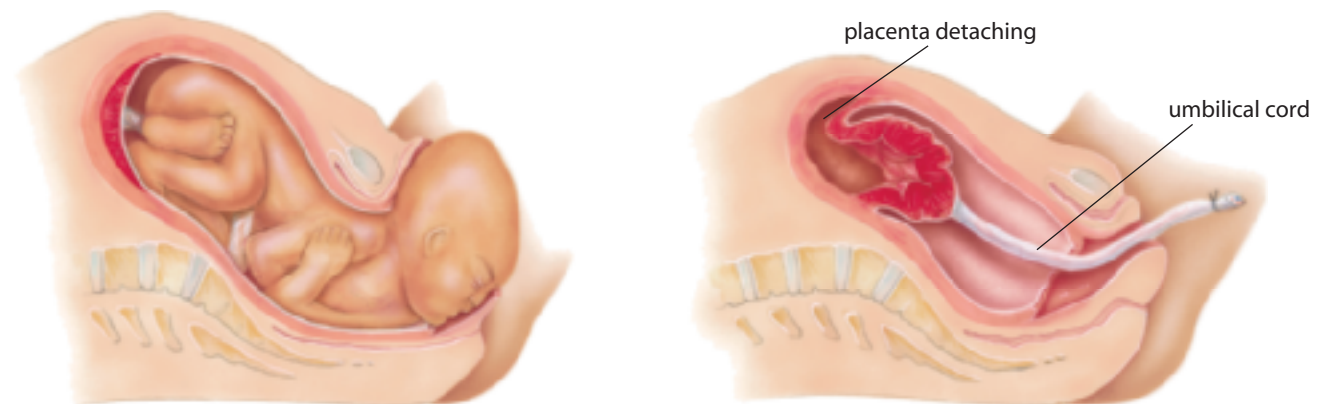
Some women elect to give birth to a baby at home ("home birth"), rather than in a hospital setting. In either case, a woman may prefer the services of a midwife to that of a physician. What are the roles and responsibilities of a midwife? What is the current status of midwives in Alberta as compared with the rest of Canada?



**Figure 15.15** Three stages of parturition (birth)



- A Dilation stage** Uterine contractions and oxytocin cause the cervix to open, or dilate. During this stage, the amniotic sac breaks and the amniotic fluid is released through the vagina. The dilation stage usually lasts from 2 to 20 hours.



- B Expulsion stage** Forceful contractions push the baby through the cervix to the birth canal. As the baby moves through the canal, the head rotates, making it easier for the body to pass through the birth canal. This stage usually lasts from 0.5 to 2 hours.
- C Placental stage** About 10 to 15 minutes after the baby is born, the placenta and umbilical cord are expelled from the uterus. The expelled placenta is called the afterbirth.



## BiologyFile

### Web Link

Alberta is home to the only public, not-for-profit Cord Blood Bank in Canada. Why do some people choose to collect and save (“bank”) the blood that remains in the umbilical cord after birth? Who can benefit from this choice?

[www.albertabiology.ca](http://www.albertabiology.ca)  
WWW

section to protect herself and her baby from injury or infection.

Once the baby is breathing normally, the umbilical cord is clamped, cut, and tied. (There are no nerves in the umbilical cord, so no pain is felt.) The baby is now cut off from the source of protection and nutrients it has depended on for nine months. It must breathe, ingest food, and eliminate wastes on its own. The cord eventually shrivels, and the place where the cord was attached to the fetus becomes the navel.

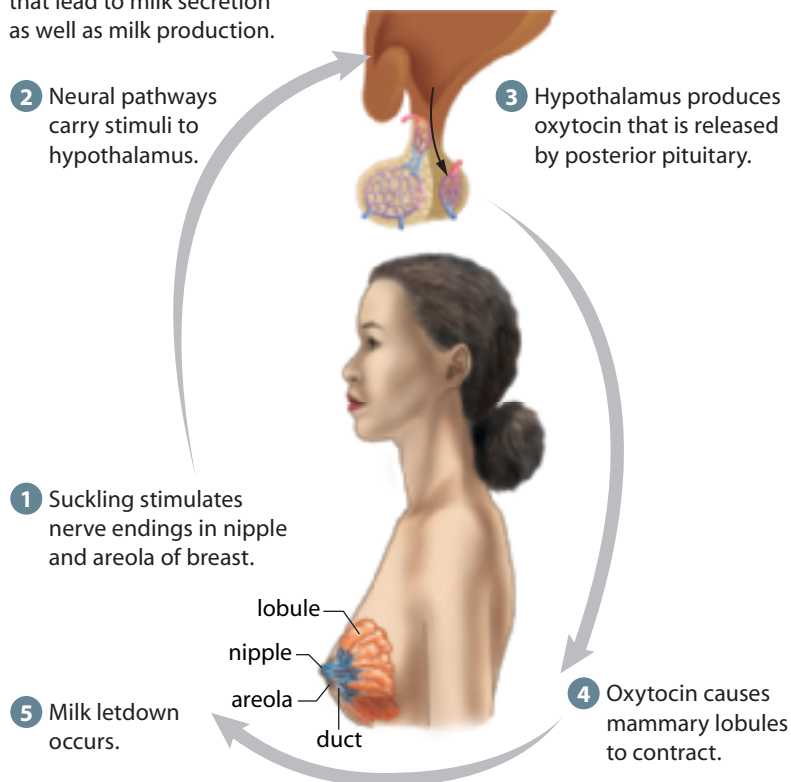
29 What hormones are involved during parturition (birth)?

30 What is a Caesarean section?

## Lactation and the Suckling Reflex

Hormones control the onset of **lactation**—the secretion and formation of breast milk in the mother. Prolactin, the hormone that is needed for milk production, is not secreted during pregnancy. High levels of estrogen and

**Figure 15.16** A suckling baby initiates the events that lead to milk secretion as well as milk production.



progesterone suppress its production in the anterior pituitary. Once the mother has given birth, however, the anterior pituitary begins to produce and secrete prolactin. Milk production starts within a few days. Before then, the breasts secrete colostrum, a thin yellowish fluid that is similar to milk but contains more protein and less fat. Colostrum and milk also contain antibodies from the mother, providing the baby with protection from various infectious agents.

Figure 15.16 shows how a suckling baby stimulates the release of milk from the mother’s breast. When a baby suckles, it stimulates nerve endings in the nipple and areola (circular area of different-coloured skin around the nipple). The nerve impulses travel to the hypothalamus, which, in turn, stimulates the posterior pituitary to release oxytocin. Oxytocin causes contractions within the mammary lobules. The mammary lobules contain alveoli, which are sacs with cells that produce milk. The lobules end in mammary ducts at the nipple. Contractions within the lobules cause milk to flow to the ducts, where the infant can draw it out by suckling. If suckling does not occur, or if it stops, milk production stops within a few days. Conversely, increased suckling stimulates increased milk production which can continue for several years.

31 What is lactation?

32 Describe the role of oxytocin in lactation.

## Section 15.2 Summary

- Body growth is the main characteristic of the fetal stage, which extends from the ninth week until birth.
- During the third and fourth months, the skeleton is forming bone, and the sex of the fetus becomes distinguishable.
- From the fifth month through the ninth month, the fetus continues to grow and to gain in body mass. Fat is

## Stem Cells

Imagine being able to repair human body parts with tissue grown especially for the purpose. For instance, people who have had heart attacks could receive new cardiac (heart) cells. Instead of waiting for organ transplants, people with failing livers, kidneys, or lungs could have healthy new organs grown for them. People who have lost the use of their legs through paralysis might be able to walk again with new nerve cells growing in their spinal cords. The key to these technological feats is stem cells.

### What are Stem Cells?

Stem cells are unspecialized or undifferentiated cells. This means that they have not yet begun to develop into red blood cells, muscle cells, or any other of the 200 or so cell types that make up the human body.

Stem cells have two important features. First, they can replicate (make copies of themselves) for a long time by dividing. Second, under suitable laboratory conditions, stem cells can be coaxed to give rise to cells with special functions, such as heart muscle cells and neurons (nerve cells).

There are two main types of stem cells: adult stem cells (also called somatic stem cells) and embryonic stem cells. In spite of their name, adult stem cells are found in humans of all ages. In fact, one source of adult stem cells for medical use is the umbilical cords of newborns. Small numbers of these stem cells have now been found in many different human organs and tissues.

Embryonic stem cells, as their name implies, come from embryos—about four or five days after fertilization. The source of embryonic stem cells has been an assisted reproduction technique called *in vitro* fertilization. In this process, embryos are produced in a lab; more are produced than are implanted in the woman who wishes to become pregnant. Scientists now also have the ability to create embryos solely for research, but many countries, including Canada, have banned this technique as unethical.

Embryonic stem cells are pluripotent, which means that they can become many different types of cells in the human body. Until very recently, it was thought that adult stem cells could only give rise to the different types of cells in the tissues where they were found. For example, basic blood stem cells found in bone marrow could become red blood cells, white blood cells, and so on. However, recent research has shown that many adult stem cells can be made to develop into a wider range of specialized cells. For instance, in the laboratory, blood stem cells have yielded muscle cells, including heart muscle cells, and nerve cells. This is an exciting area of

research for two reasons: first, it would avoid the ethical issues of embryonic stem cell research, and second, it could produce repair tissues from a person's own body cells that would be a perfect match.

### Stem Cell Research in Canada

Working together, Alberta-born biophysicist James Till and Toronto physician Ernest McCulloch discovered stem cells in 1960. In 1992, neuroscientist Samuel Weiss of the University of Calgary was the first to show that adult stem cells exist in the human brain. Today, Canada is still in the forefront of stem cell research. Dr. Weiss, for example, is now researching how the brain's stem cells could be used to help people who have had strokes. Meanwhile, researchers at the University of Alberta are working on a stem cell treatment for Type 1 Diabetes, while an Ottawa scientist is working with heart stem cells that could be used in the treatment of heart attacks.

Many important questions about stem cells still remain to be answered. Among them: how many different types of adult stem cells can be found in the human body, and in what tissues? What is the purpose of adult stem cells in the body? Why do they remain in an undifferentiated state, when all the cells around them have differentiated?

• • •


1. One of the first diseases to be treated with stem cells was leukemia. Research what this treatment was and why it worked. How has the treatment changed today?
2. Depending on their source, stem cells may be referred to as totipotent, pluripotent, and multipotent. What are the differences among these types of stem cells, and where are they found in the body?
3. Some people (including some scientists) consider stem cell research and use objectionable. What is the foundation of the controversies surrounding stem cells? What steps has Canada taken to restrict the ways in which stem cell research can be performed?

deposited beneath the skin to help insulate the newborn, and the fetus kicks, stretches, and moves freely within the amniotic sac.

- Teratogens are factors that can adversely affect the health of a fetus.
- Examples of teratogens include alcohol, tobacco, illegal drugs (such as cocaine), environmental toxins (such as pesticides), maternal infections (such as chicken pox and measles), lack of nutrients (especially folic acid), and too much of certain nutrients (such as vitamin C).

- The hormones oxytocin and prostaglandins help to stimulate uterine contractions, assisting the movement of the fetus in the process of parturition.
- The stimulus of suckling results in the secretion of oxytocin from the posterior pituitary, stimulating the contraction of the milk glands and ducts for lactation.

## Section 15.2 Review

1. In what ways does the fetal period of development differ from the embryonic period of development?
2. During which trimester do the following events occur?
  - a) heart starts beating
  - b) the body is larger in proportion to the head
  - c) fatty tissues are deposited beneath the skin
  - d) brain cells are connecting to form more intricate networks
  - e) external reproductive organs are distinguishable as male or female
  - f) eyelashes form
  - g) contractions felt by the mother signal the onset of labour
  - h) skin appears wrinkled
  - i) nervous system starts to function
  - j) external reproductive organs are present but not distinguishable as male or female
  - k) the fetus produces urine
  - l) the fetus adopts the “fetal position”
  - m) blood cells and major blood vessels start to form
  - n) the head is larger in proportion to the body
3.
  - a) Which of the following is not a teratogen: x-rays, folic acid, alcohol, mercury, HIV, nicotine, tetracycline (an antibiotic), vitamin C?
  - b) Explain why the answer you chose in (a) is not a teratogen and why the others are.
4. What is parturition?
5.
  - a) How many stages of parturition are there?
  - b) Describe what occurs during each of these stages.
6. Describe two hormonal changes that occur in the mother’s body as parturition occurs.
7. Outline how hormones are involved in lactation and the suckling reflex. 
8. In the traditional birthing practices of Inuit women, the women increased their consumption of caribou, char, muktuk (whale blubber and skin), and seal, and they limited their intake of berries. They did not eat any aged food. (Source: *Midwifery and Aboriginal Midwifery in Canada*, National Aboriginal Health Organization, 2004, p. 24.) Infer at least two reasons for these food choices and omissions.

## SECTION 15.3

# Reproduction, Technology, and Society

### Section Outcomes

In this section, you will

- **describe** different reproductive technologies
- **evaluate** various reproductive technologies based on their effectiveness and safety, and **justify** your evaluation

### Key Terms

reproductive technologies  
in vitro fertilization (IVF)  
sterile  
infertile  
artificial insemination  
surrogate mother  
superovulation  
abstinence  
tubal ligation  
vasectomy  
contraceptive technologies

On July 25, 1978, Leslie Brown made history by giving birth to a healthy baby girl. Louise Joy Brown, born in Great Britain, was the world's first "test tube baby." Her life began in a laboratory. Scientists removed an egg from her mother and mixed it with sperm from her father. After two and a half days, scientists placed the fertilized egg in Leslie's uterus. Almost nine months later, Louise was delivered by Caesarean section.

The success of the first test-tube baby gave many infertile couples hope that they, too, could have a child. Over 1.5 million test tube babies have been born since 1978. The new technology stimulated, and continues to stimulate, controversy, however. Is it ethical? Will people find ways to abuse the technology? In the decades since Louise's birth, many new forms of **reproductive technologies**—technologies that enhance or reduce reproductive potential—have been developed. And many of the same social and ethical questions are still being asked.

The technology used in the conception of Louise Brown is called **in vitro fertilization**, or **IVF**. (*In vitro* is Latin for "in glass," referring to the Petri dish in which fertilization takes place.) IVF is one example of a technology that was designed to enhance the reproductive potential of couples who wish to have children but are unable to conceive. Other reproductive technologies are designed for couples who are physically able to conceive children but do not wish to do so. In this section, you will consider a range of reproductive technologies within each of these two broad categories.

### Technologies That Enhance Reproductive Potential

The term **sterile** is used to describe men and women who are unable to have any children. Men and women who have

difficulty conceiving children are described as infertile. Couples are considered to be **infertile** when they have been trying unsuccessfully to become pregnant for a year or more. Researchers have identified some causes of infertility and sterility. The precise cause of a couple's infertility cannot always be identified or explained, however.

A man may be infertile or sterile for any of the following reasons:

- obstruction in the ductus deferens or epididymis, which may be caused by complications arising from STIs or from other blockages in the testicles
- low sperm count, caused by numerous factors including overheated testicles, smoking, and alcohol intake
- high proportion of abnormal or non-viable sperm, caused by factors including overheated testicles, exposure to toxic chemicals or radiation, and infections such as STIs
- inability to achieve an erection or ejaculation (also known as erectile dysfunction or impotence), caused by factors including vascular disease, nervous system injury, stress, hormonal imbalance, medication, smoking, and alcohol intake.

A woman may be infertile or sterile for any of these reasons:

- blocked oviducts, often an effect of STIs
- failure to ovulate, caused by hormonal imbalances that occur for a variety of reasons, including being malnourished
- endometriosis, a painful condition in which endometrial tissues grow outside the uterus
- damaged eggs, which may be caused by environmental factors such as exposure to toxic chemicals or radiation

Some causes of infertility can be corrected with medical treatment or a healthier lifestyle. Couples who remain unable to have children, however, may consider one of the following technologies to increase their chances of having a child.



## BiologyFile

### Web Link

The space age and the continued presence of humans in space have spawned questions that would not have occurred to early researchers of reproduction. For example, how do sperm behave in microgravity conditions? In what ways could their behaviour and movement affect fertility? What role might gravity play in human development?

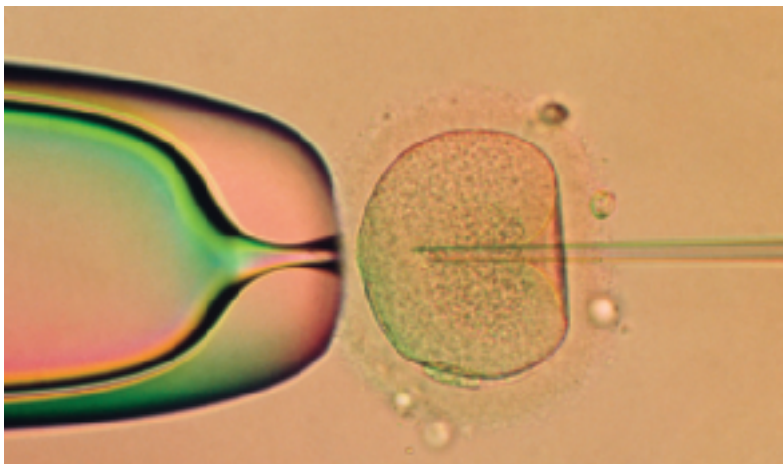
[www.albertabiology.ca](http://www.albertabiology.ca)  
WWW

## Artificial Insemination

Artificial insemination (AI) has been used for decades as a way to promote breeding success among domestic animals. It had also been used by human couples for years, before the first success of IVF. Artificial insemination continues to be refined and is still useful when the man is sterile or infertile. In **artificial insemination**, sperm are collected and concentrated before being placed in the woman's vagina. In some cases, the sperm are donated by the woman's male partner. In other cases, the sperm are from a stranger. Sperm banks provide a source of sperm samples that have been gathered for this purpose.

## In Vitro Fertilization

As in the case of Leslie Brown, IVF offers a solution for women with blocked oviducts. Today, ultrasound machines are used to identify specific follicles that are close to ovulation. Immature eggs can be retrieved directly from these follicles. The eggs are combined with sperm in laboratory glassware (see Figure 15.17). After fertilization, the developing embryo is placed in the uterus. A slight variation on IVF is Gamete Intrafallopian Transfer (GIFT), in which the eggs and sperm are brought together in the oviduct rather than *in vitro*. This procedure has a higher success rate than IVF.



**Figure 15.17** In a variation of *in vitro* fertilization, performed when a sperm is unable to penetrate the egg *in vitro*, sperm may be injected into the egg—a technique called intracytoplasmic sperm injection. It is used to help men with very low sperm counts, high numbers of abnormal sperm, or injuries or illnesses that prevent men from providing a sperm sample through ejaculation.

## Surrogate Mothers

Sometimes, an infertile couple contracts another woman to carry a baby for them. The woman who carries the baby is called the **surrogate mother**. Using AI or IVF, one or both gametes may be contributed by the contracting couple.

## Superovulation

**Superovulation** is the production of multiple eggs as a result of hormone treatment. Women who ovulate rarely or not at all may receive treatment with hormones that stimulate follicle development and ovulation. Superovulation is also often used in conjunction with other artificial reproductive technologies.

33 Give two reasons that a man might be infertile or sterile, and identify two reproductive technologies that could help.

34 Give two reasons that a woman might be infertile or sterile, and identify two reproductive technologies that could help.

## Technologies That Reduce Reproductive Potential

Sometimes, couples who are fertile wish to avoid or delay conceiving a child. Any behaviour or technology that prevents conception is a form of contraception, or birth control. There are several different forms of contraception, each with its own advantages and disadvantages. Some examples are described briefly below.

## Abstinence

The surest way to avoid conceiving a child is simply not to have sexual intercourse. Complete **abstinence** also has the important advantage of ensuring almost total protection from STIs. Not all couples, however, are willing to abstain entirely from a sexual relationship.

## Surgical Sterilization

As shown in Figure 15.18, both men and women can have surgery to make them infertile or sterile. In women, a procedure called a tubal ligation is used. **Tubal ligation** involves cutting the oviducts and tying off the cut ends. This ensures that the ovum never encounters sperm and never reaches the uterus. The ovum disintegrates in the oviduct. The equivalent procedure in men is called a **vasectomy**. The ductus deferens is cut and tied. The man is still able to have an erection and ejaculate, but his semen does not contain any sperm. Effectiveness of the procedure at preventing conception is nearly 100 percent for both men and women.

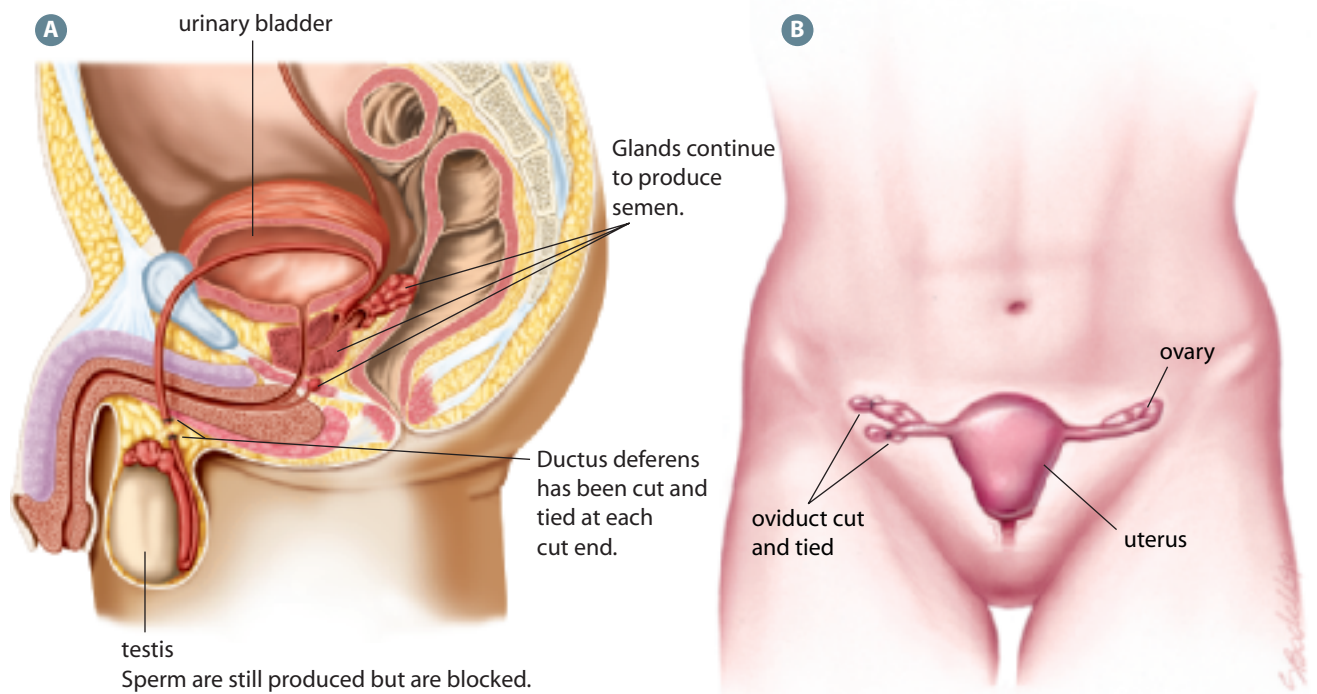
## Hormone Treatments

Several **contraceptive technologies** work by changing the balance of reproductive hormones within a woman's body. Hormone medications may be taken orally (through an oral contraceptive or birth control pill), by injection, or by implants inserted under the skin. The artificial hormones mimic the effect of progesterone and inhibit the release of FSH and LH from the anterior pituitary.

As a result, the woman does not ovulate. While hormone treatments are a very reliable form of contraception, with effectiveness ranging from 90 to 99 percent, they do have some side effects. Common side effects include an increased risk of blood clots, strokes, and breast cancer.

A more intensive hormone treatment can also be taken for emergency use. It is not a form of contraception. A woman may use an emergency hormone treatment to reduce the risk of conception following unprotected sexual intercourse. The most commonly used type is known as the "morning-after pill," although in fact it is a treatment of several pills taken within three days after intercourse. The pills deliver high doses of synthetic estrogen and progesterone. These hormones disrupt the ovarian cycle and can prevent or delay ovulation. If fertilization has already taken place, these hormones can also prevent the embryo from implanting in the uterus. The most common side effects of this treatment include vomiting and painful cramps. Effectiveness ranges from about 95 percent if taken within 24 hours after unprotected intercourse to 85 percent if

**Figure 15.18** Surgery can be used to render men (A) and women (B) sterile.



taken within 24 to 48 hours. Effectiveness drops significantly to about only 5 percent if taken within 48 to 72 hours.

### Physical or Chemical Barriers

Many contraceptive technologies are designed to prevent sperm from reaching the ovum. Physical barriers include male or female condoms (effectiveness about 85 percent), a latex cap—called a diaphragm—that fits over the cervix (effectiveness about 90 percent), and the contraceptive sponge (effectiveness ranging from about 70 to 90 percent depending on whether the woman has given birth and the care taken in using it). Spermicides—chemical barriers that kill sperm—include jellies, foams, and creams. Effectiveness is about 75 percent. Chemical barriers and physical barriers can be used together, which increases their effectiveness. Condoms have the additional advantage of offering some protection against the transmission of STIs.

### Natural Family Planning

Some couples refrain from sexual intercourse during the time of the woman's cycle when she is most fertile (that is, from a week before her ovulation to a day or two afterward). This is known as natural family planning or the rhythm method. Because a woman's cycle can vary from month to month, the couple must pay careful attention to the subtle signals of the woman's body, such as body temperature and the properties of the cervical mucus. This method is among the least reliable forms of birth control, with an effectiveness estimated at about 70 percent.

35 What is the most effective method to avoid conceiving a child?

36 Which technology for preventing conception also protects against the transmission of sexually transmitted infections?

## Social and Ethical Questions

When Louise Joy Brown was born, there was a wave of public concerns about the prospect of IVF being used in “baby factories” to mass-produce new humans. These concerns have proven to be unfounded. Many people, however, remain uncomfortable with technologies that interfere with the natural processes of conception and childbirth. Individual reproductive technologies also raise a number of difficult questions, including the questions below:

- What rights should a zygote have? Many reproductive technologies involve the gathering and fertilization of several eggs. Only one or a few of the resulting zygotes may be implanted and carried to term. The rest are destroyed before being implanted. Although this practice is legal in Canada, many people see the deliberate creation and destruction of human zygotes as immoral. A related issue is the commercialization of reproduction. What happens to the way we value human life if we buy and sell human gametes?
- What rights should gamete donors and surrogate parents have? Should a man or woman who has donated gametes to an infertile couple have any rights as a parent? On the other hand, should a gamete donor have the right to remain anonymous even if the child wants to meet his or her biological parent? If a surrogate mother decides that she wants to keep the baby she has carried for another couple, should she have the right to break her contract? Should the answer be the same if her own ovum is used in the procedure? These and other legal questions continue to be tested in courts around the world.
- How far should reproductive technologies go? It is already simple to sort sperm into those that are likely to carry an X chromosome and those that are likely to carry a Y chromosome. This means that couples using artificial insemination, *in vitro* fertilization, or gamete intrafallopian transfer

technologies can select the sex of their babies. As well, zygotes can be tested for a number of genetic disorders before being implanted. As genetic screening becomes ever more sophisticated, ethical and moral questions arise about the extent to which people should be able to “design” their children. (You will

explore some of these questions in more depth in Chapter 18.)

- Does everybody have the right to be a parent? Should reproductive technologies (which can be very expensive) be available only to individuals who are able to pay for them, or should they be funded by the

## Thought Lab

15.2

## Evaluating Reproductive Technologies: Safety and Effectiveness

### Target Skills

**Evaluating**, from published data, the effectiveness and safety of various reproductive technologies

**Justifying**, through the use of clear and logical arguments, a decision about the effectiveness and safety of reproductive technologies

People who seek to enhance their ability to conceive or to prevent it require advice from qualified health professionals to determine the best course of action for their particular situations. Many factors are involved in making this determination. Two of these factors are the safety of any given available technology and its effectiveness.

These two factors, safety and effectiveness, require further elaboration to clarify their meaning. For example, to what or to whom does safety refer: the person undergoing treatment, the embryo/fetus, or both? What does effectiveness mean, and how is it to be quantified? How reliable is the method used to quantify it?

In this Thought Lab, you will gather information and data to assess and evaluate the safety and effectiveness of various technologies for enhancing and preventing conception. Based on your findings, you will offer and justify an opinion about the effectiveness and safety of these technologies.

### Procedure

1. Working in small groups, select at least three of the technologies from each column of the following lists. (Therefore, you will select a minimum of six technologies.)

Selected Technologies for Enhancing Conception	Selected Technologies for Preventing Conception
<ul style="list-style-type: none"> <li>• artificial insemination (AI)</li> <li>• assisted hatching (also called laser assisted hatching)</li> <li>• gamete intrafallopian transfer (GIFT)</li> <li>• in vitro fertilization (IVF)</li> <li>• intracytoplasmic sperm injection (ICSI)</li> <li>• surrogacy</li> <li>• tubal embryo transfer (TET)</li> <li>• zygote intrafallopian transfer (ZIFT)</li> </ul>	<ul style="list-style-type: none"> <li>• condoms</li> <li>• fertility awareness methods</li> <li>• intrauterine device (IUD)</li> <li>• lactational amenorrhea (LAM)</li> <li>• oral contraceptives (pills containing both estrogen and progestin (synthetic progesterone))</li> <li>• progestin-only contraceptives</li> <li>• spermicides</li> <li>• tubal ligation</li> <li>• vasectomy</li> </ul>

2. With the members of your group, discuss the meanings of the terms “safety” and “effectiveness” as they apply to reproductive technologies. Develop preliminary definitions for these terms.
3. Conduct research to find data or information about the safety and effectiveness of each of the technologies you have selected. **ICT**
4. In the course of your research, you may find that your definitions of the terms “safety” and “effectiveness” require modification or replacement. Redefine these terms with the members of your group. Then consult with other groups to compare definitions. As a class, develop definitions that everyone can agree to use. **ICT**
5. Reexamine the information and data you have gathered in light of the class definitions of safety and effectiveness. As necessary, conduct additional research to refine your findings. **ICT**
6. Consult with other groups to prepare a master chart that summarizes findings for all the technologies investigated.

### Analysis

1. Based on your research, what key factors influenced your definitions of “safety” and “effectiveness”? List them in order of priority. What seems to be considered an acceptable risk to take to conceive or prevent conception of a child?
2. Based on your research and the summary in the master chart, decide which conception-enhancing and which conception-preventing technology is the most safe and effective technology. Use clear and logical arguments to justify your opinion. (You may answer this question as a group, as an individual, or both.)

### Extension

3. List three other factors that you think would affect a person’s or a couple’s determination of the best course of action for enhancing or preventing conception.



Canadian health-care system? Should a mother who has completed menopause but wants another child have the same access to reproductive technologies as a young woman who wants to start a family? Should access to reproductive technologies be limited to individuals or couples who meet certain criteria, such as age, marital status, income, and health? Would limiting access be unfair discrimination, since fertile individuals and couples do not have to meet similar criteria in order to become parents?

These are only a few of the legal, moral, and ethical questions that surround reproductive technologies. In the coming years, Canadian governments, courts, spiritual leaders, families, and individuals will continue to debate these and similar reproduction-related questions.

### Section 15.3 Summary

- Reproductive technologies have been developed to assist couples in conceiving a child as well as assist couples in preventing conception.

- People who are sterile or infertile may be helped by reproduction-enhancing technologies and practices such as artificial insemination, *in vitro* fertilization (IVF), surrogate motherhood, and superovulation.
- People who wish to reduce the likelihood of conception may benefit from technologies and practices such as abstinence, surgical procedures that prevent eggs from entering the uterus (tubal ligation) or sperm from being a component of semen (vasectomy), hormone treatments, physical barriers such as condoms and diaphragms, chemical barriers such as spermicides, and natural family planning (also called the rhythm method).
- The ability to enhance and prevent conception raises social and ethical issues that challenge individuals, courts, and governments to critically examine their views and beliefs about the value of human life and when that life begins.
- These issues have been debated for decades, and they continue to be debated.

## Section 15.3 Review

1. For each of the following situations, suggest a reproductive technology that might be appropriate. Briefly explain your suggestion.
  - a) The male has a low sperm count. The female is reproductively healthy.
  - b) The male has a healthy sperm count. The female rarely ovulates but is otherwise reproductively healthy.
  - c) The male has a healthy sperm count. The female has blocked oviducts.
  - d) A male is about to undergo radiation therapy. He currently has no female partner, but he wants to have children in the future.
  - e) A female has no male partner but wants to conceive.
2. Design a table to summarize at least three methods for enhancing reproductive potential. Your summary table should include the following information: name and description of each method, how it works, and who would use it. **ICT**
3. Design a table to summarize at least five common methods for reducing reproductive potential (contraception). Your summary table should include the following information: name and description of each method, its effectiveness, how it works, and safety concerns. **ICT**
4. Explain how *in vitro* fertilization is different from artificial insemination.
5. Briefly describe three examples of issues that have been raised over the technologies used to enhance and reduce reproductive potential.

Human prenatal development begins at fertilization. A single sperm joins with an egg to form a zygote.

The embryonic period occurs during the first two months of the first trimester. Cleavage follows, with successive mitotic cell divisions, leading to the formation of a morula. The morula arrives at the uterus and hollows to form a blastocyst consisting of an outer trophoblast layer and an inner cell mass. The blastocyst implants in the uterine wall, and trophoblast cells secrete human chorionic gonadotropin, which prevents menstruation.

During the second week, the amniotic cavity forms as the inner cell mass flattens, forming the embryonic disk. Through gastrulation, ectoderm and endoderm form, followed by the formation of mesoderm, establishing the three primary germ layers. Through morphogenesis, cells in a particular germ layer differentiate and develop into specific organs and organ systems.

During the third week, the extra-embryonic membranes form, some of which will eventually develop

into the life-supporting placenta and umbilical cord. Gradually, structures appear, including the notochord, neural tube, arm and leg buds, heart, facial structures, skin specializations, and skeleton.

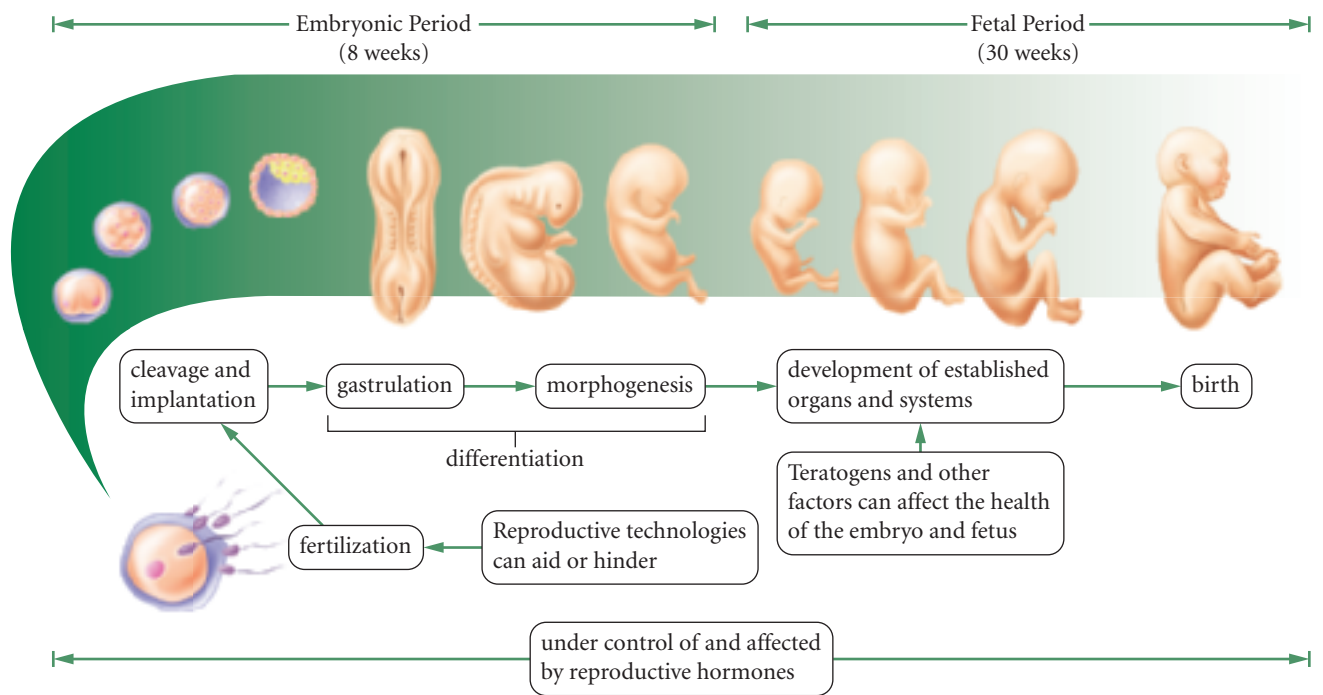
The fetal period occurs during the last month of the first trimester and over the remaining two trimesters. In the fetal period, existing structures formed via morphogenesis are elaborated and refined. Throughout prenatal development, teratogens exposed to or ingested by the mother can affect the health of the embryo and fetus.

During parturition, uterine contractions expel the baby, the placenta, and the umbilical cord.

Some reproductive technologies (such as *in vitro* fertilization and superovulation) are designed to enhance reproductive potential. Some reproductive technologies (such as condoms and surgical sterilization) are designed to restrict or suppress reproductive potential.

Issues surround the use of reproductive technologies.

## Chapter 15 Graphic Organizer

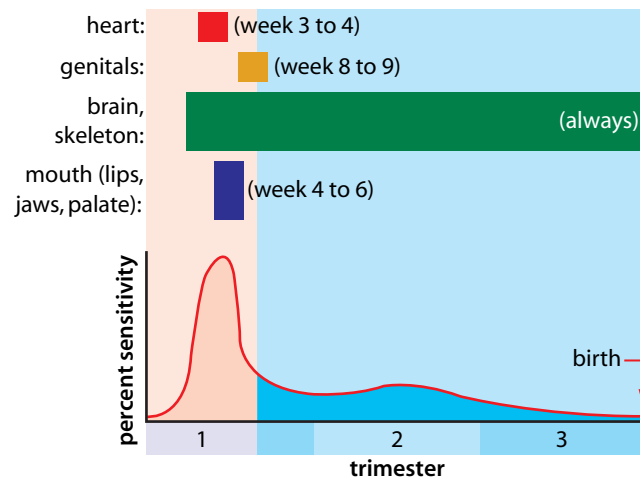


### Understanding Concepts

- In terms of embryonic and fetal changes, explain how the following terms are related: development, growth, differentiation.
- List the sequence of events that occur during the process of fertilization.
- Distinguish between a morula and a blastocyst.
- What is the significance of the inner cell mass?
  - How is the inner cell mass different from the trophoblast?
- Describe the functions of hCG (human chorionic gonadotropin).
- What is the relationship between the embryonic disk and the primary germ layers?
- List at least three major body parts or organs that are derived from ectoderm.
  - List at least three major body parts or organs that are derived from endoderm.
  - List at least three major body parts or organs that are derived from mesoderm.
- Describe the formation of the placenta, and explain its main functions.
- Distinguish between the chorion and the amnion.
- Describe the function of amniotic fluid.
- Explain how the yolk sac and the allantois in humans are related, and list the functions of each.
- List five major changes that occur during the embryonic period of development and five major changes that occur during the fetal period of development.
- Explain the term morphogenesis.
- Describe the role of progesterone in initiating parturition.
  - Describe the events that occur during parturition.
- Explain how chemical teratogens can end up in the blood system of the embryo or fetus.
- List two beneficial health habits and two detrimental health habits during pregnancy and their consequences for the health of the embryo or fetus.
- Name five hormones that are associated with prenatal development, parturition, and lactation and use a table or concept map to outline their relationship and functions. **ICT**

### Applying Concepts

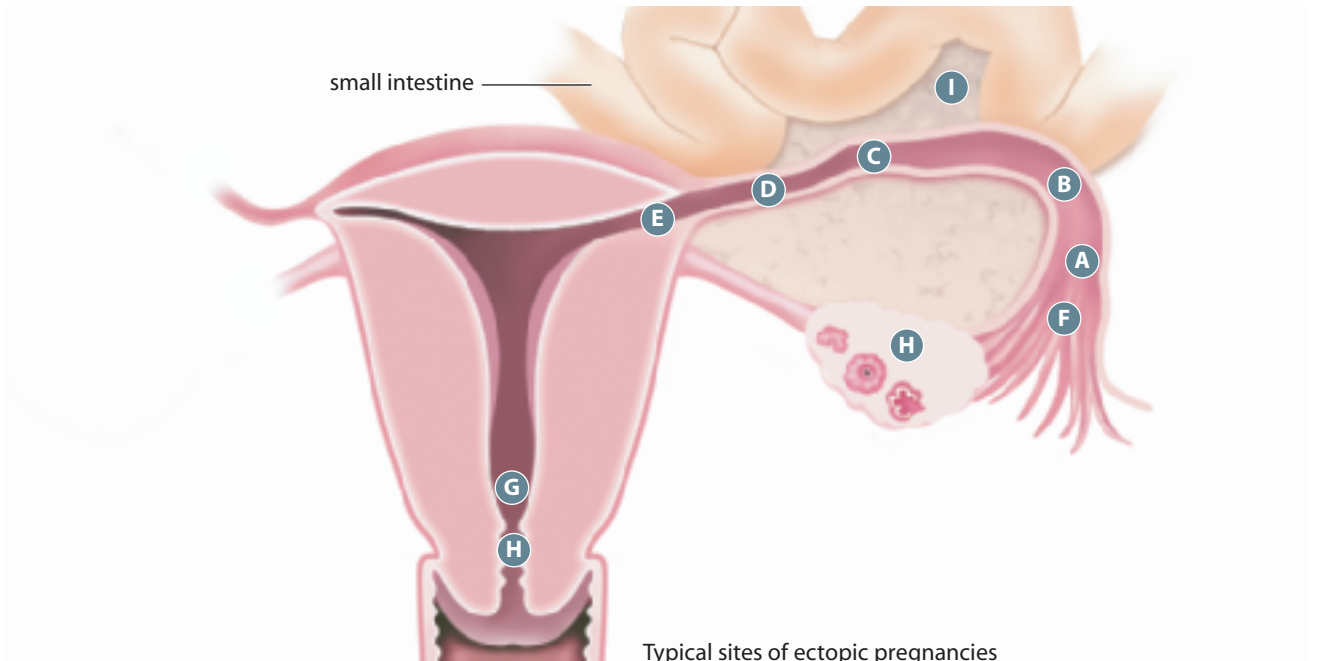
- Some scientists distinguish between morphogenesis and organogenesis. Infer what the term organogenesis refers to and how it might differ from morphogenesis.
- Translate the significance of the data and information conveyed in the following graph into words. Record your answer in a maximum of three paragraphs, with full sentences.



- During the menstrual cycle, the endometrium thickens. A friend explains that this happens to prepare the uterus for sperm to fertilize an egg. How accurate is this explanation? Give reasons to justify your answer.
- An ectopic pregnancy occurs when the blastocyst implants outside the uterus or in an abnormal site within the uterus. (The term ectopic comes from a Greek word that means “out of place.”) The letters in the diagram on the next page show, in order of frequency of occurrence, various sites of ectopic pregnancies. How likely is it that an embryo or fetus would survive an ectopic pregnancy? Explain your answer.
- You hear that there is a drug that stops the production of milk in the breast after a few days. Which hormone does the drug affect, and does the drug increase or inhibit secretion of the hormone?
- Only one sperm is needed to fertilize an egg, and yet a man who ejaculates fewer than 10 million sperm is considered to be infertile. Explain why.

### Making Connections

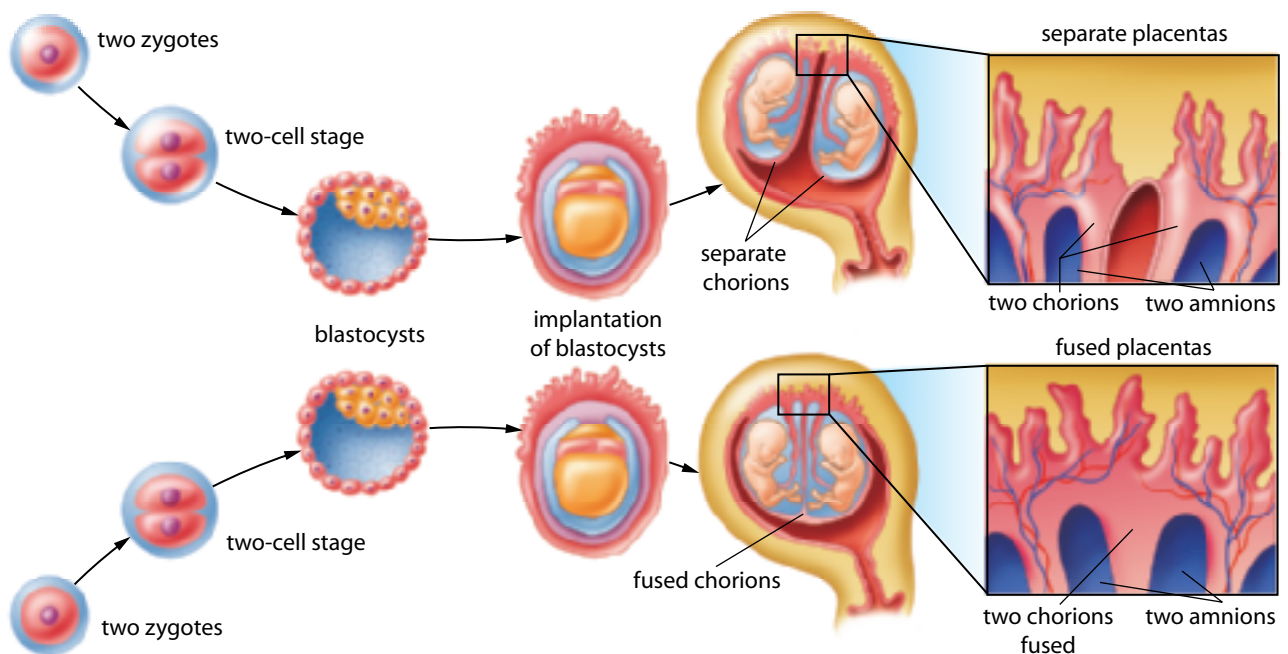
- A woman has been told by her physician that her pregnancy has progressed 44 days since her last menstrual period. Approximately how many days has the embryo been developing, and what developmental events are occurring at this time?



Typical sites of ectopic pregnancies

- 25.** For some women, secretion of GnRH (gonadatropin-releasing hormone) is inadequate, and they are considered to be sterile. They may be treated for their sterility with drugs that mimic the action of this hormone. Suggest one possible reason that such treatment is often associated with multiple births.
- 26.** The diagram below outlines the early-development events that lead to dizygotic (fraternal) twins. Such twins are not identical and may be different sexes. In the uterus, each twin has its own chorion, its own amnion,

and its own placenta. (The placentas may be separate or fused.) Monozygotic twins, on the other hand, are identical. They are always the same sex and are genetically identical. They develop from a single zygote. Such twins have two amnions but only one chorion, and they share the placenta. Based on this information and details provided in the diagram, predict the early-development events that lead to the formation of monozygotic twins. Record your prediction in the form of a sketch modelled after the diagram. **ICT**





# Career Focus: Ask a Sexual and Reproductive Health Coordinator

Wendi Lokanc-Dilizio firmly believes that sexual health is a positive part of general well-being, not simply the absence of illness or disease. Her goal is to provide the information, motivation, and personal insight people need in order to develop personal skills that will support their positive sexual health. How to accomplish this goal is the challenge. “Even though Canadians have diverse values and opinions on human sexuality, sexual health education needs to be accessible to all people and it should be provided in an age-appropriate, culturally sensitive manner that is respectful of an individual’s right to make informed choices about sexual and reproductive health. That is my job.”

## Q How do you define sexual and reproductive health?

First and foremost, sexual health is part of personal health and healthy living. It involves emotional, physical, mental, and social well-being. Here at the Calgary Health Region, our approach is two-fold: first, we want to work towards the positives such as the ability to develop rewarding personal relationships and the joy of desired parenthood; second, we want to help people avoid the negatives such as unwanted pregnancy and sexually transmitted infections.

## Q Are sexually transmitted infections a significant problem?

Unfortunately they are, and they pose a particular threat to the health of specific groups. The rates of infections such as chlamydia and gonorrhea are highest among teens and young adults, so the need for knowledge and information for this group is urgent. Neglecting to provide this education can have significant consequences. For example, untreated chlamydia infection could lead to pelvic inflammatory disease and infertility, chronic pelvic pain, ectopic pregnancy, and increased susceptibility to HIV infection.

## Q What would a typical day at work look like for you?

The appeal of this job for me is that there is no typical day. My mornings often begin with a brief meeting with colleagues. When I turn to the day’s email, it can be a bit daunting to see the lack of basic sexual health knowledge that is demonstrated in the questions I receive through the website. The questions are often complex and can involve biological, emotional, psychological, social, economic, political, cultural,

ethical, legal, religious, and even spiritual elements. It can take quite a bit of research and work on my part to provide the best response.

## Q What motivated you to enter this field?

As a nurse, I always had an interest in community development and health promotion, if not specifically sexual health promotion. I was fortunate to find a role model in this field who was absolutely passionate about what he did, and that had a big influence on me.

## Q What qualities do you think a person needs to do this kind of work?

Well, truthfully, this is not for everyone. Sexual health can be sensitive and controversial, so it requires people who have the personal qualities, training, and professional preparation that includes:

- biological knowledge of human sexuality and reproductive functions
- knowledge of general sexual health issues
- teaching and clinical skills
- an ability to respond respectfully to the sexual health education needs of diverse groups
- a capacity to discuss sexual health in a positive and sensitive manner
- conflict management and resolution skills
- an understanding of issues surrounding sexual orientation and gender
- insight to help people evaluate the ways that media can affect sexual health
- a commitment to a professional code of ethics on sexual health education, counselling and clinical services

## Other Careers Related to Sexual and Reproductive Health Promotion

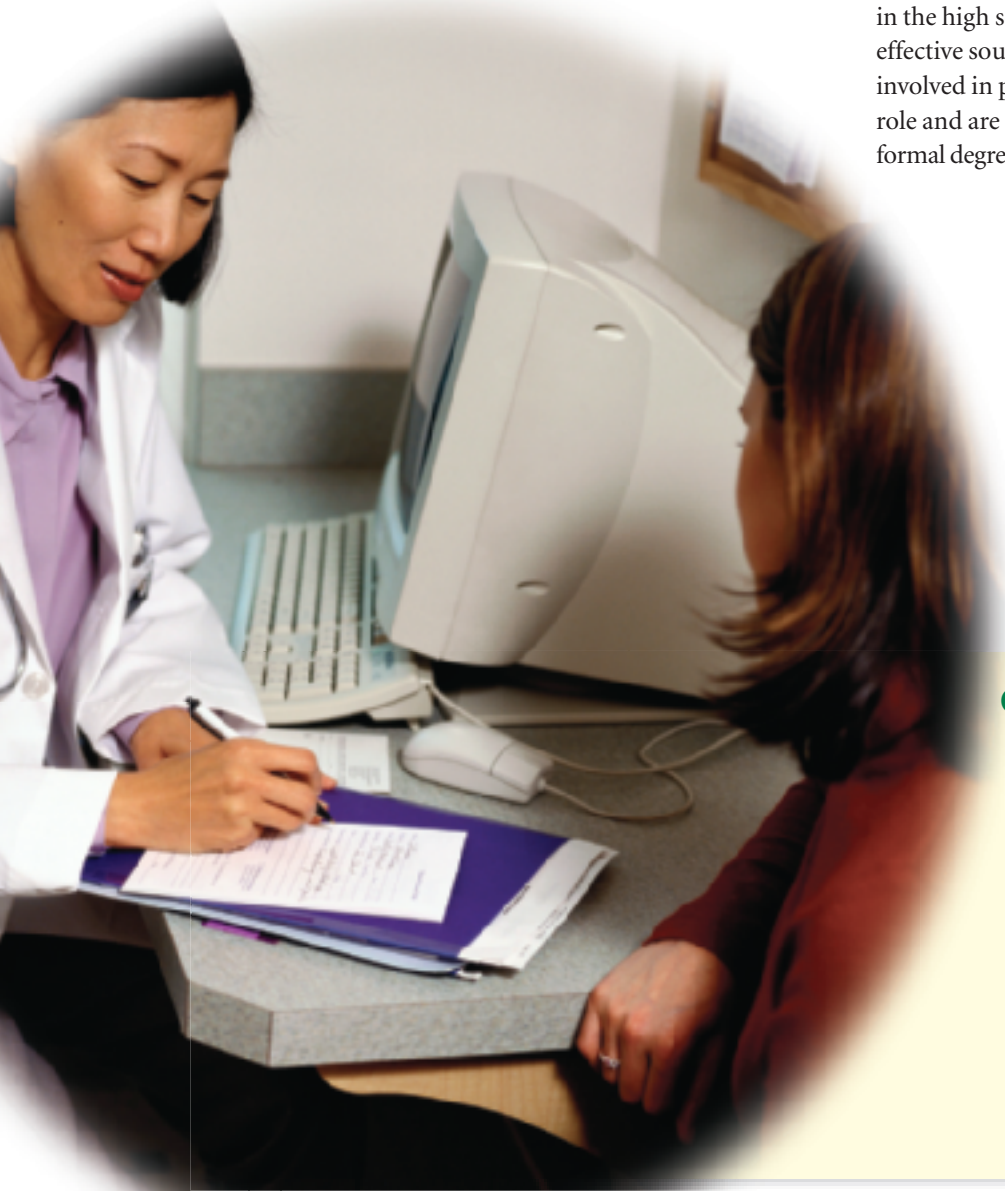
**Teachers and Other Educators** People from a variety of educational backgrounds provide sexual health education through schools, colleges, universities, health care settings, public health programs, social service agencies, as well as community and religious organizations. Whether in an academic or a community setting, educators provide students with information, motivation and self-esteem, and teach them the skills necessary to maintain sexual health.

**Community and Public Health Workers** Practitioners in community and public health work to promote positive lifestyles and create a supportive environment for prevention of disease and protection of health. Sexual health education is an integral part of public health and addresses the broader environmental and lifestyle factors

that can impact public health. A degree in social work, nursing, or a relevant college certificate of diploma is generally required to work in the community health field.

**Clinical Counsellor or Therapist** Counsellors and therapists teach individuals to feel positive about themselves by providing them with the opportunity to develop the knowledge, personal insight, motivation and behavioural and decision making skills that are consistent with each individual's personal values. Some therapists are self-employed practitioners, while others work in hospitals or clinics. A graduate degree is generally required to work as a clinical counsellor or therapist.

**Peer education and counselling** Peers can have a significant influence on behaviour. Trained volunteers in the high school, university and college setting are an effective source of sexual health education. Individuals involved in peer education are trained specifically for their role and are carefully supervised by professionals. No formal degree or certificate is required to be a peer counsellor.

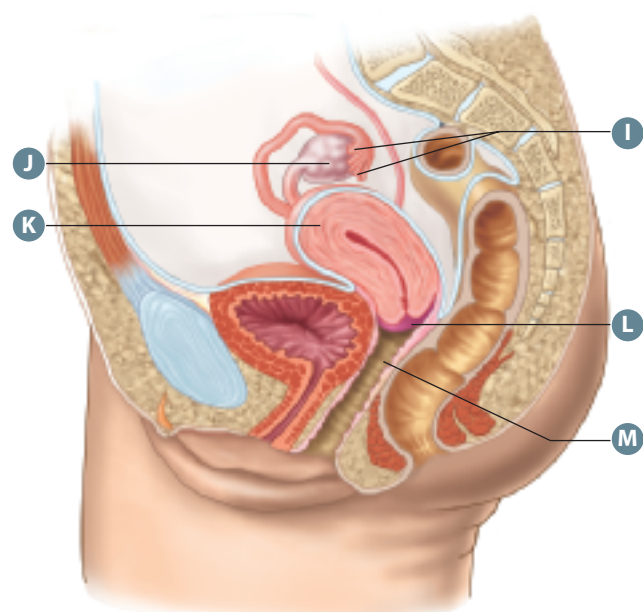
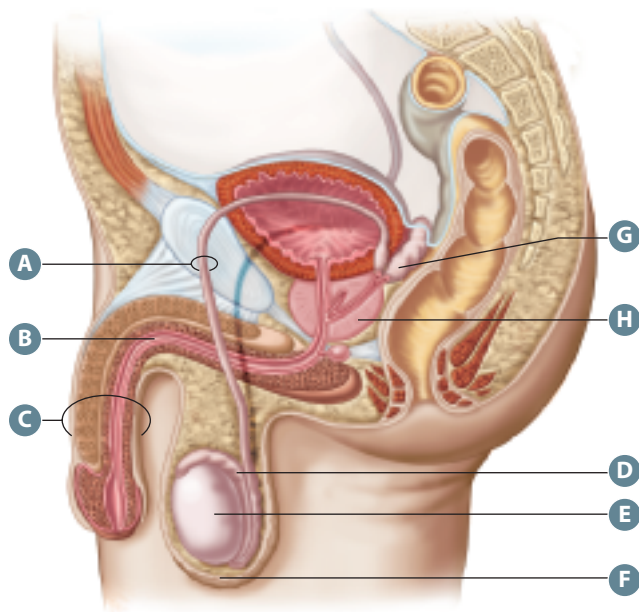


### Go Further...

1. Discuss how socio-economic or environmental factors such as income, social environment, education levels, and access to services affect sexual health.
2. What segments of our society might require specific sexual health education? Discuss the challenges and issues and suggest ways in which society could meet their needs.
3. Mass media exerts a strong influence on sexual behaviour. How can individuals critically evaluate what they see, hear, and read in the media about sexual norms and practices?

## Understanding Concepts

- How is the human reproductive system different from all other systems of the human body?
- Describe three ways in which the male and female reproductive systems are similar and three ways in which they are different.
- Compare and contrast the female and male sex cells. **ICT**
- Identify the three primary germ layers, and name the cellular body in which they first appear.
- Describe the menstrual cycle.
- Distinguish among the following structures: seminiferous tubules, Sertoli cells, interstitial cells. Use a sketch to record your answer. **ICT**
- List the components of semen.
  - Identify the structures that contribute to semen.
  - Semen is mainly an alkaline fluid. Explain why.
- Name the structures of the male and female reproductive systems indicated by the letters in the diagrams below.
- Briefly describe the functions of each structure you identified in question 8.
- Describe the role that hormones play in regulating primary and secondary sex characteristics in females and in males.
- Which of these hormones—estrogen, GnRH, progesterone, FSH, and LH—is the correct match for the following statements:
  - secreted by the follicular cells
  - stimulates maturing of female sex organs
  - maintains the uterine lining during pregnancy
  - secreted by the corpus luteum
  - stimulates development and function of the corpus luteum
  - promotes thickening of the endometrium
  - stimulates development of ovarian follicles
  - high concentrations inhibit GnRH secretion
- Describe the relationship between internal feedback mechanisms and the regulation of male reproductive hormones.
- Distinguish between the inner cell mass and the trophoblast.
- Name the three primary germ layers, and list two organs or systems that develop from each layer.
- Identify the extra-embryonic membranes that form in support of a human embryo, and briefly describe their function.



16. What is the function of the seminiferous tubules?
17. **a)** Is the acrosome part of the male or female reproductive system?  
**b)** Describe the function of the acrosome.
18. What prevents an egg from being fertilized by more than one sperm?
19. Name two methods that are effective at preventing fertilization *and* protecting against sexually transmitted infections.
20. Distinguish between a morula and a blastocyst.
21. Can women become pregnant after menopause? Why or why not?
22. Which hormone or hormones prepare the mammary glands for lactation?
23. Make a sketch to show where fertilization usually takes place in the female reproductive system. **ICT**
24. Copy the following table into your notebook and complete it.

Hormone	Produced by	Target organ(s)	Effect(s)
Testosterone			
	• hypothalamus		• stimulates release of FSH and LH
		• ovaries, uterus	• inhibits ovulation • stimulates thickening of endometrium
			• stimulates development of sex organs • stimulates gamete production

25. Describe how chromosomal factors and hormones each influence the development of the male and female reproductive systems.
26. Contrast the means by which male and female gametes are transported from their site of origin to the site of fertilization. In what ways do these different transportation mechanisms contribute to reproductive function?

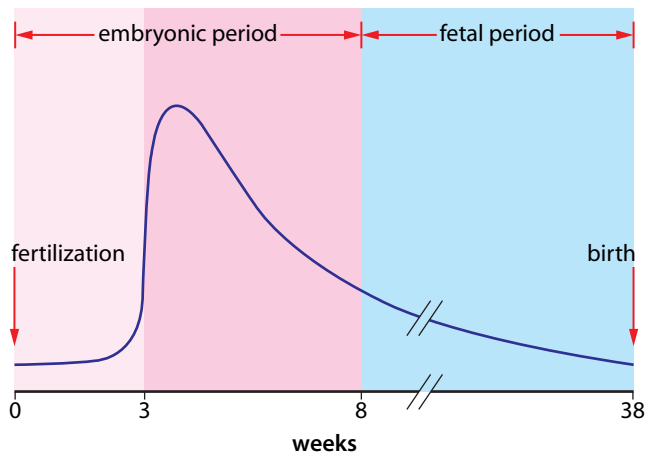
27. Identify at least one hormone associated with each of the following, and briefly describe the effect of the hormone(s).  
**a)** fertilization  
**b)** development of the placenta  
**c)** parturition
28. Outline, in the form of a diagram, the feedback mechanism involved in the control of the ovaries. **ICT**

### Applying Concepts

29. Most of the organs of the adult human are present by the end of the first eight weeks of prenatal development. Use paragraphs or point form notation to list at least eight key events that occur during this period of time.
30. Eggs and sperm are genetically very similar, but structurally they are very different. Explain why this is the case.
31. Failure of the testes to descend into the scrotum causes sterility in males. Explain why.
32. Most reptiles—for example, crocodiles, alligators, and turtles—develop in hard-shelled eggs. Scientists hypothesize that birds share the same evolutionary lineage as reptiles. Based on this hypothesis, infer the extra-embryonic structures you would expect to observe in a reptile egg, and explain your reasoning.
33. Why is it necessary for human gametes to have 23 pairs of chromosomes rather than 46?
34. Describe the function of the corpus luteum (a) if an egg is fertilized and implants in the endometrium and (b) if an egg is unfertilized.
35. If several different methods of enhancing reproductive potential are used at the same time, a baby could have as many as five “parents.” Explain how this is possible.
36. Which of the following would be an indication that ovulation is soon to occur: the cervical mucus is becoming thick and sticky, an increase in body temperature, or a marked rise in the level of LH in the blood? Explain your answer.
37. If a male’s testes were removed, would he still be able to produce male sex hormones? Explain.



38. Suggest one possible interpretation for the following graph.



### Making Connections

39. A 35-year-old female long-distance runner wants to have children with her male partner, but they have been unable to conceive for over one year. Tests on her partner's semen reveal that his sperm count is at a healthy level, and his sperm are in good condition.
- Based on the above information, suggest at least two reasons that may explain why the couple has been unable to conceive.
  - Suggest a course of action the couple could try before they turn to reproductive technologies. Explain why your suggestions might help.
  - If the couple remains infertile, what reproductive technologies might help them to conceive?
40. As the fetus grows, the uterus enlarges greatly. Instead of being confined to its usual location in the pelvic cavity, it extends upward and may eventually reach the level of the ribs. The organs of the abdominal region are displaced upward and are compressed against the diaphragm. The enlarging uterus also presses on the urinary bladder. Based on this information, infer three likely effects of the expanding uterus on the mother's body.
41. If a woman has one ovary surgically removed, can she still become pregnant? Why or why not?
42. If a male has a vasectomy, is he still able to produce sperm? If so, what happens to those sperm? How is the composition of semen changed in a person who has had a vasectomy?

43. Use a table to compare the roles of FSH in males and in females. **ICT**
44. Imagine that you have been commissioned to plan, write, and produce a pamphlet for a public health organization to demonstrate the effects of teratogens and other environmental factors on the development of an embryo and fetus. Create an outline that shows the main points that your pamphlet will cover and emphasize. Also describe two visuals that you will include in the pamphlet. (The visuals can be photographs, illustrations, graphs, or data tables.) Note: Read this question carefully to determine exactly what you are being asked to provide as an appropriate response.
45. If parents do not have access to genetic testing methods and wish to know the sex of their unborn baby, they usually have to wait until between the eighteenth and twenty-second week of development to find out. Based on your knowledge of reproductive development, explain why the sex of the unborn baby cannot be determined easily before this time.

Use the following information to answer the next question.

Amenorrhea is the absence of menstruation. (The term comes from Greek words that literally mean "absence of monthly flow".) Amenorrhea is not a disorder. Rather, it is a symptom that reflects a condition that usually is not serious. Nevertheless, any condition in which menstruation does not occur requires evaluation to determine the cause.

Amenorrhea is categorized as two types. Primary amenorrhea is the absence of menstruation by age 16.

(**Note:** The onset of menstruation varies widely, commonly occurring between the ages of 11 and 16.)

Secondary amenorrhea is the absence of three or more menstrual periods in a row.

Causes of primary amenorrhea include low levels of FSH, a pituitary tumour, anorexia nervosa, thyroid disorders, GnRH deficiency, Cushing's disease, genetic abnormalities, and obstructions of the vagina. Causes of secondary amenorrhea include the use of oral contraceptives (birth control pill), certain medications, thyroid disorders, excessive exercise, stress, and low body weight. Treatment, if deemed necessary, depends on the cause.

46. Infer three other common, logical causes of amenorrhea, either primary or secondary.

Use the following information to answer the next questions.

A pregnant thirty-one-year-old Chilean woman with normal menstrual history and two previous, uneventful pregnancies was seen by her doctor at eight weeks gestation. She had a single, intrauterine pregnancy. A pelvic ultrasound showed multicystic ovaries measuring 5 cm × 3.5 cm each and containing many fluid-filled sacs. Two weeks later she was admitted to the hospital complaining of abdominal pain. This time a pelvic ultrasound showed her right ovary was 13.2 cm × 8.0 cm, and the left was 13.4 × 9.7 cm. The patient was discharged when the pain settled and advised to rest at home.

At 16 weeks gestation she was admitted again, due to acute abdominal pain, nausea, and vomiting. Physical examination revealed a very large abdominal mass, extending from her pelvis to her ribs. The abdominal ultrasound showed giant, tumor-filled ovaries, approximately 19 cm × 15 cm each, and a normal fetus and placenta. Both ovaries were removed (a bilateral oophorectomy). After the operation the woman was fine, and she spontaneously delivered a 3.8-kg, 52-cm male infant at 39 weeks. The placenta weighed 600 g and was of normal macroscopic appearance. Lactation commenced spontaneously. She fully breastfed for ten days; she then maintained partial breastfeeding until 10 weeks after the birth.

Hormone replacement therapy (HRT) was started two months after the baby's birth. The woman's doctor had taken blood samples to measure her hormone levels at 37 weeks gestation and then at 8 hours, 4 days, 5 weeks, and 2 months post-partum (after the delivery). The results of

these blood tests are presented in the two tables (37 weeks) and (post-partum) below. In the first table, the blood test results for eight Chilean women with normal pregnancies are shown as the control. In the second table, results for 25 women who breastfed and maintained amenorrhoea (lack of a menstrual period) for more than 6 months post partum are provided as the control.

Hormonal profile at 37 weeks of gestation in an oophorectomized pregnant woman compared to non-oophorectomized pregnant women at 38 weeks.

Group	FSH (IU/L)	Estrogen (nmol/L)	Progesterone (nmol/L)	Prolactin (µg/L)
Patient	6.1	78.2	1256	251
Controls	NM	39–114	328–897	120–457

Post-partum hormonal profile of an oophorectomized nursing woman

Time post-partum	FSH (IU/L)	Estrogen (pmol/L)	Progesterone (nmol/L)	Prolactin (µg/L)
8 h	<4.0	4864	NM	235
4 days	5.9	202.2	4.3	229
5 weeks				
Patient	31.4	239	<1.6	162
Controls	0.9–6.9	73–426	0.4–3.2	159
2 months				
Patient	68.0	136	NM	123
Controls	1.2–8.1	51–360	0.4–2.7	NM

NM = not measured nmol = nanomole ( $10^{-9}$ ) pmol = picomole ( $10^{-12}$ )

47. The woman's doctor did not to remove her ovaries when she first presented with abdominal pain at 10 weeks gestation and an ultrasound showed that her ovaries were full of cysts. Explain why you think this decision was made.
48. Identify an important reproductive hormone that the doctors did not measure in these tests, and explain why it wasn't necessary to test for this hormone.
49. a) Analyze the change in follicle stimulating hormone (FSH) level from the end of gestation to two months post-partum for both the oophorectomized, nursing woman and the control women.  
b) Explain why there is a difference.
50. Why was HRT given to the patient at 2 months post-partum?
51. Why is the concentration of estrogen similar at the end of gestation for both the patient and the controls?
52. Why was the woman able to deliver her baby normally and spontaneously breastfeed afterwards?