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 dieocious
→ 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**

penis contains **erectile tissues** that surrounds the urethra

→ fill with blood during sexual arousal

corpus spongiosum (lower – surrounds urethra)
passes along ventral side of penis and encloses urethra

2 **coropora cavernosum** (upper)
on dorsal side

all contain numerous tiny blood sinuses = lacunae

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 on 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

→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 **eipdidymis** 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

→ 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. <u>Ovaries</u>

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. <u>Uterine Tubes</u> (=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 ovulatioin
→ 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. <u>Uterus</u>

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. <u>Vagina</u> (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 **interstital 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

decrease in testosterone can cause sterility

2. stimulates 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
relatively weak
promotes protein synthesis, growth
not masculinizing

Negative feedback loop maintains constant level of testosterone in blood:

→high testosterone levels inhibit LH

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**

2. **spermatogonia** remain dormant in childhood

3. at puberty they begin to divide (mitosis)

4. some **spermatogonia** begin moving away from the wall of the tubule and enlarge to become **primary spermatocytes**

From this point on the cells will be undergoing **meiosis** and become genetically different from all other cells in body
→ they must be protected from immune system

tight junctions between **Sertoli cells** form a **blood-testis barrier**
→ prevents antibodies and other large molecules in the blood and intercellular fluid from getting to the germ cells

5. **primary spermatocyte** undergoes meiosis I to produce **secondary spermatocytes**

   chromosome # reduced by half (=haploid)

6. **secondary spermatocyts** undergo another division to produce **spermatids**

   one primary spermatocyte produces 4 spermatids

7. spermatids mature into sperm cells

   loss of excess cytoplasm
   growth of tail (=**flagellum**)

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 whities)
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

corresponding decline sperm count and libido

by age 65 sperm count is typically ~1/3rd of 20's

as testosterone and inhibin levels decline pituitary produces more FSH & LH

→ can cause mood changes, hot flashes and less often illusion of suffocation

most men pass through this stage with little or no lasting effects

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

involve a complex combination of several interdependent hormonal cycles

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 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

→ reproduction ceases

Development of Follicle Cells

a. Primary Oocyte

within the ovary immature egg cells = **primary oocyte**s 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 Follcile

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

mature (graafian) 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

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

egg nest → follicle → antrum develops → Graafian follicle → Corpus ovulation → Luteum → Corpus Albicans

d. Corpus Albicans

corpus albicans = scar tissue

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

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

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

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)

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

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 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

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

→ 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

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 matastasizes 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)

erectile 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