Chapter 4  Adapted from Tortora 10th ed.

LECTURE OUTLINE

A.  Introduction (p. 93)
  1.  Sexual reproduction is a process by which a male gamete (sperm) unites with a female gamete (secondary oocyte).
  2.  Pregnancy is a sequence of events that begins with fertilization, proceeds to implantation, embryonic development, and fetal development, and normally ends with birth about 38 weeks later.
  3.  Developmental biology is the study of the sequence of events from the fertilization of a secondary oocyte to the formation of an adult organism.
  4.  From fertilization through the eighth week of development, the developing human is called an embryo and this stage is called the embryonic period; embryology is the study of the developing embryo.
  5.  The fetal period begins at week nine and continues until birth; during this time the developing human is called a fetus.
  6.  Prenatal development includes both embryonic and fetal periods; it is divided into three periods of three calendar months each called trimesters (first, second, and third trimesters).

B.  Embryonic Period (p. 94)
  1.  First Week of Development
    i.  fertilization:
      a.  during fertilization, the genetic material from the haploid spermatozoon and haploid secondary oocyte merges into a single diploid nucleus
      b.  fertilization normally occurs in the uterine (Fallopian) tube about 12 to 24 hours after ovulation
      c.  sperm swim (due to the actions of their tails) from the vagina into the cervical canal; the journey through the rest of the uterus and then into the uterine tubes results mainly from contractions of the walls of these organs
      d.  although sperm undergo maturation in the epididymis, they are not able to fertilize an oocyte until they undergo capacitation in the female reproductive tract
         - during this process, the sperm’s tail beats more vigorously and its plasma membrane’s ability to fuse with the oocyte’s plasma membrane is enhanced
         - binding of sperm cells to zona pellucida receptor molecules triggers the acrosomal reaction in which acrosomal enzymes are released to help the sperm cells penetrate the corona radiata and the zona pellucida
      e.  normally only one spermatozoon penetrates and enters a secondary oocyte
         - this event is called syngamy and it triggers events that prevent polyspermy
      f.  once a spermatozoon has entered a secondary oocyte, the oocyte completes meiosis II
      g.  when a spermatozoon has entered a secondary oocyte, its nucleus develops into a male pronucleus; the nucleus of the ovum develops into a female pronucleus
h. the two pronuclei fuse to form a single diploid nucleus that contains 46 chromosomes (23 from each pronucleus)
   - the fertilized ovum is called a **zygote**

i. **dizygotic (fraternal) twins** are produced from the independent release of two secondary oocytes and the subsequent fertilization of each by different spermatozoa

j. **monozygotic (identical) twins** develop from a single fertilized ovum that splits at an early stage in development, usually within 8 days after fertilization, into two embryos
   - separations that occur later typically produce **conjoined twins**, in which the twins are joined together and share some body structures

ii. **cleavage of the zygote**:
   a. after fertilization, rapid mitotic cell divisions called **cleavage** occur
   b. the progressively smaller cells produced by cleavage are called **blastomeres**
   c. the solid sphere of blastomeres, still surrounded by the zona pellucida, is called a **morula**; it is about the same size as the original zygote

iii. **blastocyst formation**:
   a. the morula travels through the uterine tube and, after 4 or 5 days, enters the uterine cavity where it becomes bathed by glycogen-rich **uterine milk** that is secreted by the endometrium; at the 32-cell stage, this fluid enters the morula to form a fluid-filled **blastocyst cavity**
   b. the developing mass is now called a **blastocyst**, which has the following components:
      1. outer covering of cells called the **trophoblast**; it ultimately forms the fetal portion of the placenta
      2. an **inner cell mass**; part of the inner cell mass develops into the embryo
   c. the blastocyst remains free within the uterine cavity for about 2 days, during which time the blastocyst hatches from the zona pellucida

iv. **implantation**:
   a. **implantation** occurs about 6 days after fertilization, a process by which the blastocyst attaches to and embeds itself within the endometrium; following implantation, the endometrium is called the **decidua**
   b. as the blastocyst implants, usually on the posterior wall of the fundus or body of the uterus, it is oriented so that the inner cell mass faces the endometrium
   c. different regions of the decidua are named based on their positions relative to the site of the implanted blastocyst:
      1. **decidua basalis** is the portion of the endometrium located between the embryo and the stratum basalis; it becomes the maternal part of the placenta
      2. **decidua capsularis** is the portion of the endometrium located between the embryo and the uterine cavity
      3. **decidua parietalis** is the remaining modified endometrium that lines the noninvolved areas of the rest of the uterus
2. Second Week of Development (p. 99)
   i. development of the trophoblast:
      a. the trophoblast develops two layers in the region of contact between the blastocyst and endometrium:
         1. outer syncytiotrophoblast which secretes enzymes that enable the blastocyst to penetrate into the endometrium
         2. inner cytotrophoblast that is composed of distinct cells
            - these two layers of trophoblast become part of the chorion as they undergo further growth
            - the trophoblast produces human chorionic gonadotropin (hCG)
   ii. development of the bilaminar embryonic disc:
      a. the inner cell mass differentiates into the hypoblast (primitive endoderm) and the epiblast (primitive ectoderm) which together from a flat disc called a bilaminar embryonic disc
      b. a small cavity appears in the epiblast and eventually enlarges to form the amniotic cavity
   iii. development of the amnion:
      a. it is a thin, protective membrane that forms from the epiblast and initially overlies the bilaminar embryonic disc
      b. as the embryo grows, the amnion comes to completely surround the embryo,
         creating an amniotic cavity that becomes filled with amniotic fluid
         - amniotic fluid serves as a shock absorber for the fetus, helps regulate fetal body temperature, and prevents adhesions between the fetal skin and surrounding tissues
         - embryonic cells are sloughed off into amniotic fluid and may be examined via amniocentesis
      c. the amnion usually ruptures just before birth and with its fluid constitutes the “bag of waters”
   iv. development of the yolk sac:
      a. migrating hypoblast cells form a thin exocoelomic membrane; together with the hypoblast, the latter forms the wall of the yolk sac, formerly called the blastocyst cavity
      b. in humans, the yolk sac is relatively, empty, small and progressively decreases in size but it has several important functions including supplying nutrients during the second and third weeks of development, providing blood cells during the third through sixth weeks, containing cells that will eventually differentiate into primitive germ cells, forms part of the gut, acts as a shock absorber, and prevents dehydration of the embryo
   v. development of sinusoids:
      a. small spaces called lacunae develop within the syncytiotrophoblast
      b. the lacunae fuse to form larger, interconnected lacunar networks
      c. endometrial capillaries expand to form sinusoids
      d. maternal blood and endometrial secretions enter the lacunar networks to provide embryonic nutrition and to serve as a disposal site for embryonic wastes
vi. development of the extraembryonic coelom:
   a. the extraembryonic mesoderm develops around the amnion and yolk sac
   b. cavities develop in the extraembryonic mesoderm, which then form a single larger cavity called the extraembryonic coelom

vii. development of the chorion:
   a. the chorion develops from the trophoblast and the extraembryonic mesoderm
   b. it surrounds the embryo and, later, the fetus
   c. it eventually becomes the major embryonic component of the placenta
   d. it protects the embryo and fetus from maternal immune responses and it produces human chorionic gonadotropin (hCG)
   e. the inner layer of the chorion eventually fuses with the amnion; the extraembryonic coelom is now called the chorionic cavity and the bilaminar embryonic disc becomes connected to the trophoblast by the connecting (body) stalk, the future umbilical cord

3. Third Week of Development (p. 102)
   i. gastrulation:
      a. the bilaminar embryonic disc is transformed into a trilaminar embryonic disc consisting of three primary germ layers: the ectoderm, mesoderm and endoderm
      b. gastrulation begins with formation of the primitive streak, a faint groove on the dorsal surface; at the head end, a rounded primitive node develops
      c. invagination results in formation of the three primary germ layers, i.e., the ectoderm, mesoderm and endoderm

         Table 4.1 lists the structures produced by these three primary germ layers

      d. a hollow tube called the notochordal process develops; the later forms a solid cylinder called the notochord, which plays a very important role in tissue induction
      e. the (1) oropharyngeal membrane and the (2) cloacal membrane develop, but subsequently degenerate (1) to connect the oral cavity to the throat and the remainder of the GI tract, and (2) to form the openings of the anus and urinary and reproductive tracts
      f. an outpouch of the yolk sac, called the allantois, develops; it functions in early formation of blood and blood vessels and is associated with development of the urinary bladder

   ii. neurulation:
      a. the notochord induces formation of the neural plate whose lateral edges of the latter develop into neural folds; the depression between the latter is called the neural groove
      b. the neural folds fuse resulting in formation of the neural tube which subsequently develops into the brain and spinal cord
      c. some neural tube cells develop into the neural crest, which subsequently develops into nerves, meninges and several skeletal and muscular components of the head
d. the head end of the neural tube develops into three enlarged primary brain vesicles, from which the brain develops

iii. development of somites:
   a. the mesoderm forms paired columns of paraxial mesoderm, paired intermediate mesoderm, and paired lateral plate mesoderm structures
   b. the paraxial mesoderm soon segments into cube-shaped somites
   c. each somite differentiates into a myotome (which develops into skeletal muscles of the neck, trunk and limbs), a dermatome (which forms connective tissue, including the dermis), and a sclerotome (which develops into vertebrae and ribs)

iv. development of the intraembryonic coelom:
   a. small spaces appear in the lateral plate mesoderm and merge into a larger cavity called the intraembryonic coelom
   b. consequently, the lateral plate mesoderm is split into the splanchnic mesoderm and the somatic mesoderm, each of which develops into specific structures

v. development of the cardiovascular system:
   a. angiogenesis, the formation of blood vessels, begins when mesodermal cells differentiate into hemangioblasts which then develop into angioblasts which then aggregate to form blood islands; the latter develop into blood vessels
   b. blood cells arise from pluripotent stem cells
   c. the heart develops when the cardiogenic area forms a pair of endocardial tubes which subsequently fuse to form a single primitive heart tube; the latter becomes S-shaped, begins to beat, and then joins with blood vessels

vi. development of the chorionic villi and placenta:
   a. fingerlike projections of the chorion called chorionic villi grow and blood capillaries develop within them
   b. they continue growing until they are bathed in maternal blood sinuses called intervillous spaces
      - however, maternal and fetal blood do not normally mix
   c. exchange of substances occurs between the maternal blood in the intervillous spaces and fetal blood flowing through capillaries within the chorionic villi
   d. placentation is the process of forming the placenta, the site of exchange of nutrients and wastes between the mother and fetus
      - shaped like a pancake, it consists of a fetal portion formed by chorionic villi and a maternal portion formed by the decidua basalis
   e. the actual connection between the placenta and embryo is through the umbilical cord, which develops from the connecting stalk; it consists of:
      1. two umbilical arteries that carry deoxygenated fetal blood and wastes from the fetus to the placenta
      2. one umbilical vein that carries oxygenated blood and nutrients from the placenta into the fetus
      3. supporting mucous connective tissue called Wharton's jelly that develops from the allantois
4. Fourth Week of Development (p. 109)
   i. **organogenesis**, the development of body organs and systems, begins during the fourth through eighth weeks of development
   ii. significant events during the fourth week include:
      a. embryonic folding, including formation of a **head fold**, **tail fold**, and two **lateral folds**
      b. formation of the **primitive gut**, which differentiates into the **foregut** (that is temporarily separated from the **stomodeum**, the future mouth), **midgut**, and **hindgut**
      c. formation of the **cloaca**, **proctodeum**, and **cloacal membrane**
      d. formation of the **pharyngeal (branchial) arches**, **pharyngeal clefts**, **pharyngeal (branchial) pouches**
      e. formation of the **otic placode**, **lens placode**, **upper limb buds**, **lower limb buds**, **heart prominence**, and a **tail**

5. Fifth Through Eighth Weeks of Development (p. 109)
   i. significant events during this time period include:
      a. rapid development of the brain and head
      b. development of distinct limb regions
      c. further development of the eyes and ears
      d. the tail disappears
      e. the external genitals begin to differentiate
   ii. by the end of the eighth week, the embryo has clearly human characteristics

C. Fetal Period (p. 111)
   1. The remaining months of development are the **fetal period**, during which time the fetus continues to develop and grows at a remarkable rate
      - organs grow rapidly and the fetus takes on a human appearance
      - by the end of the third month, the placenta is functioning
   2. The developmental biology of the various body systems will be described in their respective textbook chapters; a summary of the major developmental changes of the embryonic and fetal periods is provided in Table 4.2.

D. Maternal Changes During Pregnancy (p. 115)
   1. **Anatomical and physiological changes** in a woman that occur during pregnancy include:
      i. progressive growth of the uterus so that it eventually fills most of the abdominal cavity and pushes against abdominal organs
      ii. weight gain
      iii. increased storage of nutrients
      iv. breast enlargement in preparation for lactation
      v. lower back pain due to stress on the lower spine
   vi. specific changes in the following systems:
      a. cardiovascular system
      b. respiratory system
      c. digestive system
      d. urinary system
      e. integumentary system
      f. reproductive system
E. Labor (p. 115)

1. Obstetrics is the medical specialty that deals with the management of pregnancy, labor, and the neonatal period (the first 28 days after birth).

2. Labor is the process by which the fetus is expelled from the uterus through the vagina to the outside of the body; parturition also means giving birth.
   i. true labor begins when uterine contractions (spreading as waves from the top of the uterus and moving downward) occur at regular intervals; it has the following symptoms:
      a. the contractions usually produce pain
      b. as the interval between contractions shortens, the contractions intensify
      c. there may be localization of pain in the back, which is intensified by walking
      d. evidence of "show", a discharge of blood-containing mucus that accumulates in the cervical canal during labor
      e. dilation of the cervix
   ii. in false labor, pain is felt in the abdomen at irregular intervals and the above symptoms of true labor are absent
   iii. true labor can be divided into three stages:
      a. the stage of dilation is the time (6-12 hours) from the onset of labor to the complete dilation (to 10 cm) of the cervix
         - there are regular contractions of the uterus
         - the amniotic sac usually ruptures spontaneously; if not, it is ruptured deliberately
      b. the stage of expulsion is the time (10 minutes to several hours) from complete cervical dilation to delivery of the baby
      c. the placental stage is the time (5-30 minutes or more) after delivery until the placenta or "afterbirth" is expelled by powerful uterine contractions
         - these contractions also constrict blood vessels that were torn during delivery and therefore decrease the likelihood of hemorrhage
   iv. a premature infant is generally considered to be a baby weighing less than 2,500 g at birth; the body of such a baby is not yet ready to sustain some critical functions, and thus survival is uncertain without medical assistance
   v. after birth, the umbilical cord is tied off and severed; the short remnant of the cord withers and falls away usually within 12-15 days after birth
   vi. the area where the cord was attached develops a scar called the umbilicus (navel)

F. Key Medical Terms Associated with Development (p. 117)

1. Students should familiarize themselves with the glossary of key medical terms.