

# 19

## Development

### Learning Outcomes

#### 19.1 The First Stages of Development

- Identify the cellular stages of development with reference to slides of early sea star development. 254–255
- Identify the tissue stages of development with reference to slides of frog development. 256–257

#### 19.2 The Organ Stages of Development

- Associate the germ layers with the development of various organs. 258
- Describe the significance of the process of induction during development. 258
- Identify which organs develop first in a vertebrate embryo (e.g., frog, chick, and human). 259–262
- Compare the later development of humans to that of chicks. 263

#### 19.3 Extraembryonic Membranes, the Placenta, and the Umbilical Cord

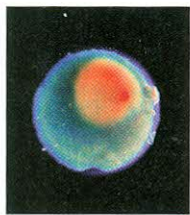
- Distinguish between and give a function for the extraembryonic membranes, the placenta, and the umbilical cord. 264–266

#### 19.4 Human Fetal Development

- Trace the main events of human fetal development. 267–268

### Introduction

The early development of animals is quite similar, regardless of the species. The fertilized egg, or zygote, undergoes successive divisions by cleavage, forming a mulberry-shaped ball of cells called a morula and then a hollow ball of cells called a blastula. The fluid-filled cavity of the blastula is the blastocoel. Later, some of the surface cells fold inward, or invaginate, eventually forming a double-walled structure. The outer layer is called the ectoderm, and the inner layer is the endoderm. Between these layers, a middle layer, or mesoderm, arises. The embryo is now called a gastrula. In particular, the presence of yolk (nutrient material) influences how the gastrula comes about. All later development can be associated with the three germ layers (ectoderm, endoderm, and mesoderm) that give rise to different tissues and organ systems.



zygote 100×



embryo at one week; implants in uterine wall



embryo at eight weeks



fetus at three months



fetus at five months

Development occurs in stages.

(zygote): © Anatomical Travelogue/Science Source; (embryo, 1 week) © Bettman/Corbis; (embryo, 8 weeks) © Neil Harding/Getty Images; (fetus, 3 months) © Petit Format/Science Source; (fetus, 5 months) © John Watney/Science Source

## 19.1 The First Stages of Development

In this section, we will consider the cellular and tissue layer stages of development.

### Cellular Stages of Development

The cellular stages of development include the following:

- **Zygote formation:** A single sperm fertilizes an egg and the result is a zygote, the first cell of the new individual.
- **Morula formation:** Zygote divides into a number of smaller cells until there is a cluster of 16–32 cells called a morula.
- **Blastula formation:** The morula becomes a blastula, a hollow ball of cells.

#### Observation: Cellular Stages of Development in the Sea Star

The cellular stages of development are remarkably similar in all animals. Therefore, we can view slides of sea star development to study the cellular stages of human development (Fig. 19.1). A sea star is an invertebrate that develops in the ocean and, therefore, will develop easily in the laboratory where it can be observed.

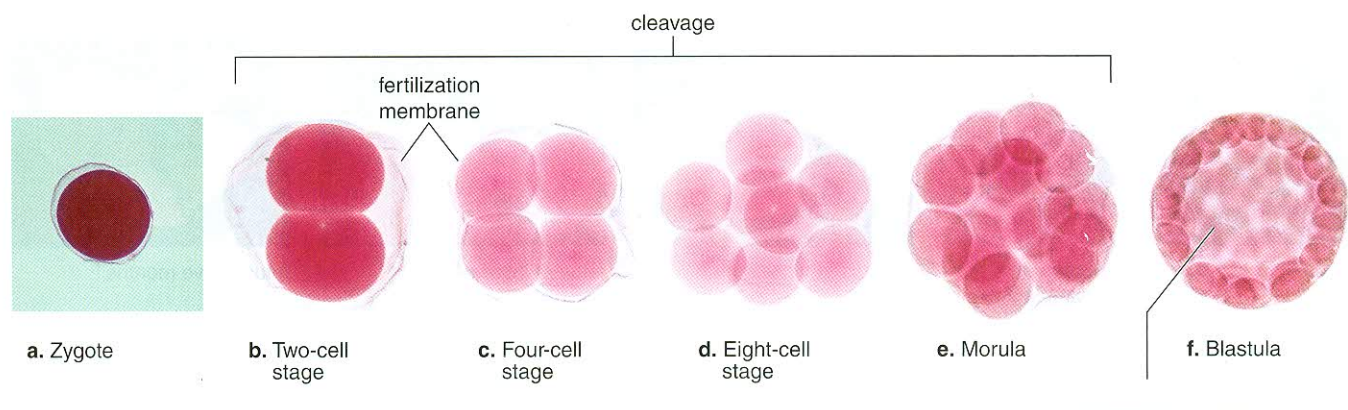
Obtain slides or view a model of sea star development and note the following:

1. **Zygote.** Both plants and animals begin life as a single cell, a zygote. A zygote contains chromosomes from each parent. Explain your answer. \_\_\_\_\_  
\_\_\_\_\_
2. **Cleavage.** View slides showing various numbers of cells due to the process of cleavage, cell division without growth until the morula stage. Is the morula about the same size as the zygote? \_\_\_\_\_  
Explain your answer. \_\_\_\_\_  
\_\_\_\_\_
3. **Blastula.** The cavity of a blastula is called the blastocoel. *Label the blastocoel in Figure 19.1.* The formation of a hollow cavity is important to the next stage of development.

#### Figure 19.1 Sea star development.

All animals, including sea stars and humans, go through the same cellular stages from cleavage to blastula. (Magnification: zygote is 400x; b-f are 75x)

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## Observation: Cellular Stages of Development in Humans

In Figure 19.2, or in a model of human development, observe the same stages of development already observed in sea star slides. Also, observe that fertilization in humans occurs in an oviduct following ovulation. As the embryo undergoes cleavage, it travels in the oviduct to the uterus.

If the embryo splits at the 2-cell stage, the result is identical twins. (Fraternal twins arise when two separate eggs are fertilized.) How might you account for the development of identical triplets? \_\_\_\_\_

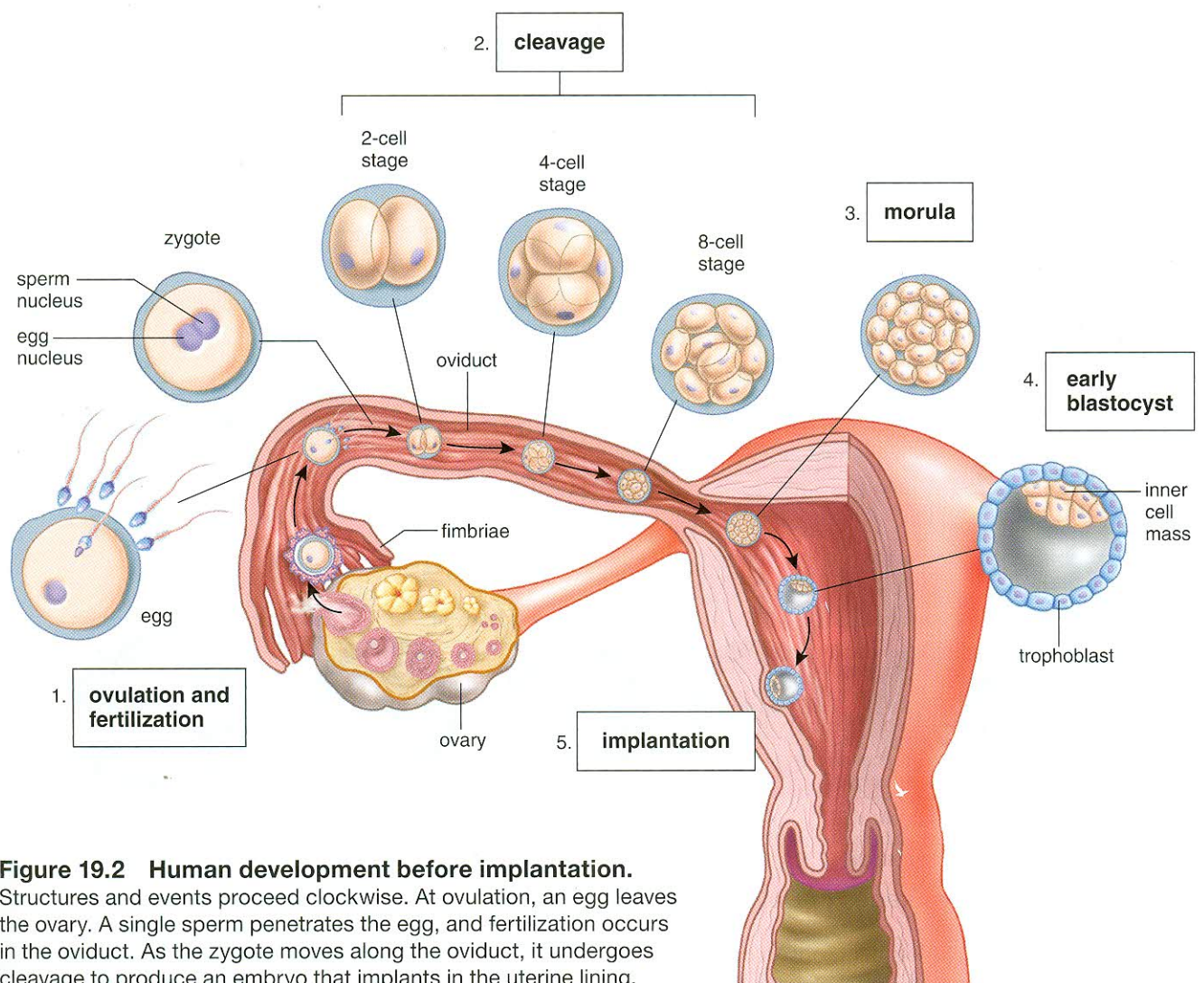
\_\_\_\_\_

\_\_\_\_\_

The blastula in humans is called a blastocyst. The blastocyst contains an **inner cell mass** that becomes the embryo, and the outer group of cells (the trophoblast) will become membranes that nourish and protect it. At about day 6, the blastocyst has reached the uterus and implants into the uterine wall, where it will receive nourishment from the mother's bloodstream.

What's the main difference between the cellular stages in a sea star and in a human? \_\_\_\_\_

\_\_\_\_\_



**Figure 19.2 Human development before implantation.**

Structures and events proceed clockwise. At ovulation, an egg leaves the ovary. A single sperm penetrates the egg, and fertilization occurs in the oviduct. As the zygote moves along the oviduct, it undergoes cleavage to produce an embryo that implants in the uterine lining.

## Tissue Stages of Development

The tissue stages of development include the following:

- **Early gastrula stage.** This stage begins when certain cells begin to push or invaginate into the blastocoel, creating a double layer of cells. The outer tissue layer is called the **ectoderm**, and the inner tissue layer is called the **endoderm**.
- **Late gastrula stage.** Gastrulation is not complete until there are three layers of cells. The third tissue layer, called **mesoderm**, occurs between the other two layers already mentioned.

### Observation: Tissue Stages of Development in Frogs

It is traditional to view gastrulation in a frog. A frog is a vertebrate, and so its development is expected to be closer to that of a human than is the development of a sea star. In Figure 19.3, note that the yellow (vegetal pole) cells are heavily laden with yolk, and the blue (animal pole) cells are the ones that invaginate into the blastocoel, forming the early gastrula.

1. **Early gastrula stage.** Obtain a cross section of a frog gastrula. Most likely, your slide is the equivalent of Figure 19.3b, number 3, in which case you will see two cavities, the old blastocoel and newly forming *archenteron*, which forms once the animal pole cells have invaginated. The archenteron will become the digestive tract, and the blastopore will become the anus.
2. **Late gastrula stage:** Invagination of cells occurs at the lateral and ventral lips of the blastopore only because the cells heavy laden with yolk (yellow cells) do not invaginate.

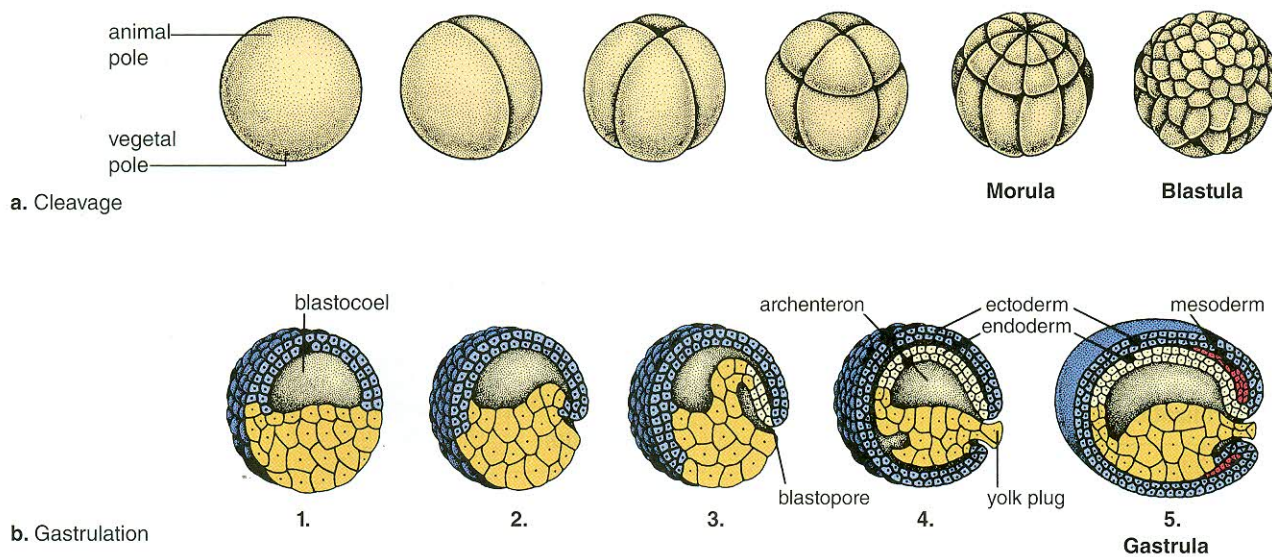
Name the germ (tissue) layers that are now present in the embryo. \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Figure 19.3 Drawings of frog developmental stages.**

a. During cleavage, the number of cells increases but overall size remains the same. b. During gastrulation, three tissue layers form. Blue = ectoderm; yellow = endoderm; red = mesoderm.

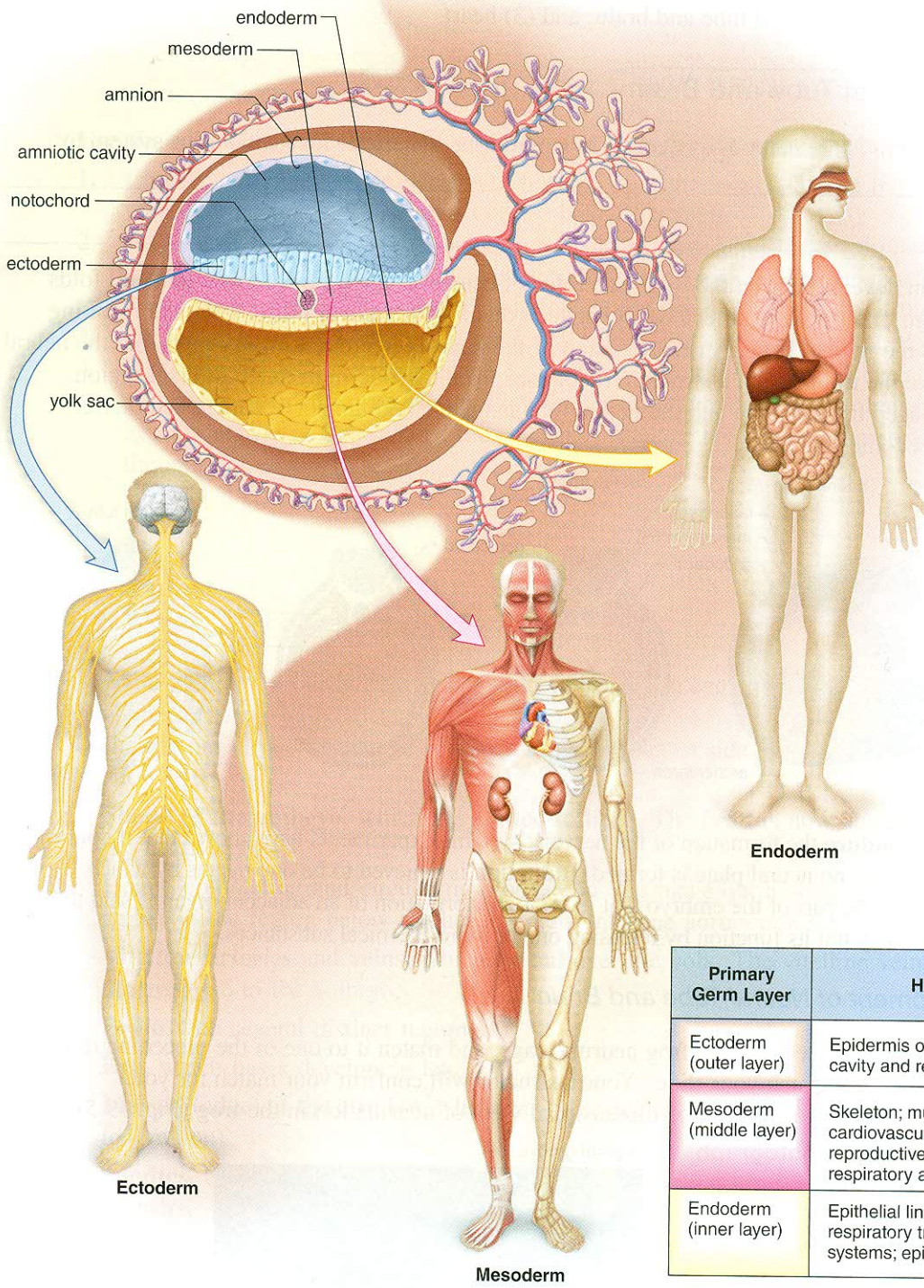


### Observation: Tissue Stages of Development in a Human

In a model of human development, observe the same stages of development already observed in frog slides. After implantation, gastrulation in humans turns the inner cell mass into the **embryonic disk**. Figure 19.4 shows the embryonic disk, which has the three layers of cells we have been discussing: the ectoderm, mesoderm, and endoderm. Figure 19.4 also shows the significance of these layers, often called the **germ layers**. The future organs of an individual can be traced back to one of the germ layers.

**Figure 19.4 Embryonic disk.**

The embryonic disk has three germ layers called ectoderm, mesoderm, and endoderm. Organs and tissues can be traced back to a particular germ layer as indicated in this illustration.



Primary Germ Layer	Human Adult Structures
Ectoderm (outer layer)	Epidermis of skin; epithelial lining of oral cavity and rectum; nervous system
Mesoderm (middle layer)	Skeleton; muscular system; dermis of skin; cardiovascular system; urinary system; reproductive system; outer layers of respiratory and digestive systems
Endoderm (inner layer)	Epithelial lining of digestive tract and respiratory tract; associated glands of these systems; epithelial lining of urinary bladder

## 19.2 The Organ Stages of Development

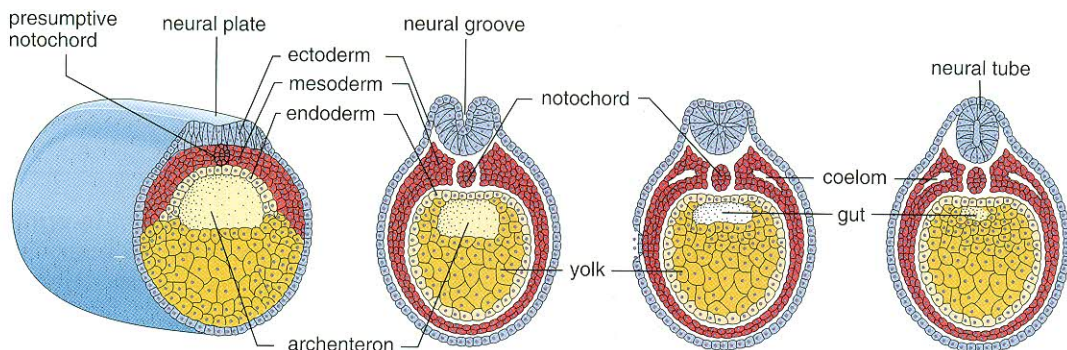
As soon as all three embryonic tissue layers (ectoderm, endoderm, and mesoderm) are established, the organ level of development begins. It continues until all organs have formed. Figure 19.4 pertains to the organ stages of development because it shows which germ layers give rise to which organs.

The first organs to develop are the (1) digestive tract (you have already observed the start of the archenteron during gastrulation); (2) neural tube and brain; and (3) heart.

### Development of the Neural Tube and Brain

One of the first systems to form is the nervous system. Why might it be beneficial for the nervous system to begin development first? \_\_\_\_\_

During nervous system development in the frog, two folds of ectoderm grow upward as the neural folds with a groove between them. The flat layer of ectoderm between them is the **neural plate**. The tube resulting from closure of the folds is the **neural tube**. An examination of the neurula in cross section shows that the neural tube develops directly above the **notochord**, a structure that arises from mesoderm in the middorsal region. Later, the notochord is replaced by vertebrae and the neural tube is then called the nerve cord. The anterior portion of the neural tube becomes the brain.



Neurulation

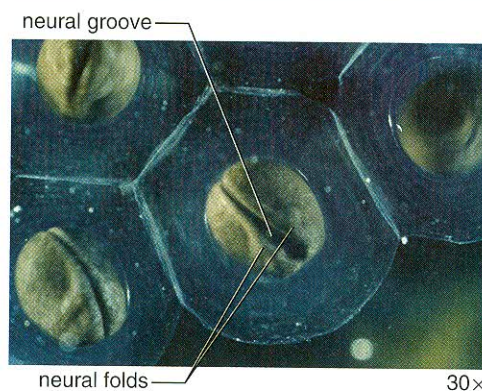
The notochord is said to **induce** the formation of the nervous system. Experiments have shown that if contact with notochord tissue is prevented, no neural plate is formed. **Induction** is believed to be one means by which development is usually orderly. The part of the embryo that induces the formation of an adjacent organ is said to be an **organizer** and is believed to carry out its function by releasing one or more chemical substances.

#### Observation: Development of Neural Tube and Brain

1. Obtain a slide showing a cross section of a frog neurula stage, and match it to one of the preceding drawings. Which drawing seems to best match your slide? Your instructor will confirm your match for you.
2. Obtain and examine frog embryos for a three-dimensional view of neurulation in the frog (Fig. 19.5).

**Figure 19.5 Photograph of frog embryos during neurulation.**

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## Development of the Heart

A chick embryo offers an opportunity to view a beating heart in an embryo. Your instructor may show you various stages. In particular you will want to observe the chick embryo from the 48-hour stage up to the 96-hour stage.

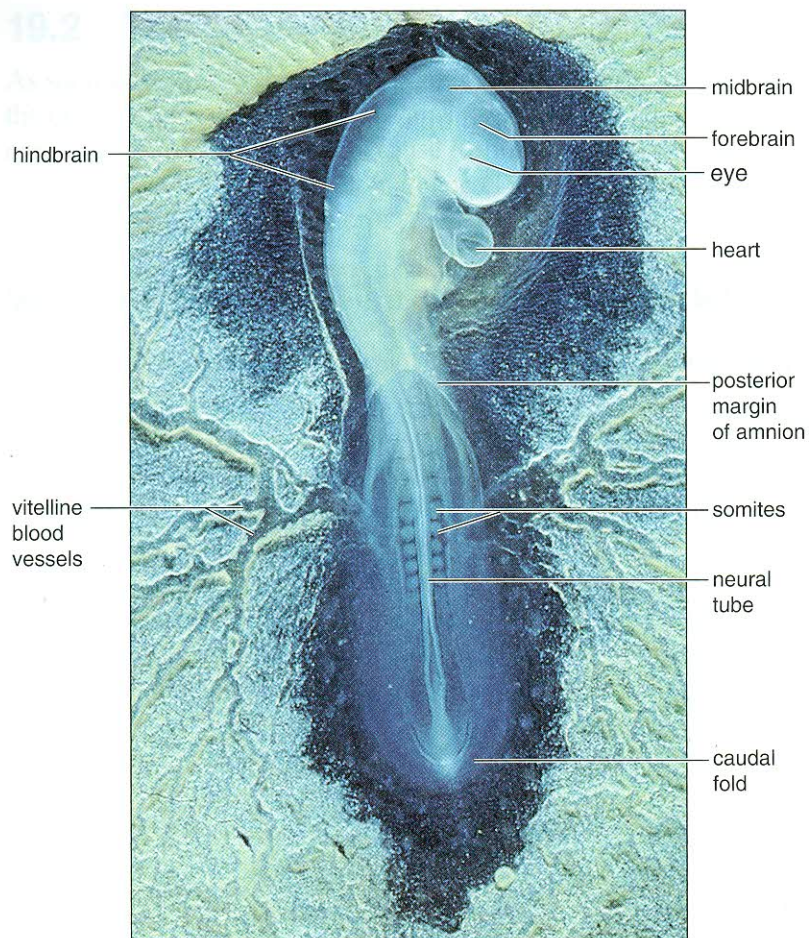
### Observing Live Chick Embryos

Use the following procedure for selecting and opening the eggs of live chick embryos:

1. Choose an egg of the proper age to remove from the incubator, and put a penciled  $\times$  on the uppermost side. The embryo is just below the shell.
2. Add warmed chicken Ringer solution to a finger bowl until the bowl is about half full. (Chicken Ringer solution is an isotonic salt solution for chick tissue that maintains the living state.) The chicken Ringer solution should not cover the yolk of the egg.
3. On the edge of the dish, gently crack the egg on the side opposite the  $\times$ .
4. With your thumbs placed over the  $\times$ , hold the egg in the chicken Ringer solution while you pry it open from below and allow its contents to enter the solution. If you open the egg too slowly or too quickly, the shell may damage the delicate membranes surrounding the embryo.

### Observation: Forty-Eight-Hour Chick Embryo

1. Follow the standard procedure for selecting and opening an egg containing a 48-hour chick embryo.
2. The embryo has turned so that the head region is lying on its side. Refer to Figure 19.6, and identify the following:
  - a. **Shape of the embryo**, which has started to bend. The head is now almost touching the heart.
  - b. **Heart**, contracting and circulating blood. Can you make out a ventricle, an atrium, and the aortic arches in the region below the head? Later, only one aortic arch will remain.
  - c. **Vitelline arteries and veins**, which extend over the yolk. The vitelline veins carry nutrients from the yolk sac to the embryo.
  - d. **Brain** with several distinct regions.
  - e. **Eye**, which has a developing lens.
  - f. **Margin (edge) of the amnion**, which can be seen above the vitelline arteries (see next section for amnion).
  - g. **Somites**, blocks of developing muscle tissue that differentiate from mesoderm, which now number 24 pairs.
  - h. **Caudal fold** of the amnion. The embryo will be completely enveloped when the head fold and caudal fold meet the margin of the amnion.



3x

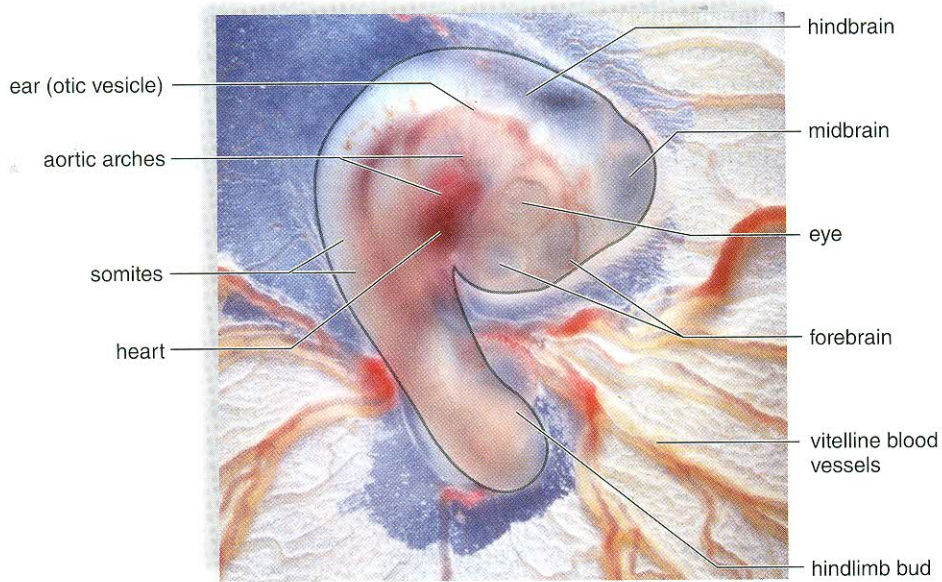
**Figure 19.6** Forty-eight-hour chick embryo.

The most prominent organs are labeled.

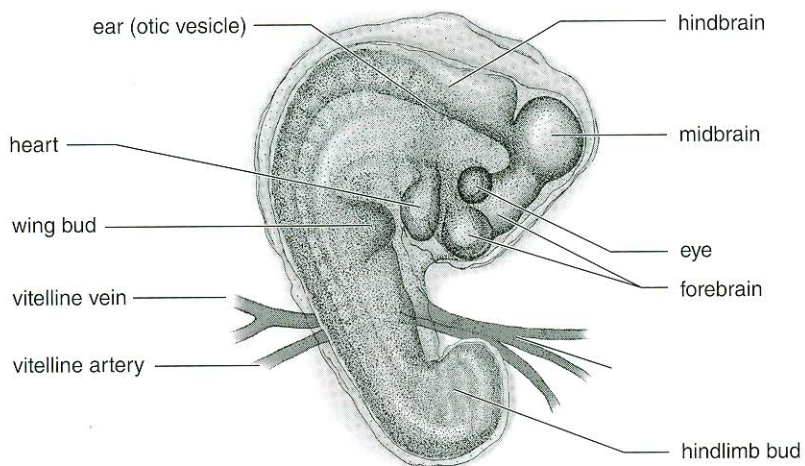
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### **Observation: Older Chick Embryos**

As a chick embryo continues to grow, various organs differentiate further (Fig. 19.7). The neural tube closes along the entire length of the body and is now called the spinal cord. The allantois, an extraembryonic membrane, is seen as a sac extending from the ventral surface of the hindgut near the tail bud. The digestive system forms specialized regions, and there is both a mouth and an anus. The yolk sac, the extraembryonic membrane that encloses the yolk, is attached to the ventral wall, but when the yolk is used up, the ventral wall closes.



a. Photograph



b. Drawing

Key:	
<b>Brain region</b>	<b>Becomes:</b>
forebrain	cerebrum
	diencephalon
midbrain	relay station
hindbrain	pons, cerebellum
	medulla oblongata

**Figure 19.7** Ninety-six-hour chick embryo.

Brain regions listed in the key can now be seen.

(a) © Carolina Biological Supply/Phototake

## Observation: Development of Human Organs

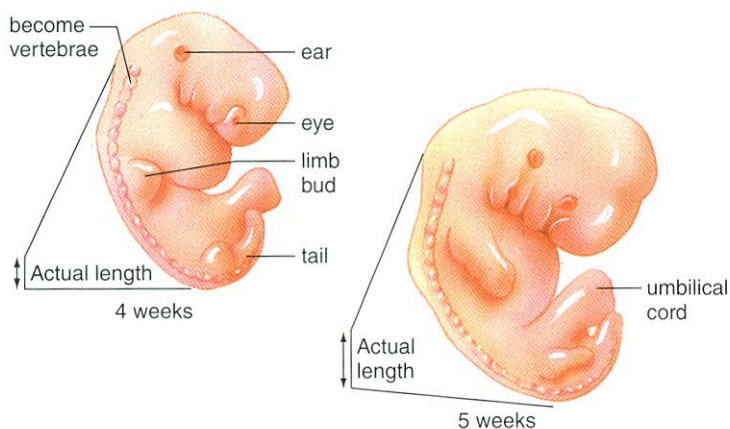
Study models or other study aids available that show the development of the nervous system and the heart in humans and/or show models of human embryos of different ages. Also view Figure 19.8, which depicts the external appearance of the embryo from the fourth to the seventh week of development.

During the embryonic period of development, the growing baby is susceptible to environmental influences, including the following:

- Drugs, such as alcohol; certain prescriptions; and recreational drugs. These can cause birth defects.
- Infections such as rubella, also called German measles, and other viral infections.
- Nutritional deficiencies.
- X-rays or radiation therapy.

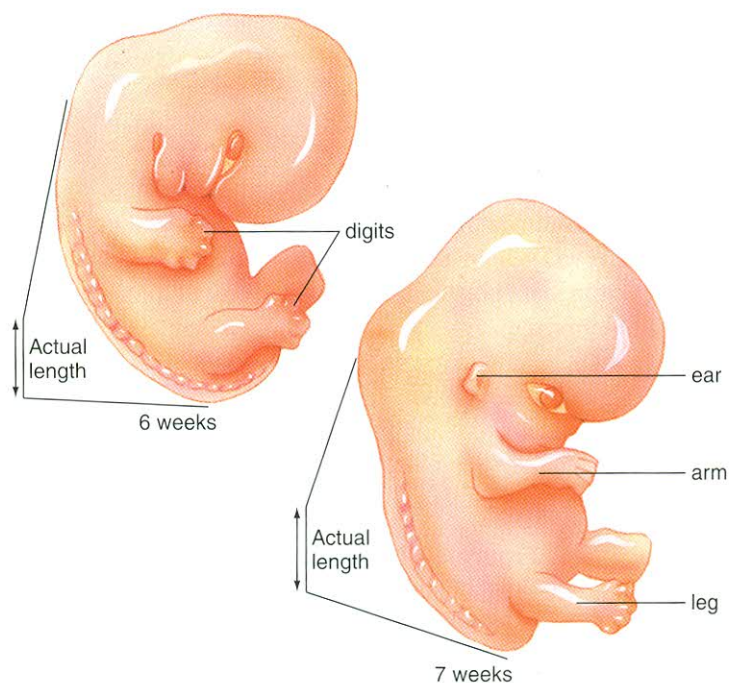
**Figure 19.8 External appearance of the human embryo.**

a. Weeks 4 and 5. b. Weeks 6 and 7.



a. Weeks 4 and 5

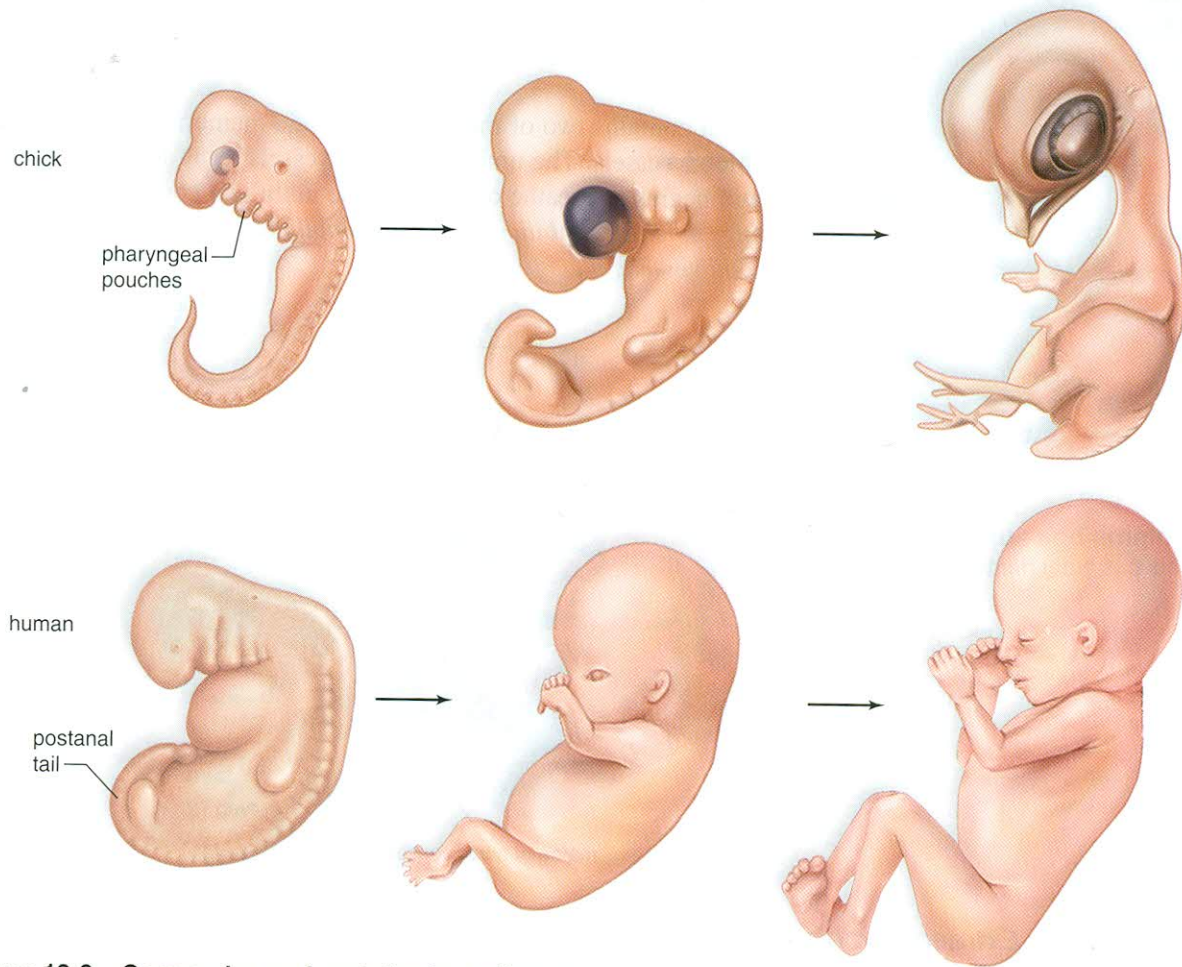
- Head dominant, but body getting longer.
- Limb buds are visible.
- Eyes and ears begin to form.
- Tissue for vertebrae extend into tail.



b. Weeks 6 and 7

- Head still dominant, but tail has disappeared.
- Facial features continue to develop.
- Hands and feet have digits.
- All organs are more developed.

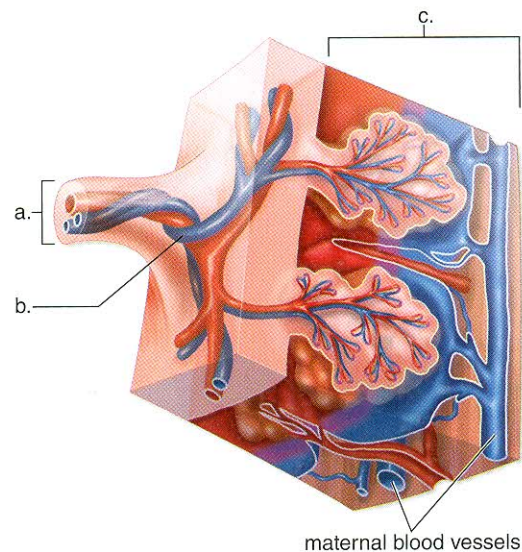
As illustrated in Figure 19.9, the early stages of human development are quite similar to those of the chick. Differences become marked only as development proceeds.



**Figure 19.9 Comparison of vertebrate embryos.** Successive stages in the development of chick and human. Early stages (*far left*) are similar; differences become apparent as development continues.

## 19.3 Extraembryonic Membranes, the Placenta, and the Umbilical Cord

- The **extraembryonic membranes** take their name from the observation that they are not part of the embryo proper. They are outside the embryo, and therefore they are “extra.”
- In humans, the **placenta** is the structure that provides the embryo with nutrient molecules and oxygen and takes away its waste molecules, such as carbon dioxide. The fetal half of the placenta contains the fetal capillaries. The maternal half of the placenta is the uterine wall where maternal blood vessels meet the fetal capillaries.
- The **umbilical cord** is a tubular structure that contains two of the extraembryonic membranes (the allantois and the yolk sac) and also the **umbilical blood vessels**. The umbilical blood vessels bring fetal blood to and from the placenta. When a baby is born and begins to breathe on its own, the umbilical cord is cut and the remnants become the navel. *In this drawing, label the umbilical cord, the umbilical blood vessels, and the placenta, which contains the maternal blood vessels.*



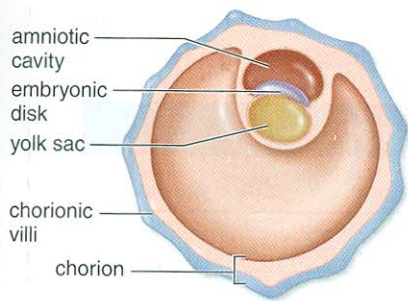
### Observation: The Extraembryonic Membranes

In a model, and in Figure 19.10, trace the development of the extraembryonic membranes. Also, note the development of the placenta and the umbilical cord. The extraembryonic membranes are as follows:

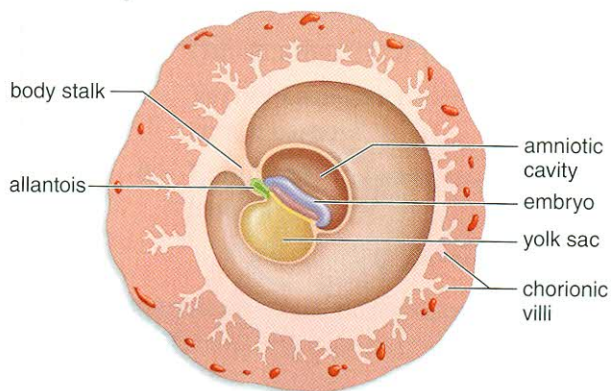
- **Chorion.** The chorion is the outermost membrane, and in chicks it lies just below the porous shell, where it functions in gas exchange. In humans, an outer layer of cells surrounding the inner cell mass at the blastocyst stage becomes the chorion. Notice in Figure 19.10 that the treelike **chorionic villi** are a part of the chorion.
- **Amnion.** The amnion forms the amniotic cavity, which envelops the embryo and contains the amniotic fluid that cushions and protects the developing offspring (Fig. 19.11). All animals, whether the sea star, the frog, the chick, or the human, develop in an aqueous environment. Birth of a human is imminent when “the water breaks,” and the amniotic fluid is lost.
- **Allantois.** The allantois serves as a storage area for metabolic waste in the chick. In humans, the allantois extends into the umbilical cord. It accumulates the small amount of urine produced by the fetal kidneys and later contributes to urinary bladder formation. Its blood vessels become the umbilical blood vessels.
- **Yolk sac.** The yolk sac is the first embryonic membrane to appear. In the chick, the yolk sac does contain yolk, food for the developing embryo. In humans, the yolk sac contains plentiful blood vessels and is the first site of blood cell formation.

**Figure 19.10 Development of extraembryonic membranes in humans.**

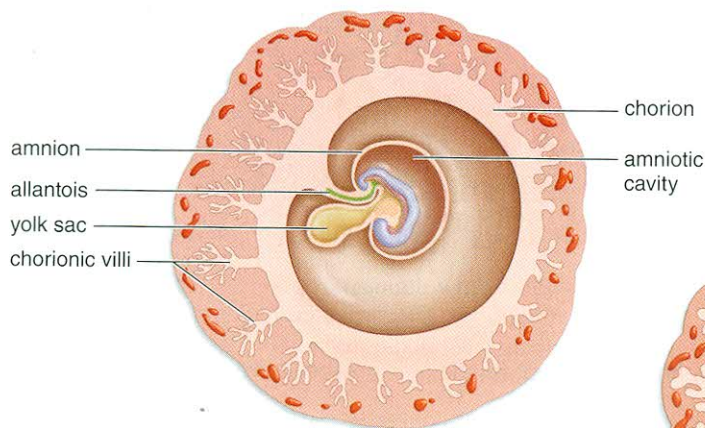
**a.** At first, no organs are present in the embryo, only tissues. The amniotic cavity is above the embryonic disk, and the yolk sac is below. The chorionic villi are present. **b, c.** The allantois and yolk sac, two more extraembryonic membranes, are positioned inside the body stalk as it becomes the umbilical cord. **d.** At 35+ days, all membranes are present, and the umbilical cord takes blood vessels between the embryo and the chorion (placenta).



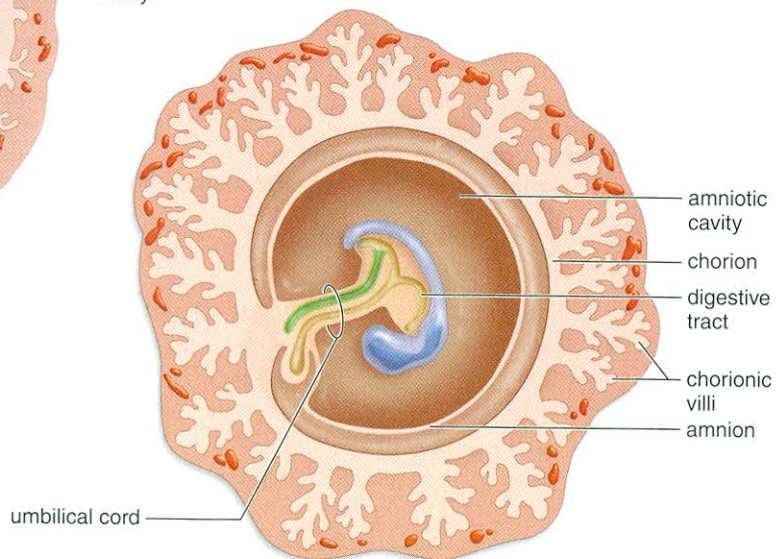
**a. 18 days**



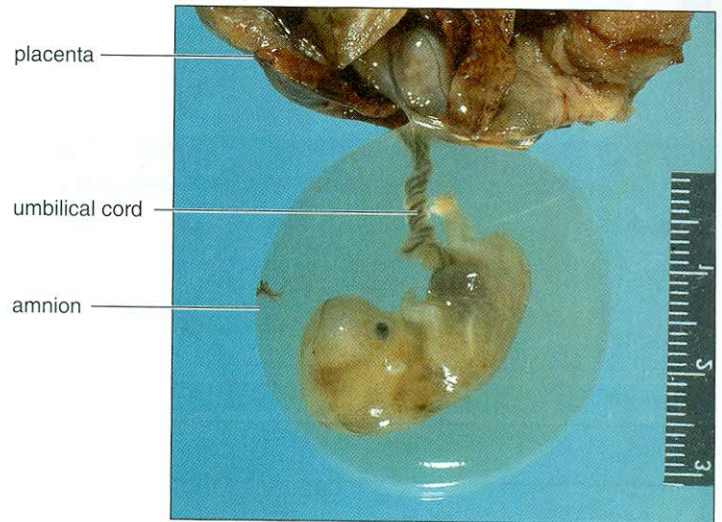
**b. 21 days**



**c. 25 days**



**d. 35+ days**



**Figure 19.11 Fetus and amnion.**

Photograph of a human fetus at 8 weeks. The scale bar is 3 cm.

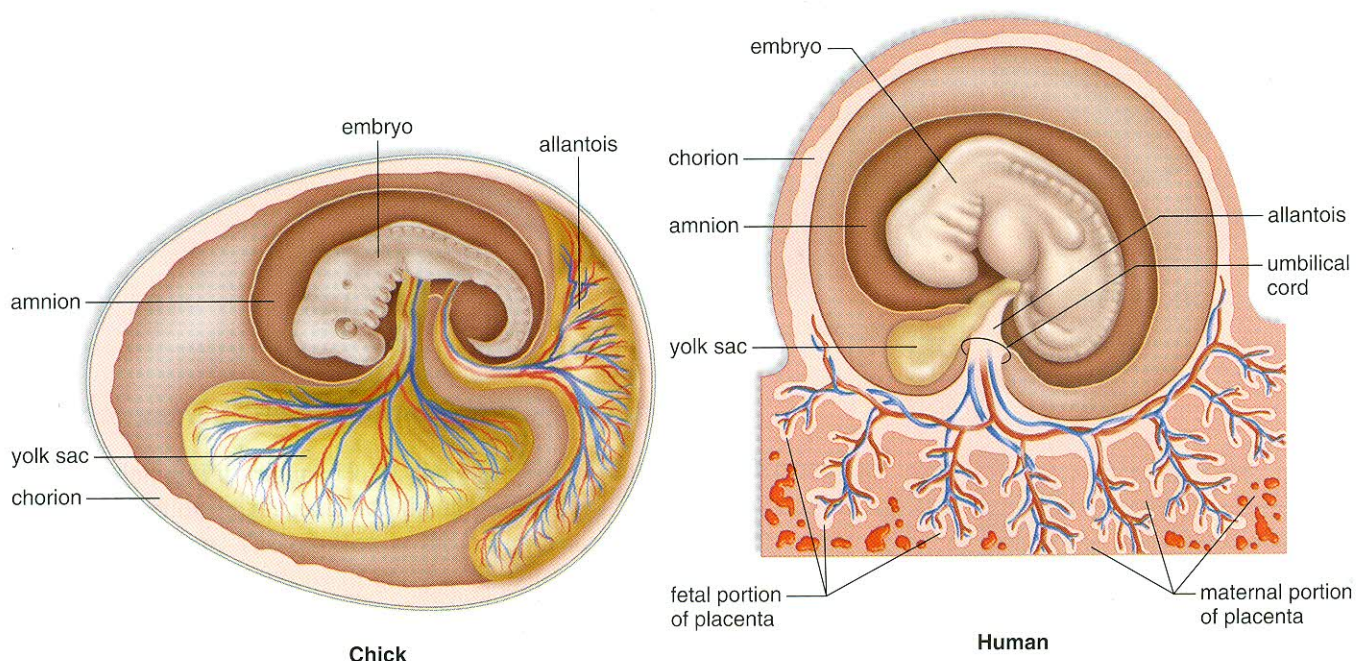
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## Comparison of Extraembryonic Membranes in Chick and Human

Consult Figure 19.12 and use the information on page 264 to complete Table 19.1, which compares the functions of the extraembryonic membranes in the chick and in the human. Reptiles, which we now know include birds, were the first animals to have extraembryonic membranes. These membranes allowed reptiles to develop on land. They also allow mammals, including humans, to develop inside the uterus of the mother.

**Table 19.1 Functions of Extraembryonic Membranes in Chick and Human**

Membrane	Chick	Human
Amnion		
Allantois		
Chorion		
Yolk sac		



**Figure 19.12 Extraembryonic membranes.**

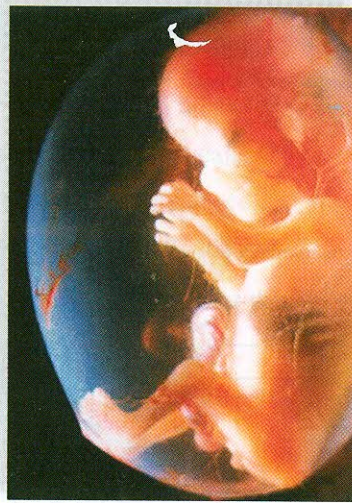
The chick and a human have the same extraembryonic membranes, but except for the amnion, they have different functions.

## 19.4 Human Fetal Development

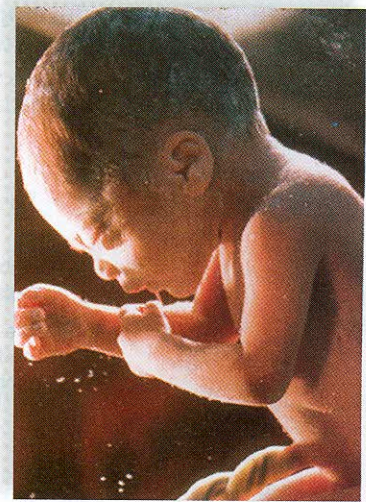
During fetal development (last seven months), the skeleton becomes ossified (bony), reproductive organs form, arms and legs develop fully, and the fetus enlarges in size and gains weight.

### Observation: Fetal Development

- Using Table 19.2 and Figure 19.13 to assist you, examine models of fetal development.
- In Table 19.2, note the following.
  - External genitals:** About the third month, it is possible to tell male from female if an ultrasound is done.
  - Quickening:** Fetal movement is felt during the fourth or fifth months.
  - Vernix caseosa:** Beginning with the fifth month, the skin is covered with a cheesy coating called vernix caseosa.
  - Lanugo:** During the sixth and seventh months, the body is covered with fine, downy hair termed lanugo.



Three- to four-month-old fetus



Seven- to eight-month-old fetus

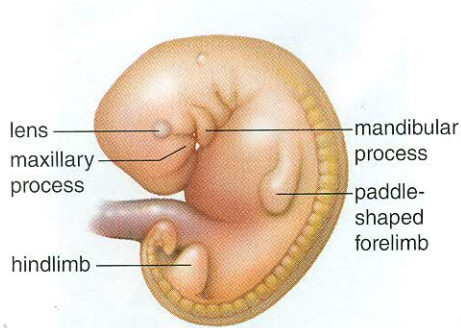
(left) © Petit format/Science Source; (right) © Petit format/Science Source

**Table 19.2 Fetal Development**

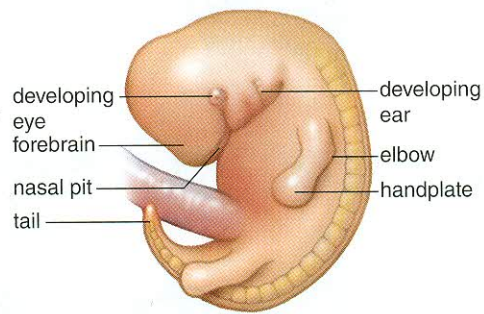
Month	Events for Mother	Events for Baby
Third month	Uterus is the size of a grapefruit.	Possible to distinguish sex. Fingernails appear.
Fourth month	Fetal movement is felt by those who have been previously pregnant. Heartbeat is heard by stethoscope.	Bony skeleton visible. Hair begins to appear. 150 mm (6 in.), 170 g (6 oz).
Fifth month	Fetal movement is felt by those who have not been previously pregnant. Uterus reaches up to level of umbilicus and pregnancy is obvious.	Protective cheesy coating, called vernix caseosa, begins to be deposited. Heartbeat can be heard.
Sixth month	Doctor can tell where baby's head, back, and limbs are. Breasts have enlarged, nipples and areolae are darkly pigmented, and colostrum is produced.	Body is covered with fine hair called lanugo. Skin is wrinkled and reddish.
Seventh month	Uterus reaches halfway between umbilicus and rib cage.	Testes descend into scrotum. Eyes are open. 300 mm (12 in.), 1,350 g (3 lb).
Eighth month	Weight gain is averaging about a pound a week. Difficulty in standing and walking because center of gravity is thrown forward.	Body hair begins to disappear. Subcutaneous fat begins to be deposited.
Ninth month	Uterus is up to rib cage, causing shortness of breath and heartburn. Sleeping becomes difficult.	Ready for birth. 530 mm (20½ in.), 3,400 g (7½ lb).

**Figure 19.13 Human development.**  
Changes occurring from the fifth week to the eighth month.

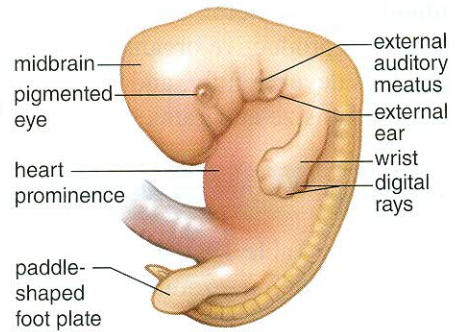
(g) © Chris Downie/E+/Getty RF; (h) © James Stevenson/Science Source



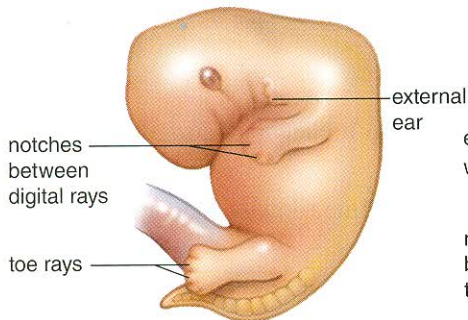
a. 35 ± 1 day (10–12 mm)



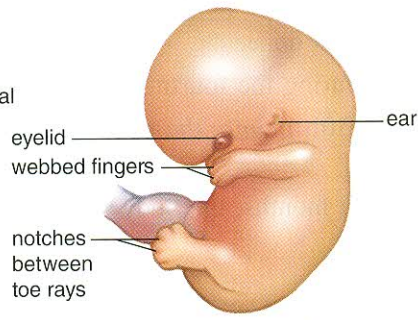
b. 37 ± 1 day (12.5–15.75 mm)



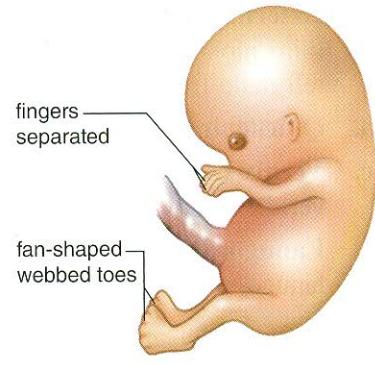
c. 40 ± 1 day (16–21 mm)



d. 45 ± 1 day (22–24 mm)



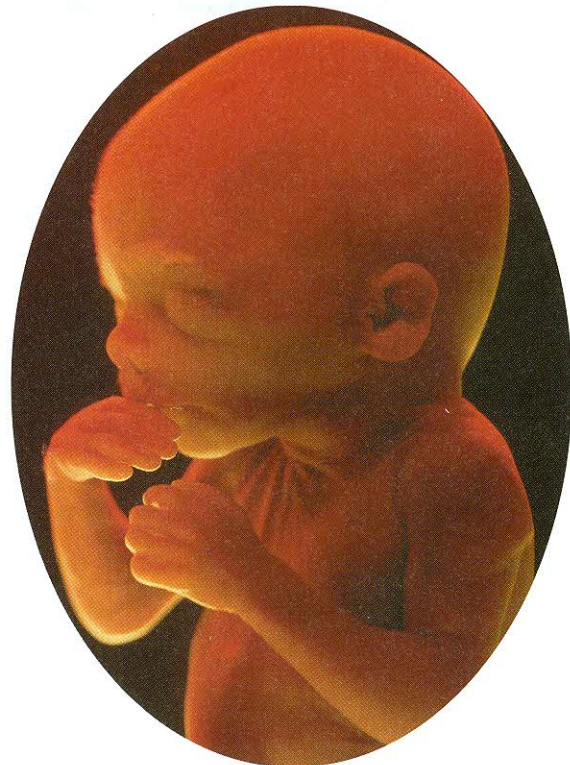
e. 49 ± 1 day (28–30 mm)



f. 52 ± 1 day (32–34 mm)



g. Three- to four-month-old fetus



h. Seven- to eight-month-old fetus

## Laboratory Review 19

- \_\_\_\_\_ 1. What results from the fertilization of an egg by a single sperm?
- \_\_\_\_\_ 2. What is cell division that lacks growth called?
- \_\_\_\_\_ 3. What is the solid cluster of 16 to 32 embryonic cells called?
- \_\_\_\_\_ 4. What is the hollow cavity of a blastula called?
- \_\_\_\_\_ 5. Which part of a human blastocyst becomes the embryo, the inner cell mass or the trophoblast?
- \_\_\_\_\_ 6. During what developmental stage do tissues begin to form?
- \_\_\_\_\_ 7. What does the archenteron become?
- \_\_\_\_\_ 8. What primary germ layer gives rise to the pseudostratified ciliated columnar epithelium that lines the trachea?
- \_\_\_\_\_ 9. What replaces the notochord?
- \_\_\_\_\_ 10. Which extraembryonic membrane has a similar function in chicks and humans?
- \_\_\_\_\_ 11. What extraembryonic membrane is the first site of blood cell formation in humans?
- \_\_\_\_\_ 12. Where is metabolic waste stored in a chick?
- \_\_\_\_\_ 13. During what month of human development is it possible to distinguish the gender of the fetus?
- \_\_\_\_\_ 14. What is the name of the protective cheesy coating that begins to be deposited in the fifth month of human development?

### Thought Questions

15. Some invertebrate animals (covered in an upcoming laboratory exercise) have only two primary germ layers, ectoderm and endoderm. What structures are likely to be missing from these animals? Justify your reply.
  
16. Chorionic villus sampling and amniocentesis are prenatal tests that can be done to check for certain genetic conditions or a chromosomal condition.
  - a. What part of the human blastocyst gives rise to the chorion and amnion?
  
  - b. What do these layers have in common?
  
17.
  - a. If the notochord is removed, will ectoderm in this location become a neural tube? Explain.
  
  - b. If ectoderm above the notochord is removed and replaced with belly ectoderm, will the belly ectoderm become a neural tube? Explain.