Section XII
Reproductive physiology

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About this Chapter

• The reproductive organs and how they work
  – the major endocrine functions of sexual glands
  – actions of sex hormones
• Regulation of testicular or ovarian function
  – Hypothalamic-pituitary- sexual gland axis
• Menstrual cycle
• Pregnancy, parturition & lactation
Peggy and Larry have just about everything to make them happy, but one thing is missing. After five years of marriage, they have been unable to have a child.

Infertility specialist Dr. Coddington begins his workup of Peggy and Larry by asking detailed questions about their reproductive histories. Based on the answers to these questions, he will then order tests to pinpoint the problem.
The brain directs reproduction

- Hypothalamus and Anterior pituitary
- Control pathways for sex steroids are similar in males and females
The Male Reproductive System

The testes produce sperm and testosterone
Spermatogenesis

**Seminiferous tubules**
- Spermatids
- Spermatocytes
- Spermatozoa
- Sertoli cells

**Interstitial tissue**
- Leydig cells
  - (Testosterone)
- Capillaries
Sertoli cells regulate sperm development, secrete inhibin, activin, growth factor, enzymes, and androgen binding protein.

Basement M. preventing large molecules in the interstitial fluid from entering but allowing testosterone to enter easily.
Spermatozoa Structure

- **Head**
  - Acrosome
  - Nucleus
- **Midpiece**
  - Centrioles
  - Mitochondria
- **Tail: flagellum**
  - Microtubules
Regulation of Spermatogenesis

Spermatogenesis requires gonadotropins and testosterone
Effects of Testosterone in the male

1. Required for initiation and maintenance of spermatogenesis (acts via Sertoli cells)
2. Decreases GnRH secretion via an action on the hypothalamus
3. Inhibits LH secretion via a direct action on the anterior pituitary
4. Induces differentiation of male accessory reproductive organs and maintains their function
5. Induces male secondary sex characteristics; opposes action of estrogen on breast growth
6. Stimulates protein anabolism, bone growth, and cessation of bone growth
7. Required for sex drive and may enhance aggressive behavior
8. Stimulates erythropoietin secretion by the kidneys
Dr. Coddington first analyzes Larry’s sperm. The shape, motility and concentration of the sperm are normal.
The Female Reproductive System

More complicated due to the cyclic nature of gamete production

- Ovary
- Fallopian tube
- Uterus
- Vagina
The ovary produce eggs and hormones

- Follicle
- Oocytes
- Granulosa cells
- Thecal cells
- Corpus luteum
The uterus is the structure in which fertilized eggs implant and develop during pregnancy.
The Menstrual Cycle

- Female humans produce gametes in monthly cycles. These cycles are commonly called menstrual cycles.
  - ovarian cycle: changes that occur in follicles of the ovary
  - uterine cycle: changes in the endometrial lining of the uterus
Ovarian cycle

- Follicular phase: Egg matures
- Ovulation: Egg released
- Luteal phase: Corpus luteum
Uterine cycle

The endometrial lining of the uterus goes through its own cycle regulated by ovarian hormones

- Menses
- Proliferative phase
  - endometrium adds a new layer of cells
- Secretory phase
Endocrine Control of Menstrual Cycle

- Hypothalamic control
  - GnRH (Gonadotropin-releasing hormone)
- Anterior pituitary control
  - FSH (Follicle-stimulating hormone)
  - LH (Luteinizing hormone)
- Ovary control
  - Estrogen, progesterone and inhibin
- Feedback control
  - Ovary
  - Anterior pituitary
Ovarian Cycle

1. Early Follicular Phase
2. Late Follicular Phase and Ovulation
3. Early to Mid-Luteal Phase
4. Late Luteal Phase
Early Follicular Phase

- Gonadotropin secretion ↑
- Estrogen secretion ↑
  - Negative feedback
  - Positive feedback
- Endometrium proliferate
Late Follicular Phase & Ovulation

- Estrogen secretion peaks
  - Positive feedback
- inhibin and progesterone
- LH surge
- Endometrium thickens
- Ovulation occurs
- Luteal cells → progesterone
Early to Mid-Luteal Phase

- Corpus luteum produces steadily increasing amounts of progesterone and estrogen.
- The combination of estrogen and progesterone exerts negative feedback on the hypothalamus and anterior pituitary.
- Gonadotropin secretion further suppressed by luteal inhibin production, remains shut down.
- Endometrium continues its preparation for pregnancy.
- Progesterone thermogenic ability.

(c) Early to mid-luteal phase
Late Luteal Phase

- Corpus luteum → corpus albicans
- Progesterone and estrogen ↓
- FSH and LH ↑
- Menstruation
<table>
<thead>
<tr>
<th>DAY(S)</th>
<th>MAJOR EVENTS</th>
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<tbody>
<tr>
<td>1–5</td>
<td>Estrogen and progesterone are low because the previous corpus luteum is regressing. <em>Therefore:</em> (a) Endometrial lining sloughs. (b) Secretion of FSH and LH is released from inhibition, and their plasma concentrations increase. <em>Therefore:</em> Several growing follicles are stimulated to mature.</td>
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<tr>
<td>7</td>
<td>A single follicle (usually) becomes dominant.</td>
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<tr>
<td>7–12</td>
<td>Plasma estrogen increases because of secretion by the dominant follicle. <em>Therefore:</em> Endometrium is stimulated to proliferate.</td>
</tr>
<tr>
<td>7–12</td>
<td>LH and FSH decrease due to estrogen and inhibin negative feedback. <em>Therefore:</em> Degeneration (atresia) of nondominant follicles occurs.</td>
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<tr>
<td>12–13</td>
<td>LH surge is induced by increasing plasma estrogen. <em>Therefore:</em> (a) Oocyte is induced to complete its first meiotic division and undergo cytoplasmic maturation. (b) Follicle is stimulated to secrete digestive enzymes and prostaglandins.</td>
</tr>
<tr>
<td>14</td>
<td>Ovulation is mediated by follicular enzymes and prostaglandins.</td>
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<tr>
<td>15–25</td>
<td>Corpus luteum forms and, under the influence of low but adequate levels of LH, secretes estrogen and progesterone, and so plasma concentrations of these hormones increase. <em>Therefore:</em> (a) Secretory endometrium develops. (b) Secretion of FSH and LH is inhibited, lowering their plasma concentrations. <em>Therefore:</em> No new follicles develop.</td>
</tr>
<tr>
<td>25–28</td>
<td>Corpus luteum degenerates (if egg is not fertilized). <em>Therefore:</em> Plasma estrogen and progesterone concentrations decrease. <em>Therefore:</em> Endometrium begins to slough at conclusion of day 28, and a new cycle begins.</td>
</tr>
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</table>
Ovarian Hormones

- Estrogens
- Progesterone
The two-stage model of estrogen synthesis holds that androgen precursors are synthesized in the outer layer (theca cells) of the ovarian follicles and diffuse to the inner layer (granulosa cells) for conversion to estrogens; LH drives the former, FSH the latter.
Estrogen secretion throughout sexual life
Actions of Estrogens

• Effects on the Female Genitalia
  – Facilitate the growth of the ovarian follicles
  – Increase the motility of the uterine tubes
  – Uterine muscle becomes more active and excitable

• Effects on Endocrine Organs
  – Decrease FSH secretion
  – Increase angiotensinogen and thyroid-binding globulin
Actions of Estrogens

• **Effects on the CNS**
  – Responsible for estrous behavior

• **Effects on the Breasts**
  – Duct growth and breast enlargement

• **Female Secondary Sex Characteristics**
  – Feminizing hormones

• **Other Actions**
  – Salt and water retention
  – Lowing plasma cholesterol
Actions of Progesterone

• Effects on the uterus
  – progestational changes in the endometrium
  – antiestrogenic effect on the myometrial cells
• Effects on the breasts
  – induces differentiation of estrogen-prepared ductal tissue
  – supports the secretory function of the breast during lactation
• Effects on the brain
  – thermogenic
Control of ovarian function

- **Hypothalamic control**
  - GnRH stimulates the secretion of FSH and LH.
  - LH regulates thecal cells, whereas granulosa are regulated by both LH and FSH.

- **Feedback control**
  - Theca cells provide androgens to granulosa, and they also produce the circulating estrogens that inhibit the secretion of GnRH. Inhibin from the granulosa inhibits FSH secretion.
Peggy is instructed to track her body temperature daily. Several months’ temperature tracking revealed that Peggy is ovulating regularly.
Pregnancy, Parturition and lactation

- Sex Determination
- Fertilization
- Zygote Development
- Placenta and Further Embryonic Development
- Birth: Parturition
- Lactation
Sex Determination

- Dimorphism:
  - Males → sperm
  - Females → eggs

- Chromosomes
  - Autosomes
  - Sex Chromosomes
    - X - chromosome
    - Y - chromosome
Sex determination

- The sex chromosomes determine genetic sex. Female: XX, male: XY

In humans, sex is determined by the father. Sperm bear either an X or a Y sex chromosome; eggs have a single X.
possible defects produced by maternal nondisjunction of the sex chromosomes at the time of meiosis

- Female: XX (normal); XO
  (congenital ovarian dysgenesis, Turner syndrome)
- Male: XY (normal); XXY zygote
  (congenital testicular dysgenesis, Klinefelter syndrome)
- YO will die
Fertilization: Union of Male & Female Chromosomes

1. Sperm capacitation
2. Penetration
3. Nuclear fusion
4. Zygote
Zygote Development: Cell Division & Implantation

Cell divisions
Blastocyst
Migration to Uterus
Implantation
A postcoital test shows that sperm are present in the cervical mucus, but not moving.

Dr. Coddington explains that it is likely that Pegg’s cervical mucus contains antibodies that destroy Larry’s sperm.

**Intrauterine insemination** is recommended.

(Sperm washed to move antigenic material are introduced into the uterus)
the developing embryo floats in amniotic fluid. It obtains oxygen and nutrients from the mother through the placenta and umbilical cord.

Some material is exchanged across placental membranes by diffusion, but other material must be transported.
Birth: Parturition

• Labor
  – Baby
  – Placenta

(a) Fully developed fetus
(b) Cervical dilation
(c) Delivery
(d) Expulsion of the placenta
Lactation: Producing and Releasing Milk

- Estrogen & progesterone
  - Prep mammary tissues
- Prolactin inhibiting H
- Prolactin → milk production
- Sucking stimulus →
  - Oxytocin →
    - "Milk let-down" reflex
Reproductive Maturation: Puberty

- Increase production of sex hormones
- Maturation of reproductive organs & gamete production
- Sexual characteristics
  - Males: pubic hair, beard, deep voice, "wedge" body form & ↑ muscle mass
  - Females: menarche, pubic hair, breasts & "pear shape" body form
Later in Life

• Menopause: Female "Change-of Life"
  – Ovaries $\downarrow$ responding to GnRH
  – $\downarrow$ Levels of estrogen & progesterone produced
  – Cease egg development
  – "Hot flashes", $\uparrow$ osteoporosis risk
  – (hormone replacement debate)

• "Andropause" (?): Male changes are gradual
  – $\downarrow$ Sex hormones: $\downarrow$ muscle mass, $\downarrow$ libido, $\downarrow$ erections
  – Viagra: PNS $\rightarrow$ NO $\rightarrow$ cGMP $\rightarrow$ $\downarrow$ degradation
• Genes and hormones direct bipotential reproductive tissues to differentiate into males or females
• Spermatogenesis is regulated by FSH & LH, testosterone and inhibin influence on spermatocytes, Sertoli & Leydig cells
• Menstrual cycle coordinates egg maturation with endometrium, and is regulated by GnRH, → LH & FSH → estrogen, progesterone & inhibin
• Describe the endocrine control of menstrual cycle.
• Describe the physiological effects of estrogens and progesterone.
• What side effects would you predict in women athletes who take anabolic steroids to build muscles?