Reproductive System

**Function:** producing offspring

- propagation of the species
  - in terms of evolution
    - the only reason all the other systems exist

Only major system that doesn’t work continuously
- only activated at puberty

Unlike most other organisms on planet
- mammals only reproduce sexually

Humans are dioecious
- separate sexed (many animals are monoecious or hermaphrodites)

In 7th week of embryonic development genes are activated that trigger differentiation of gonads

Anatomy of Male Reproductive System

**Major Organs**

**External Reproductive Organs**
- penis and scrotum

**Internal Organs:**
- these structures form continuous tube:
  - **Testes**
    - epididymus
    - vas deferens
    - ejaculatory duct
    - urethra in penis

**Accessory organs**
- seminal vesicles
- prostate gland
- bulbourethral glands

1. **Penis and Scrotum**

   **penis** is transfer organ
   - glans ➔ expanded head
   - prepuce ➔ foreskin
     - both have modified sebaceous glands that produce waxy secretion = smegma

   **scrotum** keeps testes at cooler temperature
   - sperm can only be produced at several degrees below normal body temp

2. **Testes (=testicles)**

   **primary reproductive organ of male**
   - testis enclosed by white fibrous **capsule**
   - interior is divided into several hundred **lobules** divided by **septa**
     - each lobule contains:

   **a. seminiferous tubules**
   - (700’ of seminiferous tubules in testes)
     - functions in **spermatogenesis**:
       - formation and maturation of sperm cells
         - in cross section:
           - seminiferous tubules appear roughly circular
             - and contain **germinal epithelium** (containing germ cells) and **sustentacular (Sertoli) cells**
           - Sertoli cells protect germ cells and promote their development
   b. **interstitial cells**
   - are scattered between the seminiferous tubules
     - function in **hormone secretion**
       - testosterone
         1. development and maintenance of secondary sexual characteristics
         2. stimulates protein synthesis
         3. promotes growth of skeletal muscles

3. **Epididymis**

   **epididymis** is highly coiled, 18’ tube that sits outside of testes
takes sperm about 20 days to make their way through the epididymus

when sperm enter epididymis they are immature, nonmotile and incapable of fertilization

\[ \text{epididymis is a site of maturation} \]

then are stored until "duty calls"

stored sperm remain fertile for 40-60 days

older sperm disintegrate and are reabsorbed by epididymis

4. **Vas Deferens (=Ductus Deferens)**

a long muscular tube leading from epididymis in scrotum, through the **inguinal canal** into the **pelvic cavity** and around the posterior side of the **bladder** where it unites with ducts from the **seminal vesicles**

5. **Ejaculatory Duct**

ducts from seminal vesicles join vas deferens to form a short ejaculatory duct that passes through the **prostate gland** and joins the urethra

6. **Urethra**

ejaculatory duct connects with urethra inside the prostate gland

urethra opens to outside via the **penis**

**Accessory Organs**

three accessory glands secrete fluids that mix with the sperm

= **semen**

1. **Seminal Vesicles** (paired)

pair of glands dorsal to bladder, each ~5 cm long

secrete viscous yellowish liquid rich in fructose, prostaglandins and other nutrients that comprises ~60% of the semen

fructose serves as energy source for sperm

2. **Prostate Gland** (single)

inferior to bladder, ~3 cm diameter (size of golf ball)

surrounds ejaculatory duct at junction with urethra

resembles a sponge; walls have >30 orifices

secretes a thin, milky, liquid that contains citric acid, calcium and various enzymes and constitutes ~30% of the semen

this buffered solution (pH~6.5) protects sperm from the acidity of male urethra and female vagina

by age 70, most (90%) of men show some degree of benign prostatic hyperplasia

\[ \rightarrow \text{can compress urethra, slow urine flow, promote bladder and kidney infections} \]

3. **Bulbourethral Glands** (paired)

small (~1cm) pea-shaped glands below prostate

during sexual arousal they produce a clear, slippery fluid that lubricates the head of the penis in preparation for intercourse

also protects sperm by helping to neutralize the acidity of residual urine in urethra

during arousal some of this fluid may appear at tip of penis and may contain sufficient sperm to fertilize the egg even without actual ejaculation

**Anatomy of Female Reproductive System**

**External Reproductive Organs:**

vulva

mammary glands

**Internal Organs**

ovaries

oviducts

uterus

vagina

1. **Vulva**

group of structures at external opening of vagina

mons pubis

labia majora

labia minor

clitoris (homologous to male penis)

Bartholins gland (for lubrication, homologous to bulbourethral glands in males)

functions:

sensory arousal

glands for lubrication

2. **Breasts (Mammary Glands)**

nutrient rich food for nursing infant
in developing countries often the best meals a person gets in his/her lifetime
→ diseases associated with cessation of nursing

each breast consists of several lobes of secretory cells embedded in connective tissue
ducts from individual glands unite to form single duct
→ duct exits through nipple

3. **Ovaries**
cortex of ovaries are covered by layer of small epithelial cells = **germinal epithelium**
below this layer 1000's of **follicles** develop
embedded in connective tissue matrix
within follicles are partially developed **egg cells**

ovaries perform two major functions:

1. **oogenesis**
   immature **egg cells** in ovary mature into ova ready for fertilization

2. **hormone secretions**

**follicle cells** in ovary secrete mainly **estrogen** and **progesterone**

4. **Uterine Tubes** (=oviducts, fallopian tubes)
open at one end to receive the egg at ovulation
opening is enlarged and partially surrounds ovary
feathery projections = **fimbriae**

fibriae, activated by hormones just before ovulation
→ become filled with blood
→ brush swollen follicle at ovulation
→ draw egg into oviduct

ciliated along its length and muscular wall to move egg down to uterus

takes 3-4 days for egg to travel ~5”
fertilization occurs here

5. **Uterus**
a thick pear-shaped, muscular organ
subdivided into:

- **fundus** = upper portion
- **body** = mid portion
- **cervix** = lower portion that extends into the vagina

receives egg from oviduct
→ if fertilized, holds embryo and fetus during development

3 layers:

- **epimetrium** (=perimetrium, =visceral peritoneum)
→ serous tissue

- **myometrium**
→ muscle layers

- **endometrium**
→ inner mucous lining

ovaries and other internal reproductive organs are held in place by several connective tissue

ligaments:

some are mainly extensions of peritoneum

- **eg. ovarian ligament** → connects ovary to uterus
- **eg. suspensory ligament** → connects ovary to pelvic wall
- **eg. broad ligament** → encloses uterine tube and connects it to sides of uterus
- **eg. round ligaments** → fibromuscular cords that help hold uterus in place

6. **Vagina** (birth canal)

leads to outside of body
muscular tube
wall is thin but very distendable
mucosa secretes lubricating fluid during sexual arousal

at its lower end, mucosa folds inward and forms a membrane = the **hymen**
which is ruptured by strenuous activity, insertion of tampons as menstrual cycle begins or first intercourse

not connected to urethra
**Physiology of Male Reproductive System**

The anterior pituitary gland serves as the primary control of reproductive function at puberty. Ant Pituitary secretes FSH & large amounts of LH (ICSH)

FSH & LH -> cause testes to increase in size and begin sperm production

LH -> triggers interstitial cells to produce testosterone

The secretion of FSH and LH is fairly constant from day to day in males.

Male hormone (=androgens) are secreted mainly by interstitial cells of testes.

Main male hormone is Testosterone.

There are two male hormones:
- Testosterone
- Androstenedione

Additional testosterone is secreted by Adrenal Cortex.

**Testosterone functions:**
1. Local effects on sperm development in seminiferous tubules
2. Stimulation of general protein synthesis
3. Promotes muscular development, bone growth, thickening of skin and growth of facial and body hair
4. Development and maintenance of secondary sexual characteristics
   - Hair pattern
   - Thickening of vocal cords and enlargement of larynx to lower of voice pitch
5. Behavioral changes (~ sex drive, aggression, courtship behaviors)

Androgens are also produced in women ovary & adrenal cortex.

Promotes protein synthesis, growth, not masculinizing.

Negative feedback loop maintains constant level of testosterone in blood:

> High testosterone levels inhibit LH

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**Spermatogenesis**

Process of sperm production.

> Process takes ~ 70-80 days

Sperm are produced in seminiferous tubules.

**Sertoli Cells** = specialized cells in the seminiferous tubules facilitate spermatogenesis.

1. Produce a blood-testes barrier.
   - Forms just before puberty.
   - Protects developing sperm cells from certain proteins, hormones, ions and drugs that might damage sperm cells.
   - Also keeps sperm from diffusing into the blood.
   - Mature sperm are very immunogenic.
2. Nourish developing sperm cells.
   - They secrete fluid rich in proteins, enzymes and testosterone into the seminiferous tubules.
3. Also phagocytize any damaged sperm cells.

Sperm develop from a type of stem cell = spermatogonia.

**Steps of spermatogenesis:**
1. During prenatal development, primordial germ cells colonize embryonic gonad and become spermatogonia.
young adult male produces ~300,000 sperm/minute; 400 Million/day
by the time spermatozoa form they are near the lumen of the seminiferous tubules
spermatozoa are released and washed down the tubule

Spermatozoan Structure
composed of a head, midpiece and tail

a. head
long "pear" shaped
tip = acrosome – thin lysosome that caps the head
contains enzymes that will be used to penetrate the egg & enzyme inhibitors

b. midpiece
cylinder that contains numerous mitochondria
produce the ATP needed for propulsion

c. tail
bundle of filaments = flagellum
only cell in body with flagellum
means of locomotion

Semen (=seminal fluid)
mixture of sperm and glandular secretions
typical discharge is 3 – 5 ml
~10% is sperm (200-300 M sperm cells) and fluids from spermatic ducts
30% prostatic fluid
60% fluid from seminal vesicles
trace from bulbourethral glands
today sperm count in healthy young male:
average ~60M sperm/ml
ranges between 40-120M sperm/ml
is highly variable
a sperm count lower than 35 M/ml is usually associated with infertility
[20 yrs ago(1980's) count was 90-100M/ml]
environmental factors can affect sperm production or damage sperm cells:
overcrowding
smoking
stress
radiation
poor nutrition
modern clothing (tighty whites)
pollution

The Aging Male Reproductive System
fertility and sexual function decline with age
due to declining levels of sex hormones
~ age 50 men go through a period of physical and psychological change = climacteric
in males, testosterone secretion peaks at 20 then declines steadily to only ~20% of peak level by age 80

Effects of male’s age on fertility
takes 32 months on average for a 50 year old to father a child compared with 6 months for a man under 20
children of older dads are also more likely to have chromosomal disorders (though risk rises slower with fathers age than with mothers age)
older men are also more likely to father children with autism, epilepsy or schizophrenia

Physiology of Female Reproductive System
the major female reproductive processes:

a. hormone secretion by ovary

b. development of follicle cells surrounding egg

c. oogenesis & ovarian cycle
maturation of egg

d. menstrual cycle
development & shedding of uterine lining

the maturation of the egg, ovulation, hormone production and preparation of uterine lining are all cyclic events
not continuous as in males
these cycles are roughly 28 days long and have different names depending on the process in focus

Hormone Production
Ant Pituitary begins secreting small amounts of
FSH & LH at ~7-8 yrs old

FSH & LH production increases until ~11-13 yrs old = Puberty

→ triggers menstrual cycle & development of secondary sex characteristics

→ stimulate follicle cells in ovary to begin secreting estrogen & progesterone

Estrogen functions:
1. development and maturation of reproductive tract
2. development and maintenance of secondary sexual characteristics
   → change in fat distribution
   → enlargement of mammary glands
   → inhibits growth of extremities

Estrogen concentration in women peaks at puberty

→ this tends to inhibit GH

→ growth slows

Male androgens don’t have this inhibitory effect on growth

3. behavioral changes (= sex drive, courtship behaviors)

Progesterone functions:
1. has its greatest effect on estrogen primed tissues
2. changes that favor pregnancy and lactation
   → endometrial thickening

Development of Follicle Cells

a. Primary Oocyte

within the ovary immature egg cells = primary oocytes are enclosed within primordial follicles

each month secretions of FSH stimulates some of these to develop into primary follicles

mitosis & development of these cells

→ they begin to produce estrogens

b. Graaffian Follicle

by 10 days or so only one primary follicle remains and has matured into a mature follicle (= graffian follicle)

mature (graffian) follicle contains egg surrounded by fluid filled antrum

→ this is the follicle that will ovulate

c. Corpus Luteum

after ovulation, the follicle collapses and becomes the corpus luteum

→ secretes large amounts of progesterone

development of mammary glands

Oogenesis

egg maturation begins in the fetus

in fetus, immature egg cells (= oogonia) multiply by mitosis until 5th month of gestation

→ to produce 6 to 7 million germ cells which develop into primary oocytes

most of these degenerate before birth

→ at birth only ~2 million primary oocytes remain

more degenerate until at puberty ~400,000 remain

→ this is the woman’s lifetime supply for egg production.

→ of these ~400 mature in a woman’s lifetime

during reproductive years, 10-20 primary oocytes and follicles begin to develop each month.

normally just one of these reaches maturity and ovulates and the rest degenerate

as follicle cells develop, egg develops within under influence of FSH & LH from Ant. Pituitary

egg undergoes meiosis but stops as secondary oocyte (metaphase II) until fertilization

when woman reaches menopause (~50 yrs) very few primary follicles are left in ovaries

The Ovarian & Menstrual Cycles

a. follicular or proliferative phase

days 1 - 6; lasts ~6 days

→ a single follicle matures

→ as follicle develops it secretes increasing amounts of estrogen

→ endometrium cells proliferate

b. ovulatory phase

days 6 - 10; last ~ 5 days

→ ovulation = release of mature egg from ovary

c. luteal or secretory phase

days 10 - 23; lasts ~11-13 days

→ follicle cells left behind after ovulation develop into corpus luteum

→ corpus luteum secretes increasing amounts of progesterone

progesterone production raises basal body temperature .5 – 1.0º F during luteal phase

egg antrum Graffian Corpus Corpus

nest → follicle → develops → follicle → ovulation → Luteum → Albicans

d. Corpus Albicans

corpus albicans = scar tissue
continued increase in development of endometrium

d. menstrual phase

days 23 - 28; lasts ~5-6 days
uterine endometrium is shed = menstruation

Mammary Glands

during pregnancy breast development is stimulated by estrogen and progesterone secreted by placenta

at birth shedding of placenta
«cuts off source of these hormones
«stimulates Ant. Pit. to secrete prolactin

Prolactin stimulates lactation (devel of milk in glands)
usually takes several days for full milk production

Suckling of infant further stimulates secretion of prolactin

oxytocin (from Post. Pituitary)
«promotes ejection of milk into ducts
«feedback: more suckling → more milk released

The Aging Female Reproductive System

women’s fertility window

age affects success of pregnancy:
under 25: the younger, the higher the risks for mother and child
25-35: the best decade to reproduce
35-45: risks rise rapidly; for many women over 40 IVF with donor eggs is safest option

may be accompanied by headache

hormonal changes may also cause mood changes

female climacteric is accompanied by menopause
the cessation of menstruation and end of fertility

menopause usually occurs between ages 45 and 55 (ave=52)

45-55: difficult; IVF required
over 55: still very rare, uses donor eggs

~ age 50 women go through a period of physical and psychological change = climacteric

women also experience menopause at about the same time

female climacteric is brought about by declining ovarian function

generally begins when ovaries are down to their last 1000 eggs or so

the follicles and ova that are left are less responsive to gonadotropins

follicles therefore secrete less estrogen and progesterone

the uterus, vagina and breasts atrophy, bone mass declines

vagina becomes thinner and drier:
intercourse may become uncomfortable
vaginal infections are more common

blood vessels constrict and dilate in response to shifting hormone balances
«sudden dilation of cutaneous arteries may cause hot flashes
may occur several times a day

Birth Control Methods

Condoms

earliest records “condom use” were in 1359 BC when Egyptian men wore sheaths over their penises for decoration

evolved into early condoms which were made of linen or sheep caecum; very expensive

Birth Control Pills, Patches, Shots, Implants, Vaginal Rings

generally safe, effective and convenient

easy to get with prescription, relatively low cost

most consist of a combination of two hormones; estrogen and progestin; others just progestin

the daily dosages given prevent ovulation so there is no egg to be fertilized by the sperm

Shots & implants work in a similar way but without the need to remember each day

Sponges, Diaphragms, Cervical Caps, Female Condoms

cover or block the cervix
some also release spermicides

**IUD’s**

block sperm from reaching egg

some also have progestin to prevent ovulation

they are effective for 5 to 12 years depending on brand

**Rhythm Method**

only form of birth control condoned by the Catholic Church

abstain from sex during a woman’s fertile period

estimated to be 90% effective

more likely to cause conceptions outside the fertile period,

as egg become less viable, they are more likely to produce abnormal embryos that are not viable

people concerned about embryonic death should be aware that these effects are more frequent in women practicing the rhythm method than in women having random unprotected sex

millions of people worldwide using the rhythm method results in more embryonic deaths than a policy of practicing condom use & having abortions in case of condom failure

**The Morning After Pill (RU-486)**

also called the abortion pill

used to prevent pregnancy up to 5 days after unprotected sex

in high doses progesterone receptor moderators (PRM’s) like mifepristone (RU-486) terminate an early pregnancy by halting development of the placenta

in smaller doses could also combat endometriosis, fibroids and even brain cancers since they block the action of progesterone

PRM’s would also stop periods all together which could reduce the incidences of breast cancer

In April, 2013, it was ruled that it could be bought over the counter with no age restrictions (still not in effect though)

**Vasectomies and Female Sterilization**

generally reversible for men, permanent for women

requires surgery

**Male Hormonal Contraception**

experimental hormonal contraceptive based on testosterone may be applied as patch topical gel or injection

oral dose of testosterone is dangerous and may cause liver damage

the formation of egg and sperm require a different kind of cell division

**Meiosis**

most human cells contain 46 chromosomes

each chromosome contains several 100 genes (~500-600 genes/chromosome)

these genes are the instructions that must be passed on to new cells

most cells in the body are produced by **MITOSIS**

→ a type of cell division that produces genetically identical copies

each cell in your body has all genes for all instructions a human needs

the formation of egg and sperm require a different kind of cell division

**Meiosis**

each of our cells has 46 chromosomes – but they come in pairs

we have two of each kind of chromosome

or 23 pairs of chromosomes
→ 1 of each pair from mom; 1 from dad
the formation of egg and sperm require sex cells that have only one set of chromosomes
when the sperm cell fertilizes the egg then the fertilized egg has 46 chromosomes again
only sex cells (eggs and sperm) are formed by Meiosis
meiosis occurs during spermatogenesis and oogenesis
the process is similar to meiosis but with some important differences
in mitosis chromosomes replicate during interphase and the cell divides (PMAT) once to produce 2 identical cells each with 46 (23 pairs) of chromosomes
in meiosis chromosomes replicate during interphase as in mitosis, but then goes through two sets of cell divisions (PMAT) → (PMAT) to produce a total of 4 unique cells each with 23 chromosomes

Spermatogenesis
in the formation of sperm, the process works as above
4 functional sperm cells are produced from each primary spermatocyte

→ end up with 1 large cell and 3 small cells
the small cells (polar bodies) eventually degenerate and only a single functional egg cell is left

Oogenesis
egg cells are some of the largest cells in the body
the cytoplasm of the egg serves as nourishment during the earliest stages of development
after an egg is fertilized and begins dividing it takes about a week before the placenta begins to form
before that time the “preembryo” survives on food in the cytoplasm of the original cell
→ the larger the egg the more successful it will be in surviving this critical time
when an egg divides by meiosis the result is only one functional egg and three nonfunctional “polar bodies”
as the primary oocyte goes through meiosis the actual cell divisions are unequal
in the first division one cell is produced that is almost the same size as the original and a second cell containing almost no cytoplasm
in the second meiotic division the large cell divides again as above and the small polar body also divides

Disorders of Reproductive System
Males:

Hypogonadism
is present in 0.13% of males due to pituitary malfunction
symptoms:
retains juvenile physique
no secondary sex characteristics
voice remains high pitched
some feminizing traits
eg. arrangement of fat deposits characteristic of women
malfunction usually occurs before puberty but can be caused later by mumps or other inflammation

Hypergonadism
leads to excessive development of genitalia and secondary sex characteristics

Prostate Cancer
second most common cancer in men (after lung cancer)
affects ~9% of men over 50 yrs old
more common in american blacks than whites, rare among Japanese
often metastasizes to nearby lymph nodes and then to lungs and other organs

Erectile Dysfunction
about 20% of men in 60’s and 50% in 80’s experience erectile dysfunction (=impotence)
erectic dysfunction can also result from hypertension, atherosclerosis, medication, prostate surgery, diabetes mellitus and psychological causes

Pollutants have been implicated in dramatic effects especially on the male reproductive system
These pollutants are estrogen mimics called **endocrine disruptors** such as common herbicides, insecticides, industrial chemicals used in detergents and cosmetics.

Possible effects include:
- Declining fertility
- Increase in cases of undescended testes
- Reproductive abnormalities

Also correlated with:
- The rate of testicular cancer has tripled in the last 50 yrs
- A sharp drop (19%) in sperm count