Development throughout Life

Lecture Presentation
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Development throughout Life

OUTLINE:

- Periods of Development in Human Life
- Prenatal Period
- Birth
- Birth Defects
- Milk Production by Mammary Glands
- Postnatal Period
Periods of Development in Human Life

- Prenatal period
  - Period of development before birth
- Postnatal period
  - Period of development after birth
- Prenatal development is divided into three periods
  1. Pre-embryonic (from fertilization through week 2)
  2. Embryonic (from week 3 through week 8)
  3. Fetal (from week 9 until birth)
Table 18.1 Review of Major Events during Prenatal Development

<table>
<thead>
<tr>
<th>Period</th>
<th>Major Events</th>
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| Pre-embryonic period (fertilization to week 2) | Fertilization  
Cleavage  
Formation and implantation of the blastocyst  
Beginning of formation of extraembryonic membranes and placenta |
| Embryonic period (weeks 3–8)    | Gastrulation  
Formation of tissues, organs, and organ systems                                |
| Fetal period (week 9 to birth)  | Continued differentiation and growth of tissues and organs  
Increase in length as measured from head to rump  
Increase in weight |
Figure 18.2 *The developing human.*

(a) A zygote

(b) A blastocyst implanting into the wall of the uterus

(c) An embryo about 7 weeks old

(d) A fetus about 5 months old
Prenatal Period

- The pre-embryonic period begins with fertilization, the union between the nucleus of an egg and the nucleus of a sperm.
- Typically, an egg lives only 12 to 24 hours after its release.
- Most eggs get fertilized with the sperm within 12 hours of the egg’s release.
  - Major events of the pre-embryonic period:
    - Fertilization
    - Cleavage
    - Formation and implantation of the blastocyst
    - Beginning of formation of extraembryonic membranes and placenta
Figure 18.3 Early stages in the reproductive process.

Step 1: Ovulation
A secondary oocyte is released from the ovary and swept into the oviduct.

Step 2: Fertilization
A single sperm penetrates the secondary oocyte. Eventually, the sperm and egg nuclei will fuse, resulting in a fertilized egg, or zygote.

Step 3: Cleavage
The zygote soon undergoes rapid mitotic cell divisions as it moves along the oviduct toward the uterus, becoming a pre-embryo that consists of two cells, then four cells, then eight cells, and so on.

Step 4: Morula
By day 4, successive divisions produce a morula, a solid ball of cells that enters the uterus.

Step 5: Blastocyst
By day 6, the pre-embryo becomes a blastocyst, a hollow ball of cells with a fluid-filled cavity. The blastocyst has freed itself from the zona pellucida and can increase in size.

Step 6: Implantation
The blastocyst attaches to the uterine lining (endometrium) and begins to digest its way inward. The cells of the inner cell mass begin to form primary germ layers.
Fertilization

- Occurs in the oviduct

- Enzymes from the sperm’s acrosome create a pathway through layers surrounding the secondary oocyte (corona radiata and zona pellucida)

- The sperm enters the cytoplasm of the secondary oocyte

- The zona pellucida hardens, preventing entry by additional sperm
Fertilization

- The secondary oocyte completes its second meiotic division and is considered an ovum.
- The nucleus of the sperm and that of the ovum fuse.
- Zygote: a fertilized ovum contains genetic material from the mother and father (23 chromosomes each).
Figure 18.4 Fertilization.

- **Step 1:** Secretions from the female reproductive tract alter the surface of the plasma membrane of the sperm.
- **Step 2:** The sperm contacts the corona radiata, and enzymes spill out of the acrosome.
- **Step 3:** The enzymes disrupt cellular attachments, allowing passage of the sperm through the corona radiata and then the zona pellucida.
- **Step 4:** The sperm contacts the plasma membrane of the secondary oocyte, and their plasma membranes fuse.
- **Step 5:** The sperm enters the cytoplasm of the secondary oocyte.
- **Step 6:** Granules near the plasma membrane of the secondary oocyte release their enzymes, causing the overlying zona pellucida to harden.
- **Step 7:** The nucleus of the sperm and the nucleus of the egg fuse, and fertilization is completed.
Cleavage

- Rapid series of mitotic cell divisions
- Begins as the zygote moves down the oviduct toward the uterus
- By day 4, pre-embryo is a solid ball of 12 or more cells called a morula
Cleavage

- If the ball of cells splits, then two pre-embryos are formed
  - Identical twins (monozygotic twins)
  - Conjoined twins form if splitting is incomplete
- If two secondary oocytes are released from the ovaries and fertilized by different sperm, then two pre-embryos may develop
  - Fraternal twins (dizygotic twins)
Figure 18.5 Twins.

(a) Identical twins result when a single fertilized egg splits in two very early in development.

(b) Rarely, the splitting is incomplete, and conjoined twins result.

(c) Fraternal twins result from the fertilization of two oocytes by different sperm.
Cleavage

- Blastocyst: formed by day 6
  - Ball of cells with an inner fluid-filled cavity
  - Two parts: inner cell mass and trophoblast
    - Inner cell mass
      - Becomes the embryo proper and some of the embryonic membranes
    - Trophoblast
      - Gives rise to the extraembryonic membrane, called the chorion, that is the embryo’s contribution to the placenta (organ that delivers oxygen and nutrients to the embryo and carries carbon dioxide and other wastes away)
Implantation

- Begins about six days after fertilization
- Blastocyst becomes imbedded in the endometrium of the uterus
- Normally occurs high up on the back wall of the uterus
- An ectopic pregnancy results if the blastocyst implants outside the uterus, usually in an oviduct
Figure 18.6 *Implantation.*
Implantation

- Human chorionic gonadotropin (HCG)
  - Hormone produced by the blastocyst during implantation (later produced by the placenta)
  - Maintains the corpus luteum and stimulates it to continue producing progesterone
    - Progesterone is essential for maintenance of the endometrium
  - Screened for in many pregnancy tests
Implantation

- Infertility
  - Inability to become pregnant (female) or to cause a pregnancy (male)
  - A couple is considered infertile if conception does not occur after one year of unprotected sexual intercourse
  - Implantation can be a major hurdle
Ethical Issues: Making Babies

- Assisted reproductive techniques (ARTs)
  - Hormones
  - Artificial insemination (AI)
  - Intracytoplasmic sperm injection (ICSI)
  - In vitro fertilization (IVF)
  - Gamete intrafallopian transfer (GIFT)
  - Zygote intrafallopian transfer (ZIFT)
Extraembryonic Membranes

- Toward the end of the pre-embryonic period, four membranes—the amnion, yolk sac, allantois, and chorion—begin to form around the pre-embryo.
  - Amnion
  - Yolk sac
  - Allantois
  - Chorion
Figure 18.7 *Extraembryonic membranes.*
Extraembryonic Membranes

- Amnion
  - Encloses embryo in a cavity filled with amniotic fluid
  - Fluid serves a protective cushion

- Yolk sac
  - Site of early blood cell formation
  - Contains primordial germ cells that migrate to the gonads where they become either sperm or oocytes
Extraembryonic Membranes

- **Allantois**
  - Small membrane whose blood vessels become part of the umbilical cord, which is the rope-like connection between the embryo and placenta

- **Chorion**
  - Outermost membrane
  - Becomes the embryo’s contribution to the placenta
Extraembryonic Membranes

- Placenta
  - Functions
    - Allows oxygen and nutrients to diffuse from maternal blood into embryonic blood
    - Allows wastes, such as carbon dioxide and urea, to diffuse from embryonic blood into maternal blood
    - Produces hormones essential for continued pregnancy (e.g., HCG, estrogen, and progesterone)
The Placenta

- Structure
  - Forms from the chorion of the embryo and the endometrium of the mother
  - Chorionic villi
    - Fingerlike processes of the chorion
    - Provide exchange surfaces for nutrients, oxygen, and wastes
The Placenta

- Placenta previa
  - Condition in which the placenta forms in the lower part of the uterus and covers the cervix
  - Delivery by Cesarean section is necessary
**Figure 18.8 The placenta.**

Oxygen and nutrients diffuse from pools of maternal blood into capillaries within the chorionic villi and are carried to the fetus via vessels in the umbilical cord. Fetal wastes move in the opposite direction.

(a) The placenta begins to form at about 2 weeks (shortly after implantation) and is fully developed by about 12 weeks.

(b) The internal structure of the placenta
Embryonic Period

- Gastrulation
- Formation of tissues, organs, and organ systems
- Three processes produce the embryo, which has a distinctly human appearance by the end of the embryonic period
  - Cell division
    - Continues from the pre-embryonic period
  - Cell differentiation
    - Cells become specialized with respect to structure and function
  - Morphogenesis
    - Development of overall body organization and shape
Gastrulation

- Cells within the embryonic disk differentiate and migrate to form three primary germ layers from which all tissues and organs form
  - Ectoderm—outermost
  - Mesoderm—middle
  - Endoderm—innermost
- Embryo is called a gastrula at this time
- Key part of morphogenesis
Figure 18.9 Early stages of development in cross section.

**Early blastocyst:** Hollow ball of cells with a fluid-filled cavity.

**Late blastocyst:** Pre-embryo, with the embryonic disk, two layers of cells that become the embryo proper.

**Gastrula:** Embryo with three primary germ layers (ectoderm, mesoderm, and endoderm).

- **Day 4:** Inner cell mass, Blastocyst cavity, Trophoblast.
- **Day 6:** Amniotic cavity, Embryonic disk.
- **Day 10:** Yolk sac, Ectoderm, Mesoderm, Endoderm.
- **Day 16:**
Gastrulation

- Ectoderm: forms the nervous system
  - Forms the epidermis and its derivatives (hair, nails, oil glands, sweat glands, mammary glands)

- Mesoderm: gives rise to muscle, bone, connective tissue, and organs such as heart, kidneys, ovaries, and testes
  - Forms the notochord, a flexible rod that defines the long axis of the embryo and gives it some rigidity
Gastrulation

- Endoderm: forms the lining of the urinary, respiratory, and digestive tracts
  - Forms some organs and glands (pancreas, liver, thyroid gland, and parathyroid glands)
Development of the Central Nervous System

- Process called neurulation, embryo called neurula
- Notochord induces the overlying ectoderm to thicken and eventually form a fluid-filled tube called the neural tube
  - Brain develops from anterior end
  - Spinal cord develops from posterior end
Development of the Central Nervous System

- Failure of neural tube to develop and close properly leads to birth defects
  - Spina bifida: part of the spinal cord develops abnormally
    - Some cases can be corrected with surgery
  - Anencephaly: incomplete development of the brain
    - Stillbirth or death shortly after birth
Figure 18.10 Formation of the central nervous system from ectoderm.

**Day 17**

- **Dorsal views of the embryo**
  - Amnion
  - Amniotic cavity

- **Cross sections through the embryo**
  - Neural plate
  - Ectoderm
  - Mesoderm
  - Endoderm
  - Notochord
  - Yolk sac

**Step 1:** The ectoderm overlying the notochord thickens to form the neural plate.

**Day 18**

- **Dorsal views of the embryo**

- **Cross sections through the embryo**

**Step 2:** The neural plate folds inward, forming the neural groove.

**Day 21**

- **Dorsal views of the embryo**

- **Cross sections through the embryo**

**Step 3:** The raised sides of the neural groove, called neural folds, grow upward.

**Day 23**

- **Dorsal views of the embryo**

- **Cross sections through the embryo**

**Step 4:** The neural folds fuse to form the neural tube, which will develop into the brain and spinal cord.
Development of the Central Nervous System

- Somites
  - Blocks of mesoderm alongside the neural tube
  - Form the skeletal muscles of the neck and trunk, connective tissues, and vertebrae
Development of the Reproductive System

- Sex chromosomes (X and Y) determine gender of embryo
  - XX (female)
  - XY (male)
- Development of testes in XY embryos begins about six weeks after fertilization, prompted by the SRY region of the Y chromosome
  - Testosterone produced by the testes directs development of male reproductive organs
- Female embryos lack a Y chromosome, so ovaries develop
- Internal and external reproductive structures are formed by end of the third month
Figure 18.11 Development of external genitalia.

**Undifferentiated stage at 6 weeks’ gestation**

- **Female development**
  - Bud between legs
  - Urogenital fold
  - Urogenital groove
  - Labioscrotal swelling
  - No Y chromosome

**10 weeks’ gestation**

- Development of reproductive structures does not require hormones.

**14 weeks’ gestation**

- **Male development**
- Development of reproductive structures requires testosterone from developing testes.

- Clitoris
- Labia minora
- Labia majora
- Anus
- Glans penis
- Shaft of penis
- Scrotum
- Anus
Prenatal Period

Picking Your Baby's Gender
Embryonic Development

Development in humans begins with the formation of a fertilized egg, or zygote, which then undergoes a rapid series of cell divisions resulting in a ball of cells no bigger than the original fertilized egg. This ball of cells then undergoes numerous transformations that eventually give rise to tissues and organs. This tutorial explores the major steps in embryonic development and describes how one embryonic tissue layer develops into the central nervous system.

Press "PLAY" to begin Animation.
Fetal Period

- Continued growth and differentiation of tissues and organs
- Increases in length
- Increases in weight
- Allometric growth
  - Difference in the relative rates of growth of various parts of the body
  - Occurs before and after birth
Figure 18.12 Allometric growth.
Fetal Circulation

- Several organs (e.g., lungs, kidneys, and liver) do not perform their postnatal functions in the fetus
- Most blood is shunted past these organs through temporary vessels or openings
Fetal Circulation

- Shunts
  - Ductus venosus: allows most blood to bypass the fetal liver and enter the inferior vena cava
  - Foramen ovale: small hole in the wall between the right atrium and left atrium
    - Allows most blood to bypass lungs
  - Ductus arteriosus: connects pulmonary trunk to aorta
    - Diverts most blood away from lungs
Fetal Circulation

- At birth, when all organs take on their postnatal functions, fetal circulation converts to the postnatal pattern
  - Ductus venosus and ductus arteriosus constrict, shrivel, and form ligaments
  - Foramen ovale closes
    - Failure to close = blue babies
Figure 18.13 *Fetal circulation and changes at birth.*

**Diagram:**
- **Superior vena cava**
- **Right atrium**
- **Right ventricle**
- **Inferior vena cava**
- **Liver**
- **Placenta**
- **Umbilical cord**
- **Ductus arteriosus**
- **Ductus venosus**
- **Foramen ovale**
- **Umbilical vein**
- **Umbilical arteries**
- **Aorta**
- **Pulmonary trunk**
- **Left atrium**
- **Left ventricle**
- **Lung**
- **Abdominal aorta**
- **Inferior vena cava**
- **Hepatic portal vein**
- **Navel (belly button)**
- **Common iliac artery**

(a) Fetal circulation is characterized by a connection to the placenta (the umbilical cord) and several bypasses surrounding organs that do not yet perform their postnatal functions.

(b) At birth, the umbilical cord is tied off and cut, leaving the navel (belly button). The bypasses close, allowing more blood to reach the now functional organs of the newborn.
Birth

- Also called parturition
- Usually occurs about 38 weeks after fertilization
- Marks the transition from prenatal to postnatal development
- Oxytocin from the posterior pituitary gland prompts uterine contractions
  - Positive feedback cycle
Birth

- Labor: process by which fetus is expelled from the uterus
  - Three stages
    1. Dilation
    2. Expulsion
    3. Placental
Birth

- Dilation stage
  - Begins with onset of contractions
  - Continues until cervix is fully dilated
- Expulsion stage
  - Begins with full dilation
  - Ends with delivery of baby
- Placental stage
  - Begins with delivery of baby
  - Ends when placenta is expelled from mother’s body
Figure 18.14 The stages of labor.

**Step 1: Dilation stage**
 Begins with the onset of regular contractions and ends when the cervix is dilated 10 cm (about 4 in.)

**Step 2: Expulsion stage**
 Begins with full dilation of the cervix and ends with delivery of the baby

**Step 3: Placental stage**
 Begins with delivery of the baby and ends with expulsion of the placenta
Birth

- Position of baby during birth
  - Most babies are born head first, facing the vertebral column of their mother
  - Some are born buttocks first = breech birth
    - Associated with difficult labor and delivery
Birth

- State of development at birth
  - Full-term infant
    - Baby born at least 38 weeks after fertilization
  - Premature infant
    - Baby born before 37 weeks of gestation
Birth Defects

- Developmental defects present at birth
- May concern structure, function, behavior, or metabolism

Causes

- Genetic (e.g., changes in number or structure of chromosomes)
- Environmental (e.g., drugs, radiation)
  - Cause major defects during critical periods of rapid cell differentiation (most during the pre-embryonic period)
Figure 18.16 Critical periods in development.
Milk Production by Mammary Glands

- Lactation: production and ejection of milk from the mammary glands
  - Hormones
    - Prolactin from the anterior pituitary promotes milk production
    - Oxytocin from the posterior pituitary stimulates milk ejection
Milk Production by Mammary Glands

- **Schedule**
  - Colostrum is produced immediately after birth
  - Milk is produced by about day 3
  - Both fluids contain antibodies and special proteins to boost the immune system
Postnatal Period

- Period of growth and development after birth
- Stages
  - Infancy (birth to 12 months)
  - Childhood (13 months to 12 or 13 years)
  - Adolescence (puberty to late teens)
  - Adulthood (generally reached by 20 or 21 years of age)
Postnatal Period

- **Aging**
  - Normal and progressive decline in the structure and function of the bodies of adults
  - Changes to organ systems occur gradually
Table 18.2 Changes in Organ Systems as We Age

<table>
<thead>
<tr>
<th>Organ System</th>
<th>Some Changes That Occur with Aging</th>
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| Integumentary | Wrinkles appear as skin becomes thinner and less elastic.  
Sweat glands decrease in number, making regulation of body temperature more challenging.  
Hair thins owing to death of hair follicles and turns gray as pigment-producing cells die. |
| Skeletal | Bones become lighter and more brittle, especially in women after menopause.  
About 7.6 cm (3 in.) of height are lost as the intervertebral disks deteriorate and the vertebrae move closer together.  
Joints become stiff and painful owing to decreased production of synovial fluid. |
| Muscular | Muscle mass decreases owing to loss of muscle cells and decreased size of remaining muscle cells. |
| Nervous | Brain mass decreases.  
Movements and reflexes slow as conduction velocity of nerve fibers decreases and release of neurotransmitters slows.  
Hearing becomes less acute as hair cells in the inner ear are lost.  
Ability of the eye to focus declines as the lens of the eye stiffens.  
Smell and taste become less acute. |
| Endocrine | In women, production of estrogen and progesterone decreases with menopause.  
In men, production of testosterone decreases.  
In both sexes, production of growth hormone decreases. |
| Cardiovascular | Cardiac output decreases as walls of the heart stiffen.  
Blood pressure rises as arteries become less elastic and clogged by fatty deposits. |
| Respiratory | Lung capacity decreases as alveoli break down and lung tissue becomes less elastic. |
| Digestive | Basal metabolic rate declines.  
Ability of the liver to detoxify substances declines. |
| Urinary | In both sexes, kidney mass declines, as does the rate of filtration of the blood by nephrons.  
Particularly in women, the external urethral sphincter weakens, causing incontinence.  
In men, the prostate gland (part of the reproductive system) enlarges, causing painful and frequent urination. |
| Reproductive | In men, fewer viable sperm are produced.  
In women, ovulation and menstruation cease at menopause. |
Possible Causes of Aging

- Changes in critical organ systems
- Cessation of cell division
- Damage to DNA and other macromolecules
- Genes, environment, and lifestyle determine the human life span
Possible Causes of Aging
High-Quality Old Age

- Aging is a normal biological process that, at present, cannot be slowed, stopped, or reversed
- Today, the maximum documented life span for humans is 122 years, a record established by Madame Jeanne Calment of France
- Life expectancy for babies born in the United States today is about 77 years
High-Quality Old Age

- Lifestyle is the factor over which we have the most personal control
  - Healthy lifestyle includes proper nutrition, plenty of exercise and sleep, refraining from smoking, and routine medical checkups
  - Lifestyle choices made when young can delay some aspects of aging
You Should Now Be Able To:

- Describe the periods of development in human life
- Know the stages of the prenatal period
- Understand the processes involved during birth
- Know the main birth defects
- Understand milk production by mammary glands
- Know the postnatal period and ways to improve aging