ANIMAL REPRODUCTION

- Cells divide to reproduce

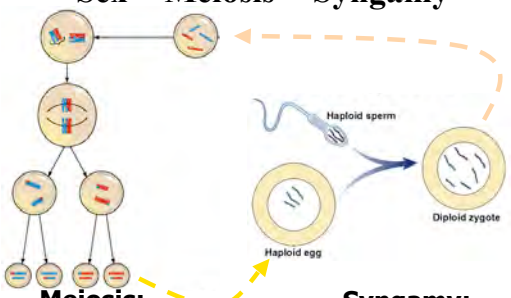
I. Asexual Reproduction
offspring from single parent
(daughter cells have identical DNA as parent cell)

Budding *Hydra*

II. Sexual Reproduction
offspring from union of egg and sperm (combine some DNA from both parent cells)

Sperm cells and egg cell

Sex = Meiosis + Syngamy



Meiosis:
2n → 1n
Diploid → haploid

Syngamy:
1n → 2n
Haploid → diploid

Sexual Reproduction Produces Genetic Variation

- Variation arises from
  - I. Independent chromosome assortment in meiosis
  - II. Crossing-over between homologous chromosomes in meiosis
  - III. Random process of fertilization

REPRODUCTION

- Asexual
- Sexual
  - Attraction, Courtship, and Mating
  - Fertilization
  - Production of Young

Biological Benefits of Asex

1. Eliminate problem to locate, court, & retain suitable mate.
2. Doubles population growth rate.
3. Avoid "cost of meiosis":
   - genetic representation in later generations isn't reduced by half each time
4. Preserve gene pool adapted to local conditions.

The Evolutionary Enigma of Sexual Reproduction

- Sexual reproduction produces fewer reproductive offspring than asexual reproduction, a so-called reproductive handicap

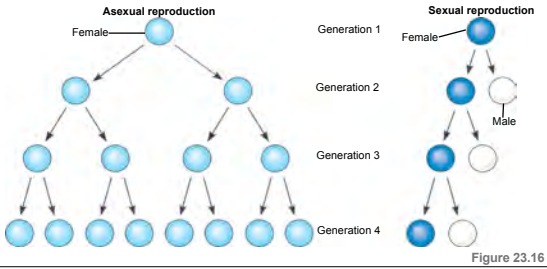


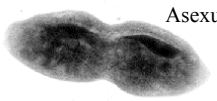
Figure 23.16

Biological Benefits of Sex

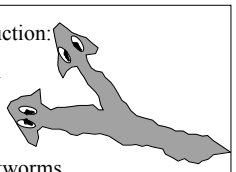
1. Reinforcement of social structure
2. Variability in face of changing environment.
   - why buy four lottery tickets w/ the same number on them?

Relative benefits: Support from organisms both asexual in constant & sexual in changing environments

- aphids have wingless female clones & winged male & female dispersers
- ciliates conjugate if environment is deteriorating



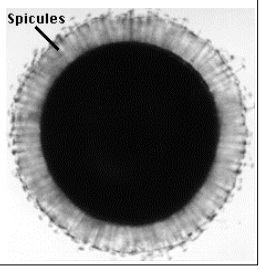
Asexual Reproduction:
Fission



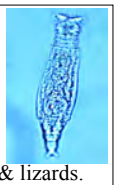
- Divide in two
  - protozoans, anemones, flatworms

Asexual Reproduction:
Cloning

- Grow cells
  - Gemmules of sponges.



Asexual Reproduction:
Parthenogenesis

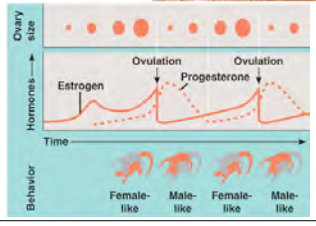


- Eggs develop w/o fertilization
  - some rotifers, fish, crustaceans, insects, & lizards.
- *Obligatory*
  - Whiptails
- *Facultative*
  - Snakes
  - Aphids

Whiptails — *Cnemidophorus uniparens*

Parthenogenesis

- Derived parthenogenesis & pseudocopulation in whiptail lizards



TWO SEXES

- **Conjugation (isogamtes)**
  - Ciliate protozoans with + & - mating types.
- **Dioecious**: separate sexes
  - one sex makes small haploid gametes (sperm)
  - the other makes big ones (eggs)
- **Monoecious**: both sexes in one individual.
  - Can make both sperm & eggs
  - But usually not at the same time

Simultaneous Hermaphrodites

- Advantageous if limited mobility and sperm dispersal and/or low population density
- Guarantee that any member of your species encountered is the "right" sex
- Self fertilization still provides some genetic variation
- Or prevent self-fertilization by
  - copulation
  - producing sperm or eggs at different times

sponges, flatworms, snails, earthworms

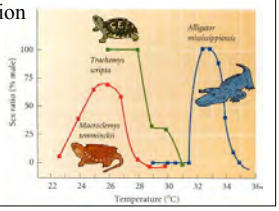
Simultaneous sperm exchange

Sequential Hermaphrodites

- **Protandry**: male ➔ female when all else equal
  - make sperm when small
    - you still make more than needed
  - make eggs when large
    - costlier & bigger
  - e.g., anemonefish
- **Protogyny** : female ➔ male when all else isn't equal
  - especially if big individuals get more mates
    - be a big male
  - e.g., wrasses

Determinate (fixed) Gender

- Gametic determination
  - Heterogenic male determination (XY male; XX female)
  - Heterogenic female determination (ZW female; ZZ male)
  - Haplotypic male determination (XO male; XX female)
- Environmental determination
  - Temperature
  - Intrauterine position



External Fertilization

- Only in water
  - gametes must be moist.
- Gamete release is synchronized.

Broadcast Spawning

•E.g. marine inverts - larval mortality is high.

- Release in response to:
  - smell of other gametes
  - environmental cues
    - •Palolo Worm
- Make buoyant to concentrate at surface

Courtship Spawning

- In fish & some marine inverts
- Behaviors stimulate gamete release
- Produce fewer eggs but add in parental care
  - it's a balance of investment strategy

Internal Fertilization

- Terrestrial forms need internal fertilization so gametes don't dry out
- Decreases energy spent on sperm production
- Ensure large amounts of *your* sperm are on target
- Allow females to store concentrated sperm

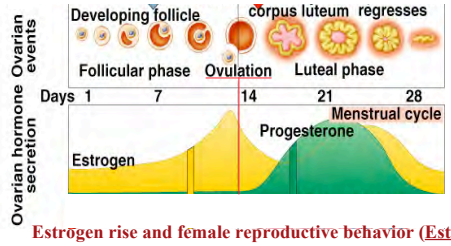
- **Spermatophores** are sperm packages
  - –spiders, frogs
- Adpressed Cloacas
  - –birds lack intromittive organs

Copulatory Organs

- Legs
  - – squids & spiders
- Claspers
  - – sharks & rays
- Penises
  - – insects
  - – turtles, crocodiles
  - – lizards, snakes w/ **hemipenes**
  - – marsupials w/ bifurcated penis
  - – eutherian mammals w/ penis & **bacculum**.

Estrogens & Ovulation

Ovulation triggered by a sharp rise in estrogens



Estrogen rise and female reproductive behavior (Estrus)

- **Proceptive behavior**: "flirting" — advertising sexual state
- **Receptive behavior**: "in heat" – attentive to male courting
- **Conceptive behavior**: accepting copulation

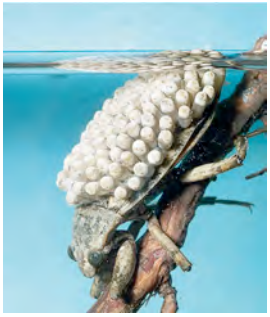
Oviparity: Egg Laying

- Yolk w/ protein & fats
  - – Energetically *very* expensive!
- Protective Coating
  - – jelly-like substance in aquatic forms
  - – earthworm's cocoon
  - – horny egg case of some sharks
  - – calcareous or leathery shell of birds & reptiles

Continued Parental Investment

- Nest guarding
- Brooding

- **Resource allocation**
  - – Less energy spent on egg production
  - – Use energy insuring development of fewer offspring
  - – Often, females spend energy on egg production
  - – Males do the parental care



Ovoviviparity: Retain Eggs Internally

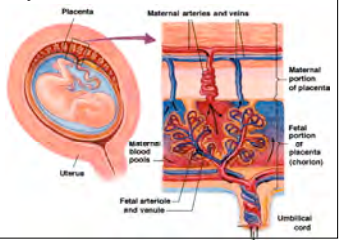
- "Mobile nest"
- Keeping eggs warmer speeds development.
  - – Cold climate reptiles retain eggs rather than laying them.

Dogfish shark "candle" from female's uterus

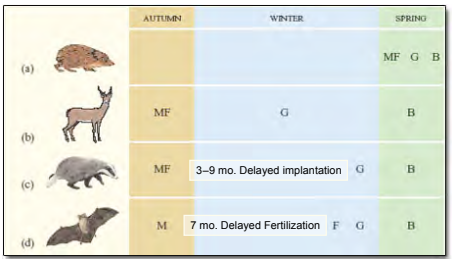
"Candle" opened to show small embryos with large yolk

Viviparity: Maternal Nourishment

- Maternal Nourishment
  - Spreads maternal energy demand over longer time period
  - Allows embryo to grow beyond original egg size
- **Placenta** connects embryo to mother for nutrition & gas exchange.
  - Placental mammals
  - Reptiles (rattlesnakes & sea snakes)
  - Fish (sharks, guppies, surf perch)



Delayed Fertilization & Delayed Implantation



- How the reproductive cycles of four mammals native to Britain are related to the winter.
  - Figure 1.2 Reproductive cycles of (a) hedgehog, (b) red deer, (c) badger and (d) noctule bat, in relation to the winter.
  - M=mating; F=fertilization of the egg(s); G=gestation; B=birth.

Aphids — a little bit of everything!

1. .**Asexual** (parthenogenic) **viviparity**
   - And "telescoping generations" (born pregnant!)
2. Seasonally alternating with a dioecious generation having:

Sexual oviparity

•Parthenogenic live birth (all females)
•And the baby being born already has a baby!

Aphids — a little bit of everything!

- Aphid yearly cycles

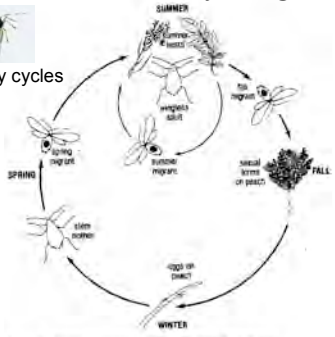
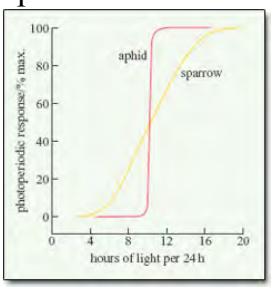


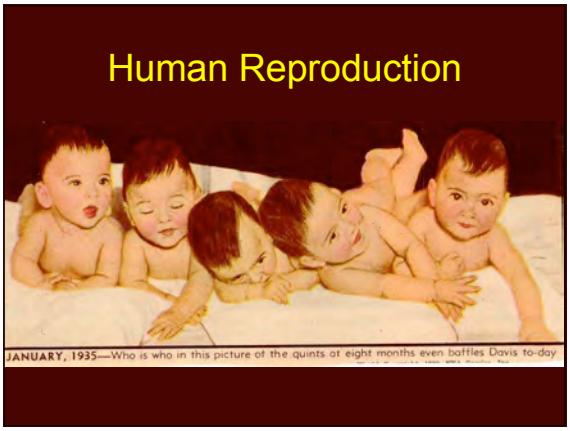
Figure 26. Seasonal population cycle of green peach aphid in areas with cold winters.

Photoperiod & Seasonal Sex

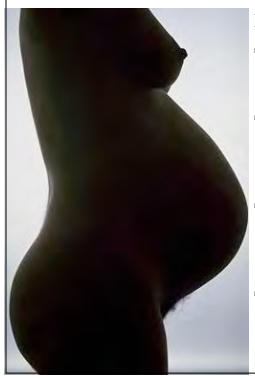


- Figure 1.1 Critical photoperiodic responses in two species: transition from sexual to asexual reproduction in the vetch aphid (Megoura viciae) and testicular development in the white-crowned sparrow (Zonotrichia leucophrys).

Human Reproduction



Human Reproduction



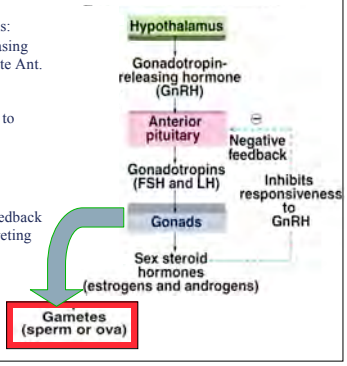
Reproductive Anatomy

- Gonads — make gametes
  - Female: ovaries — make ova
  - Male: testes — make sperm
- Sexual Accessories — ducts
  - Female: oviducts [fallopian tubes] / uterus / vagina
  - Male: epididymus / vas deferens
- Genitalia — external
  - Female: clitoris / labia minora / labia majora
  - Male: penis / scrotum
- Secondary sexual characteristics
  - Female: enlarged breasts & mammaries / broad pelvis / ↑cutaneous fat
  - Male: ↑muscle & skeletal mass / beard

Feedback Control of the Anterior Pituitary

Sex hormones & gametogenesis:

1. Hypothalamus secretes releasing homone (GnRH) to stimulate Ant. Pituitary.
2. Ant. Pituitary secretes gonadotropins (LH & FSH) to stimulate gonads to:
   1. Grow & mature
   2. Secrete sex steroids
   3. **Make gametes**
3. Sex steroids from gonads feedback to inhibit pituitary from secreting more gonadotropin.



Onset of Puberty

- FSH and LH secretion is high in newborn, but falls to low levels in few weeks.
- At puberty:
  - Brain maturation increases GnRH secretion.
  - Decreased sensitivity of gonadotropin to negative feedback.
- During late puberty, pulsatile secretion of LH and FSH increase during sleep.
  - Stimulate a rise in sex steroid secretion.

Spermatogenesis

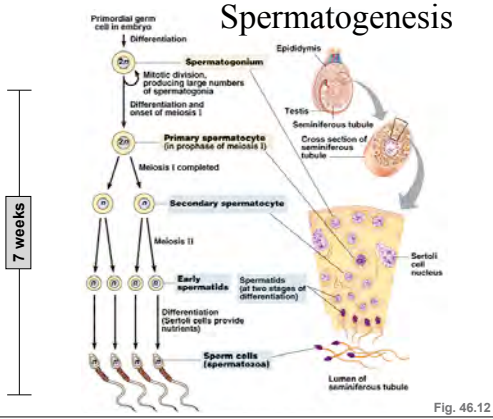
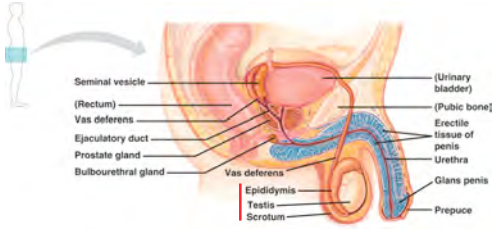


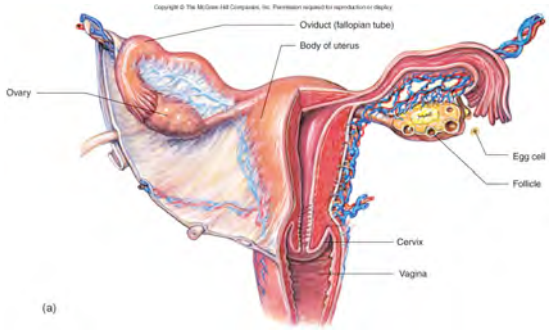
Fig. 46.12

Spermatogenesis



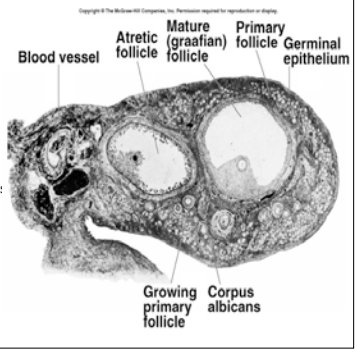
- From seminiferous tubules, sperm pass to **epididymis**
  - Mature for another 3 weeks
  - Become motile
  - Non-ejaculated sperm reabsorbed

Ovulation & Menstrual Cycles



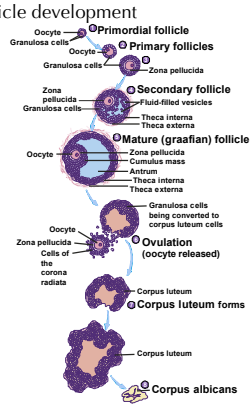
Ovarian Cycle

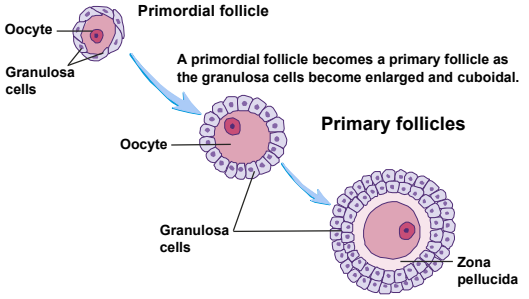
- At 5 mo. gestation, ovaries contain 6-7 million oogonia.
- Oogenesis of sex cells arrested in meiotic [sexual] division (primary oocyte).
- Most degenerate:
  - 2 million primary oocytes at birth.
  - 400,000 primary oocytes at puberty.
- 400 oocytes ovulated during the reproductive years.



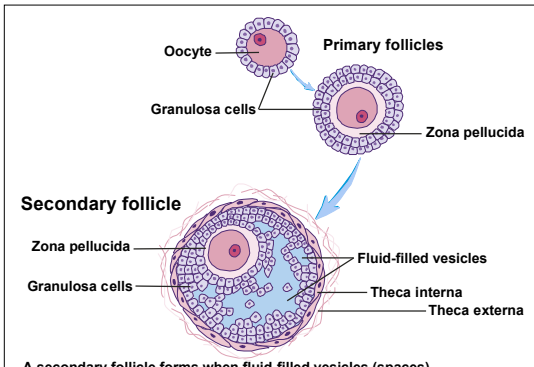
Ovarian follicle development

1. The primordial follicle consists of a primary oocyte surrounded by a single layer of squamous granulosa cells.
2. A primordial follicle becomes a primary follicle as the granulosa cells become enlarged and cuboidal.
3. The primary follicle enlarges. Granulosa cells form more than one layer of cells. The zona pellucida forms around the oocyte.
4. A secondary follicle forms when fluid-filled vesicles (spaces) develop among the granulosa cells and a well-developed theca becomes apparent around the granulosa cells.
5. A mature follicle forms when the fluid-filled vesicles form a single antrum. When a follicle becomes fully mature, it is enlarged to its maximum size, a large antrum is present, and the oocyte is located in the cumulus mass.
6. During ovulation the oocyte is released from the follicle, along with some surrounding granulosa cells of the cumulus mass called the corona radiata.
7. Following ovulation, the granulosa cells divide rapidly and enlarge to form the corpus luteum.
8. When the corpus luteum degenerates, it forms the corpus albicans.

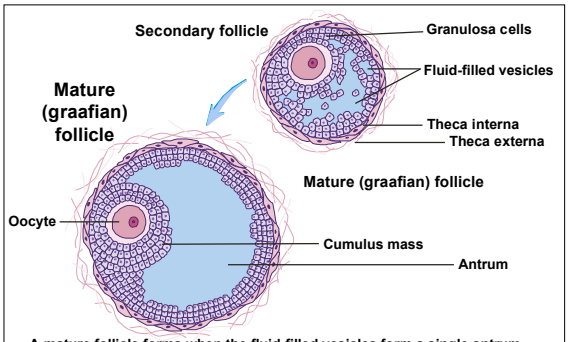




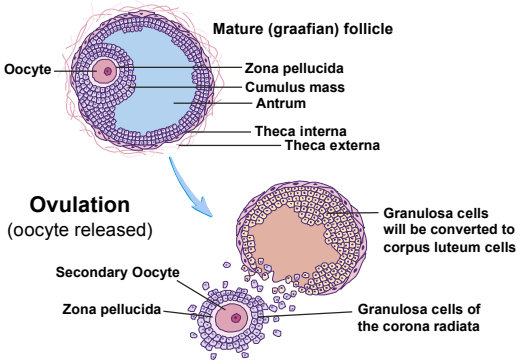
The primary follicle enlarges. Granulosa cells form more than one layer of cells. The zona pellucida forms around the oocyte.



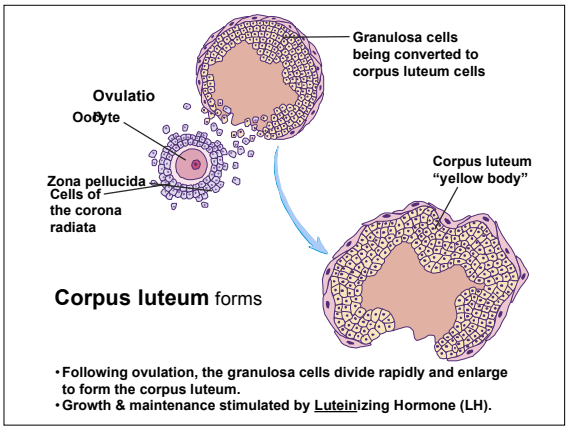
A secondary follicle forms when fluid-filled vesicles (spaces) develop among the granulosa cells and a well-developed theca becomes apparent around the granulosa cells.

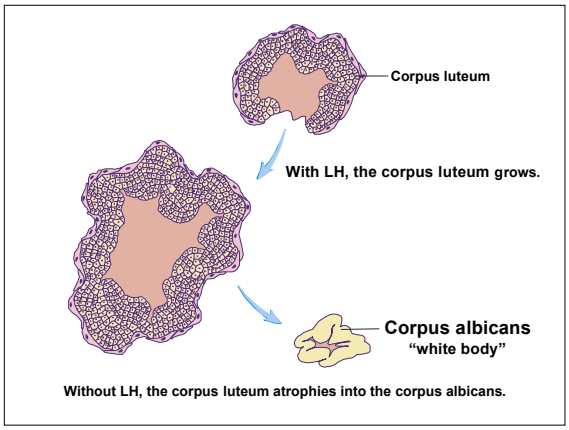


- A mature follicle forms when the fluid-filled vesicles form a single antrum. When a follicle becomes fully mature, it is enlarged to its maximum size, a large antrum is present, and the oocyte is located in the cumulus mass.
- At this stage the oocyte finally completes its first meiotic division to form a haploid secondary oocyte. It them arrests at metaphase 2.

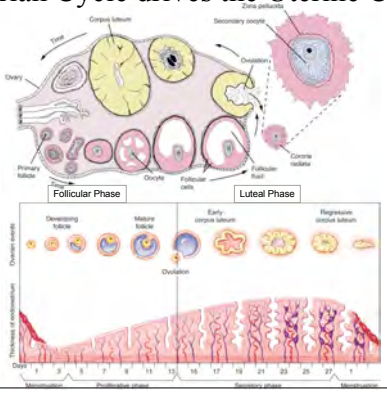


During ovulation the oocyte is released from the follicle, along with some surrounding granulosa cells of the cumulus mass called the corona radiata.

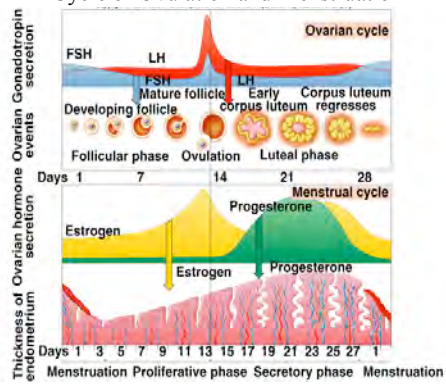




Ovarian Cycle drives the Uterine Cycle



Cycle of Ovulation and Menstruation



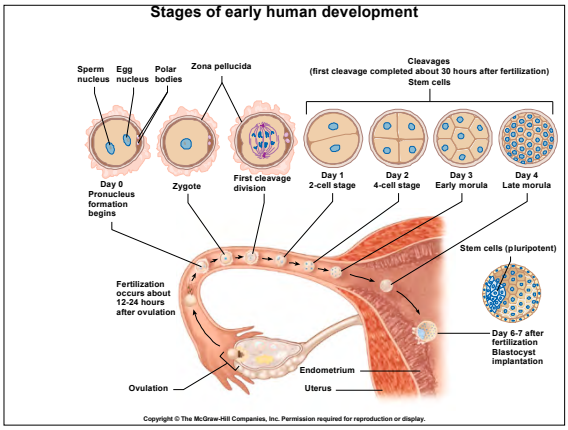
Menstrual Cycle

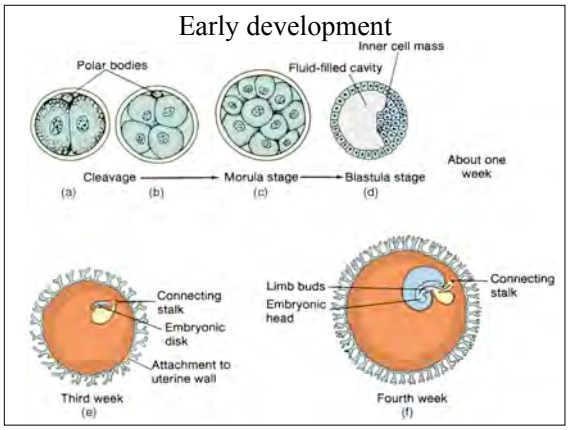
Table 20.6 Phases of the Menstrual Cycle

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 of endometrium (due to progesterone stimulation)

Menstrual vs. Estrous Cycles

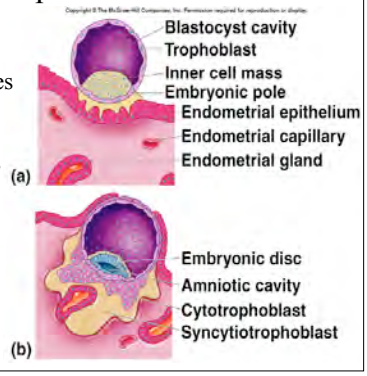
- Human – menstrual ("monthly) ~28 days
  - **Day 1 = first day of menses**
  - **Menses → follicular phase → luteal phase → menses**
- Non-human mammal – estrous cycle
  - Length varies by species
  - Less endometrial thickening – reabsorbed instead of shed
    - No menses
  - **Day 1 = first day of estrus**
  - **Estrus → luteal phase → follicular phase → estrus**

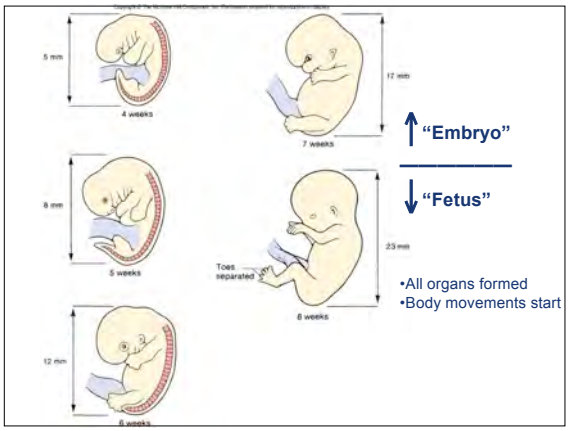




Implantation

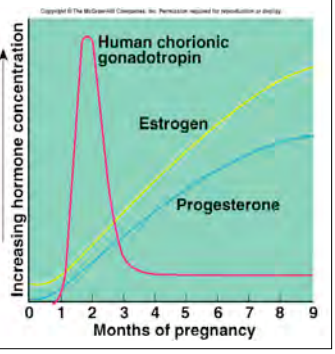
- 6th day after fertilization, blastocyst attaches to uterine wall.
- Trophoblast cells produce enzymes that allow blastocyst to burrow into endometrium.





hCG (Human Chorionic Gonadotropin)

- Trophoblast (chorion) cells secrete hCG:
  - Produces effects similar to LH.
  - Signals corpus luteum not to degenerate.
  - Prevents immunological rejection of implanting embryo.
  - Has thyroid-stimulating ability.
- Basis of pregnancy test.
- Once placenta forms and produces sex steroids, corpus luteum no longer needed.

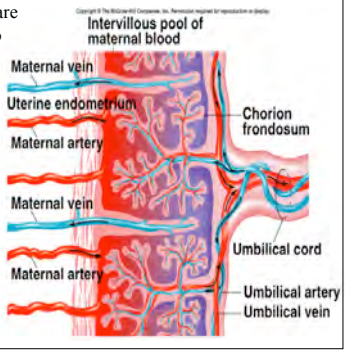


Formation of the Placenta

Maternal and fetal blood are brought very close, but do not mix.

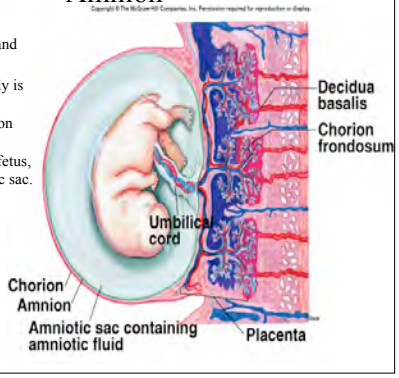
Placental Functions:

- Gas exchange
- Nutrient exchange
- Waste exchange
- Immune rejection protection
- Synthesizes hormones & enzymes



Amnion

- Envelop the embryo and umbilical cord.
- Amniotic fluid initially is isotonic, but as fetus develops; concentration changes by urine and sloughed cells of the fetus, placenta, and amniotic sac.



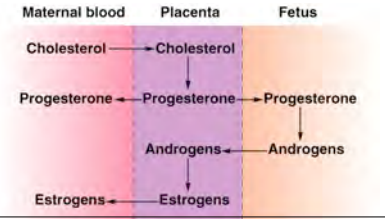
Other Placental Hormones

- hCS (chorionic somatomammotropin):
  - Causes diabetic-like effect:
    - "Glucose sparing" effects by maternal tissues.
      - Ensure sufficient supply of glucose for placenta and fetus.

Other Placental Hormones (continued)

Sex steroids — replace role of corpus luteum

1. Estrogens — from fetal-placental unit
   - Placenta uses androgens from fetal adrenal cortex as precursors for estriol.
2. Progesterone



Other Placental Hormones (continued)

Sex steroids — replace role of corpus luteum

1. Estrogens — from fetal-placental unit
   - Placenta uses androgens from fetal adrenal cortex as precursors for estriol.
2. Progesterone

- Enlargement of mother's uterus and endometrial growth, but inhibit contractions.
- Growth of mammary glands & ducts, but inhibit prolactin secretion (milk production).
- Suppresses LH and FSH (stop ovulating).

Parturition

- Estrogen in late pregnancy:
  - Stimulates production of oxytocin & prostaglandin receptors in myometrium.
  - Produces gap junctions between myometrium cells in uterus.
- Factors responsible for initiation of labor are incompletely understood.

BIRTH CONTROL

BIRTH CONTROL

EFFECTIVENESS

- Measured by number of unwanted pregnancies per 100 females per year
- Theoretical effectiveness rate
  - Rate if used consistently and correctly
  - Seldom achieved
- Actual effectiveness rate
  - Rate actually achieved
  - Improves with practice
- No birth control - 85 pregnancies per 100 females per year

BIRTH CONTROL

TYPES OF METHODS

1. Prevent gametogenesis ("making gametes")
2. Prevent fertilization
3. Prevent implantation
4. Prevent gestation

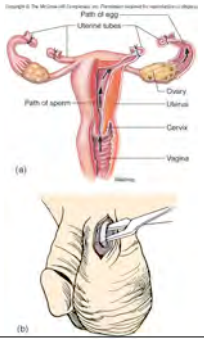
BIRTH CONTROL

PREVENTING PRODUCTION OF GAMETES

- Castration (!)
- Prevent ovulation by simulating pregnancy with sex steroids
  - (negative feedback on FSH)
  - Birth control pills
  - Combination pills
  - Norplant
- Male pill?

BIRTH CONTROL

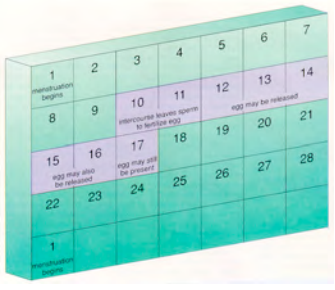
PREVENTING FERTILIZATION



- Sterilization
  - Vasectomy
  - Tubal ligation
- Barrier methods
  - Condom
  - Diaphragm
  - Spermicides

BIRTH CONTROL

PREVENTING FERTILIZATION NATURAL METHODS



- Rhythm method
- Withdrawal
  - Coitus interruptus

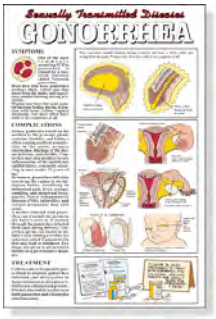
BIRTH CONTROL

PREVENTING IMPLANTATION

- Intra Uterine Device
- Morning After Pills

SEXUALLY TRANSMITTED DISEASES

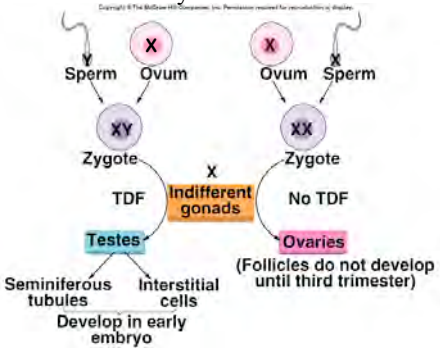
- STDs are contagious diseases
- Spread by sexual contact
- Bacterial
  - Chlamydia, Gonorrhea & Syphilis
- Viral
  - Genital herpes, Genital warts
  - HIV - AIDS
- Protozoan
  - Trichomoniasis
- Fungus
  - Candidiasis



PREVENTING THE SPREAD OF STDs

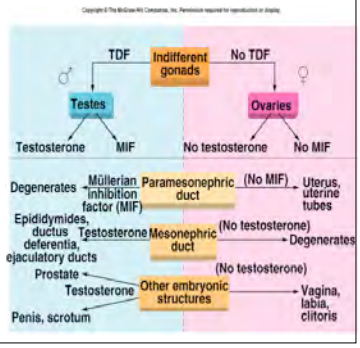
- Abstinence
- Monogamy
- Latex condoms

Chromosomal Sex and Development of Embryonic Gonads

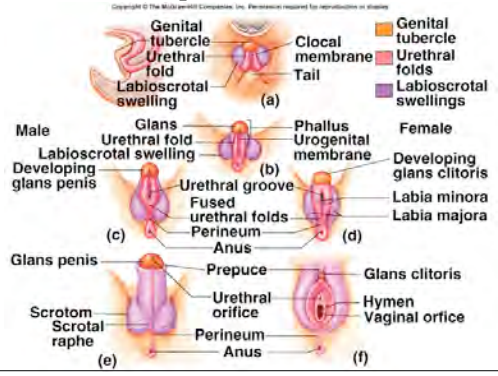


Development of Accessory Sex Organs and Genitalia

- Presence or absence of testes determines the accessory sex organs and external genitalia.
- Male accessory organs derived from wolffian ducts.
  - Sertoli cells secrete MIF (müllerian inhibition factor).
- Female accessory organs derived from mullerian ducts.



Development of Genitalia



Disorders of Embryonic Sexual Development

- Hermaphroditism:
  - Both ovarian and testicular tissue is present in the body.
- Pseudohermaphrodite:
  - Individual with either testes or ovaries but not both.
    - Have accessory sex organs and external genitalia that are incompletely developed or inappropriate.
    - Most common cause of female pseudohemaphroditism is congenital adrenal hyperplasia.
    - In the male, one cause is testicular feminizing syndrome:
      - Normal functioning testes, but lack receptors for testosterone.