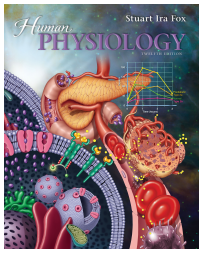
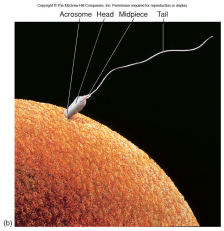


Chapter 20

Reproduction

Lecture PowerPoint

I. Sexual Reproduction



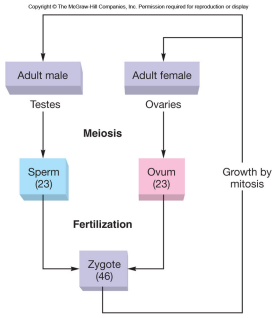
Sexual Reproduction

- Genes from two individuals are combined in random ways to produce a new individual.
  - Allows for genetic variation and adaptability to a changing environment

Sexual Reproduction

- Germ cells become gametes (sperm and ova) in the gonads via meiosis.
- Ova and sperm are fused in fertilization.
- The new individual progresses from zygote → embryo → fetus.

Sexual Reproduction



Chromosomes

- Each zygote gets 23 chromosomes from mom and 23 from dad.
  - Produces 23 pairs of homologous chromosomes
  - 22 pairs are autosomal chromosomes = have the same (but not identical) genes on them.
  - The last pair are the sex chromosomes.

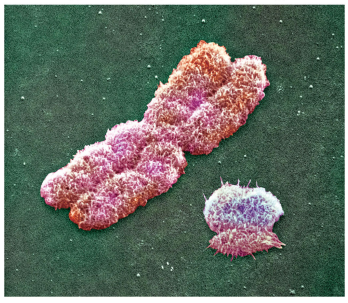
Sex Chromosomes

- Females have two X chromosomes.
  - Mom always passes on an X chromosome.
- Males have an X and a Y chromosome.
  - Dad can pass on *either* an X or a Y chromosome.
  - The sex of a child is determined by the contributing sperm.

Sex Chromosomes

- X and Y look different and have different genes.
  - X has 1,090 genes while Y has only 80 genes.
  - The Y chromosome has many testis-specific genes.

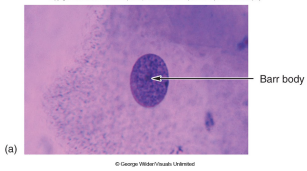
Sex Chromosomes

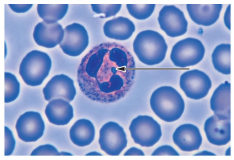


Sex Chromosomes

- In females, one of the two X chromosomes is inactive.
  - This produces a visible Barr Body.
  - This is an easy way to visually determine the sex of a cell.

Sex Chromosomes





Formation of Gonads

- After fertilization, the gonads and associated structures are identical in males and females.
  - Embryonic gonads can become *either* testes or ovaries.
  - The signal that determines which is called testis-determining factor (TDF).
  - This is coded for by a gene on the Y chromosome.

Formation of Testes

- Soon after the production of TDF in XY embryos, the seminiferous tubules form.
  - Germinal cells and Sertoli cells differentiate 45−50 days after fertilization.
  - The Leydig cells (those that make testosterone) appear around day 65.

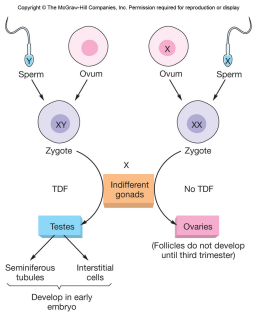
Formation of Testes

- The Leydig cells begin making large amounts of testosterone ~8 weeks after fertilization.
  - This stimulates the development of the rest of the male reproductive organs.
- As the testes develop, they descend into the scrotum.

Formation of Ovaries

- Without TDF, XX embryos do not develop testes.
- Follicular cells do not appear until the second trimester.

Formation of Ovaries



Formation of Accessory Sex Organs

- Between days 25 and 50, both male and female embryos have two systems of ducts:
  - Wolffian ducts: can become male tract
  - Mullerian ducts: can become female tract

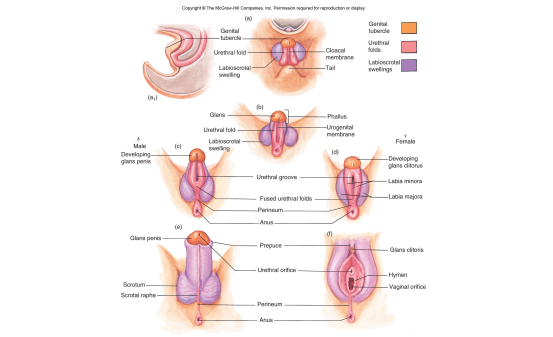
Formation of Accessory Sex Organs

- In the growing testes, the Sertoli cells secrete Mullerian-inhibiting factor.
  - This makes the Mullerian duct regress.
  - Testosterone from the Leydig cells stimulates the development of the Wolffian duct (epididymis, ductus deferens, seminal vesicle).
  - Without this inhibition and stimulation, the Mullerian ducts develop into fallopian tubes and a uterus.

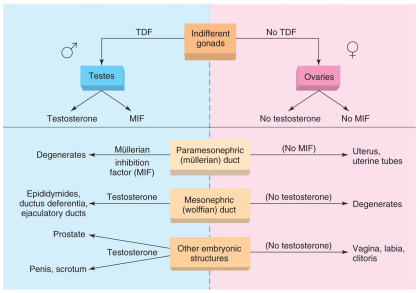
Formation of External Genitalia

- Identical in males and females for first 6 weeks of life
  - Both sexes have a urogenital sinus, labioscrotal swelling, genital tubercle, and urethral fold.
  - Testosterone masculinizes these into the scrotum, prostate gland, and penis.
  - Without testosterone, these become the labia and clitoris.

Development of External Genitalia



Regulation of Sexual Development



Developmental Timetable

Table 20.1 | A Developmental Timetable for the Reproductive System

Approximate Time After Fertilization		Developmental Changes	
Days	*Trimester*	*Indifferent*	*Male*	*Female*
19	First	Germ cells migrate from yolk sac.		
25–30		Wolffian ducts begin development.		
44–48		Müllerian ducts begin development.		
50–52		Urogenital sinus and tubercle develop.		
53–60			Tubules and Sertoli cells appear.	
			Müllerian ducts begin to regress.	
60–75			Leydig cells appear and begin testosterone production.	Formation of vagina begins.
			Wolffian ducts grow.	Regression of wolffian ducts begins.
105	Second			Development of ovarian follicles begins.
120				Uterus is formed.
160–260	Third		Testes descend into scrotum.	Formation of vagina is complete.
			Growth of external genitalia occurs.	

Disorders of Sexual Development

- Hermaphroditism: Both ovarian and testicular tissue exist in the body.
  - Some people have an ovary on one side and a testis on the other, while others have fused ovotestes.
  - Due to a problem in zygotic mitosis, not every cell receives the full Y chromosome.

Disorders of Sexual Development

- Pseudohermaphroditism: The individual has ovaries *or* testes, but accessory structures are not complete or are inappropriate for the genetic sex.
  - Female pseudohermaphroditism: may be due to excessive secretion of adrenal androgens in a female = congenital adrenal hyperplasia.
    - Both Mullerian and Wolffian duct derivatives and male external genitalia

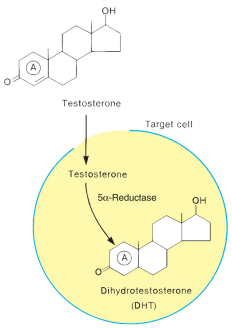
Disorders of Sexual Development

– Male pseudohermaphroditism: may be due to testicular feminization syndrome whereby testes make testosterone but testosterone receptors don't work.
  - Female external genitalia form, but there is no uterus or fallopian tubes because the Mullerian duct still degenerated.
  - There is no male tract either because the Wolffian duct was not stimulated.

Disorders of Sexual Development

– Male pseudohermaphroditism: may also occur because of inability to make the enzyme 5^{α}-reductase, which converts testosterone into DHT in target cells.
  - This is required for masculinization of external genitalia.

Disorders of Sexual Development



II. Endocrine Regulation of Reproduction

Sex Hormone Secretion

- The testes stop making testosterone by the third trimester, and the ovaries don't make embryonic sex hormone.
- Sex hormone secretion does not occur again in either sex until the gonads are stimulated at puberty.
- At this time, the anterior pituitary begins releasing gonadotropic hormones.

Gonadotropic Hormones

- Follicle-stimulating hormone (FSH) and luteinizing hormone (LH) are produced in both males and females with three effects:

1. Stimulation of spermatogenesis or oogenesis
2. Stimulation of gonadal hormone secretion
3. Maintenance of the structures of the gonads

Regulation of FSH and LH

- Release of FSH and LH is controlled by the release of gonadotropin-releasing hormone (GnRH) from the hypothalamus.
- Regulated by a negative-feedback loop where rising levels of gonadal hormone:
  - Inhibit GnRH release
  - Inhibit pituitary response to GnRH

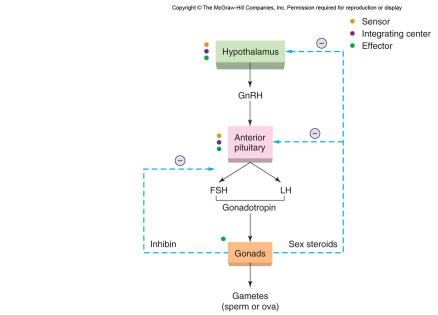
Regulation of FSH and LH

- Aside from the usual gonadal hormones (testosterone, estrogen, and progesterone), the gonads also secrete inhibin.
  - Secreted by Sertoli cells in testes
  - Secreted by granulosa cells of ovarian follicles
  - Specifically inhibits release of FSH (no effect on LH)

Regulation of Hormones

- Similar in males and females, but male secretion is constant while female secretion is cyclical.
- At one point in the female cycle, estrogen has a positive effect on LH release.

Regulation of Hormones



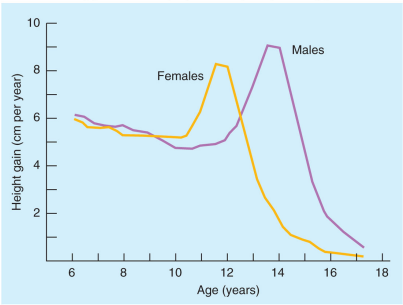
Puberty

- Secretion of FSH and LH is elevated at birth and stays high for the first 6 months of postnatal life.
  - This declines to almost nothing until puberty.
- Puberty begins with a release of LH.
  - This results in increases in testosterone or estrogen secretion.
  - These hormones produce secondary sex characteristics.

Secondary Sex Characteristics

- In girls: growth spurt, breast development, menarche (first menstrual flow)
- In boys: occurs later; body, muscle, penis, and testis growth
- In both sexes: body hair is stimulated by androgens from adrenal gland at puberty

Secondary Sex Characteristics



Female Sexual Development at Puberty

Table 20.2 | Development of Secondary Sex Characteristics and Other Changes That Occur During Puberty in Girls

Characteristic	Age of First Appearance	Hormonal Stimulation
Appearance of breast buds	8–13	Estrogen, progesterone, growth hormone, thyroxine, insulin, cortisol
Pubic hair	8–14	Adrenal androgens
Menarche (first menstrual flow)	10–16	Estrogen and progesterone
Axillary (underarm) hair	About 2 years after the appearance of pubic hair	Adrenal androgens
Eccrine sweat glands and sebaceous glands; acne (from blocked sebaceous glands)	About the same time as axillary hair growth	Adrenal androgens

Male Sexual Development at Puberty

Table 20.3 | Development of Secondary Sex Characteristics and Other Changes That Occur During Puberty in Boys

Characteristic	Age of First Appearance	Hormonal Stimulation
Growth of testes	10–14	Testosterone, FSH, growth hormone
Pubic hair	10–15	Testosterone
Body growth	11–16	Testosterone, growth hormone
Growth of penis	11–15	Testosterone
Growth of larynx (voice lowers)	Same time as growth of penis	Testosterone
Facial and axillary (underarm) hair	About 2 years after the appearance of pubic hair	Testosterone
Eccrine sweat glands and sebaceous glands; acne (from blocked sebaceous glands)	About the same time as facial and axillary hair growth	Testosterone

Onset of Puberty

- Depends on activity levels and amount of body fat
  - Leptin secreted by adipose cells is required for the onset of puberty.
  - Exercise may inhibit GnRH secretion.
  - More active, slimmer girls begin puberty later.
  - Melatonin from the pineal gland may play a role, but this is not proven in humans.

Human Sexual Response

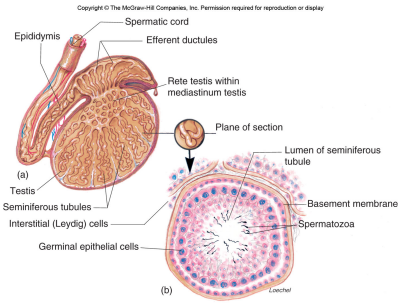
- Four phases:
  1. Excitation: characterized by increased muscle tone, vasocongestion of sexual organs; also called arousal
  2. Plateau: continued vasocongestion
  3. Orgasm: contraction of the uterus/vagina and male ejaculatory organs
  4. Resolution: body returns to pre-excitation condition
     - Men experience a refractory period.

III. Male Reproductive System

Testes

- Have two compartments:
  - Seminiferous tubules: where spermatogenesis occurs
    - FSH receptors are found here, on Sertoli cells.
    - FSH influences spermatogenesis.
  - Interstitial tissue: where Leydig cells make testosterone; also filled with blood and lymphatic capillaries
    - LH receptors found here on Leydig cells
    - Testosterone secreted in response to LH

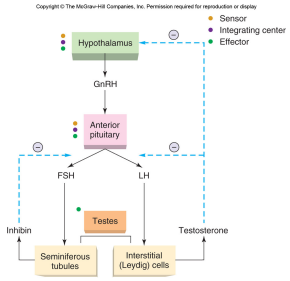
Testis Structure



Gonadotropin Secretion

- LH secretion is controlled by rising testosterone secretion through negative feedback.
- FSH secretion is controlled by testosterone and inhibin secretion.
  - Inhibin is released from the Sertoli cells of the seminiferous tubules.

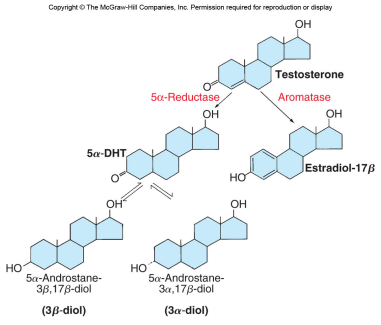
Gonadotropin Secretion



Testosterone in the Brain

- Testosterone is converted to its derivatives in brain cells.
  - Converted by 5α-reductase to DHT or to estradiol by aromatase enzyme
  - Estradiol is used to inhibit LH secretion.

Testosterone in the Brain



Action of Testosterone

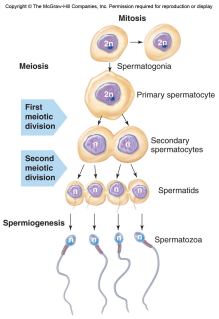
Table 20.4 | Actions of Androgens in the Male

Category	Action
Sex Determination	Growth and development of wolffian ducts into epididymis, ductus deferens, seminal vesicles, and ejaculatory ducts
	Development of urogenital sinus into prostate
	Development of male external genitalia (penis and scrotum)
Spermatogenesis	At puberty: Completion of meiotic division and early maturation of spermatids
	After puberty: Maintenance of spermatogenesis
Secondary Sex Characteristics	Growth and maintenance of accessory sex organs
	Growth of penis
	Growth of facial and axillary hair
	Body growth
Anabolic Effects	Protein synthesis and muscle growth
	Growth of bones
	Growth of other organs (including larynx)
	Erythropoiesis (red blood cell formation)

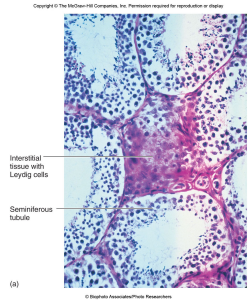
Spermatogenesis

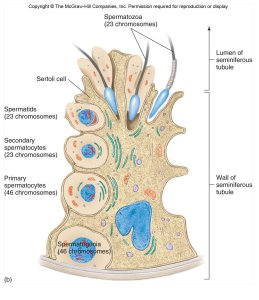
- Diploid spermatogonia first go through mitosis.
- One of the daughter cells (the primary spermatocyte) continues through meiosis.
- After meiosis I → 2 secondary spermatocytes.
- After meiosis II → 4 spermatids.

Spermatogenesis



Spermatogenesis Within the Seminiferous Tubules

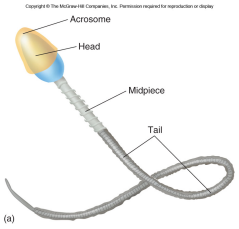


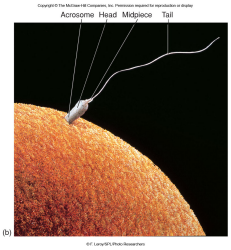


Spermiogenesis

- Maturation of spermatids into functioning spermatozoa
  - Mature spermatozoa have a flagellum, head, midpiece, and acrosome cap.

Spermiogenesis





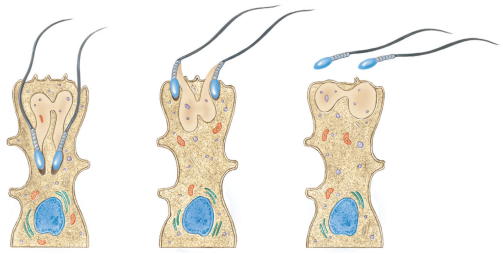
Spermiogenesis and Sertoli Cells

- Sperm development requires Sertoli cells.
  - Sertoli cells create a blood-testis barrier controlling what can enter the seminiferous tubules and preventing the immune system from developing antibodies against the sperm.
  - They also secrete FAS ligand, which binds to an FAS receptor on T cells, stimulating apoptosis.
    - This creates an immunologically privileged site.

Spermiogenesis and Sertoli Cells

- Sertoli cells envelop the developing sperm.
  - They phagocytize some of the spermatid cytoplasm in spermiogenesis.
  - They secrete androgen-binding protein (ABP) into the seminiferous tubule lumen. This binds to testosterone and concentrates it in the tubule.
    - ABP production is stimulated by FSH.
    - Testosterone stimulates spermatogenesis and spermiogenesis.

Spermiogenesis and Sertoli Cells



Hormonal Control of Spermatogenesis

- Testosterone is required to stimulate meiosis and early spermatid maturation.
  - Testosterone is secreted by the Leydig cells after stimulation by LH.
  - FSH enhances spermatogenesis through the action of the Sertoli cells that are stimulated to make ABP, which concentrates the testosterone levels.
    - FSH ensures optimal fertility

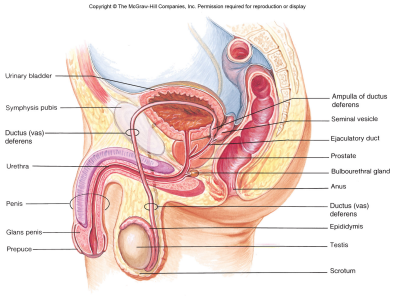
Male Accessory Sex Organs

- Spermatids move from the seminiferous tubules → rete testis → efferent ductules → epididymis.
- The epididymis is the site of sperm maturation and storage.
- In ejaculation, spermatozoa move from the epididymis → ductus deferens → ejaculatory duct → urethra.

Male Accessory Sex Organs

- The seminal vesicle and prostate gland add fluid to the sperm to form semen.
  - Seminal fluid: contains fructose (energy for sperm)
  - Prostate fluid: contains citric acid, calcium, and coagulation proteins

Male Accessory Sex Organs



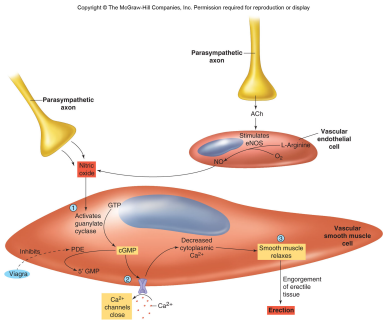
Erection

- Results from blood flow into erectile tissues of the penis:
  - Corpora cavernosa and corpus spongiosum
- Due to parasympathetic nerve–induced vasodilation of the arterioles leading to the corpora cavernosa

Erection

- Nitric oxide serves as the neurotransmitter.
  - Activates guanylate cyclase to produce cGMP → Closes Ca^{2+} channels → Decreases cytoplasmic Ca^{2+} levels → Relaxes muscles
- Venous outflow of blood is partially blocked during an erection.

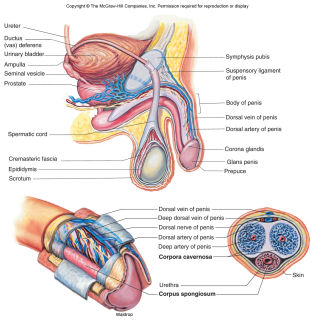
Nitric Oxide and Erection



Control of the Erection

- Controlled by the hypothalamus and the sacral region of the spinal cord
  - Can occur due to conscious sexual thought (hypothalamus → spinal cord → penis) or sensory stimulation (penis → spinal cord → penis)

Erectile Tissues of the Penis



Emission and Ejaculation

- Emission is the movement of semen into the urethra.
- Ejaculation is the forceful expulsion of semen from the urethra.
  - Both are under sympathetic nervous system control.
  - Contraction of smooth muscles in the tubules, seminal vesicle, prostate, and muscles at base of penis is involved in ejaculation.

Male Fertility

- A sperm count < 20 million/ml semen is called oligospermia and is considered less fertile.
  - May be caused by heat, drugs, or anabolic steroids

Male Fertility

Table 20.5 | Semen Analysis

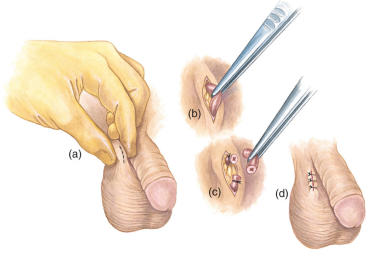
Characteristic	Reference Value
Volume of ejaculate	1.5–5.0 ml
Sperm count	40–250 million/ml
Sperm motility	
Percentage of motile forms:	
1 hour after ejaculation	70% or more
3 hours after ejaculation	60% or more
Leukocyte count	0–2,000/ml
pH	7.2–7.8
Fructose concentration	150–600 mg/100 ml

Source: Modified from L. Glasser,"Seminal Fluid and Subfertility," *Diagnostic Medicine*, July/August 1981, p. 28. Used by permission.

Vasectomy

- Most widely used and reliable form of male contraception
  - The vas deferens is cut and tied to prohibit sperm transport.
  - A vasectomy does not affect testosterone production or ejaculation.

Vasectomy



IV. Female Reproductive System

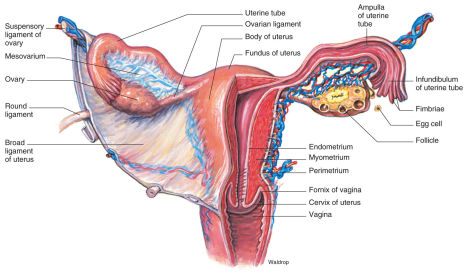
Female Accessory Reproductive Organs

- Ovaries: female gonads; site of oocyte and sex steroid production
- Fallopian tubes: have fimbriae that wrap around the ovaries and "catch" the oocyte after ovulation
  - Most common site of fertilization

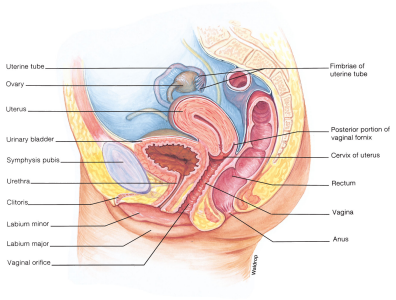
Female Accessory Reproductive Organs

- Uterus: site of embryonic development
  - Endometrium: inner layer, where embryo implants and develops
  - Myometrium: middle muscle layer; contracts to expel baby at birth
  - Perimetrium: outer connective tissue layer
  - Cervix: narrow bottom region of uterus
- Vagina

Female Accessory Reproductive Organs



Female Accessory Reproductive Organs



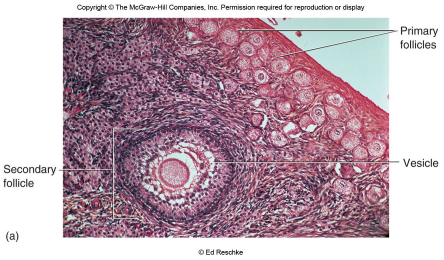
Ovarian Cycle: Oocytes

- Toward the end of gestation, a female's oogonia begin meiosis to produce primary oocytes.
  - The ovaries of a newborn girl have 2 million primary oocytes.
  - By puberty, this number is cut to about 400,000.
  - Only about 400 of these will be ovulated in her lifetime.

Ovarian Cycle: Follicles

- Primary oocytes are contained within primary follicles.
  - In response to FSH, some of the primary follicles grow to produce many layers of granulosa cells.
  - Some develop fluid-filled vesicles called secondary follicles.

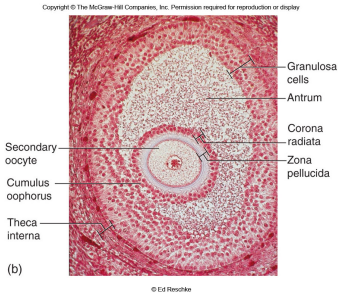
Ovarian Cycle: Follicles



Ovarian Cycle: Follicles

- Continued growth results in fused vesicles to form a single antrum.
- This is a mature Graafian follicle.
- Cell layers called the corona radiata and zona pellucida form around the oocyte.
  - These serve as a barrier for sperm entry.

Ovarian Cycle: Follicles



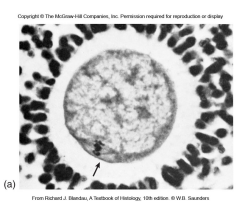
Ovarian Cycle: Follicles

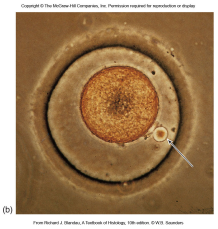
- Continued development of *one* Graafian follicle occurs because of stimulation from FSH, estrogen, and paracrine signals.
- Paracrine regulators such as androgens and FAS ligand induce apoptosis of other Graafian follicles.
  - These become atretic cells.

Ovarian Cycle: Oocytes

- As the Graafian follicle grows, the primary oocyte finishes meiosis I to become a secondary oocyte (plus a polar body, which soon degenerates).

Ovarian Cycle: Oocytes



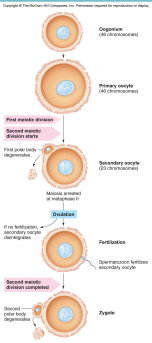


Ovarian Cycle: Oogenesis

– The secondary oocyte finishes meiosis if the cell is fertilized by a sperm.

– This produces an ovum and a second polar body, which degenerates.

Ovarian Cycle: Oogenesis

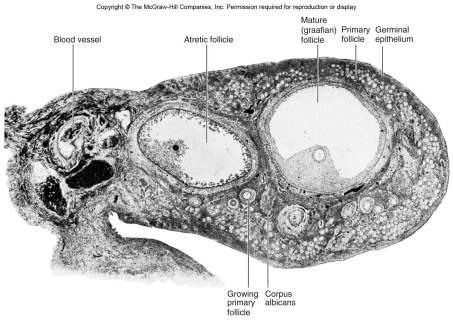


Ovarian Cycle: Estrogen

- Aside from stimulating the development of the follicles, FSH stimulates estrogen production in the follicles.

  – The bigger the follicle, the more estrogen it releases.

Ovarian Cycle: Follicles



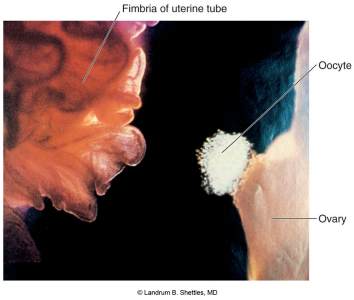
Ovarian Cycle: Ovulation

- The surviving Graafian follicle becomes so big it bulges out of the ovary.

  – Hormones stimulate the follicle to burst and release the secondary oocyte.

  – If not fertilized, the oocyte will degenerate after a few days.

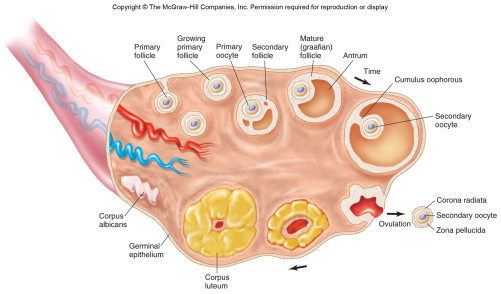
Ovarian Cycle: Ovulation



Ovarian Cycle: Corpus Luteum

- After ovulation, the remaining follicle becomes a corpus luteum.
  - This secretes both estrogen and progesterone.
  - These hormones play a role in the menstrual cycle.

Ovarian Cycle Summary



V. Menstrual Cycle

Menstrual Cycle

- Describes the 28-day cycle of endometrial buildup and sloughing in response to ovarian hormones
- Three phases:
  - Menstrual
  - Proliferative
  - Secretory
- Changes in the endometrium follow changes in the follicles of the ovaries.

Cyclic Changes in the Ovaries

- Follicular changes in the ovaries can be broken into three phases:
  - Follicular phase
  - Ovulation
  - Luteal phase

Ovarian Follicular Phase

- Lasts from day 1 through 13 (variable)
- Primary follicles → Secondary follicles → Graafian follicle (one kept)
- Characterized by increasing levels of estrogen production, reaching a high around day 12

Ovarian Follicular Phase

- Initiated by FSH
- FSH also upregulates the number of FSH receptors on the follicles → sensitivity to FSH increases
- At the end of this phase, FSH and high levels of estrogen stimulate production of LH receptors in the Graafian follicle.
- Increased estrogen also stimulates the hypothalamus to release more GnRH → LH is released from anterior pituitary
  - Called the LH surge

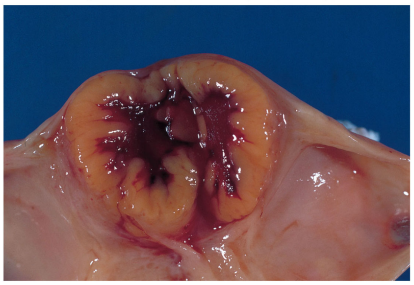
Ovulation

- FSH causes the Graafian follicle to bulge out of the ovary wall.
- LH surge begins ~24 hours before ovulation.
  - Stimulates Graafian follicle to rupture, releasing secondary oocyte

Luteal Phase

- After ovulation, LH stimulates the ruptured follicle to become a corpus luteum.
  - This secretes estrogen and progesterone.
  - Progesterone peaks ~1 week after ovulation.

Luteal Phase



Luteal Phase

- High levels of estrogen and progesterone feed back on the pituitary gland and inhibit FSH and LH secretion.
- There may also be inhibin production, which helps inhibit FSH.
- Shuts down follicle development to prevent further ovulation long enough to give the secondary oocyte a chance to be fertilized

Luteal Phase

- Ends with the degeneration of the corpus luteum around day 28
- Decreasing levels of estrogen and progesterone stimulate the sloughing of the endometrium and menstruation.

Cyclic Changes in the Endometrium

- The menstrual cycle begins with menstruation at the end of the previous ovarian cycle.
- The development of the endometrium is regulated by secretion of estrogen and progesterone in the ovaries.

Proliferative Phase

- Occurs while ovary is in the follicular phase
- Increasing levels of estrogen stimulate the growth of the stratum functionale of the endometrium.
- The endometrium also becomes more vascular and develops LH receptors.

Secretory Phase

- Occurs while the ovaries are in the luteal phase
- Secretion of progesterone stimulates the development of uterine glands, which store glycogen.
- The endometrium also becomes even thicker and more vascular.
- Endometrium is prepared to nourish a growing embryo if the oocyte is fertilized.

Menstrual Phase

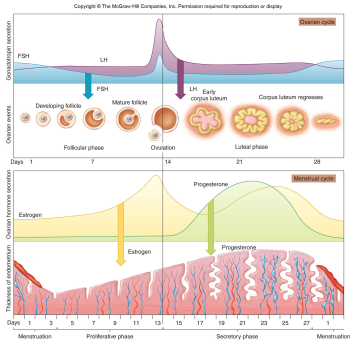
- Occurs as a result of the fall in estrogen and progesterone when the corpus luteum degenerates
- Arteries in the endometrium constrict, cells in the stratum functionale die, and this region is sloughed.

Phases of the Menstrual Cycle

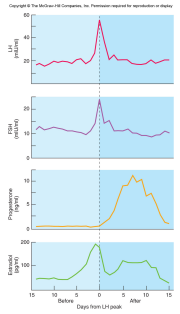
Table 20.6 | Phases of the Menstrual Cycle

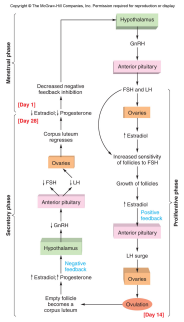
Phase of Cycle		Hormonal Changes		Tissue Changes	
Ovarian	**Endometrial**	**Pituitary**	**Ovary**	**Ovarian**	**Endometrial**
Follicular (days 1–4)	Menstrual	FSH and LH secretion low	Estradiol and progesterone remain low	Primary follicles grow	Outer two-thirds of endometrium is shed with accompanying bleeding
Follicular (days 5–13)	Proliferative	FSH slightly higher than LH secretion in early follicular phase	Estradiol secretion rises (due to FSH stimulation of follicles)	Follicles grow; graafian follicle develops (due to FSH stimulation)	Mitotic division increases thickness of endometrium; spiral arteries develop (due to estradiol stimulation)
Ovulatory (day 14)	Proliferative	LH surge (and increased FSH) stimulated by positive feedback from estradiol	Estradiol secretion falls	Graafian follicle ruptures and secondary oocyte is extruded into uterine tube	No change
Luteal (days 15–28)	Secretory	LH and FSH decrease (due to negative feedback from steroids)	Progesterone and estrogen secretion increase, then fall	Development of corpus luteum (due to LH stimulation); regression of corpus luteum	Glandular development in endometrium (due to progesterone stimulation)

Menstrual and Ovarian Cycles



Hormonal Changes Through Menstrual Cycle





Extrinsic Regulation of GnRH

- Pheromones (odor molecules) can synchronize the menstrual cycle.
  - Olfactory system has input on GnRH neurons.
- Stress and emotions can affect the menstrual cycle.
- Low body fat can produce delayed menarch, or amenorrhea (lack of menstruation).
  - Controlled by leptin

Contraceptive Pill

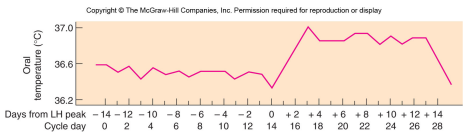
- Includes synthetic estrogen and progesterone
  - Acts like a prolonged luteal phase
  - Produces negative-feedback inhibition of GnRH, so ovulation never occurs
  - The endometrium still proliferates.
  - Placebo pills are taken for 1 week to allow menstruation.

Rhythm Method of Contraception

- Pregnancy is unlikely as long as a couple has sex more than 6 days before ovulation and more than 1 day after.
- A woman can time ovulation by taking her temperature.
- This is a pretty good indicator for when ovulation occurs but not a very reliable form of birth control.

Rhythm Method of Contraception

- Changes in hormonal secretion also change body temperature.



Menopause

- Characterized by cessation of ovarian activity and menses
  - Due to changes in the ovaries, not to decreases in FSH and LH
  - FSH and LH levels are actually elevated due to lack of negative feedback.
- Usually occurs after age 50

Menopause

- Symptoms are due to loss of estrogen.
  - Hot flashes are produced by vasomotor disturbances.
  - The walls of the urethra and vagina atrophy, and vaginal glands no longer produce lubrication.
  - After menopause, risk for atherosclerosis and osteoporosis increases.

Menopause and Osteoporosis

- Estrogen is needed for bone deposition, so menopausal women are at increased risk for osteoporosis.
  - Adipose tissue does make a weak form of estrogen called estrone.
  - Heavier women have a reduced risk of osteoporosis.

VI. Fertilization, Pregnancy, and Parturition

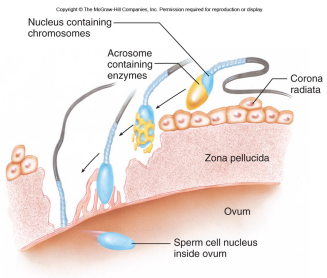
Fertilization

- Over 300 million sperm enter the female at ejaculation.
  - Only about 100 of these live to enter the fallopian tube.
  - In order to fertilize the ovum, a sperm must become capacitated. This takes at least 7 hours after ejaculation.
  - The sperm follow chemical and thermal signals toward the oocyte.

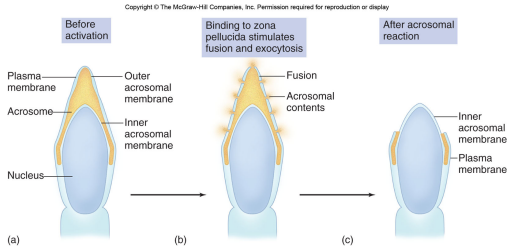
Fertilization

- Fertilization usually occurs in the fallopian tubes.
- The association between the acrosome cap and zona pellucida cells stimulates the release of acrosomal enzymes.
  - These enzymes allow the sperm to "digest" its way into the oocyte.

Fertilization



Acrosome Reaction



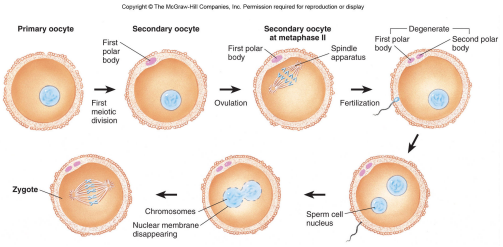
Fertilization

- When the sperm enters the oocyte, Ca^{2+} is released from the endoplasmic reticulum.
- The Ca^{2+} has several effects:
  - Prevents other sperm from entering the oocyte
  - Activates the oocyte to finish meiosis to become a haploid ovum

Fertilization

- Twelve hours after the sperm enters the oocyte, the nuclear envelope around the ovum disappears, and chromosomes join to form a diploid zygote.

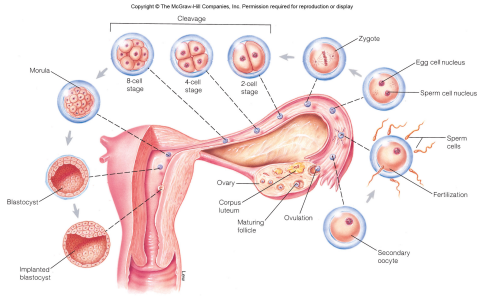
Fertilization



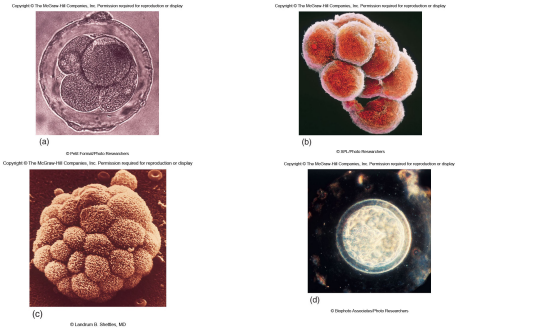
Cleavage and Blastocyst Formation

- Cleavage begins 30−36 hours after fertilization.
  - Characterized by rapid mitosis, which forms a hollow ball of cells called the blastocyst
- The blastocyst has two parts:
  - Embryoblast will become the fetus.
  - Trophoblast will become the chorion → placenta.

Cleavage and Blastocyst Formation



Cleavage and Blastocyst Formation



Embryonic Stem Cells and Cloning

- Cells of early cleavage are totipotent and will divide to become every cell in the body.
  - A cloned blastocyst can be created by implanting a somatic cell into an ovum cytoplasm in a process called somatic cell nuclear transfer.

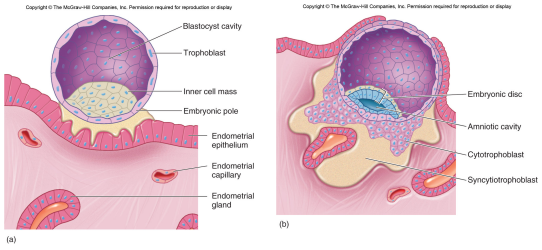
Embryonic Stem Cells and Cloning

- Embryoblast cells cultured in vitro are called embryonic stem cells and are pluripotent = able to become any type of cell in the body.
- These cells might be used therapeutically to treat diabetes type I, Parkinson disease, or spinal cord injury.

Implantation

- On the sixth day after fertilization, the trophoblast cells secrete an enzyme that allows the blastocyst to “eat” into the endometrium.

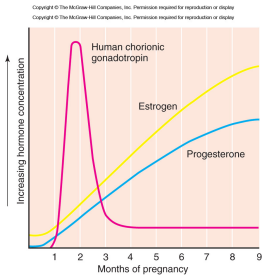
Implantation



Implantation

- While implantation occurs, the blastocyst releases chorionic gonadotropin.
  - This acts like LH to keep the corpus luteum alive to continue releasing estrogen and progesterone.
  - This keeps the endometrium thick and vascular to house the blastocyst.

Implantation



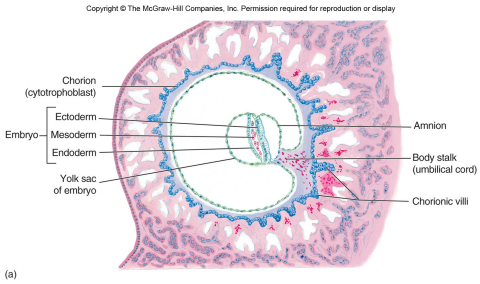
Blastocyst Development

- From day 7 to day 12, the trophoblast splits into:
  - Cytotrophoblast
  - Syncytiotrophoblast
- The developing trophoblast and embryoblast are separated by the amniotic cavity.

Blastocyst Development

- The fetal part of the blastocyst becomes:
  - Endoderm: will become the gut organs
  - Ectoderm: will become the skin and nervous system
- The mesoderm develops later and will become the muscles, bones, and connective tissues.

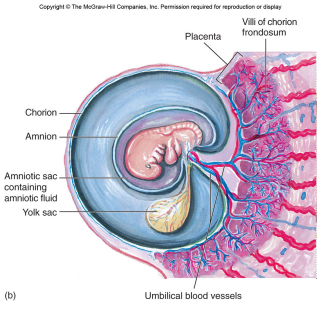
Blastocyst Development



Blastocyst Development

- The syncytiotrophoblast secretes protein-digesting enzymes and creates blood-filled cavities in the endometrium.
- The cytotrophoblast sends villi into these pools of maternal blood, forming the chorion frondosum.

Blastocyst Development



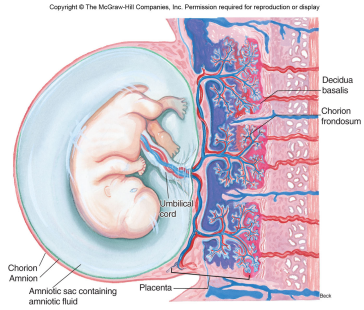
Placenta Formation

- As the blastocyst develops, the endometrium also changes to form the decidua basalis.
  - This joins with the chorion frondosum to form the placenta.
  - By the end of the second trimester, the spiral arteries of the endometrium have become tubes lined in cytotrophoblast.

Amniotic Sac Formation

- Part of the chorion envelops the growing embryo.
- The fluid-filled space between becomes the amniotic sac.
- This fluid comes from isotonic secretion, urine from the fetus, and sloughed cells.

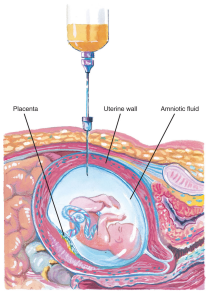
Amniotic Sac Formation



Amniocentesis

- Samples from the amniotic fluid can help diagnose genetic abnormalities such as Down syndrome.
  - Samples are taken at week 16.

Amniocentesis



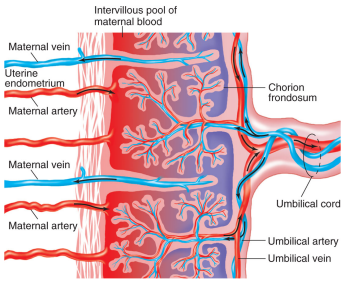
Molecule Exchange

- Umbilical arteries deliver fetal blood to placental vessels.
- This blood circulates within the placenta and returns to the fetus via the umbilical vein.
- Maternal blood is also delivered to/from the placenta.
- In this way, maternal and fetal blood do not mix.
- Molecules diffuse across tissues of the placenta for exchange.

Molecule Exchange

- Oxygen and nutrients diffuse from maternal blood to fetal blood.
- Carbon dioxide and wastes diffuse from fetal blood to maternal blood.
- The placenta degrades maternal molecules that may harm the fetus.

Molecule Exchange



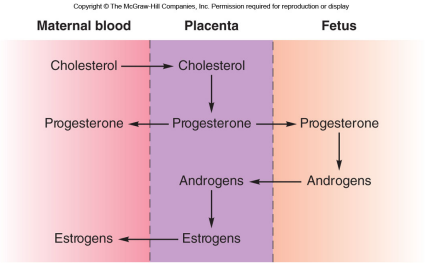
Endocrine Functions of the Placenta

- The placenta secretes protein hormones:
  - Chorionic gonadotropin: acts like LH in the ovary and as a thyroid-stimulating hormone
  - Chorionic somatomammotropin: acts similar to growth hormone and prolactin
  - They both work to increase lipolysis to increase blood fatty acid levels and glucose-sparing to increase blood glucose levels.

Endocrine Functions of the Placenta

- The placenta secretes steroid hormones:
  - Estrogen and progesterone
  - Cholesterol from maternal blood and enzymes from the fetus are needed to produce these hormones.

Endocrine Functions of the Placenta



Endocrine Functions of the Placenta

Table 20.7 | Hormones Secreted by the Placenta

Hormones	Effects
Pituitary-like Hormones	
Chorionic gonadotropin (hCG)	Similar to LH; maintains mother's corpus luteum for first 5½ weeks of pregnancy; may be involved in suppressing immunological rejection of embryo; also exhibits TSH-like activity
Chorionic somatomammotropin (hCS)	Similar to prolactin and growth hormone; in the mother, hCS acts to promote increased fat breakdown and fatty acid release from adipose tissue and to promote the sparing of glucose for use by the fetus ("diabetic-like" effects)
Sex Steroids	
Progesterone	Helps maintain endometrium during pregnancy; helps suppress gonadotropin secretion; stimulates development of alveolar tissue in mammary glands
Estrogens	Help maintain endometrium during pregnancy; help suppress gonadotropin secretion; help stimulate mammary gland development; inhibit prolactin secretion; promote uterine sensitivity to oxytocin; stimulate duct development in mammary glands

Labor and Parturition

- The powerful contractions needed to expel the fetus occur in response to oxytocin from the mother's hypothalamus and prostaglandins from the placenta.
- Labor is initiated by rising levels of corticotropin-releasing hormone (CRH) from the placenta.

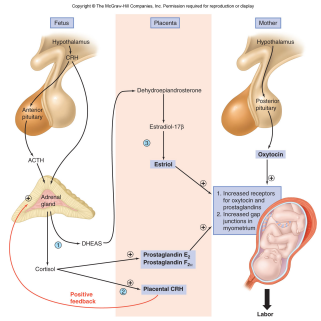
Labor and Parturition

- CRH stimulates the secretion of ACTH from the pituitary → cortisol from the adrenal glands of both mother and child.
  - Cortisol has positive feedback on CRH secretion.
  - It stimulates the production of surfactant in the fetal lungs.
- ACTH also stimulates the secretion of DHEAS in the fetus.

Labor and Parturition

- DHEAS is converted to estrogen in the placenta.
  - Estrogen makes the myometrium more sensitive to oxytocin and prostaglandins as more receptors for each--and more gap junctions between muscle cells--are formed.
  - Oxytocin and prostaglandins stimulate the release of Ca^{2+}, which stimulates muscle contraction.

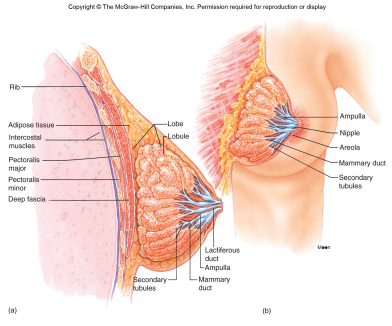
Labor and Parturition



Mammary Glands

- Mammary glands are composed of 15−20 lobes separated by adipose tissue.
- Each lobe is made up of lobules composed of glandular alveoli that secrete milk in lactation.
- Milk flows from secondary tubules → mammary ducts → the lactiferous duct → nipple.

Mammary Gland Structure



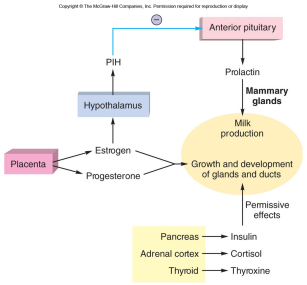
Mammary Glands in Pregnancy

- The mammary glands change during pregnancy.
  - Cortisol, thyroxine, and insulin make the mammary glands more sensitive to rising progesterone and estrogen levels.
  - Progesterone stimulates alveoli growth.
  - Estrogen stimulates tubule and duct growth.

Lactation

- Prolactin from the pituitary gland stimulates the production of milk proteins.
  - Casein and lactalbumin
- Prolactin is inhibited by PIH from the pituitary gland. PIH is stimulated by estrogen secretion.
  - When the placenta is shed at birth, estrogen levels drop, lifting inhibition on prolactin.

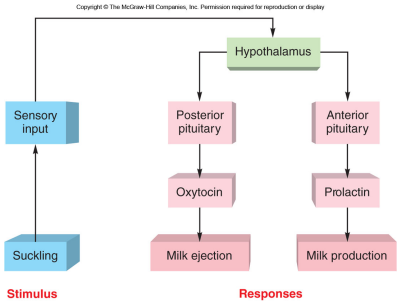
Hormonal Control of Mammary Gland Development and Lactation



Lactation

- Nursing maintains high levels of prolactin secretion via a neuroendocrine reflex that inhibits PIH secretion.
- Nursing also stimulates oxytocin secretion, which stimulates contraction of the lactiferous ducts for milk flow.

Lactation



Breast Feeding and Immunity

- IgG antibodies are passed from mother to child in utero.
- IgA antibodies are passed to the child in breast milk.
  - These provide passive immunity for the first several months of life until the baby can develop its own antibodies.

Breast Feeding and Immunity