Animal Development

Chapter 41

What Is Animal Development?

- The process by which an animal proceeds from fertilized egg through adulthood and eventual death
- Animals demonstrate two possible forms of development
  - **Indirect development**
  - **Direct development**

Indirect Development

- When the juvenile has a different body form than the adult
- Characteristics
  - Occurs in most invertebrates and some vertebrates (amphibians)
  - Adults make large numbers of eggs, each with a small **yolk** (food reserve)
  - An immature **larva** emerges from egg
  - **Metamorphosis** produces sexually mature adults

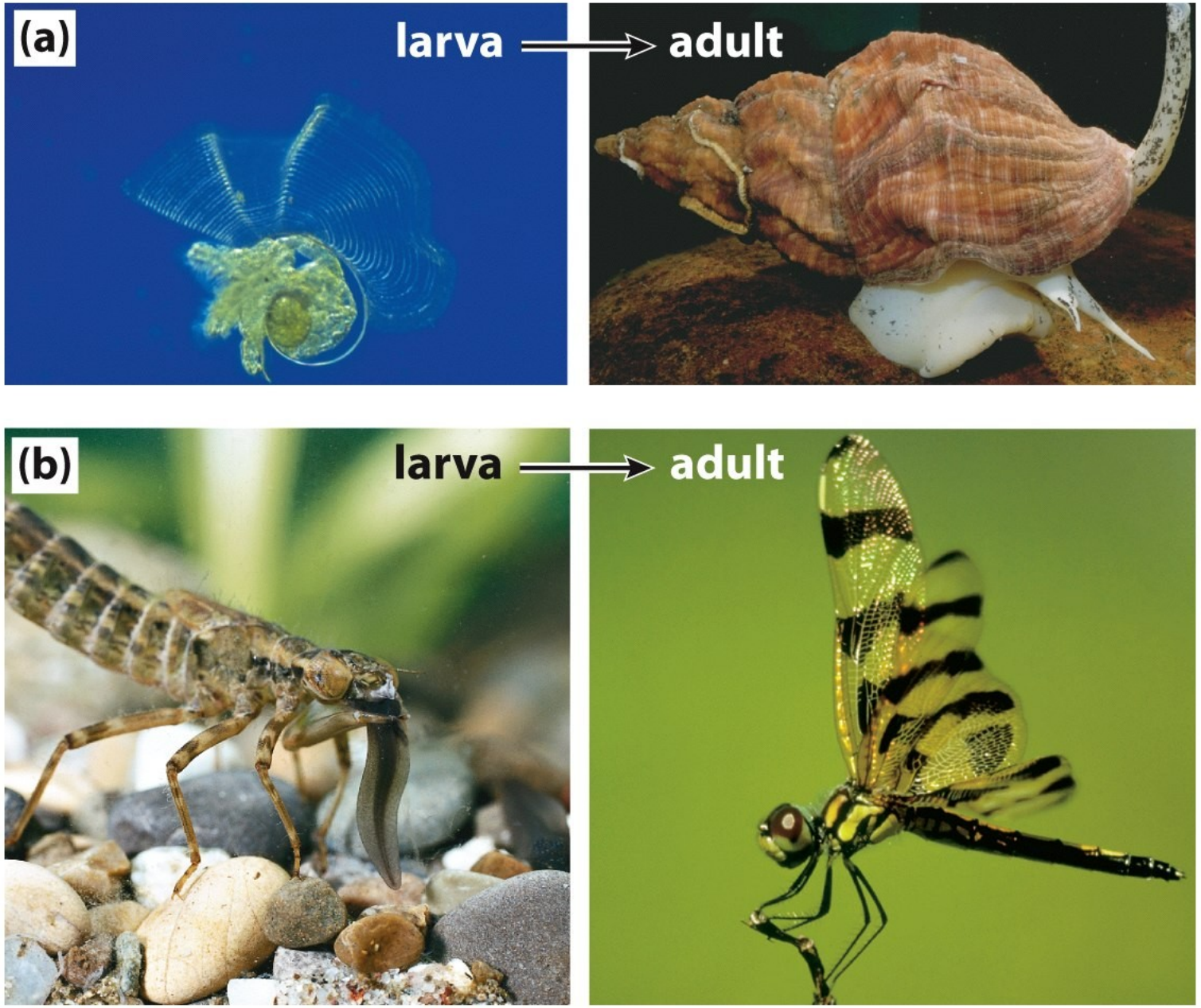


Figure 41-1 Biology: Life on Earth, 8/e

Direct Development

- When the juvenile resembles the adult form
- Characteristics
  - Occurs in reptiles, birds, mammals, and some invertebrates
  - Newborn is a sexually immature version of adult
  - Adults produce fewer offspring, but are more developed

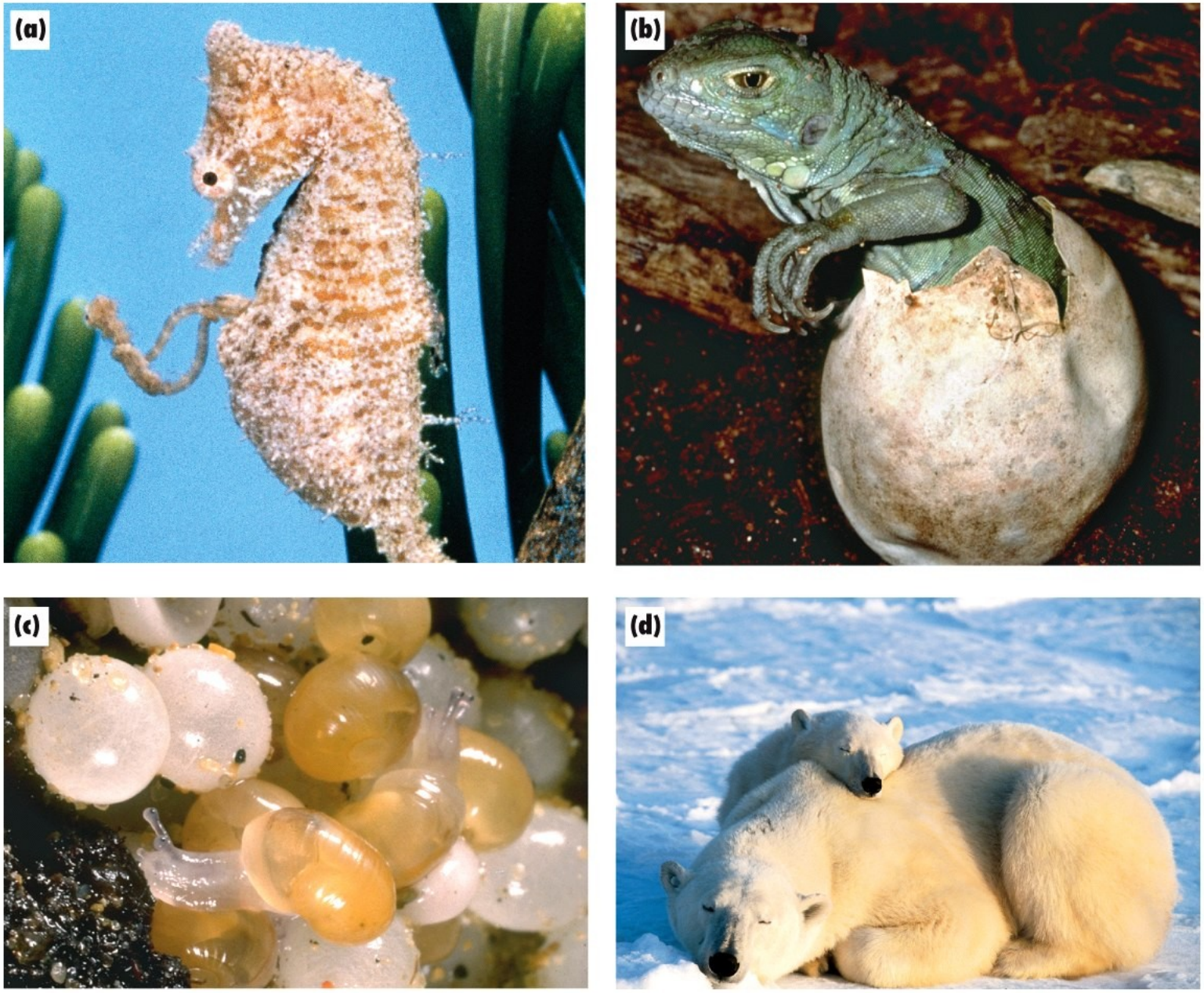


Figure 41-2 Biology: Life on Earth, 8/e

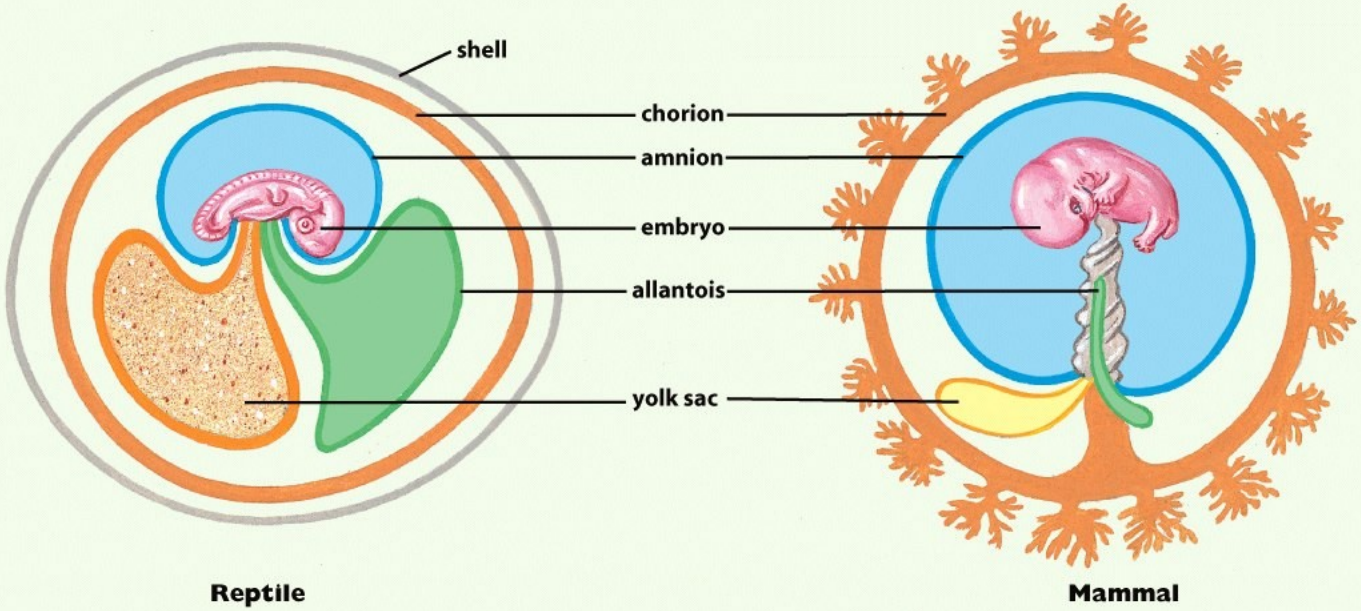
Extraembryonic Membranes

- Reptiles, birds, and mammals produce **amniotic eggs**
  - Embryo encased in protective shell and liquid-filled space
  - Acts as private pond
  - Allows embryo to be less dependent on the external environment for development

Extraembryonic Membranes

- Amniotic eggs contain four extraembryonic membranes
  - **Chorion**: lines shell, involved with O_2 and CO_2 exchange with environment
  - **Amnion**: encloses embryo in watery environment
  - **Allantois**: surrounds and isolates wastes
  - **Yolk sac**: contains stored food

Table 41-1 Vertebrate Embryonic Membranes



	Reptilian Embryo		Mammalian Embryo	
Membrane	**Structure**	**Function**	**Structure**	**Function**
Chorion	Membrane lining inside shell	Acts as respiratory surface; regulates exchange of gases and water between embryo and air	Fetal contribution to placenta	Provides surface for exchange of gases, nutrients, and wastes between embryo and mother
Amnion	Sac surrounding embryo	Encloses embryo in fluid	Sac surrounding embryo	Encloses embryo in fluid
Allantois	Sac connected to embryonic urinary tract; capillary-rich membrane lining inside of chorion	Stores wastes (especially urine); acts as respiratory surface	Membranous sac arising from the gut; varies in size	May store metabolic wastes; contributes to umbilical cord blood vessels
Yolk sac	Membrane surrounding yolk	Contains yolk as food; digests yolk and transfers nutrients to embryo	Small, membranous, fluid-filled sac	Helps absorb nutrients from mother; forms blood cells; contributes to umbilical cord

Table 41-1 Biology: Life on Earth, 8/e

Development

- A multistage process including
  - Cleavage
  - Gastrulation
  - The formation of adult structures
  - Sexual maturation

Cleavage

- **Cleavage** begins the process
  - Zygote divides mitotically without an increase in size
  - A solid round ball of cells is formed (**morula**)
  - The morula develops an internal cavity (**blastocoel**)
    - Becomes a **blastula**
  - The process of gastrulation forms three tissue layers

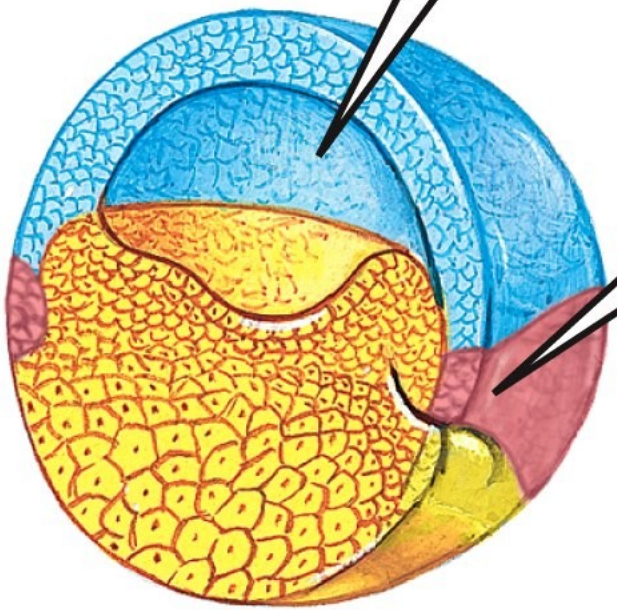
The blastula just before gastrulation.

The three embryonic tissue types have not yet formed. Colors indicate the future fate of the cells after they begin differentiating in the gastrula.

ectoderm

mesoderm

endoderm



The opening inside the blastula is the blastocoel.

The blastopore is the site at which gastrulation will begin.

Figure 41-3a Biology: Life on Earth, 8/e

Cells migrate at the start of gastrulation.
Cells migrating in will form the endoderm and mesoderm layers of the gastrula; the cells remaining on the surface will form ectoderm.

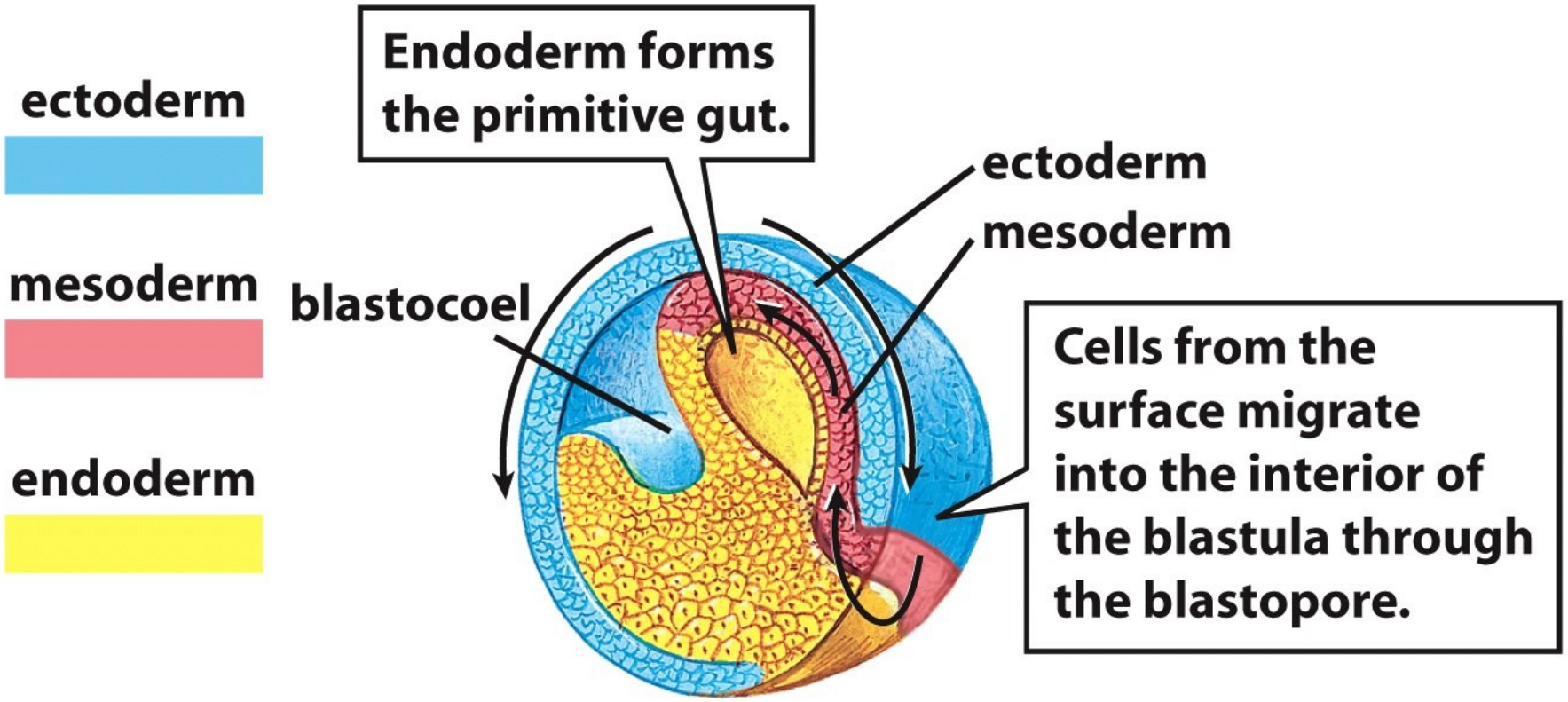


Figure 41-3b Biology: Life on Earth, 8/e

Mesoderm differentiates.

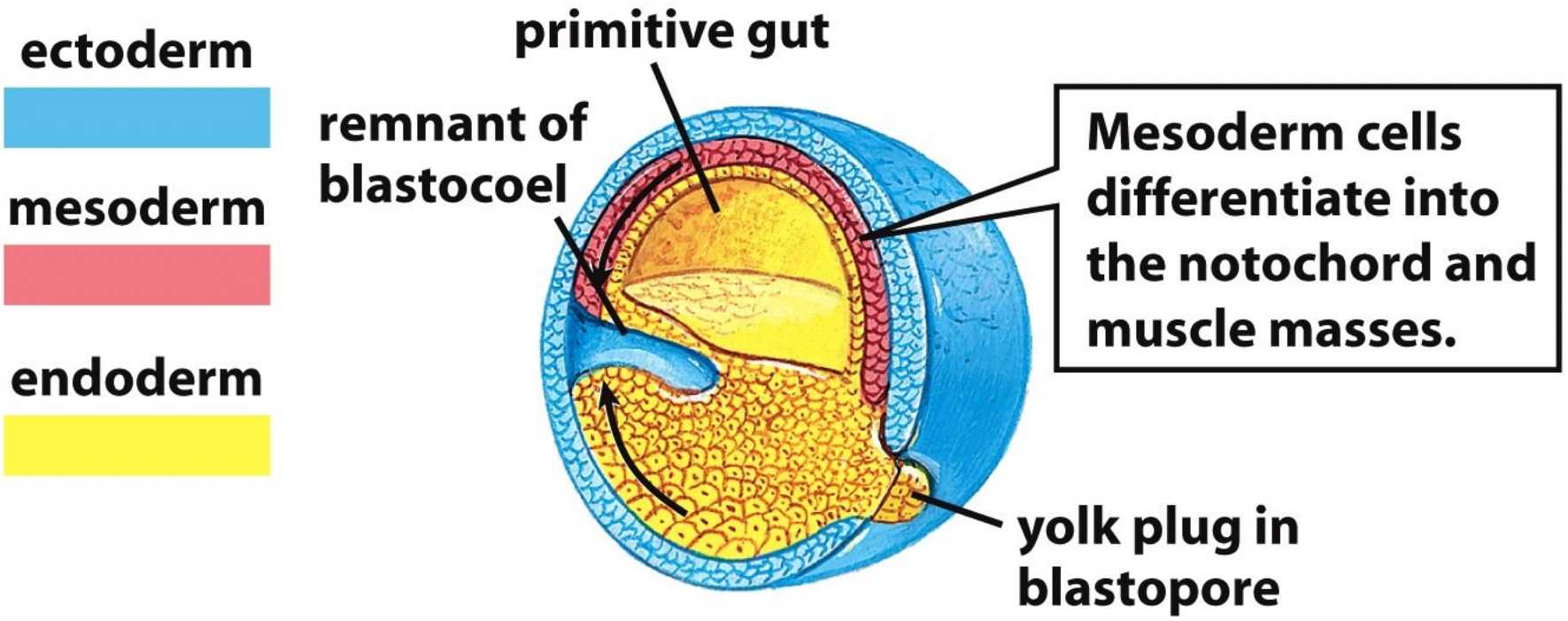


Figure 41-3c Biology: Life on Earth, 8/e

Gastrulation

- An indentation (**blastopore**) forms on one side of blastula and cells fold inward
- Folding blastula cells form three cell layers
  - **Endoderm**: inner cell layer
    - Forms digestive and respiratory tracts
  - **Mesoderm**: middle cell layer
    - Forms muscle and skeleton
  - **Ectoderm**: outer cell layer
    - Forms epidermis, circulatory, and nervous systems
  - A three-layered embryo (**gastrula**) forms

Table 41-2 Derivation of Adult Tissues from Embryonic Cell Layers

Embryonic Layer	Adult Tissue
Ectoderm	Epidermis of skin; hair; lining of mouth and nose; glands of skin; nervous system
Mesoderm	Dermis of skin; muscle, skeleton; circulatory system; gonads; kidneys; outer layers of digestive and respiratory tracts
Endoderm	Lining of digestive and respiratory tracts; liver; pancreas

Table 41-2 Biology: Life on Earth, 8/e

Adult Structures Develop

- Organs form (**organogenesis**) from each embryonic cell layer
  - Organs “sculpted” by programmed death of excess cells
- Two mechanisms of organogenesis
  - (1) Some cells die unless they receive a chemical “survival signal”
    - Example: only motor neurons that connect with muscles live

Adult Structures Develop

- Two mechanisms of organogenesis (continued)
  - (2) Some cells live unless they receive a chemical “death signal”
    - Example: when tadpoles go through metamorphosis, thyroid hormone stimulates cells in the tail to produce enzymes to digest the tail away

Figure 41-4 Biology: Life on Earth, 8/e

How Is Development Controlled?

- **Development** is the process by which an organism proceeds from fertilized egg through adulthood
- **Differentiation** is the specialization of embryonic cells into different cell types
- How do cells differentiate from one another during development?
- The zygote contains all the genes needed to direct the construction of the entire organism
- Are some genes lost as cells differentiate?

Genetic Blueprint

- No! Every adult cell contains the entire genetic blueprint for the organism
- Demonstrated in the 1950s by the experiments of King and Briggs

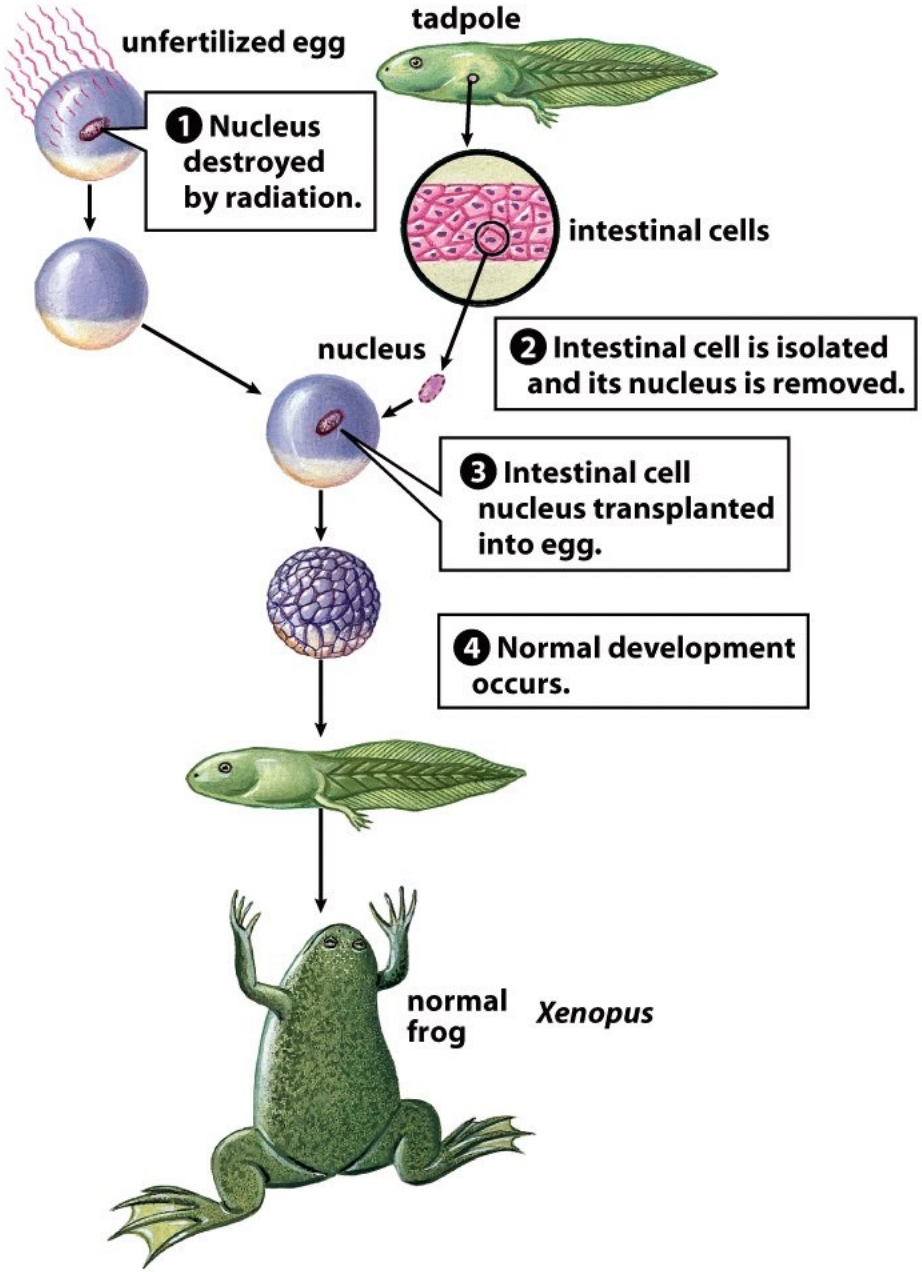


Figure 41-5 Biology: Life on Earth, 8/e

Gene Transcription

- Throughout development genes are variously expressed to direct the differentiation of cells, tissues, and organs
- Thus, development is regulated by gene transcription
- In many invertebrates, gene-regulating substances become concentrated in different places in the egg's cytoplasm
  - Distributed unevenly in early embryonic cell divisions
  - Drive cells down different developmental paths

Gene Transcription

- Later in development, **induction** can occur
  - Example: *blastopore dorsal lip cells* stimulate others to produce substances that induce differentiation into specific cell types

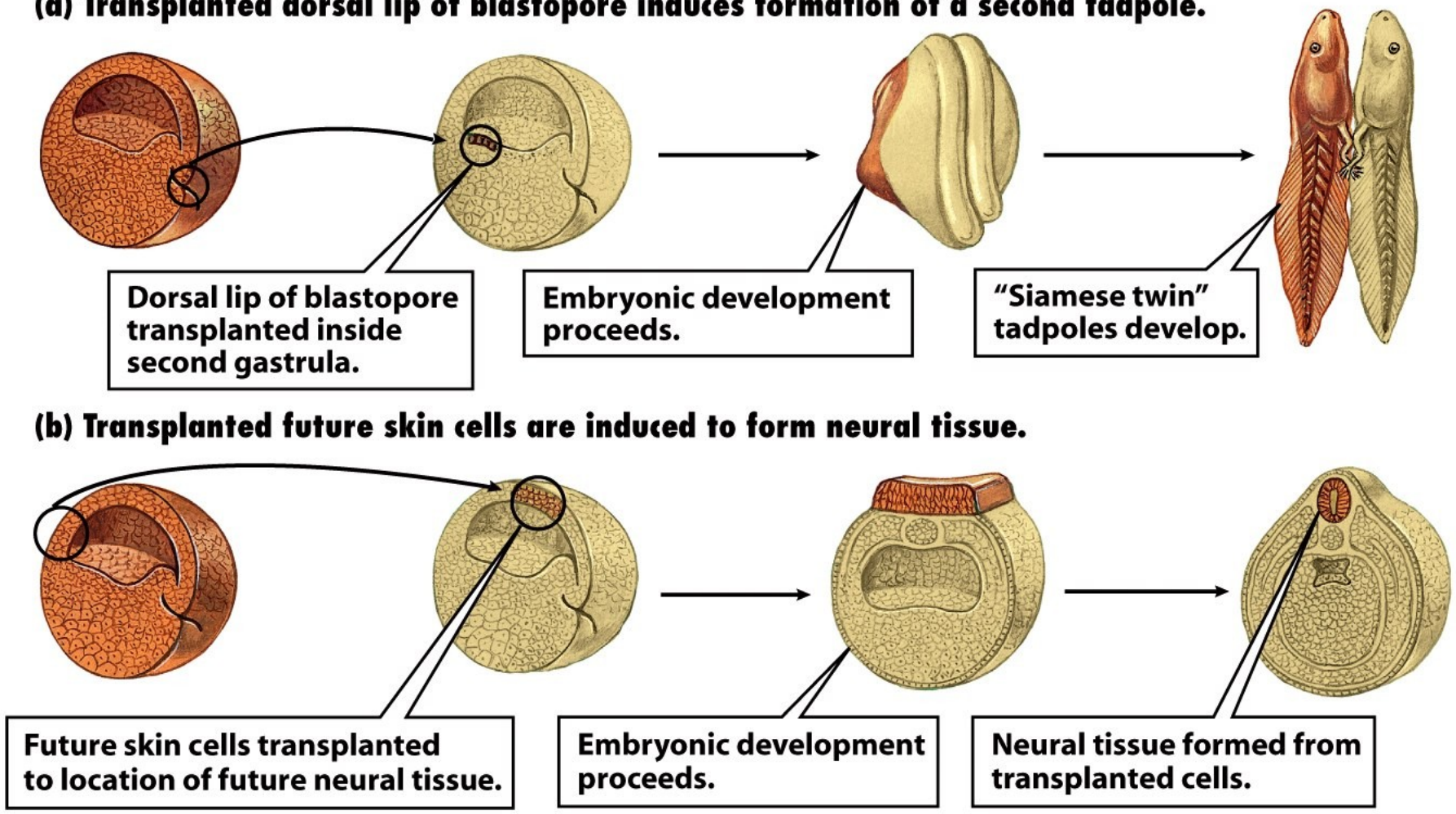


Figure 41-6 Biology: Life on Earth, 8/e

Homeobox Sequences

- How do different body regions know which genes to express to direct the development of body parts?
  - Homeobox sequences: short DNA sequences within genes that encode for DNA-binding proteins
  - Proteins bind to DNA and control which genes are expressed during development

Homeobox Sequences

- Different homeobox sequences direct the development of different body parts
- Act as master regulators, switching on all the genes needed to produce a specific body part
- Mutation of homeobox DNA can lead to leg formation where a fruit fly's antenna should be

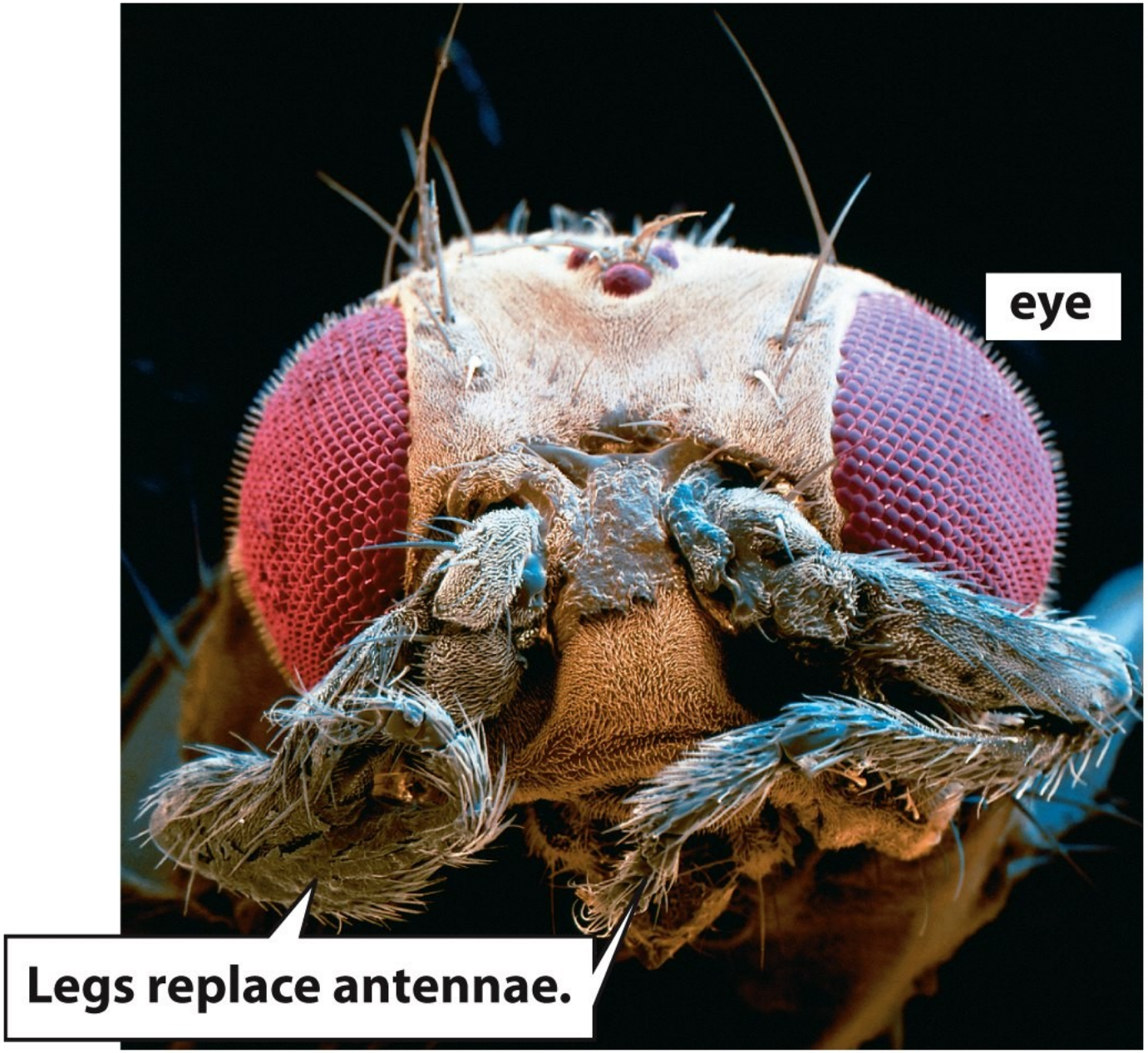


Figure 41-7 Biology: Life on Earth, 8/e

How Do Humans Develop?

- Humans develop by the same mechanisms as other animals

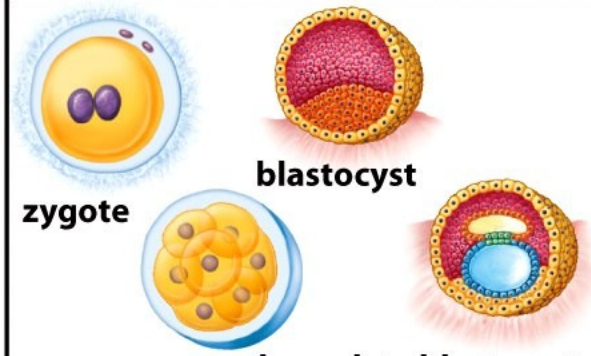
week 1	week 2	week 3	week 4	week 5	week 6
zygote to late blastula		embryo			
		 0.06 to 0.1 inches (1.5–2.5 mm)	 0.12 to 0.20 inches (3–5 mm)	 0.28 to 0.35 inches (7–9 mm)	 0.32 to 0.43 inches (8–11 mm)
Cleavage of zygote forms the morula and then the blastula, which implants in the uterus.	Blastula burrows into endometrium; forms yolk sac, amnion, and embryonic disc.	Gastrulation occurs; notochord and beginning of neural tube form; heart beats.	Neural tube closes; arm buds, tail, and pharyngeal grooves form.	Eyes begin to form; leg buds form; brain enlarges.	External ears and webbed fingers form; pharyngeal grooves and tail are disappearing.

Figure 41-8 part 1 Biology: Life on Earth, 8/e

week 7	week 8	week 10	week 12	week 16
embryo		fetus		
 0.67 to 0.79 inches (1.7–2.0 cm)	 0.90 to 1.10 inches (2.3–2.8 cm)	 1.25–1.75 inches (3.2–4.4 cm)	 2–3 inches (5–7.6 cm)	 4–5 inches (10.2–12.7 cm)
Webbed toes form; bones begin to stiffen; back straightens; eyelids begin forming.	All major organs and male genitals begin to form; arms can bend; fingers are distinct. Facial features and outer ears take shape.	After 8 weeks; the embryo is called a fetus. Red blood cells form; toes separate; eyelids have developed; major brain parts are present; hands can form fists.	Neck is well-defined; all organs are present; male and female genitals are present; arms and legs move; teeth begin to form; heartbeat can be detected electronically.	Sucking and swallowing movements occur; liver and pancreas begin functioning. Body has grown relative to the head; major organs continue developing. Mother may feel movement; weight is about 5 oz.

Figure 41-8 part 2 Biology: Life on Earth, 8/e

week 20	week 24	week 30	week 36
fetus			
 6–7 inches (15.2–17.8 cm)	 8–9 inches (20.3–22.9 cm)	 15–16 inches (38.1–40.6 cm)	 16–19 inches (40.6–48.3 cm)
Fetus may suck thumb; arms and legs can punch and kick; body can change position. Fingernails are formed, fat is deposited under skin; eyebrows and eyelashes appear.	Brain development continues, hearing develops, and eyes can move. Fetus can hiccup, squint, smile, and frown. Fetus may have hair on head. Unique foot- and fingerprints appear. Weight is about 1–1.5 pounds.	Brain development continues, eyes open and close and see light; fetus kicks and stretches. Breathing movements occur but lungs are not mature. Bones are present but flexible. Baby may survive if born.	Eyes open and close corresponding to wake and sleep cycles, body fat increases; lungs and other organs are functional. Child can grasp and orient toward light. Weight is about 5–6 pounds, and child is no longer considered premature if born. Full term is 38 weeks.

Figure 41-8 part 3 Biology: Life on Earth, 8/e

During the First Two Months

- During the first two months, rapid differentiation and growth occur
- An egg is typically fertilized in the uterine tube on the way to the uterus
  - Zygote undergoes several cleavage divisions
  - Journey takes 4 days

The first week

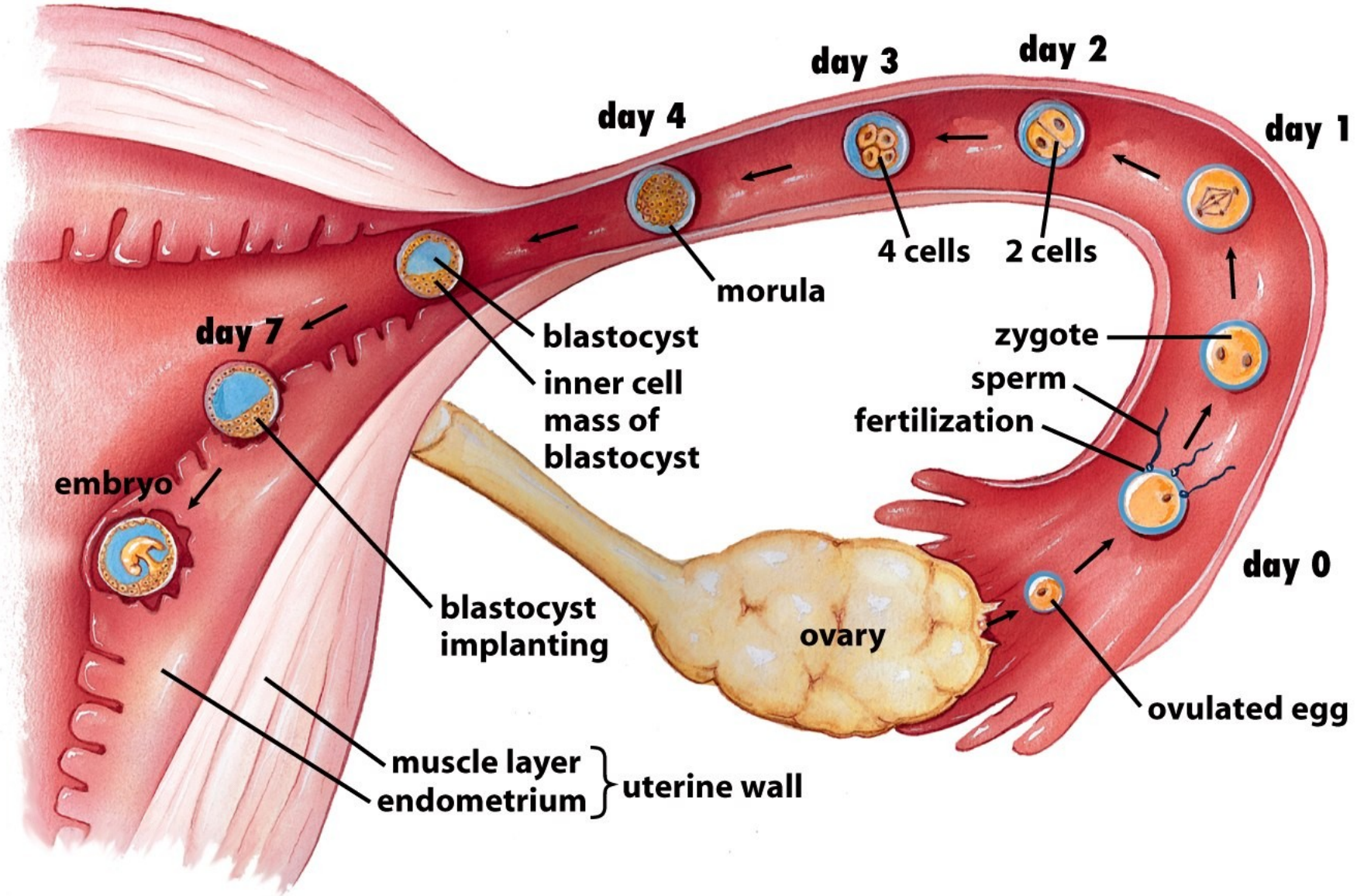


Figure 41-9a Biology: Life on Earth, 8/e

An egg within the oviduct

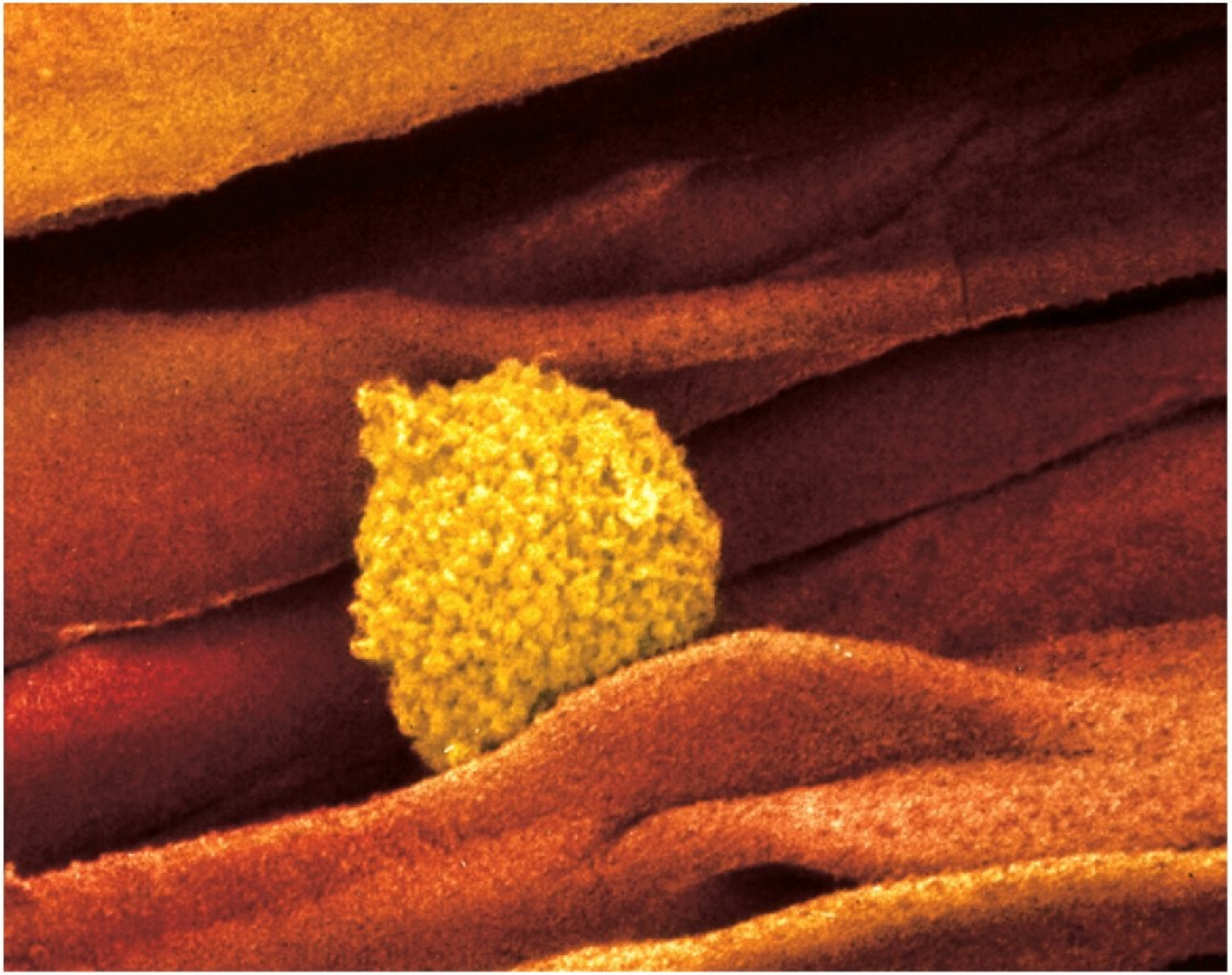


Figure 41-9b Biology: Life on Earth, 8/e

During the First Two Months

- Cell divisions lead to formation of a solid ball of cells called a **morula**
- After 1 week, the morula becomes a **blastocyst,** a hollow ball of cells with an **inner cell mass** on one side

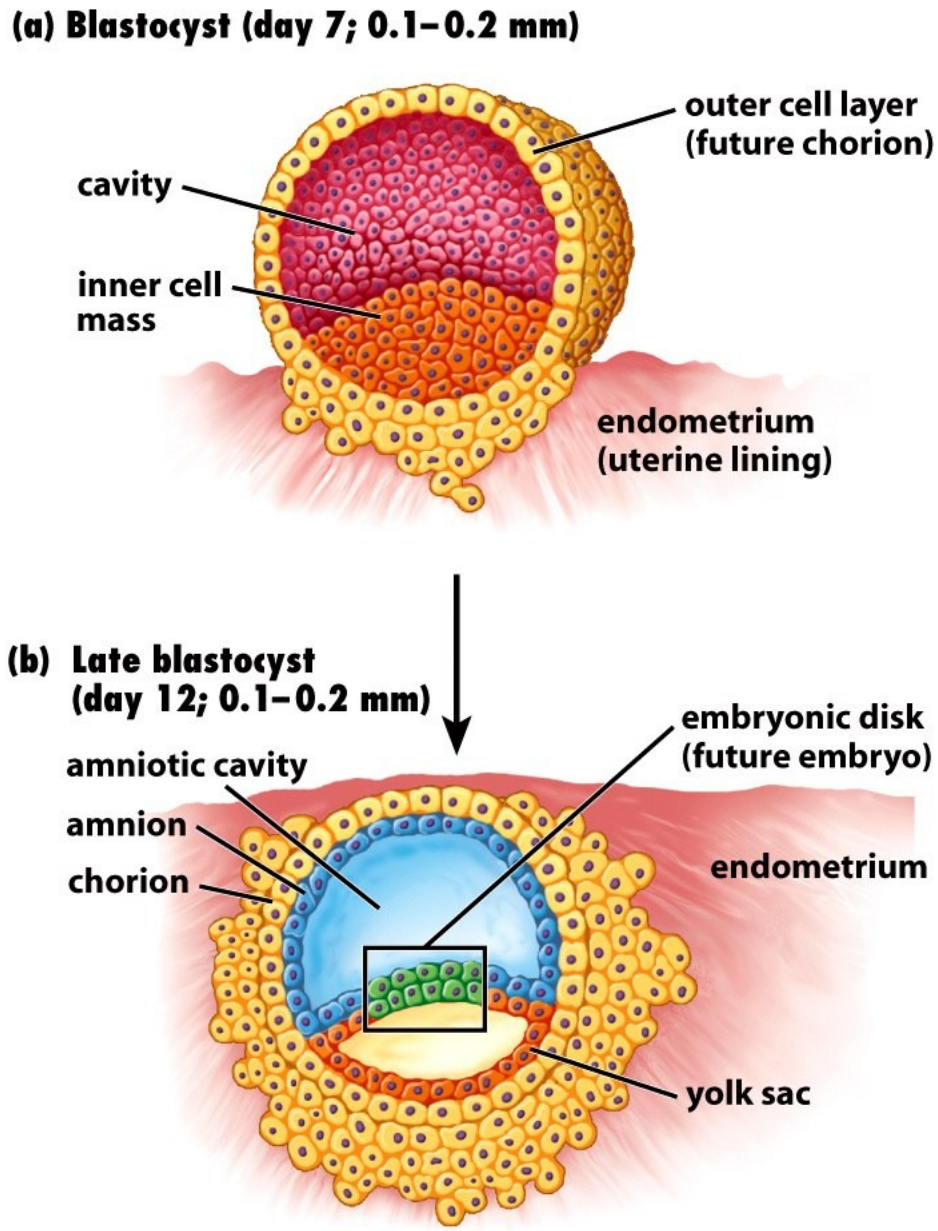


Figure 41-10 Biology: Life on Earth, 8/e

The first week

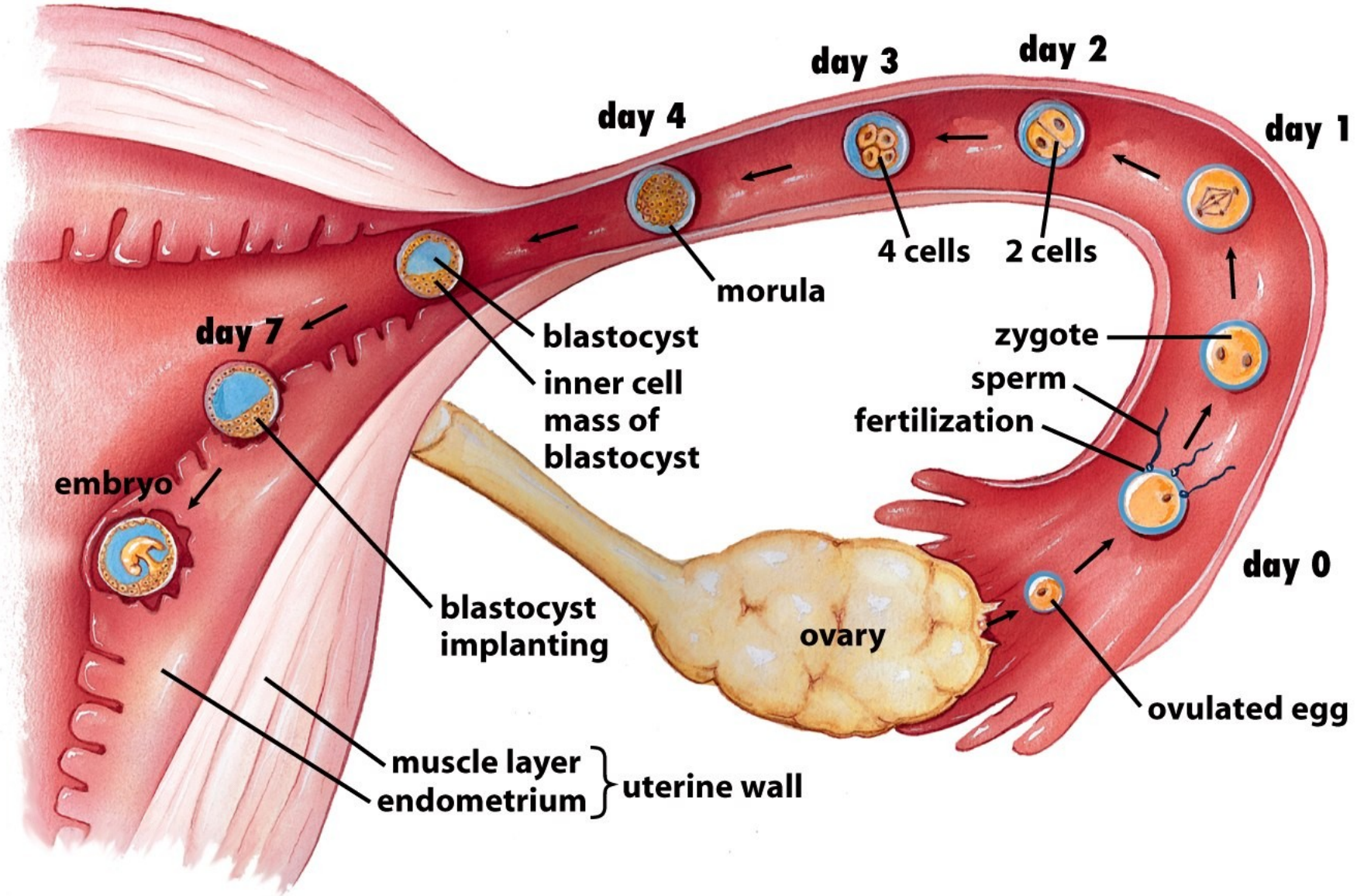


Figure 41-9a Biology: Life on Earth, 8/e

During the First Two Months

- During weeks 1–2
  - Outer blastocyst wall adheres to uterus and burrows into endometrium (**implantation**)
  - Outer cell layer becomes **chorion**
  - Inner cell mass splits forming two fluid-filled sacs, separated by **embryonic disc** (future embryo)
    - One sac forms amniotic cavity
    - Second sac becomes the yolk sac
    - Gastrulation begins at end of second week

During the First Two Months

- During week 3
  - Embryo curls and forms future head
  - Chorion extends **chorionic villi** into endometrium, starting **placenta** formation
  - Embryonic heart beats

During the First Two Months

- During week 4
  - Endoderm forms embryonic gut
  - Rudimentary tail present
  - *Body stalk* connects embryo to chorion
  - *Yolk stalk* connects yolk sac and embryonic gut
  - Embryo bulges into the uterus, completely surrounded by the amnion and is linked to the placenta by the *umbilical stalk*
  - Umbilical cord formed from merger of yolk stalk and body stalk

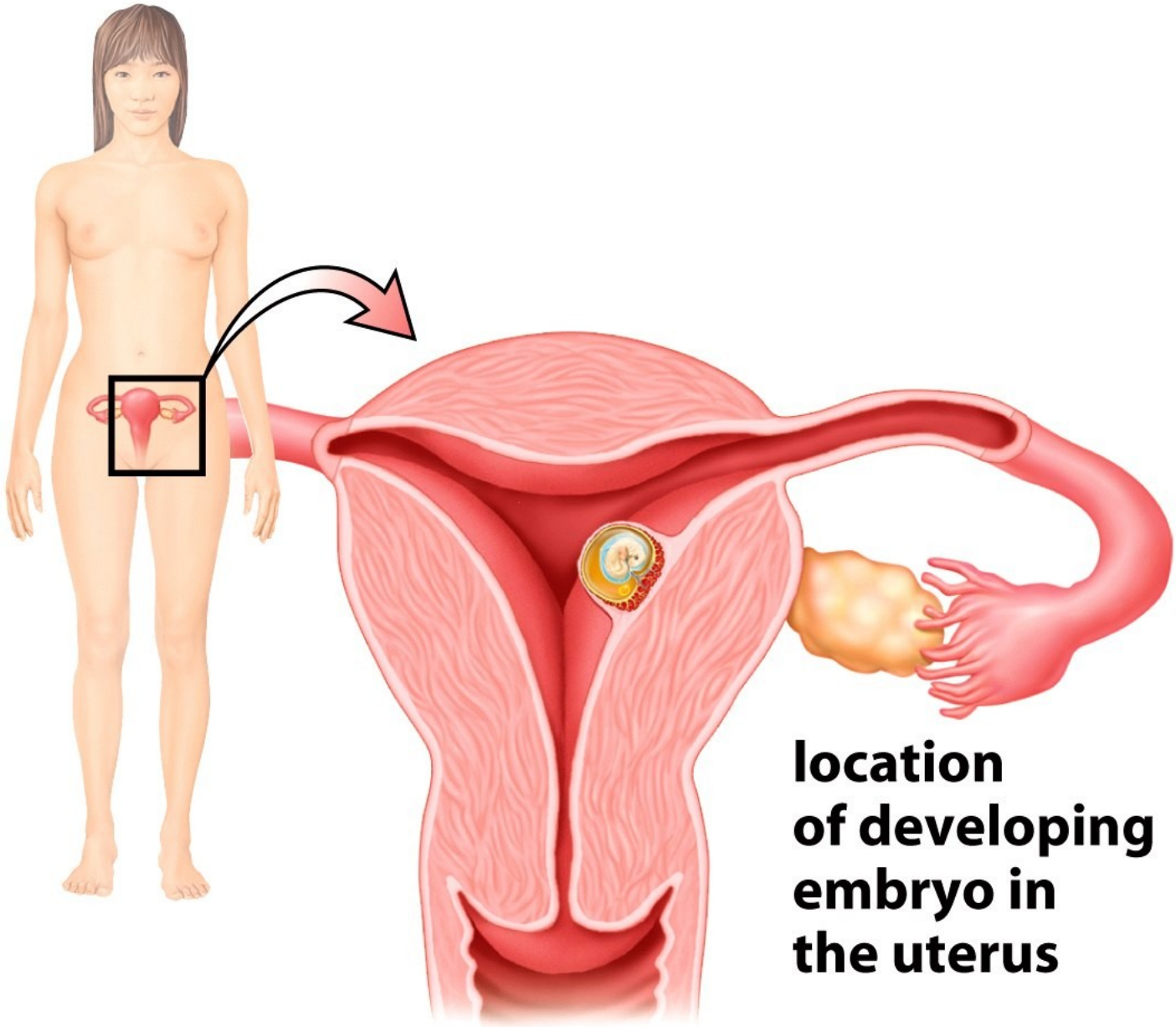


Figure 41-11 part 1 Biology: Life on Earth, 8/e

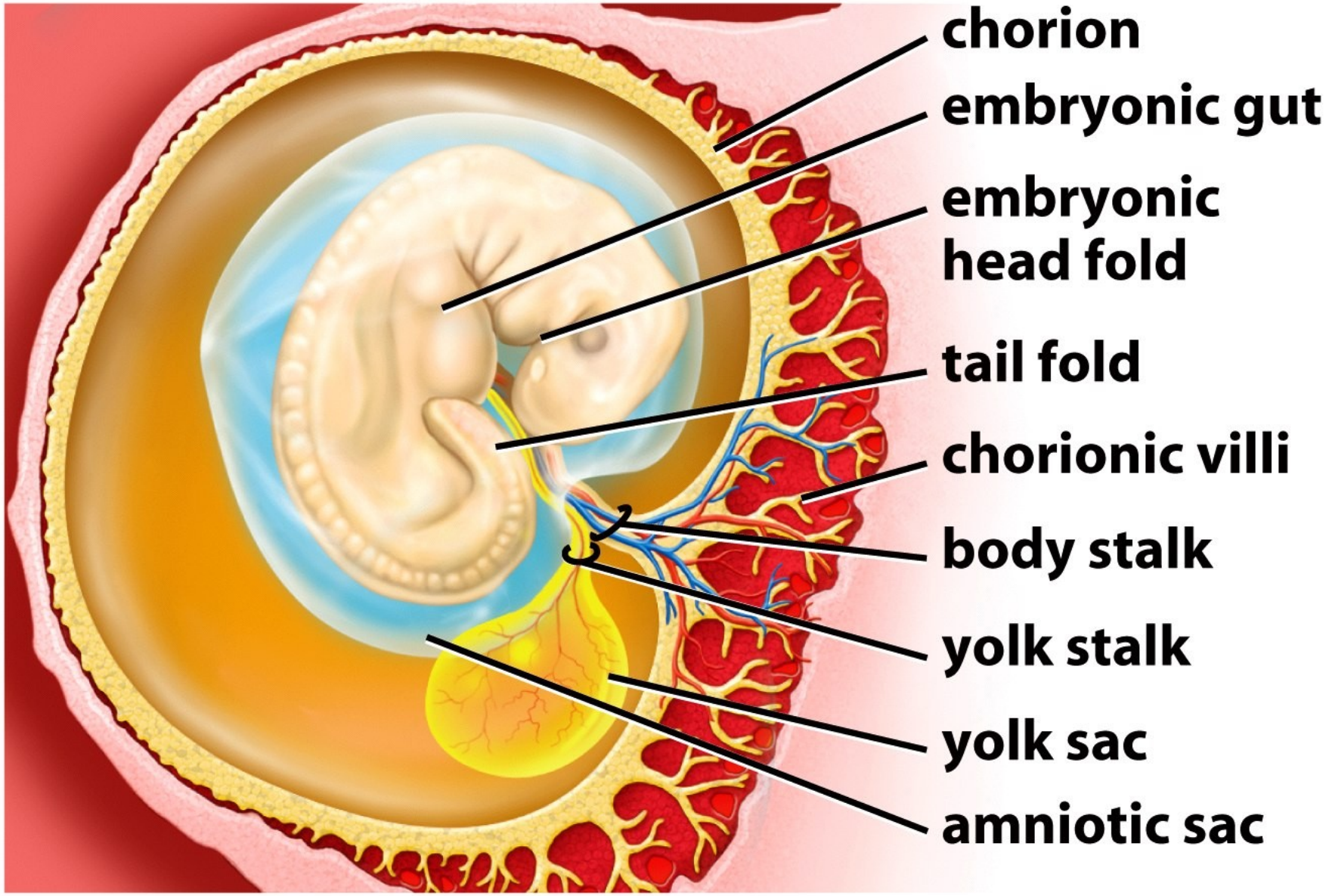


Figure 41-11 part 2 Biology: Life on Earth, 8/e

During the First Two Months

- During weeks 6–8
  - **Notochord** formed, prominent tail and *gill grooves* present
  - Has developed rudimentary heart, separate fingers/toes, rapid brain growth, gonads develop
  - By the end of the week 8, most major organs have formed

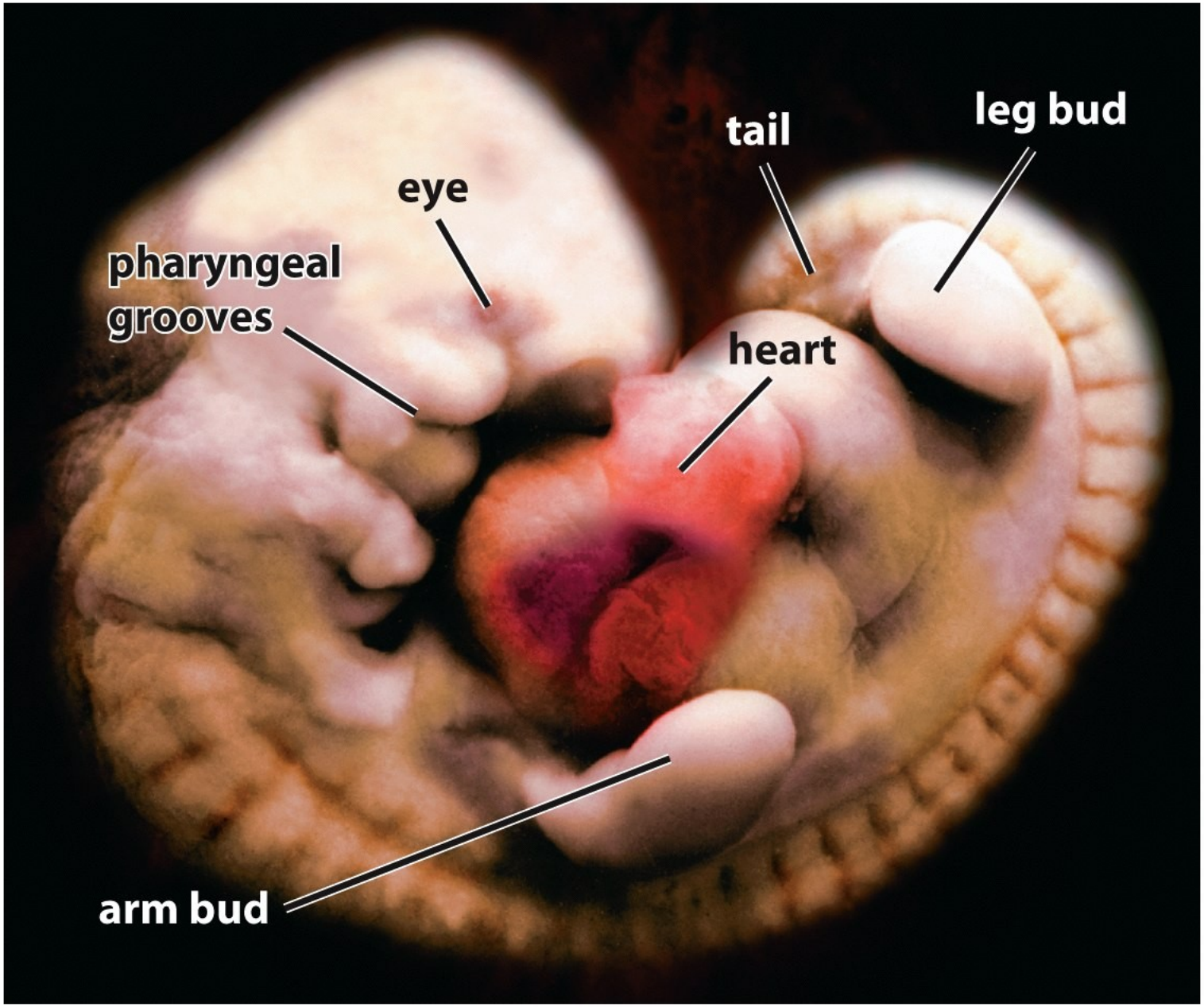


Figure 41-12 Biology: Life on Earth, 8/e

During the First Two Months

- After 2 months of development, an embryo is called a fetus and exhibits human features

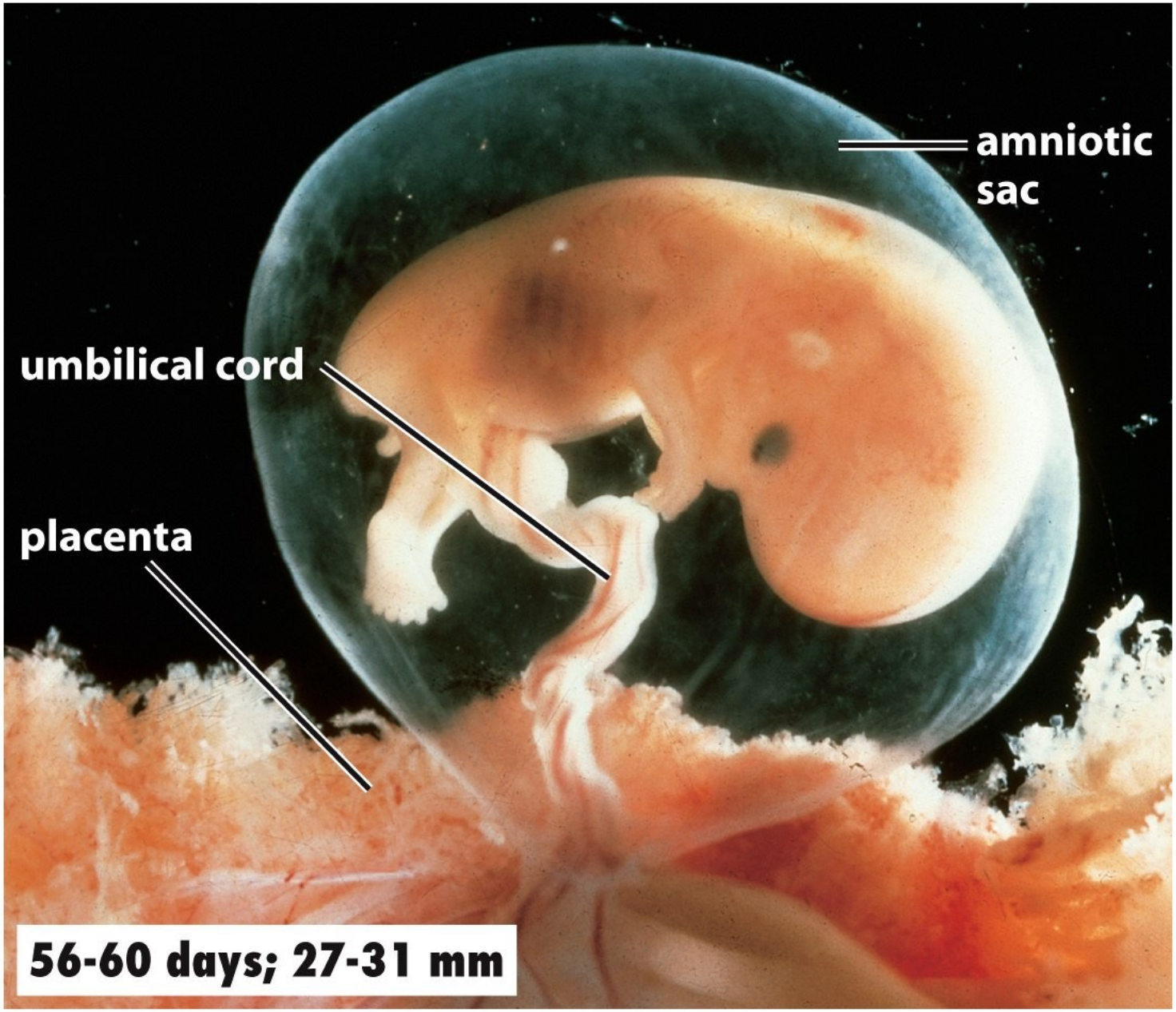


Figure 41-13 Biology: Life on Earth, 8/e

The Placenta

- Secretes estrogen and progesterone
  - Stimulate uterine and mammary growth
- Regulates exchange of material between the mother and fetus
- Materials exchanged
  - **Chorionic villi** contain fetal capillaries that bathe in maternal blood
  - Many small molecules can be exchanged between fetus and mother
    - Examples: O_2, CO_2, nutrients, and fetal urea
  - Large molecules and most cells blocked by chorionic villi

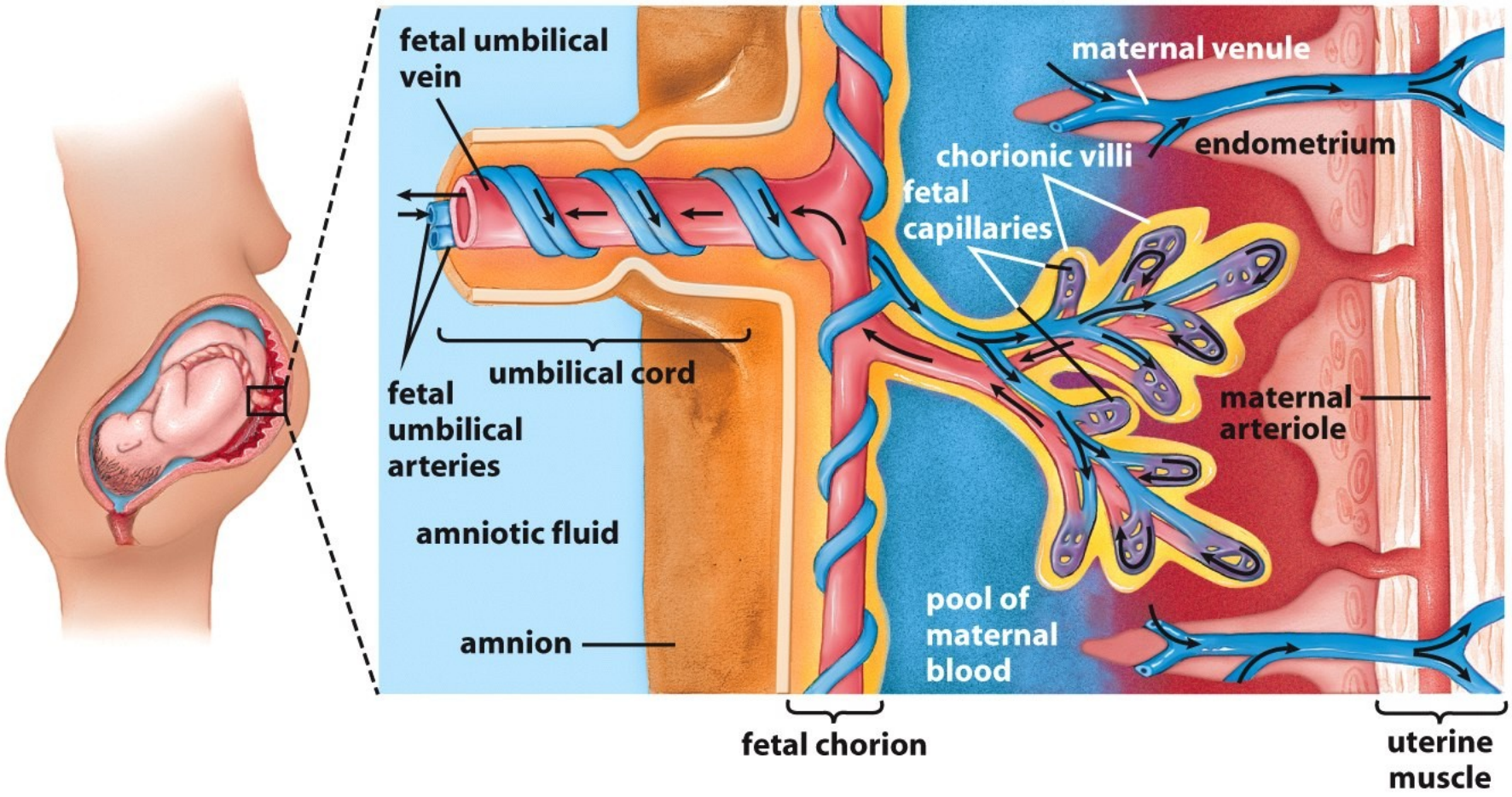


Figure 41-14 Biology: Life on Earth, 8/e

The Last 7 Months

- Growth and development continue during the last 7 months
- The rest of body “catches up” with head size
- The brain and spinal cord develop rapidly
  - The fetus can respond to stimuli after 3 months
- Many organs needed outside the uterus become functional
  - A fetus can survive outside the womb after 7 months

Labor and Delivery

- Development culminates in labor and delivery
- In final months of pregnancy, the fetus is positioned head-downwards on cervix
- Near end of 9th month, **labor** begins, resulting in *delivery*
- Near-term fetus produces steroid hormones
  - Increase estrogen and prostaglandin production by placenta and uterus
  - Makes uterus more likely to contract

Labor and Delivery

- Combination of hormones and uterine stretching initiate strong uterine contractions
  - Baby's head pushes against cervix, activating stretch receptors
  - Results in oxytocin production by anterior pituitary
- Oxytocin and prostaglandins stimulate stronger uterine contractions
  - Part of positive feedback cycle

Labor and Delivery

- Baby emerges from vagina (*birth canal*)
- Uterine contractions continue to expel placenta (*afterbirth*)

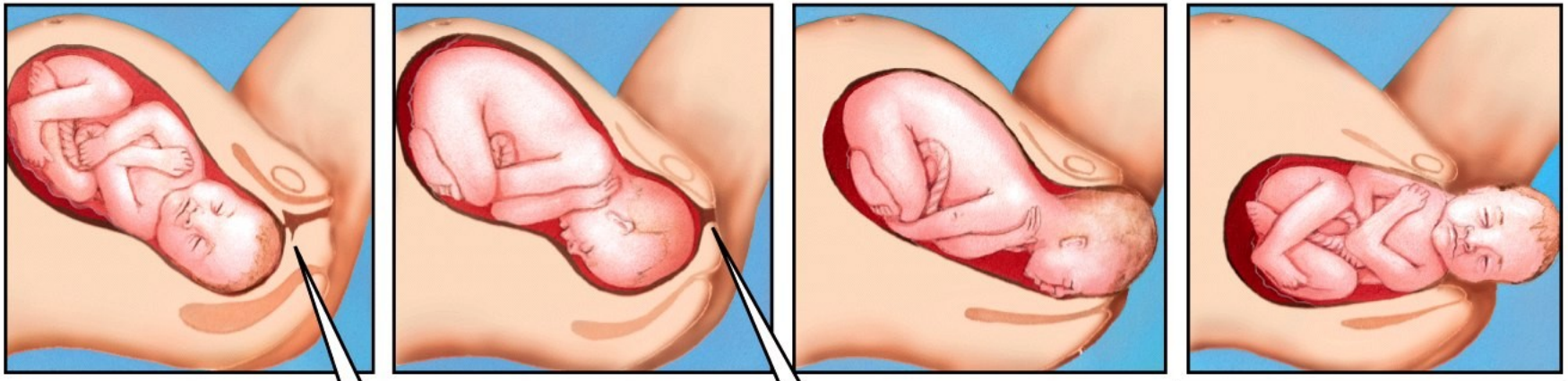


Figure 41-15 Biology: Life on Earth, 8/e

Milk Secretion

- Milk secretion is stimulated by hormones of pregnancy
- Elevated estrogen and progesterone stimulate **mammary gland** growth
- Mammary glands each have a duct that leads to the *nipple*

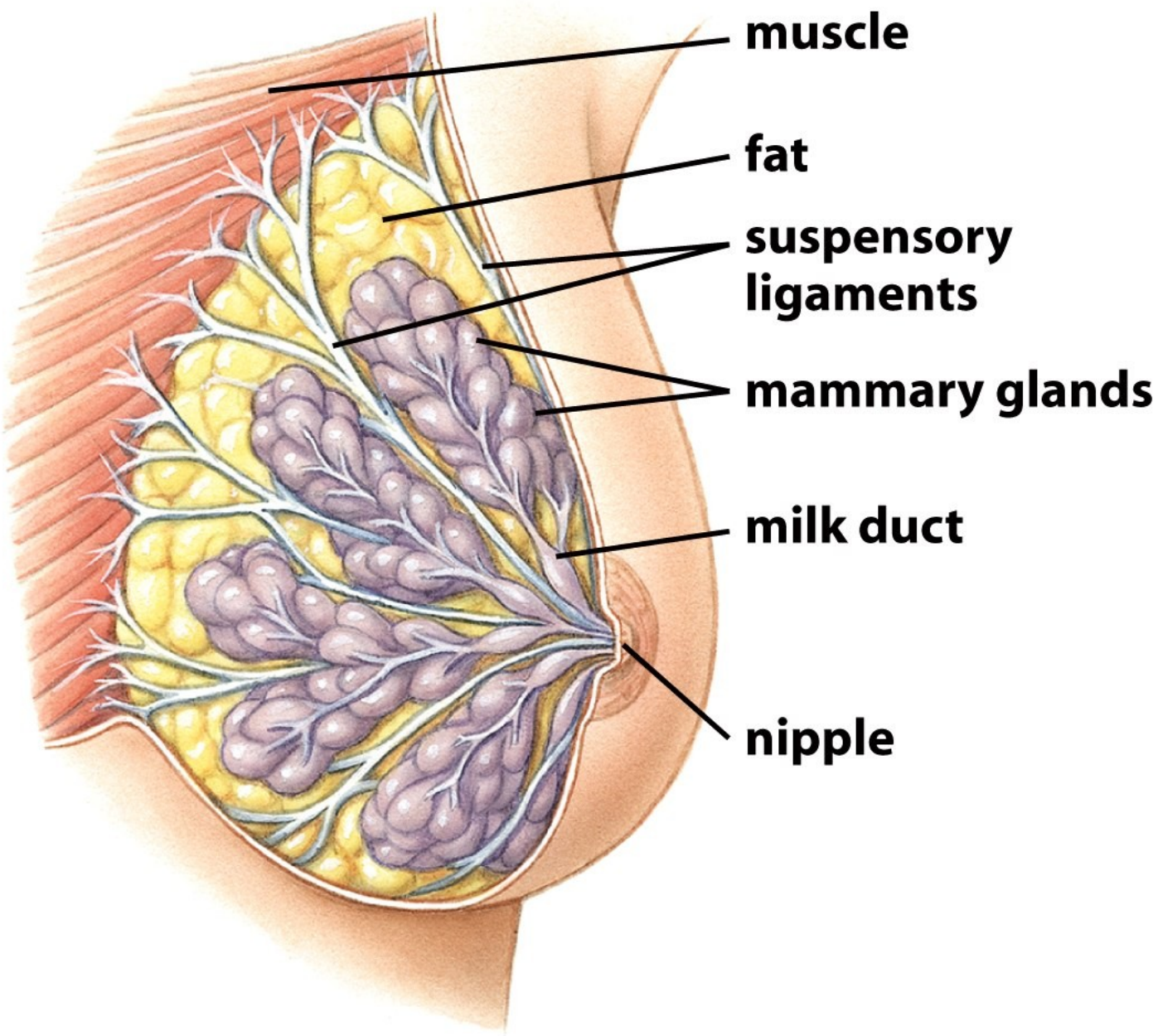


Figure 41-16 Biology: Life on Earth, 8/e

Milk Secretion

- **Lactation** (milk production)
  - Is stimulated by prolactin
  - Suckling of baby stimulates prolactin and oxytocin release
    - Oxytocin causes muscles surrounding mammary glands to contract
    - Milk ejection from nipples

Milk Secretion

- **Colostrum** fluid is released for several days after birth
  - High in proteins and antibodies to help the newborn fight infection
  - Gradually replaced by mature milk
    - Contains high lactose and fat content, lower protein content

Aging Is Inevitable

- **Aging**
  - The accumulation of damage to DNA over time
  - Reduced ability of the body to repair cell/tissue damage
    - Free radicals contribute to cell damage
  - Eventually, cells and tissues become less functional

Figure 41-17 Biology: Life on Earth, 8/e