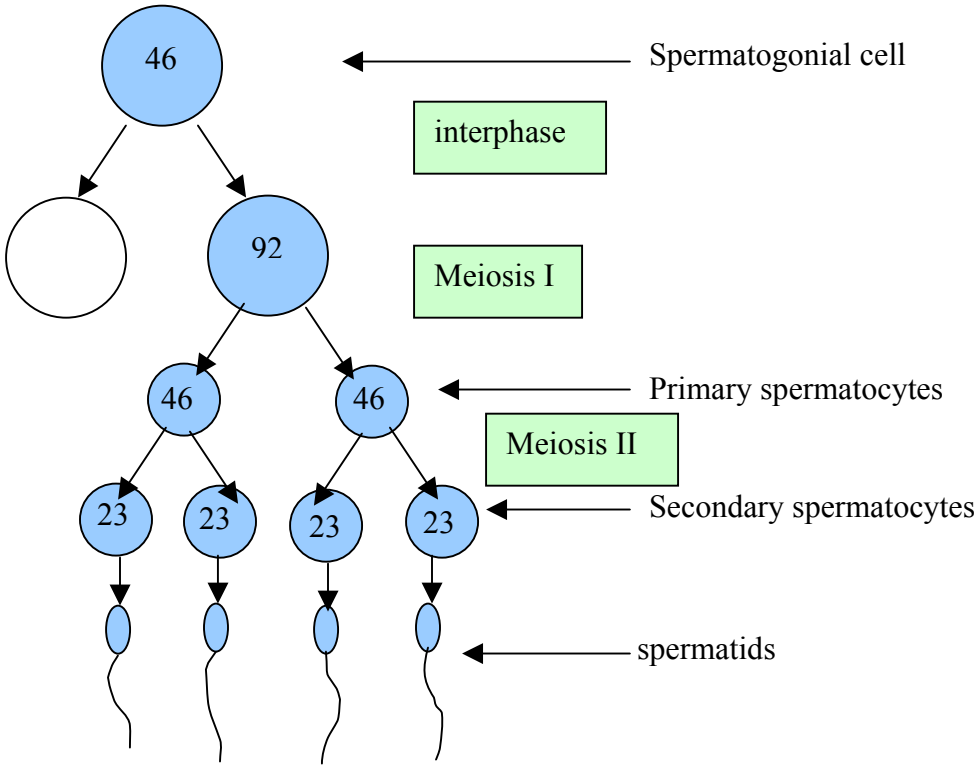
SPERMATOGENESIS

Spermatogenesis
The purpose of meiosis is to reduce the number of chromosomes in sperm and eggs (gametes). If there were no reduction in the number of chromosomes in sperm and eggs, then once the egg became fertilized by the sperm, the zygote would have 92 chromosomes. The production of sperm in males is called spermatogenesis. It comes from the Greek and literally translates as "beginning seed".

Spermatogenesis begins with a spermatogonial cell with 46 chromosomes. That cell divides and undergoes interphase to produce a cell with 92 chromosomes called the primary spermatocyte. The primary spermatocyte undergoes Meiosis I (prophase I, metaphase I, anaphase I, telophase I and cytokinesis). The resulting two cells are called secondary spermatocytes and they have 46 chromosomes each. The secondary spermatocytes undergo Meiosis II and the result is two cells from each secondary spermatocyte (a total of 4) each with 23 chromosomes. These are called spermatids. The spermatids condense to form sperm cells.



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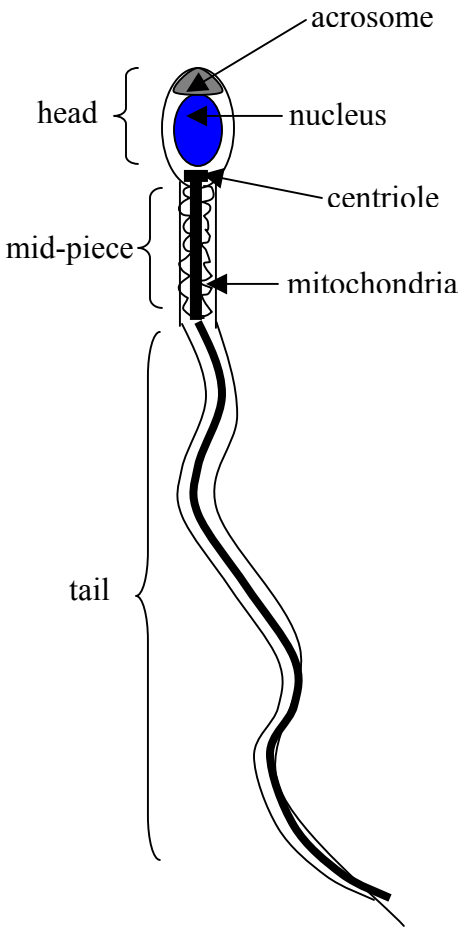
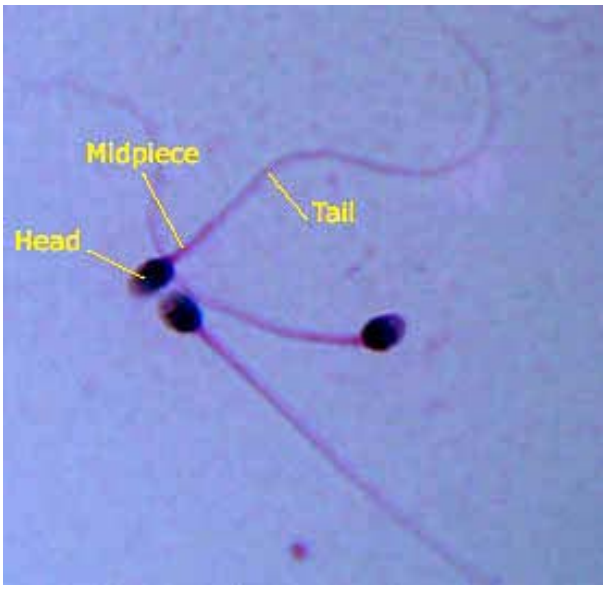
The sperm is much smaller than the egg. Sperm are composed of three parts: head, mid-piece and tail. At the very tip of the head of the sperm is a structure known as an acrosome. It is homologous to the lysosome in cells. It contains the enzyme hyaluronidase which is used to digest its way through the corona radiata and zona pellucida to penetrate the egg. The nucleus, of course, contains 23 very compact chromosomes. Behind the nucleus is a centriole that eventually forms the flagellum of the tail. The mid-piece contains the centriole and spiral shaped mitochondria around the centriole. The tail is simply another version of a flagellum.

Illustrations of sperm and egg are not to scale.





Oil immersion, human sperm

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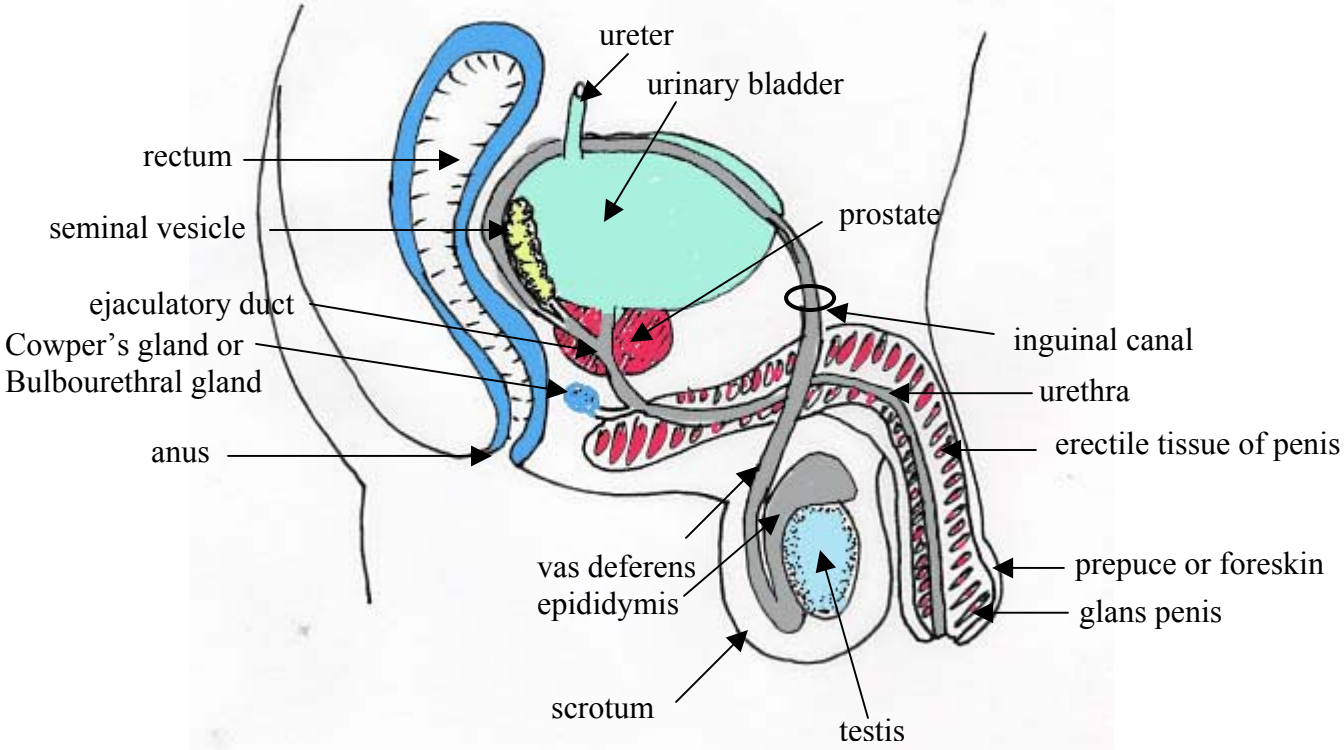
Sperm Production
One thing at which males are good is sperm production. Males generally produce, on the average, 250 million sperm cells per day. Sperm are produced in the seminiferous tubules of the testes.

Anatomy of the Male Reproductive System



Male reproductive system, side view.

Each testis (plural – testes) of the male is an oval structure approximately 4 cm long and 2.5 cm in diameter. The testis weights around 10 to 14 g. Each testis is divided into 250 to 300 lobules (small lobes). The lobules contain 3 to 4 seminiferous tubules which are thread-like ducts that can reach a length of 70 cm. It's in the seminiferous tubules of the testes that sperm are produced.

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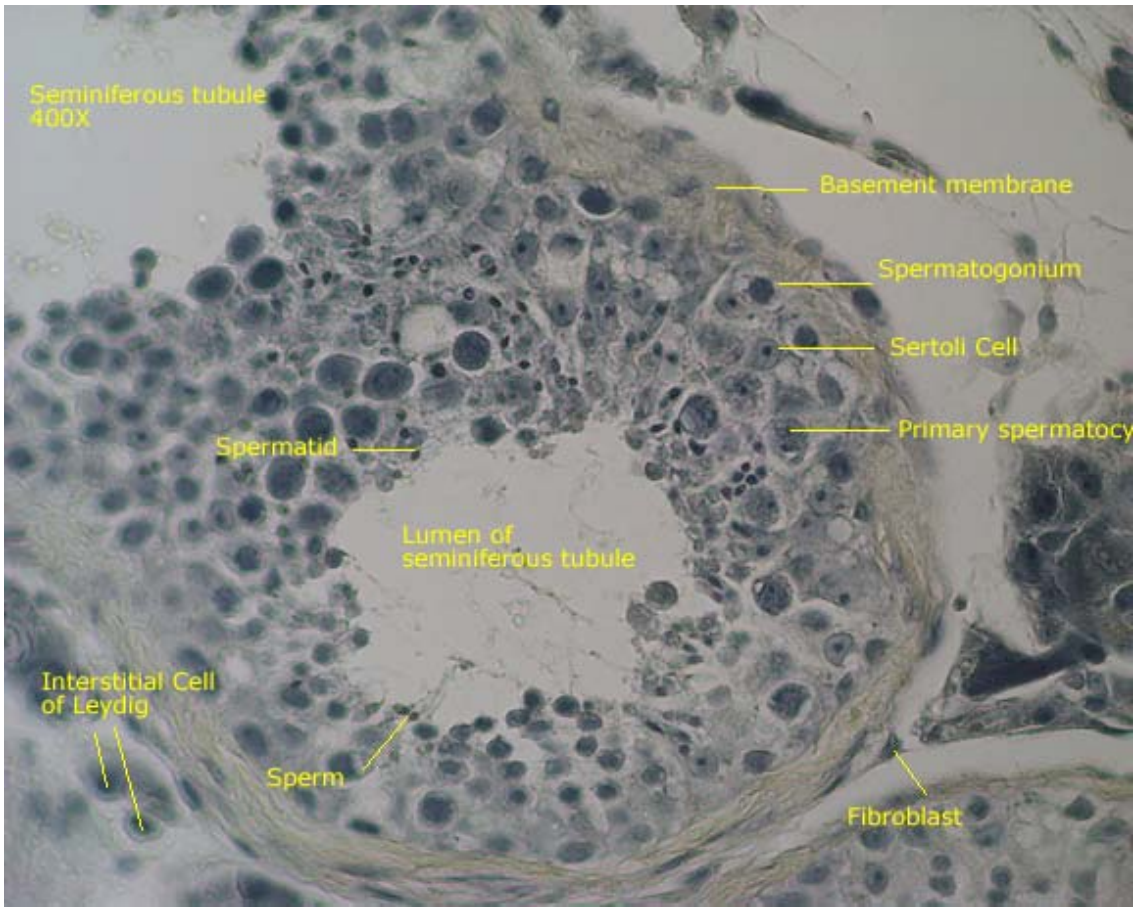

Refer to the diagram of spermatogenesis previously discussed during meiosis.
(Section of testis showing seminiferous tubules, 400X)

Each testis is held in a sac-like pouch called the scrotum. The testes may be drawn up close to the body and they may relax and fall away from the body. One of the muscles associated with this action is the cremaster muscle. When men take cold showers, the cremaster contracts and the scrotum is pulled up close to the body for body heat. If men take a warm shower, the cremaster muscle relaxes and the scrotum falls away from the body to cool the testes.

The question is why? Average body temperature is 98.6°F (37°C). This temperature is too high for sperm production. As a consequence, the scrotum is designed to hold the testes outside of the body which results in a temperature of around 96.6°F (35.8°C) which is optimal for sperm production.

At an early stage of development, the testes and ovaries (collectively referred to as gonads) are located internally near the kidneys. In females, the ovaries stay inside the body, but the testes must descend from the body cavity into the scrotum.

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In the developing fetus, there is a cord of muscle and connective tissue called the gubernaculum that runs from the testis to the scrotum. As the male fetus develops, the cord shortens pulling the testis down into the scrotum. This process begins as early as 6 weeks, and by 28 weeks, the process is complete.

To pass from the abdominal cavity into the scrotum, there must be a opening. The inguinal canal serves as that passageway. This canal remains even in adulthood. It is also a weak point in the abdominal cavity and as a consequence, pressure in the abdominal cavity may cause a portion of the intestine to push through the opening into the scrotum. This is called an inguinal hernia.

Of course, the normal process is where two testes descend into the scrotum. However, on occasions, one or both fail to descend. This failure is referred to as cryptorchidism. If both fail to descend, the male is sterile. If only one descends, the male may still father children.

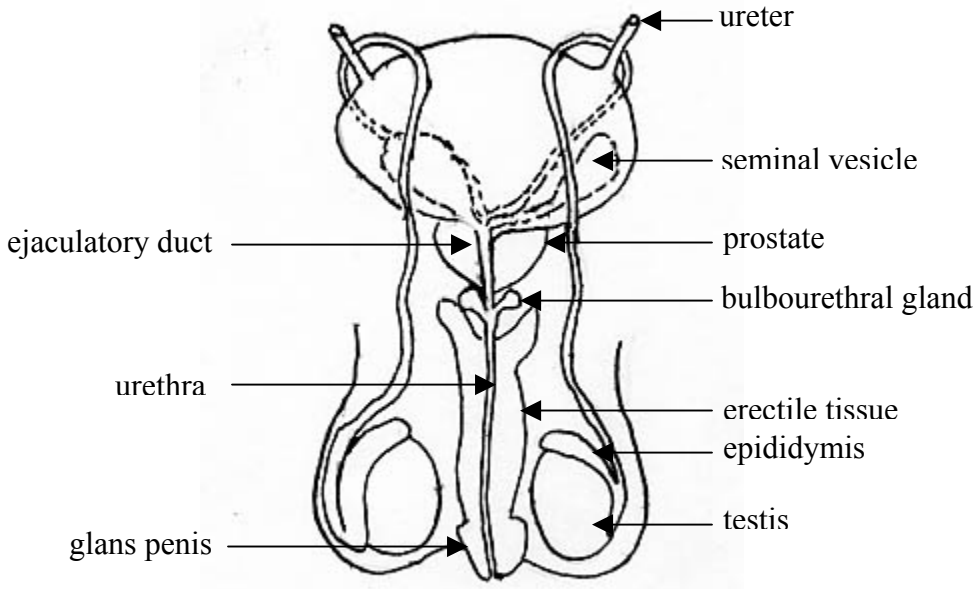
Scattered between each section of seminiferous tubule are the Interstitial Cells of Leydig. These cells produce testosterone and other male hormones. Remember, hormones are chemical messengers produced in one location of the body but have their influence in another location.

Along the length of each seminiferous tubule the process of spermatogenesis is occurring, *i.e.* primary spermatocytes, secondary spermatocytes, spermatids, and sperm. The sperm are held within in the lumen of the tubule. Sertoli cells may be found interspersed with the other cells of the seminiferous tubules. The Sertoli cells protect the layers and promote the development of each stage of spermatogenesis.

As the sperm are produced in seminiferous tubules, They pass into the epididymis overlaying the testis. The sperm may be stored there until ejaculation. During ejaculation, the sperm are propelled from the epididymis and up through the vas deferens (vas deferentia – plural) and then out via the ejaculatory duct, through the urethra and out the tip of the penis.

The two vas deferentia pass through the inguinal canals and then arch up over the urinary bladder on the back side. At this point, the vas deferentia are joined by two ducts that lead from the seminal vesicles (two). The seminal vesicles are about the size of your little finger and are around 5 cm long. Semen, the material ejaculated from the penis during organism, is composed of 60% seminal vesicle fluid, 30% prostatic fluid, 10% sperm and spermatic duct secretions with a trace from the Bulbourethral gland (Cowper's gland).

The seminal vesicles secretions are thick, yellowish and alkaline and include: (1) fructose – an energy source for sperm (2) fibrinogen – a substance that, upon ejaculation, causes semen to clot like blood (3) prostaglandins which stimulate the vaginal walls and uterus to contract to pull semen into the uterus, and to reduce the thickness of mucus in the cervical canal of the female to allow sperm to swim up the passage way more easily (4) ascorbic acid which protects sperm, and (5) local regulators.



Male reproductive system, frontal view.

The ejaculatory duct is where the ducts of the seminal vesicles join the vas deferentia, and where the vas deferentia join into one tube. The ejaculatory duct passes through the prostate gland which adds more secretions to the semen.

The prostate gland secretions are thin and milky and produce a clotting enzyme to work with the fibrinogen of the seminal vesicles. In addition, around 15 to 30 minutes after ejaculation, fibrinolysin (also in semen) break the clot of sperm apart to allow them to swim into the uterus. In addition, the prostate produces more prostaglandins (like the seminal vesicles) as well as citrate which serves as a sperm nutrient.

The ejaculatory duct becomes the urethra as it passes through the penis. Don't confuse the ureter with the urethra. The ureter is the duct that leads from the kidney to the urinary bladder. As the ejaculatory duct becomes the urethra, a pair of Bulbourethral glands (Cowper's glands) add additional components to the semen. These include a clear mucus that neutralizes the acidic content of the urine in the urethra (which would attack the sperm) and mucus to lubricate the path of the penis in the vagina of the female.

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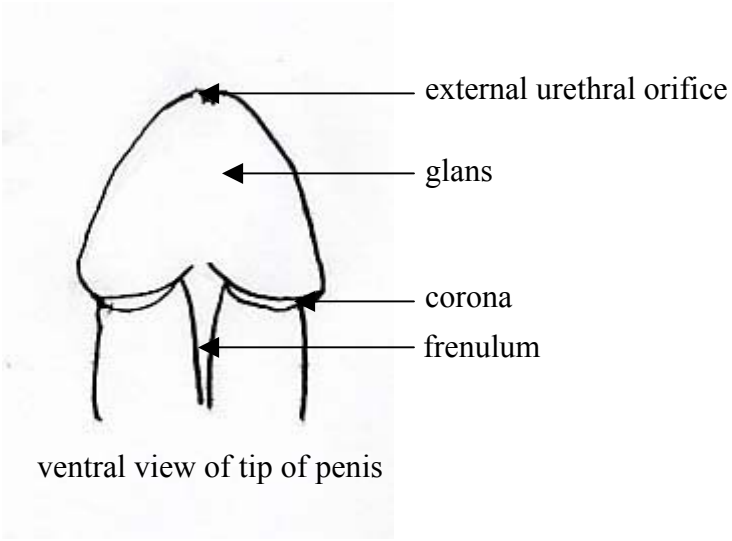
The average male ejaculates any where from 2 to 5 mL of semen and each mL may contain as many as 130 million sperm. A male with a sperm count lower than 20 to 25 million sperm/ml is considered clinically sterile. Additionally, sterility may also occur from malformed sperm. If 20% or more of the sperm are abnormal (two heads, two tails, defective tails, etc.) the male is, again, clinically sterile.

Other causes of sterility include (1) poor nutrition (2) gonorrhea or other diseases (3) testosterone deficiency, and (5) environmental conditions.

The tip of the penis is called the glans. The glans is rich in nerve endings and it's the stimulation of the glans that results in orgasm in the male. The margin of the glans is called the corona. On the ventral portion of the glans is a string of tissue called the frenulum which attaches the skin to the glans.



ventral view of tip of penis

Males are born with a foreskin or prepuce sheathing the penis. The glans penis and the undersurface of the prepuce have sebaceous glands which produce a waxy secretion called smegma.

One of the great debates through history and even today is whether or not to remove the foreskin from the penis of the newborn male. Some religious sects require the removal – a process called circumcision. In the Jewish faith, the process is called brit milah. This is performed by a mohel or circumciser. Some Christian beliefs also recognize circumcision. The question, of course, is why circumcise?

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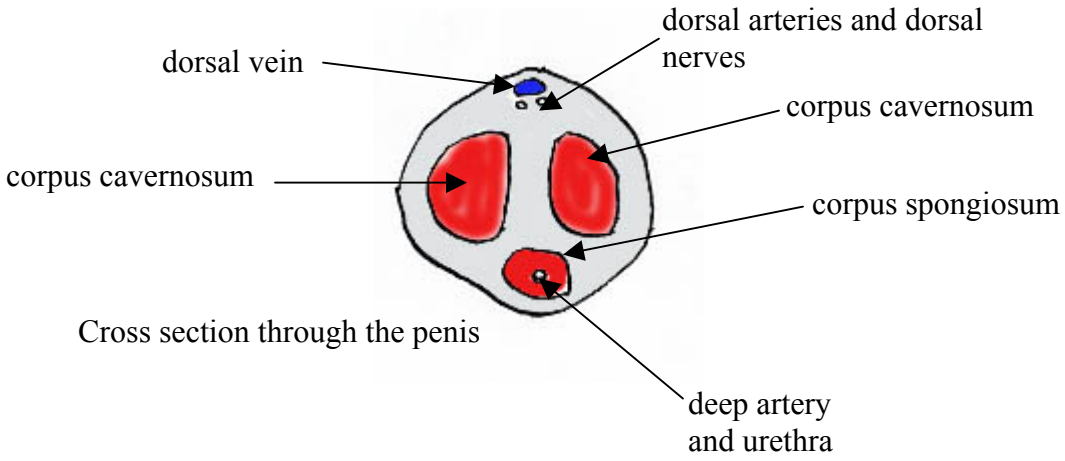
One of the earlier reasons for circumcision in western European countries in the 1800's was a means to prevent masturbation. Medically, the reason often offered is that unless smegma should be removed during general hygiene, the accumulation of smegma may lead to penile cancer. This has been disproved over the years and there is no medical reason for circumcision today. One argument against circumcision is the recognition that circumcision in newborns is more painful and stressful than first believed.

A study of the anatomy of the penis will reveal the physical mechanism for erections in males. When seen in cross section, the penis consists mainly of three bodies of erectile tissue.



There are two dorsal sponge-like cavities called the copora cavernosa (corpus cavernosum – singular). There is also a ventral cavity called the corpus spongiosum. Just under the dorsal surface of the penis is the dorsal vein, two dorsal arteries, and two dorsal nerves. In the middle of the corpus spongiosum is the deep artery and the urethra.

When a male becomes sexually excited, the veins undergo vasoconstriction and the arteries undergo vasodilation. The result is more blood flows into the penis than leaves. The only place for the additional blood to go is in the corpora cavities. When a male becomes flaccid, the reverse occurs. The vein undergoes vasodilation and the arteries undergo vasoconstriction. The result is more blood leaves the penis than enters it.

The production of sperm (and to some extent, the male sexual response) is governed by three structures in the body which secrete hormones. Reproduction function is thus governed by hormones from the hypothalamus, the pituitary gland and the gonads (testes in males, ovaries in females).

If you point your finger at the soft palate directly back into the mouth, you will be approximately showing the location of the pituitary gland. Dorsal to and somewhat in the middle of the brain is the hypothalamus.

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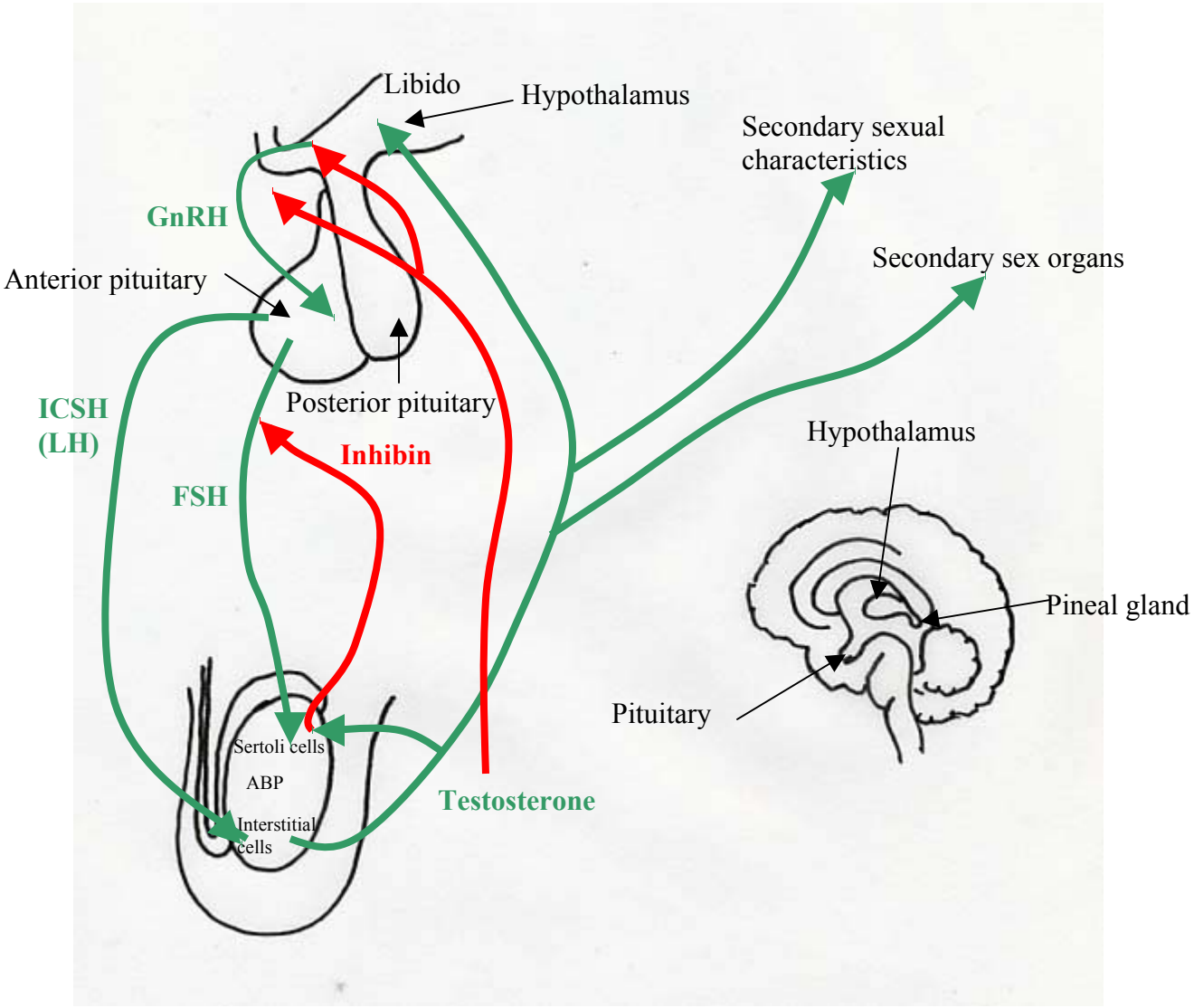

Hypothalamus
The hypothalamus produces gonadotropin-releasing hormone (GnRH). When the hypothalamus secretes GnRH, the hormone travels via a portal system to the anterior lobe of the pituitary.

Anterior Pituitary
GnRH stimulates the anterior pituitary to release two hormones: follicle-stimulating hormone (FSH) and interstitial cell-stimulating hormone (ICSH) – also known as Lutenizing Hormone (LH). Both travel to the testes for their actions.

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Gonads

ICSH stimulates the interstitial cells of Leydig of the testes to secrete androgens (such as testosterone). In addition, FSH is required for testosterone to have any effect on the testes and sperm production. FSH stimulates the Sertoli cells in the testes to secrete androgen-binding protein (ABP)

Androgen Binding Protein

Androgen Binding Protein seems to raise androgen levels in the seminiferous tubules and epididymis, although there is no definitive proof as of this writing. Androgens, however, do have functions:

1. stimulate spermatogenesis
2. inhibits GnRH of hypothalamus (which in turn, decreases the levels of FSH and ICSH)
3. stimulate the development of the secondary sexual characteristics of the male.

Testosterone

Testosterone has four effects: (1) stimulates spermatogenesis, and thus sperm production, (2) decreases the production of FSH and LH and (3) produces the effects needed for the exhibition of the secondary sexual characteristics of males (see the chapter on lipids) and (4) stimulates the brain and awakens the libido (sex drive). Testosterone also stimulates the secretion of growth hormone in humans.

Pineal Gland

The pineal gland is located just behind the hypothalamus of the brain. It produces serotonin during the day and converts serotonin into melatonin at night. Melatonin may reduce the secretion of gonadotropin which in turn, affects the hypothalamus and the anterior pituitary.

When sperm are produced faster than they can be used, a hormone from the Sertoli cells called inhibin decreases the production of FSH from the pituitary. This decrease in FSH slows down sperm production (but has no effect on testosterone production).

Sexual Response in Males

Sexual studies suffered significantly in the 1950's due to repressive attitudes until William Masters and Virginia Johnson published their groundbreaking book *Human Sexual Response*. Their book documented statistical data from more than 10,000 sexual acts performed by approximately 700 volunteer men and women.

Sexual intercourse is also known as coitus, coition, or copulation. Intercourse primarily refers to the insertion of the erect penis into the vagina or anus. Masters and Johnson divided sexual response (sexual intercourse) into four phases: (1) excitement (2) plateau (3) orgasm and (4) resolution.

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Excitement
The excitement phase in males is most evident when the male obtains an erection of the penis due to vasoconstriction of the veins of the penis and vasodilation of the arteries. Blood flows into the corpora cavernosa and corpus spongiosum to inflate the penis. This also occurs in the testes which may increase in size by as much as 50%.

The heart rate increases along with blood pressure and the rate of breathing. Myotonia (muscle tension) also occurs. The bulbourethral glands begin to secrete fluids. The excitement phase may be initiated by a broad array of stimuli including touch, sights, aromas, sounds, dreams, and simply the thought of sex. Once the glans is stimulated, the effects increase the sense of excitement.

Plateau
In this stage, there may be increased vasoconstriction and myotonia. There may also be an increase in respiratory rate, heart rate and blood pressure. This increase may only last a few seconds to a few minutes, just prior to orgasm.

Orgasm
Orgasm is reached when ejaculation occurs. Ejaculation of semen is divided into two phases: (1) emission and (2) expulsion.

Emission results from a series of contractions (peristalsis) of the vas deferentia which carries sperm from the epididymises upward towards the ejaculatory duct. Additional contractions of the seminal vesicles and prostate gland add to the content of the semen and the male experiences an urgent sense that ejaculation is eminent.

Expulsion results when nerve impulses close the urinary sphincter to prevent urine from entering the urethra. Additional secretions from the seminal vesicles and prostate occur. Expulsion of semen occurs when the urethra undergoes a series of 5 to 6 spasmodic contractions. Most of the sperm are ejected in the first one or two spurts of semen comprised primarily of sperm and prostatic fluid. Seminal vesicle secretions follow and flush the rest of the sperm from the urethra.

One method of birth control that is practiced is called the withdrawal method. Unfortunately, this method is an abysmal failure. When a male becomes excited, some secretion of semen automatically takes place and may exit the tip of the penis. This is often used to facilitate penetration by the penis. This small amount of secretion may be enough to effect pregnancy.