Unit 4 Lecture 12

THE REPRODUCTIVE SYSTEM

Reproduction is the process by which a species continues to survive. Genetic material is passed from one generation to the next through sexual reproduction. Offspring have a combination of genes from both patents. The primary reproductive organs are called gonads because they produce gametes (sperm cells in the male and ova in the female). Gonads also produce hormones. In addition to the primary sex organs are the secondary sex organs which transport, store the gametes, and accessory glands that produce materials that support the gametes.

Male Reproductive System

The function of the male reproductive system is to produce the sex steroid testosterone, to produce sperm (process is called spermatogenesis), and to deliver sperm to the female vagina. The testes (testicles) are a pair of oval glands located in the scrotum and are divided into 200-300 compartments called lobules by the tunica albuginea. Each tubule contains 1-3 seminiferous tubules. The seminiferous tubules produce:

- sperm cells,
- sustentacular (Sertoli) cells that support, protect, and nourish sperm cells and secrete inhibin (a hormone that helps regulate sperm production by inhibiting FSH), and
- Interstitial cells (cells of Leydig) which secrete testosterone.

Spermatogenesis is an ongoing process by which sperm are made and the chromosome number is reduced to (n) or the haploid number of chromosomes. Humans have 23 pairs or 46 chromosomes. Twenty-two pairs are homologous and are called autosomes. One pair (XY) is called the sex chromosomes and this chromosome determines the sex of the individual. Any individual having a Y chromosome is considered male. Therefore, it is the father of the individual that determines the sex of his offspring. Maleness is determined by activation of the SRY gene on the Y chromosome which codes for male sexual development during fetal development.

Meiosis is the process by which the gametes produce and receive the haploid number of chromosomes. The reason for this is to reduce the number of chromosomes in the offspring. Spermatogonia line the seminiferous tubules and contain 2n chromosomes (46 in humans). Spermatogonia differentiate into primary spermatocytes (2n) which then undergo two successive nuclear divisions (Meiosis I). In the chromosomes the DNA replicates and the 46 chromosomes move to the equatorial plane of the cell where they line up in pairs (synapses). Tetrad formation occurs enabling crossing over of genetic material on the chromatids. The result is two secondary spermatocytes (n),

but each chromosome is still made up of two chromatids attached by a centromere.

The second equatorial division (Meiosis II) takes place. The chromatids separate and each spermatid formed have 23 chromosomes. Each primary spermatocyte produces four spermatids. The spermatid develops into spermatozoa. This initial process takes 64 days to complete. Although not fully mature and able to swim, the sperm cell contains a head with an acrosome and nucleus, a midpiece with mitochondria, which produce energy for locomotion, and a long tail or flagellum that will propel the sperm once it fully matures. Complete maturation of the sperm takes another 12 days and occurs as the sperm are moved to the epididymis by the fluid that is secreted by the Sertoli cells. The function of spermatozoa is to fertilize an oocyte. About 300 million spermatozoa mature each day. They can survive in the female reproductive tract for up to 48 hours.

Hormones of the Brian-Testicular Axis

At puberty, gonadotropin-releasing hormone (GnRH) stimulates the pituitary gland to secrete FSH and LH (luteinizing hormone). FSH initiates the spermatogenesis and LH assists in spermatogenesis and stimulates testosterone production. In the male LH is often called interstitial cell stimulating hormone (ICSH). Testosterone is an androgen that controls the growth, development, and maintenance of the sex organs. In the male it stimulates bone growth, protein anabolism, and sperm maturation.

Testosterone also stimulates the development of male secondary sex characteristics and contributes to male sexual behavior and to the sex drive in both males and females. Although it is converted by neurons to estrogen, which is what directly affects behavior. Inhibin is a protein hormone secreted by the sustentacular cells that inhibits FSH thus helping to regulate the rate of spermatogenesis. As testosterone and inhibin levels decrease FSH and LH levels rise significantly after the age of 50 producing changes in the male called the male climacteric. Most men pass through this stage with little or no effect, but in a few cases there are mood swings, hot flashes, and illusions of suffocation similar to those of menopause.

Accessory male reproductive organs

Ducts

The duct system in the testes includes the seminiferous tubules, straight tubules and the Rete testis. Sperm leave the testes through efferent ducts and pass into the ductus epididymis (a twenty foot long duct) where sperm are stored and mature (become motile and fertile). Sperm can remain in the epididymis for about a month after which they are either expelled or reabsorbed.

The ductus (vas) deferens stores sperm or moves sperm from the epididymis to the urethra. During a vasectomy, a portion of the vas deferens is removed and the ends are tied. The vas deferens terminates at the ampulla of the ductus deferens. Ejaculatory ducts are found in the union of the duct from the seminal vesicle and the ductus deferens. They eject sperm into the prostatic urethra. The urethra serves as a passageway for both semen and urine and is composed of the prostatic urethra, the membranous urethra, and the spongy penile urethra.

Accessory sex glands secrete most of the fluid portion (seminal fluid) of semen. Seminal vesicles are a pair of glands that secrete an alkaline viscous component of the fluid. The seminal vesicles contribute about 60% of seminal fluid. Alkalinity of the fluid neutralizes the acidity of the female genital tract. Fructose in the fluid provides energy for the sperm. Prostaglandins contribute to sperm's motility and viability and fibrinogen causes semen to coagulate after ejaculation (affords a protection for sperm while in the vagina). The prostrate gland secretes a thin milky-like, slightly alkaline fluid (33% of fluid volume). Clotting enzymes activate fibrinogen and fibrinolysin breaks down the clot. The prostate gland may enlarge after 45 years old. A pair of bulbourethral glands secretes an alkaline substance that protects semen from acids in the urethra.

Semen is a mixture of spermatozoa and fluids from the accessory glands. Secretions provide fluid for movement, nutrients, and they neutralize the acid environment of the male urethra and the female genital tract. The average volume is 2.5-5cc with @ 50-150 million sperm per milliliter. If a male produces <20 million/ml, it means he is probably sterile. Semen contains an antimicrobial seminal plasmin that can destroy certain bacteria. Analysis of semen checks for volume, mobility, count, liquefaction, morphology, pH, fructose; it is always done in cases of infertility and after a vasectomy.

The scrotum is an out pouching of skin that supports the testes. It is located outside to body proper because sperm will die at the higher temperature inside of the body. The cremaster muscle elevates the testes during sexual arousal and on exposure to cold and relaxation of the moves the testes away from the body. In this way it regulates the temperature of the testes. The dartos muscle gives the scrotum a wrinkled appearance.

The function of the penis is to introduce spermatozoa into the vagina and to convey urine to outside of the body. Parts of the penis include a pair of erectile tissues called the corpora cavernosa and corpus spongiosum (contains spongy urethra) contain sinus tracts for blood. The root of the penis consists of the bulb, crura and the base of the corpus spongiosum. The distal end contains the glans penis, corona, external urethral orifice. Covering the glans penis is the prepuce or foreskin which may be removed during circumcision.

Male Sexual Response

Masters and Johnson divided intercourse into four. The phases are the excitement phase, the orgasm-emission phase (plateau), the orgasm-expulsion phase and the resolution phase. During the excitement phase visual, mental and other stimuli or physical stimulation of the genital region send impulses to the sacral region of the spinal cord. Efferent parasympathetic signals sent from the spinal cord cause:

- the deep arteries of the penis to dilate, erectile tissues of the penis engorge with blood allowing the penis to become erect
- the trabecular muscle of erectile tissue relaxes which allows the penis engorge with blood and to become erect
- the bulbourethral gland secretes bulbourethral fluid.

During the orgasm-emission phase, parasympathetic signals:

- the ductus deferens exhibits peristalsis; sperm are moved to the ampulla of the seminal vesicles which contracts moving the sperm into the urethra
- both the seminal vesicles and the prostate gland secrete their components of the seminal fluid

In the orgasm-expulsion phase semen in the urethra sends afferent signals to the spinal cord which sends afferent signals back causing

- the prostate and seminal vesicles to release additional secretions
- the internal urethral sphincter contracts forcing urine to remain in the bladder
- the bulbospongiosus and ischiocanernosus muscles contract causing the bulb and root of the penis to rhythmically compress and ejaculation to occur.

During the resolution phase efferent impulses cause

- the pudendal artery to constrict reducing blood flow to the penis,
- the trabecular muscles contract forcing blood from erectile tissues causing the penis to become flaccid.

Female Reproductive Organs

The functions of the female reproductive system are more complex than the male reproductive system. It is responsible for producing the sex steroid estrogen and the hormone progesterone. The female reproductive system also produces eggs, receives the sperm, and provides the optimal conditions for the development of the fetus.

The ovaries are a pair of glands homologous to the testes. They are supported in the body by a broad ligament that anchors the uterus to either side of the parietal peritoneum, the mesovarium, which is part of the peritoneum and attaches the ovaries to the broad ligament, the ovarian ligament that anchors the ovaries to the uterus, and the suspensory ligament that anchors the ovaries to the pelvic wall. Germinal epithelium covers the ovaries. The tunica albuginea is connective tissue immediately below the germinal epithelium.

Ovarian follicles consist of oocytes at various stages of development. A vesicular ovarian (Graafian) follicle is a large fluid filled follicle that contains an immature ovum. Its function is to secrete estrogen. The corpus luteum is a mature vesicular ovarian follicle that has released its oocyte (ovulation). The corpus luteum produces progesterone, estrogens, inhibin, and relaxin before degenerating into the corpus albicans. The functions of the ovaries are to produce and discharge a secondary oocyte and to secrete hormones.

At puberty the ovaries are activated by the gonadotropic hormones LH (luteinizing hormone) and FSH (follicle stimulating hormone). Oogenesis is the formation of a haploid ovum. In reduction division (Meiosis I), the oogonium develops into a primary oocyte (2n) during prenatal development. These do not complete meiosis until after the female reaches puberty. The primordial follicle is a primary oocyte surrounded by epithelial cells. One to two million primordial follicles are present at birth. Most degenerate till there are 40-400K at puberty.

Each month after puberty, FSH causes @20 primordial follicles to become primary follicles. Most degenerate but one primary oocyte undergoes meiosis which results in a secondary oocyte and a first polar body, each having (n) chromosomes. The secondary oocyte gets most of the cytoplasm, is surrounded by granulosa cells and the structure is now called a secondary follicle. The secondary oocyte starts Meiosis II producing another polar body and a larger cell that develops into an ovum. Meiosis II is completed after fertilization. The first polar body can also divide producing two more polar bodies that disintegrate.

It is important to note that oogenesis results in the production of only one viable oocyte, unlike spermatogenesis where millions of sperm are produced. As the follicle grows, the production of estrogen from the ovaries begins to increase dramatically, causing the granulosa cells of the follicle to grow and produce even more estrogen. Rather than feeding back to the hypothalamus and pituitary to decrease the release of luteinizing hormone (LH) and follicle stimulating hormone (FSH), this increased estrogen causes a positive feedback, dramatically increasing the levels of FSH and particularly LH. This "LH surge" causes the granulosa cells to secrete large amounts of fluid into the antrum, causing it to swell, rupture, and expel the egg. The egg will then be gathered by the fimbriae into the fallopian tube. The mature follicle then degenerates into the hormone releasing corpus luteum. The corpus luteum

will degenerate into the corpus albicans (not shown) if pregnancy does not occur.

The production of estrogen by the ovaries requires the uptake of cholesterol by the theca cells. LH stimulates the theca cells to convert the cholesterol into the hormone androstenedione (a hormone that has testosterone-like effects). A small amount of androstenedione is converted to estradiol by the theca cells and released into the adjacent granulosa cells. FSH stimulates the granulosa cells to convert the androstenedione into estradiol, which is then secreted into the blood.

Estradiol (estrogen) levels vary through the menstrual cycle. Progesterone is produced in small quantities by both the granulosa cells and the theca cells before ovulation. Luteinizing hormone stimulates both of these cells to produce the progesterone. After ovulation of the oocyte, the follicle degenerates into the corpus luteum. The corpus luteum will continue to secrete both estrogen and progesterone.

After ovulation, when the mature follicle degenerates into the corpus luteum, it continues to secrete estrogen and large amounts of progesterone in order to prepare the lining of the uterus for the implantation of the fertilized egg. Should the egg fail to be fertilized, the corpus luteum will develop into scar tissue called the corpus albicans. Progesterone levels will also vary during the menstrual cycle.

Uterine (Fallopian) tubes are the oviducts that conduct the ovum to the uterus. If fertilization occurs, it usually does so here. The structure consists of an infundibulum, a funnel shaped opening to the ovaries and fimbriae, fringe on the infundibulum. The ampulla of the uterine is the wide portion of the tube and is about 2/3 of the length of the tube. The isthmus is the short portion that attaches to the uterus. Ciliated epithelial cells that line the inside of the tube help move the ovum to the uterus. Secretory cells nourish the ovum and create a fluid in which the ovum can move. The muscularis provides peristaltic contractions that aid in ova movement.

The uterus serves as the site of menstruation, implantation of the fertilized ova, and development of the fetus and labor. Before the first pregnancy it is about 3” long, 2” wide, and 1” thick. The uterus consists of the fundus, body, cervix (secretory cells produce cervical mucus which is receptive to and protects sperm. The uterine cavity is the interior of the body of the uterus. A cervical canal contains an internal and external opening. The uterus is supported by the broad, uterosacral, cardinal and round ligaments. Layers include the perimetrium, myometrium, and endometrium. The endometrium can be divided into the stratum functionalis and the stratum basalis. During the menstrual period the uterine lining undergoes several phases under hormonal control. The stratum functionalis is shed while the stratum basalis remains to regenerate a new stratum functionalis.

The vagina serves as a passageway for menstrual flow and childbirth and as a receptacle for the penis during intercourse. The fornix is the recess that surrounds the vaginal attachment to the cervix. The vaginal orifice is the opening to the vagina and may be covered by a thin membrane called the hymen. Mucosa cells contain glycogen, which when utilized cause an acid pH. Lactobacilli are the primary organisms colonizing the vagina. Vulva is a term used to describe the external female genitalia. Vulva comprises the mons pubis, major and minor labia, clitoris, vestibule, vaginal and urethral orifices, the paraurethral glands, and the greater and lesser vestibular glands. The function of the glands is to secrete fluids before and during sexual intercourse.

The perineum is a diamond shaped area between the thighs, the buttock and the genitalia of males and females. The anterior portion is called the urogenital triangle and the posterior potion, the anal triangle.

Mammary glands are modified sweat glands located over the pectoralis major muscles. Their function is to synthesize, secrete, and eject milk (lactation). The amount of adipose tissue determines the size. Each contains 15-20 lobes and each lobe consists of lobules. The alveoli glands drain the milk into secondary tubules, then into mammary ducts to the lactiferous sinuses for storage. When ejected, milk travels from these sinuses to lactiferous ducts and out through the nipple. The pigmented area surrounding the nipple is called the areola. Development of the mammary glands occurs at puberty and depends on the presence of estrogen and progesterone. Adipose tissue is deposited, the duct system develops, and the nipple and areola grow and become pigmented. Milk production is due the hormone prolactin and milk ejection is due to the hormone oxytocin.

Female Reproductive Cycle

In general the reproductive cycle occurs approximately once each month in non-pregnant females during their reproductive years. The function is to prepare the uterus for a fertilized ovum. It involves two cycles, the ovarian cycle for maturation of the ovum and the uterine (menstrual) cycle during which there are changes in the endometrial lining of the uterus. Both are controlled by hormones. Gonadotropin releasing hormone (GnRH) from the hypothalamus stimulates the release of LH and FSH by the pituitary gland. FSH in turn stimulates initial development of the ovarian follicles and secretion of estrogen.

LH stimulates further development of the follicles, ovulation, and secretion of estrogen and progesterone. B-estradiol is the major estrogen produced. It promotes development and maintenance of female reproductive organs, secondary sex characteristics and development of the breasts in addition to regulating fluid and electrolyte balance and stimulation of protein synthesis. Progesterone helps prepare the endometrium for implantation of the fertilized ovum and prepares the mammary glands for milk secretion. Relaxin is

produced by the corpus luteum and helps dilate the cervix to ease delivery. Inhibin is also produced by the corpus luteum and it inhibits FSH and GnRH.

Phases of the Female Reproductive Cycle

- The menstrual phase lasts @ 5 days and during this time there is a discharge of 50-150 ml of blood, tissue fluid, mucous, and cells from the endometrium. It is caused by decreased levels of estrogen and progesterone which causes the blood vessels to constrict and the stratum functionalis to slough off.
- The preovulatory phase occurs during days 6 -13. This is the follicular phase during which follicles develop. In the proliferative phase endometrial repair takes place, estrogen is secreted. Close to the time of ovulation, an increased amount of LH is secreted (this is an indication of imminent ovulation and is known as the LH surge).
- Ovulation occurs about day 14 of the 28 day cycle. The corona radiata, an oocyte which is surrounded by its zona pellucida and covered by follicular cells is released by a secondary follicle. Other signs of ovulation include increased basal temperature, production of clear, stretchy cervical mucus, changes in the uterine cervix, and sometimes the presence of ovarian pain.
- The postovulatory phase, days 15 - 28, is the time between ovulation and the next menstrual cycle. During this period the endometrium thickens awaiting the fertilized ovum. An abundant amount of estrogen and progesterone are secreted by the corpus luteum. Progesterone causes the endometrium to become more vascular and glandular. High levels of progesterone and estrogen inhibit the release of FSH and LH. If fertilization does not happen, the corpus luteum degenerates into the corpus albicans, decreasing the amounts of estrogen and progesterone and initiating another ovarian and menstrual cycle. About day 25, another group of primordial follicles start to develop into primary follicles and the cycle repeats. If fertilization does occur, placental hCG maintains the corpus luteum. Both secrete estrogen and progesterone to support pregnancy and breast development for lactation.

Birth Control

Sterilization is the most reliable method. In the male, a vasectomy is performed. In the female, a tubal ligation whereby the uterine tubes are cut and the ends tied. Hormonal methods are utilized in oral contraceptive that includes both estrogen and progesterone. An IUD is an intrauterine device that is placed into the uterus to prevent implantation of a fertilized ovum. Problems with the IUD have included pelvic inflammatory disease, infertility, excess bleeding and pain.

Barrier devices include the condom, which offers some protection against STD, the diaphragm, and the cervical cap. Chemical methods are all spermicidal agents. Behavioral methods include the rhythm method which

advocates avoiding intercourse just before, during, and after ovulation. A symptom-thermal method is another behavioral method in which intercourse is avoided when signs of ovulation exist. The last behavioral method is coitus interruptus in which the penis is withdraw just before ejaculation.

Aging and the Reproductive Systems

Puberty is a time when the secondary sex characteristics begin to develop and the potential for sexual reproduction is reached. Male puberty starts at @ 10-11 years old and ends 15-17. Changes in testes result in maturation of sustentacular cells and the initiation of spermatogenesis and are controlled by an increase in FSH, LH and testosterone. Female puberty starts with the first menses (menarche) about age 12. Increases in FSH, LH and estrogen initiate the process.

Menopause is caused by the aging of the ovaries. It occurs between the ages of 40 - 52. It is the result of the ovaries becoming less responsive to gonadotropic hormones. Symptoms include hot flashes, hair loss, and mood swings, although 20% of women do not exhibit any symptoms. Estrogen replacement therapy may help reduce symptoms although that is controversial at this time. Osteoporosis is also possible due to lower levels of estrogen.

In older men, about age 55, there is a decrease in the levels of testosterone which causes a decrease in strength, sexual desire, and viable sperm although men have become fathers when they are in their nineties. Prostate disorders are common.

Female Sexual Response

Masters and Johnson also identified four phases in the female sexual response: excitement, plateau, orgasm, and resolution. In an unstimulated period, the uterus tilts forward, the vagina is relatively narrow and the labia minora are retracted. During the excitement phase and plateau phases

- the uterus stands more vertical and the cervix is withdrawn from the vagina
- the inner end of the vagina dilates
- the labia minora and vagina become reddened due to hyperemia
- secretions moisten the vagina
- the lower third of the vagina constricts the penis

During orgasm

- the orgasmic platform contracts rhythmically
- the uterus exhibits peristaltic contractions and the cervix may dip into the pool of semen. An orgasm may assist to becoming pregnant. This theory based on the fact that artificial insemination is not always successful.

At resolution

- the uterus returns to its original position,
- orgasmic platform relaxes
- the inner end of the vagina constricts and returns to its original dimensions.

Sexually Transmitted Diseases (STD)

STDs are venereal diseases spread by usually by direct sexual contact. Gonorrhea (GC) is caused by bacteria *Neisseria gonorrhoeae.* About 360,000 cases were reported in 2001 in the U.S. Untreated cases can cause sterility in females (due to scarring of the uterine tubes) and the male (scarring of the vas deferens). Pelvic inflammatory disease can lead to peritonitis, and possibly death, but a GC infection can also be asymptomatic which allows for transfer of the disease. GC can cause blindness if transmitted to newborn at birth. In the male it usually causes urethritis, with a yellow, creamy discharge and painful. The disease is treated with antibiotics.

Syphilis is caused by bacteria *Treponema pallidum*. Less than 7,000 new cases were reported in 2001. Primary syphilis is manifested by a lesion on the genitalia which is a non-painful, hard chancre. Usually it heals by itself but the organism remains in the body only to emerge as secondary syphilis in which a very infectious rash covers the body. Tertiary syphilis affects organs such as the heart or the brain. Syphilis can be transmitted to the fetus (congenital syphilis) which results in a baby with many birth defects, if it survives. Syphilis can be treated with penicillin.

Chlamydia is caused by bacteria *Chlamydia trachomatis.* More than 780,000 cases were reported in 2001 making it the most common reportable organism in the U.S. In males it causes a urethritis; in females it can cause sterilization due to scarring of the uterine tube. This organism can also be transmitted to newborns at birth causing eye infections (blindness if untreated) and/or respiratory disease. It also can be treated with antibiotics.

Genital Herpes is caused by a virus *Herpes simplex II.* About a half million cases per year are reported. Genital herpes produces painful genital blisters. It can be treated with antiviral drugs but all they do is cause the organism to go into remission; one never gets rid of it.

Genital Warts are caused by the *Human papilloma virus.* About one million cases per year are reported. There is no cure although cryotherapy, electrocautery, laser surgery are used to remove lesions. Cervical cancer is now known to be linked to the HPV virus. A vaccine is available.

AIDS is caused by the Human Immunodeficiency Virus (HIV). HIV can be transmitted through intercourse. It is mostly found in homosexual men and drug abusers, although the greatest percentage increase is in heterosexual

females. The cumulative cases and deaths reported in the U.S. from the early 1980s through December, 2001 are 820,000 cases with 470,000 deaths. Approximately 40,000 new cases are reported each year in the U.S. There is no cure.

Trichomoniasis is caused by the parasite *Trichomonas vaginalis*. It causes an inflammation of the vagina or urethra and can be treated with antibiotics.

Basic treatment guidelines require treatment of both sexual partners. Condoms offer some protection but prevention through education of the disease mechanisms is better. Then there are also the behaviors of abstinence or fidelity in a monogamous relationship that prevent the spread of STDs.