Chapter 7

Development
and
Sex Determination
Sexual Differentiation in Humans

- Begins in the 7th week of development
- Is influenced by genetic and environmental factors
Human Reproductive System

- Zygote: fertilized egg (diploid)
- Gametes: unfertilized germ cells
- Sperm: male gamete (haploid)
- Oocyte: female gamete (haploid)
- Gonads: organs where gametes and sex hormones are produced (testes and ovaries)
Male Reproductive System

- **Prostate gland**: Secretion of substances that become part of semen
- **Urethra**: Dual-purpose duct; serves as channel for ejaculation of sperm during sexual arousal, also for urine excretion at other times
- **Ejaculatory duct**: One of a pair of sperm-conducting ducts
- **Seminal vesicle**: One of a pair of glands that secrete fructose and prostaglandins, which become part of semen
- **Bulbourethral Gland**: One of a pair of glands that secrete a lubricating mucus
- **Vas deferens**: One of a pair of ducts for rapid transport of sperm
- **Epididymis**: One of a pair of ducts in which sperm complete maturation; the portion farthest from testis stores mature sperm
- **Urinary bladder**: 
- **Anus**: 
- **Erectile tissue**: 
- **Penis**: One of a pair of primary reproductive organs. Each is packed with sperm-producing seminiferous tubules and cells that secrete testosterone and other hormones.

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Spermatogenesis

Male reproductive tract, posterior view

Seminiferous tubule

Fig. 7.2
Spermatogenesis

- Sertoli cell
- Spermatogonium (diploid)
- Primary spermatocyte
- Secondary spermatocyte
- Early spermatids
- Late spermatid
- Immature sperm (haploid)

Part of the lumen of a seminiferous tubule
Spermatogenesis

- Head (DNA in enzyme-rich cap)
- Tail (with core of microtubules)
- Midpiece with mitochondria

Structure of a mature human sperm
Seminiferous tubule filled with sperm. SEM X335.

Credit: © Dr. Richard Kessel & Dr. Gene Shih/Visuals Unlimited
Human sperm. TEM.

Credit: © Dr. David Phillips/Visuals Unlimited
Female Reproductive System

**Ovary**
One of a pair of primary reproductive organs in which oocytes (immature eggs) form and mature; produces hormones (estrogens and progesterone), which stimulate maturation of oocytes, formation of corpus luteum (a glandular structure), and preparation of the uterine lining for pregnancy.

**Oviduct**
One of a pair of dilated channels through which oocytes are conducted from an ovary to the uterus, usual site of fertilization.

**Uterus**
Chamber in which embryo develops, its narrowed-down portion (the cervix) secretes mucus that helps sperm move into uterus and that bars many bacteria.

**Myometrium**
Thick muscle layers of uterus that stretch enormously during pregnancy.

**Endometrium**
Inner lining of uterus; site of implantation of blastocyst (early embryonic stage); becomes thickened, nutrient-packed, highly vascularized tissue during a pregnancy; gives rise to maternal portion of placenta, an organ that metabolically supports embryonic and fetal development.

**Clitoris**
Small organ responsive to sexual stimulation.

**Labium minor**
One of a pair of inner skin folds of external genitals.

**Labium major**
One of a pair of outermost, fat-padded skin folds of external genitals.

**Vagina**
Organ of sexual intercourse; also serves as birth canal.

**Urinary bladder**

**Urethra**

**Opening of cervix**

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Primary oocyte, not yet released from meiosis I. A cell layer is forming around it. A follicle consists of the cell layer and the oocyte.
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A fluid-filled cavity (antrum) starts forming in the follicle’s cell layer.
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Mature follicle. Meiosis I is over. The secondary oocyte and first polar body are now formed.

Primordial follicle

First polar body

Secondary oocyte

Ovary
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Ovulation. The mature follicle ruptures, releasing the secondary oocyte and first polar body.
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Ovulation. The mature follicle ruptures, releasing the secondary oocyte and first polar body.

Primordial follicle

First polar body

Secondary oocyte

Ovary

Stepped Art

Fig. 7-4, p.155
Primary oocyte, not yet released from meiosis I. A cell layer is forming around it. A follicle consists of the cell layer and the oocyte. A transparent and somewhat elastic layer, the zona pellucida, starts forming around the primary oocyte. A fluid-filled cavity (antrum) starts forming in the follicle’s cell layer.

Mature follicle. Meiosis I is over. The secondary oocyte and first polar body are now formed. Ovulation. The mature follicle ruptures, releasing the secondary oocyte and first polar body.

The corpus luteum forms from remnants of the ruptured follicle. The corpus luteum breaks down when the woman doesn’t get pregnant.
Ovulation
Timing of Meiosis and Spermatogenesis

- Large numbers of sperm are in constant production
- Four functional, equally-sized gametes per primary spermatocyte
- Over a lifetime a male produces billions of sperm
- Spermatogenesis takes approximately 48 days
- Each ejaculation can contain 200-400 million sperm
Timing of Meiosis and Oogenesis

• Unequal cytoplasmic division and produces 1 large functional gamete and 3 nonfunctional polar bodies
• Primary oocytes are produced prior to birth and are held in meiosis I
• After puberty, one oocyte completes meiosis I each monthly cycle, starts meiosis II and arrests at metaphase of meiosis II
• If fertilization occurs, it completes meiosis II
• Time for complete cycle is 12–50 years
• Release about 450 oocytes in a lifetime
<table>
<thead>
<tr>
<th>Spermatogenesis</th>
<th>Oogenesis</th>
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<tbody>
<tr>
<td>Begins at Puberty</td>
<td>Begins During Embryogenesis</td>
</tr>
<tr>
<td>Spermatogonium ↓ Primary spermatocyte ↓ Secondary spermatocyte ↓ Spermatid ↓ Mature sperm Total time</td>
<td>Oogonium ↓ Primary oocyte ↓ Secondary oocyte ↓ Ootid Mature egg-zygote Total time</td>
</tr>
<tr>
<td>16 days</td>
<td>16 days</td>
</tr>
<tr>
<td>48 days</td>
<td>12 to 50 years</td>
</tr>
</tbody>
</table>

Forms at 2 to 3 months after conception
Forms at 2 to 3 months of gestation. Remains in meiosis I until ovulation, 12 to 50 years after formation.
Less than 1 day, when fertilization occurs
1 spermatogonium $\rightarrow$ 4 mature sperm

1 oogonium $\rightarrow$ 1 oocyte + 3 polar bodies
Fertilization to Implantation

- **Fertilization** is the fusion of two gametes to produce a **zygote**
- Zygote is moved by cilia in the lining of the oviduct to the uterus
- The zygote divides by mitosis
- Forms a early embryonic stage, the **blastocyst**
Fertilization

Ovulation

Sperm enter vagina

Oviduct

Ovary

Uterus

Opening of cervix

Vagina

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Stepped Art
Fig. 7-5b, p.157
Sperm enter vagina

Nuclei fuse

Fusion of sperm nucleus with egg nucleus

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Stepped Art
Fig. 7-5b, p.157
Sperm enter vagina

Nuclei fuse

Fusion of sperm nucleus with egg nucleus

Obedience cell

Ovulation

Egg nucleus

Zona pellucida

Fertilization

Ovary

Uterus

Opening of cervix

Vagina
Sperm entering the oviduct. SEM X500.
Fertilization. SEM X4700.
Cleavage and gastrulation
(Xenopus embryo)
Blastocyst

- Mass of approximately 100 cells
- It has two parts
  - **Inner cell mass** gives rise to the embryo
  - **Trophoblast** gives rise to surrounding membranes
Implantation

• The trophoblast attaches to the **endometrium** of the uterus
• **Villi** (finger like projections) grow into the endometrium and anchor the embryo
• After approximately 12 days, the trophoblast has formed the **chorion**
• Chorion secretes **human chorionic gonadotropin (hCG)** which maintains the uterine lining (pregnancy test)
Placenta

- Highly vascular
- Formed from the chorionic villi
- Allows oxygen, wastes, nutrients, and other molecules to be exchanged between the mother and child
- Membranes that connect the embryo to the placenta form the umbilical cord
- Source of stem cells

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**DAYS 1-2**

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Fig. 7-6a-e, p.159
Fertilization

Implantation

Endometrium

DAYS 1-2  DAY 3
Endometrium

Fertilization

Implantation

Inner cell mass

DAYS 1-2 → DAY 3 → DAY 4 → DAY 5

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Fig. 7-6a-e, p.159
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Fig. 7-6a-e, p.159

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DAYS 1-2

DAYS 6-7

Trophoblast (surface layer of cells of the blastocyst)

Endometrium

Endometrium

Implantation

Fertilization

Inner cell mass

Blastocoel

Uterine cavity

Inner cell mass

DAYS 1-2

DAY 3

DAY 4

DAY 5

DAY 5

DAYS 6-7

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Fig. 7-6a-e, p.159
**DAY 10-11.** The yolk sac, embryonic disk, and amniotic cavity have started to form from parts of the blastocyst.

**DAY 12.** Blood-filled spaces form in maternal tissue. The chorionic cavity starts to form.

**DAY 14.** A connecting stalk has formed between the embryonic disk and chorion. Chorionic villi, which will be features of a placenta, start to form.
DAYS 10–11

Start of embryonic disk

Start of amniotic cavity

Start of yolk sac
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**Fig. 7-6f-h, p.159**

**DAYS 10–11**
- Start of amniotic cavity
- Start of yolk sac
- Start of embryonic disk

**DAY 12**
- Blood-filled spaces
- Start of chorionic cavity

Stepped Art
WEEK 4
Yolk sac
Connecting stalk
Embryo

WEEKS 5–6
Head growth exceeds growth of other regions

Retinal pigment

Future external ear

Upper limb differentiation (hand plates develop, then digital rays of future fingers; wrist, elbow start forming)

Umbilical cord formation between weeks 4 and 8 (amnion expands, forms tube that encloses the connecting stalk and a duct for blood vessels)

Foot plate
WEEK 8

WEEK 16

Placenta
Final week of embryonic period; embryo looks distinctly human compared to other vertebrate embryos.

Upper and lower limbs well formed; fingers and then toes have separated.

Primordial tissues of all internal, external structures now developed.

Tail has become stubby.
During fetal period, length measurement extends from crown to heel (for embryos, it is the longest measurable dimension, as from crown to rump).
Congenital Malformations

- 97% of babies are normal at birth
- Birth defects can be produced by genetic disorders or exposure to environmental agents
- Most are caused by disruptions in embryonic development
- Brain and nervous system may be damaged throughout development
Sources of teratogens

- Teratogens are environmental agents that cause developmental disruptions

**Natural in environment**

- skunk cabbage contains cyclopamine, which inhibits cholesterol biosynthesis, preventing a key developmental pathway from working; Toxoplasma gondii - cat-borne - leads to stillbirths

**Human introduced in the environment**

- methylmercury, fungicide, central nervous system disorders, cerebral palsy, mental retardation

**Infectious agents**

- Rubella (German measles), blindness, hearing loss, heart defects, mental retardation

**Drugs**

- Diethylstilbesterol (DES), synthetic estrogen, used to prevent miscarriage until 1971 (it didn’t work), structural damage to reproductive organs, increased cancer risk
Diethylstilbestrol (DES)

- prescribed to ~5 million women 1938-1971
- used to prevent miscarriage and preterm labor
- shown not to be effective in the 1950s, continued to be prescribed
- 1970s, women exposed to DES in utero had increased cervical cancer risk, morphological abnormalities of reproductive tract
- men exposed in utero often had abnormal genitalia
The Effects of Teratogens

Fig. 7.8
Fetal Alcohol Syndrome (FAS)

- A serious and widespread teratogenic problem
- Fetal Alcohol Syndrome – 1.9/1,000 births
- Fetal alcohol effect 3.5/1,000 births
- Preventable
Fetal alcohol syndrome

-characterized by small heads, low nose bridge, small brain size, mental retardation

-FAS affects 1 out of 500-750 newborns in the US

-third most common cause of mental retardation (after Fragile X and Down’s)

-intellectual and behavioral problems seen even in the absence of morphological defects
Alcohol Consumption During Pregnancy Can Result in:

- Spontaneous abortion
- Growth retardation
- Facial abnormalities
- Mental retardation
- Learning disabilities