Chapter 18
Lectures 24, 25

The Reproductive System: Maintaining the Species

The Reproductive System – Forming Gametes

Sexual reproduction requires two genders to perpetuate the species

Males contribute **sperm**

Females contribute **eggs**

Fertilization combines a sperm and an egg to produce the first cell of the new individual **(the zygote)**

- **The main purpose of the reproductive system is to produce gametes (egg and sperm) and unite them to form a new individual**
- **Gametes are produced through the process of meiosis**
  - Meiosis is a specialized type of cell division that ensures the gametes will contain the haploid chromosome number
  - A haploid gamete means that it contains half the number of chromosomes of normal body cells
  - Thus, when two haploid gametes (sperm and egg) unite to form a zygote, the original diploid number is restored
    - The diploid number is the normal and total number of chromosomes

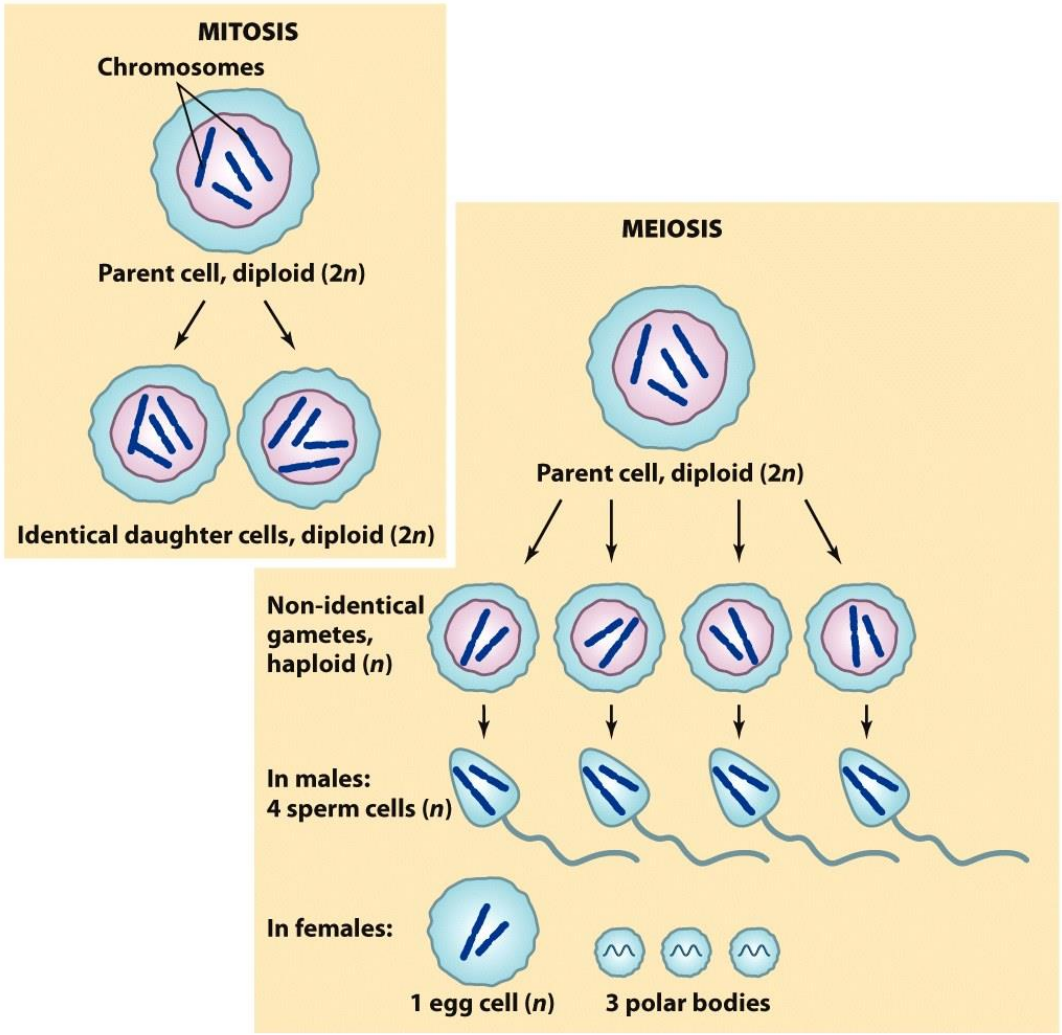
The Reproductive System – Other Functions

- **Forming gametes is only one function of the reproductive system**
- **Other functions include**
  - Triggering puberty
  - Maintaining reproductive ability
  - Stimulating secondary sex characteristics
  - Producing hormones involved in sexual maturation and general homeostasis
- **Both male and female reproductive systems are composed of**
  - Gonads – organs that produce gametes (testis in male, ovary in female)
  - Ducts – transport gametes and fertilized egg
  - Accessory glands – secrete hormones and other fluids that facilitate gamete production and survival
  - Supporting structures – help deliver and support gametes

Gametogenesis

- **Spermatogenesis**
  - In the male
  - Meiosis is the process that forms four haploid sperm
  - Males produce about 300 million sperm per day from puberty until death
- **Oogenesis**
  - In the female
  - Meiosis is the process that forms one haploid egg and up to 3 haploid polar bodies
    - The haploid egg has the potential to be fertilized by one sperm
    - The polar bodies are not viable and are quickly degraded
  - Females are born with all the eggs they will ever have

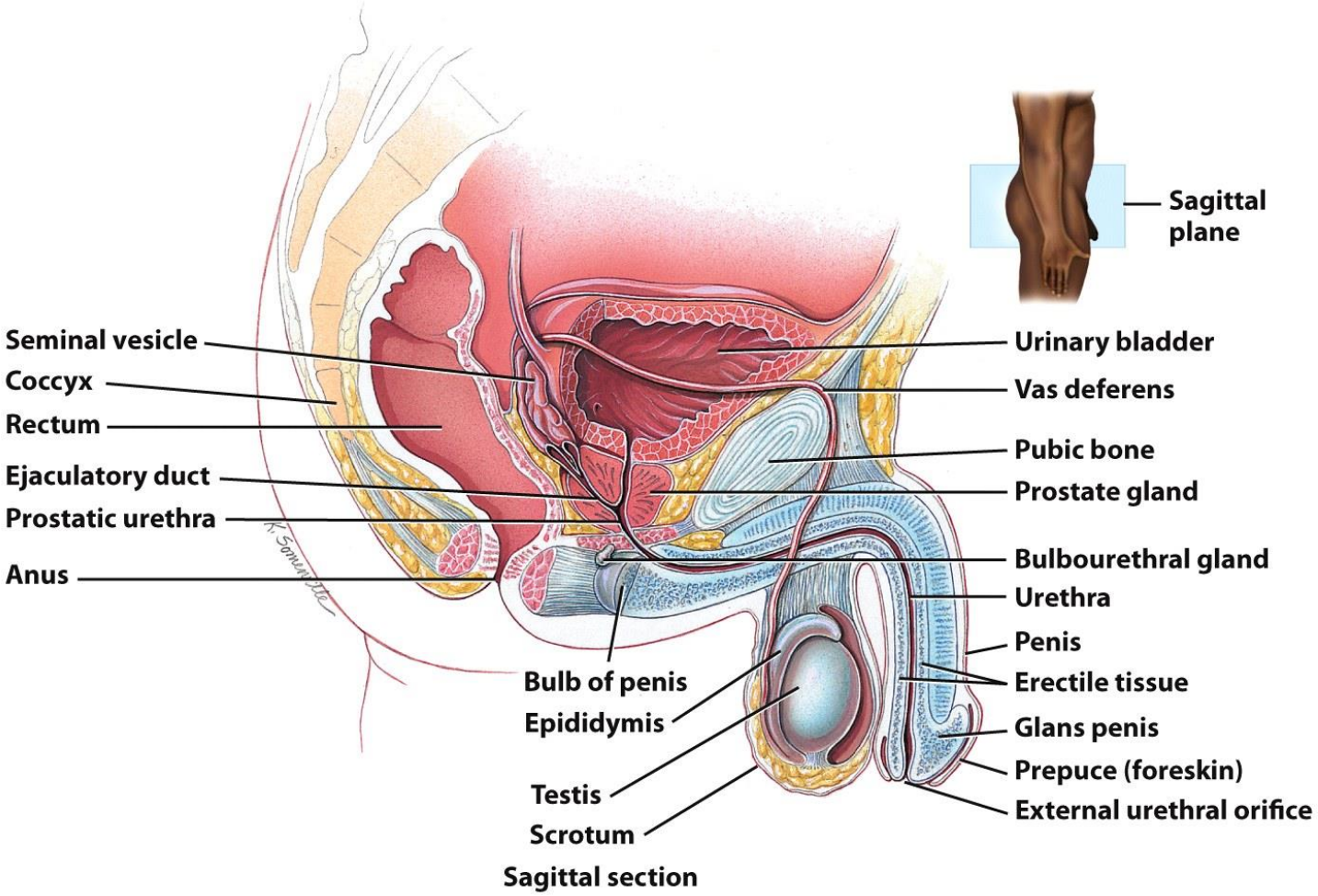
Gametes and Meiosis



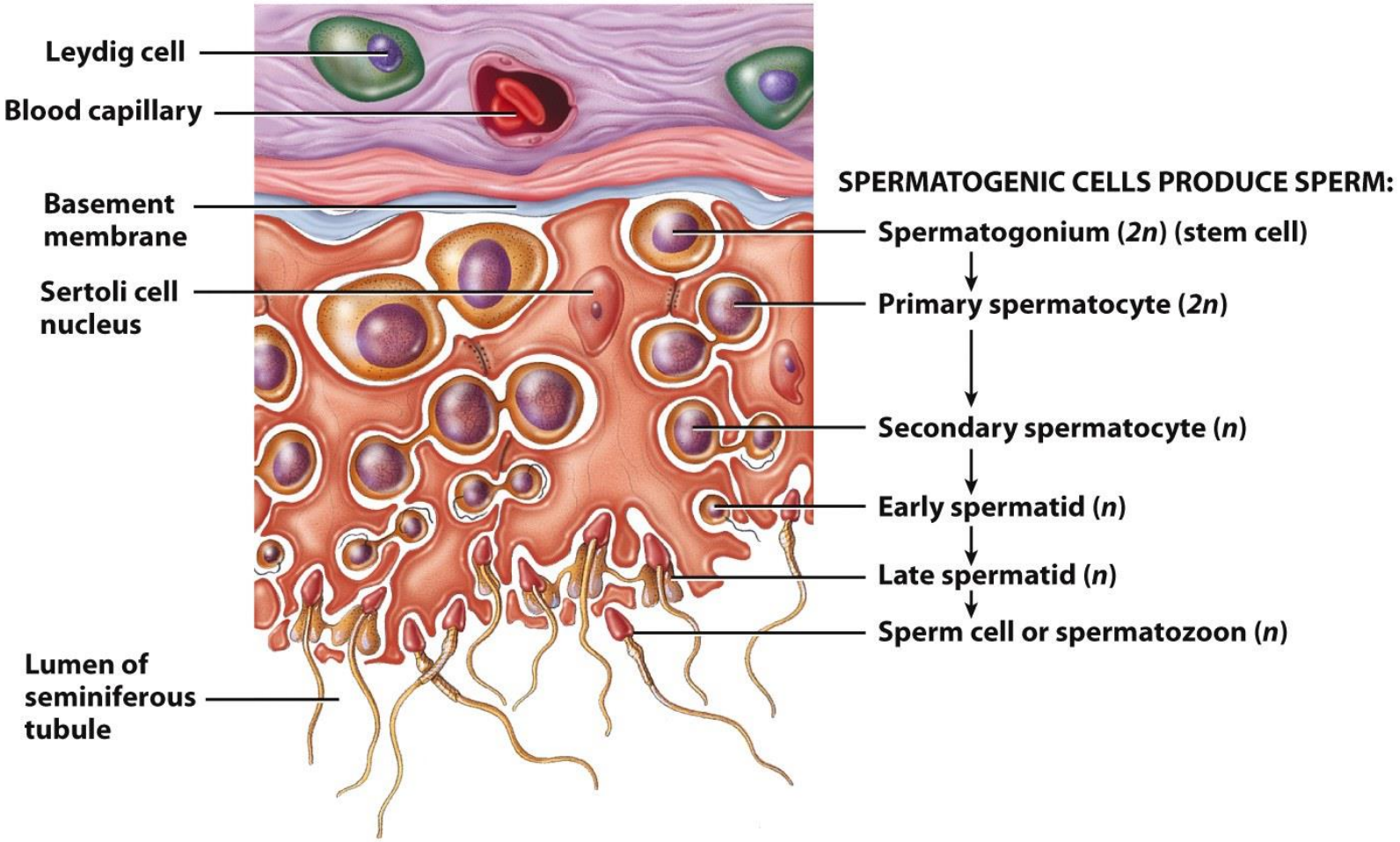
The Male Reproductive System

- **There are three main functions of the male reproductive system**
  - Produce sperm
  - Store sperm
  - Deliver the sperm to the female reproductive system
- **The male reproductive system is essentially one long tube**
  - Sperm is produced at one end - in the testes
  - Sperm moves along the length of the tube - it matures along the route
  - Sperm is released at the end of the tube - as it leaves the body
- **Accessory glands**
  - Add secretions to nourish, carry, and protect the sperm before it is released from the male's body

The Male Reproductive System – Structures



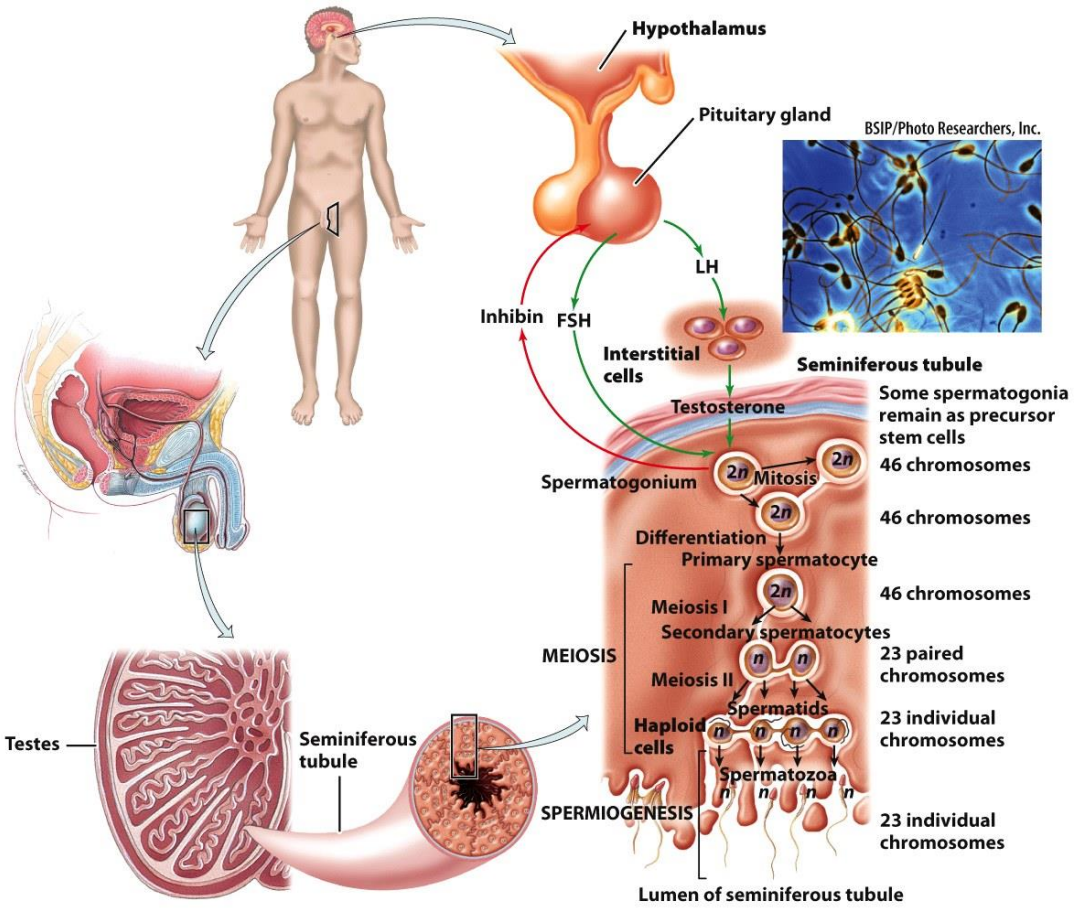
The Male Reproductive System - Structures



Transverse section of a portion of a seminiferous tubule

Spermatogenesis

- **Spermatogenesis occurs in the seminiferous tubules**
- **At puberty, spermatogenic cells begin producing sperm**
  - These divide into spermatogonia
  - Which divide into primary spermatocytes
  - Which, in turn, divide into secondary spermatocytes
  - These finally divide into spermatids
  - As the cells divide, they are pushed away from the wall of the tubule into the lumen of the seminiferous tubule



Spermatogenesis – From Diploid to Haploid

- **A normal human male produces about 300 million sperm per day from puberty until death**
- **Spermatogenesis begins with the spermatogonia**
  - Spermatogonia and primary spermatocytes are diploid cells
    - Each contains 46 chromosomes
  - A spermatogonium enters meiosis I and divides into two cells
    - At the end of meiosis I, two haploid secondary spermatocytes are formed
    - Each contains 23 chromosomes
  - Each secondary spermatocyte enters meiosis II and divides into two cells
    - At the end of meiosis II, a total of four haploid spermatids are formed
  - Each spermatid matures into a sperm (each contains 23 chromosomes)
  - *Each sperm is haploid - and ready to fertilize a haploid egg cell - and thus restore the diploid number in the zygote*

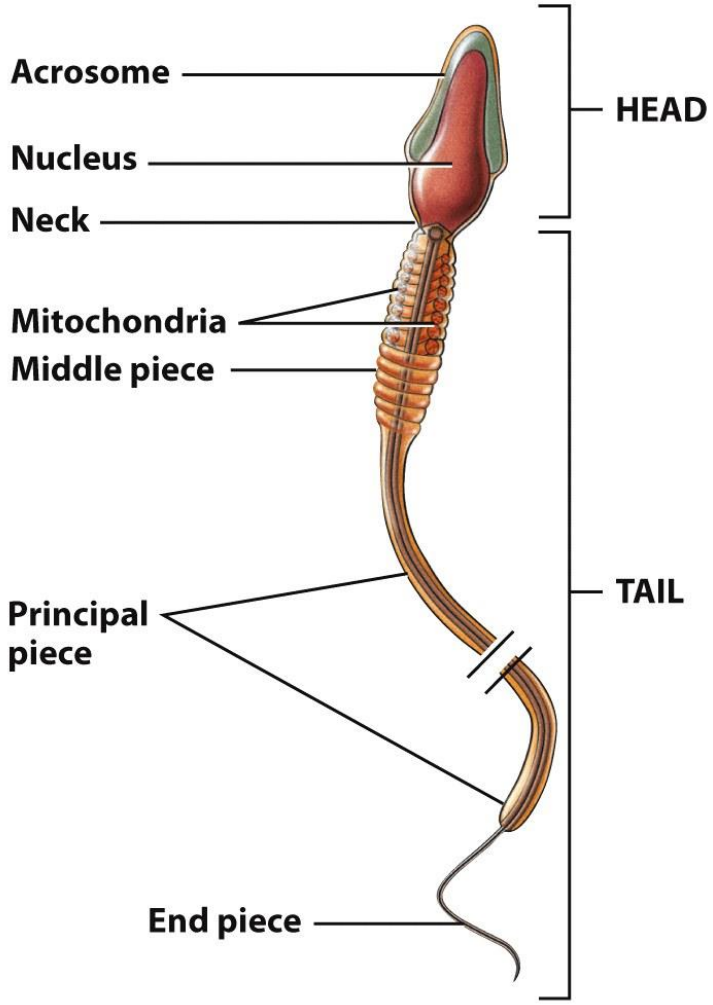
Spermatogenesis – Accessory Cells

- **Sertoli cells**
  - Assist in sperm survival by providing nourishment for the developing sperm
  - Also assist in the final maturation of sperm by removing excess cytoplasm
- **Leydig cells (interstitial endocrinocytes)**
  - Produce the hormone testosterone
  - Testosterone stimulates spermatogonia to develop into sperm

The Sperm

- **The head of the sperm includes the nucleus and acrosome**
  - The nucleus contains the paternal genetic material
  - The acrosome is a vesicle that contains digestive enzymes
    - allowing the sperm nucleus to enter the oocyte
- **The midpiece of the sperm contains many mitochondria**
  - The mitochondria produce ATP
  - The ATP provides energy for sperm movement
- **The tail of the sperm consists of one long flagellum**
  - The sperm is the only human body cell with a flagellum
    - It propels the sperm along its journey toward the egg cell

The Sperm - Structure

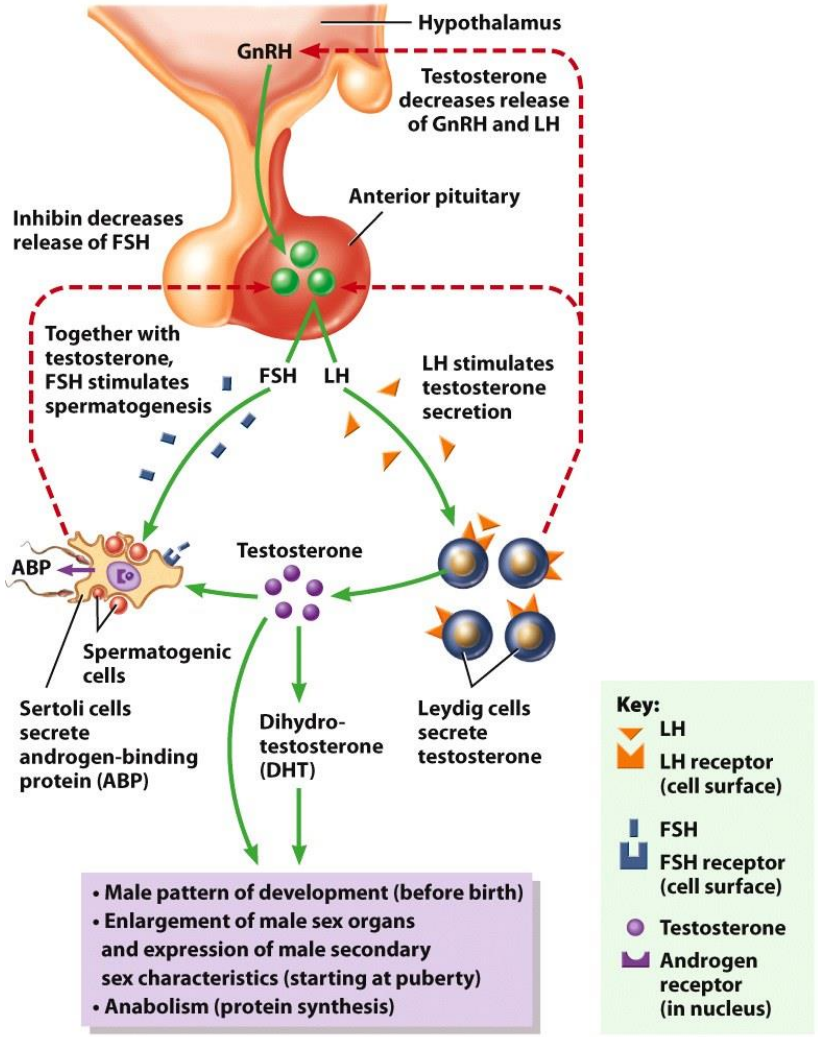


Hormonal Control of Sperm Production

- **Gonadotropin-releasing hormone (GnRH)**
  - Released by the hypothalamus
  - Triggers the anterior pituitary gland to release luteinizing hormone and follicle stimulating hormone
- **Luteinizing hormone (LH)**
  - Causes Leydig cells (interstitial cells) to produce and release **testosterone**
    - These cells reside between the seminiferous tubules
    - LH is also called interstitial cell stimulating hormone (ICSH)
- **Follicle-stimulating hormone (FSH)**
  - Stimulates Sertoli cells to secrete **androgen-binding protein** (ABP)
    - ABP binds to testosterone to keep it near the seminiferous tubules
    - Testosterone then stimulates spermatogenesis – thus increasing sperm count.

Testosterone

- **The functions of testosterone include**
  - Stimulation of male patterns of development *in utero*
  - Enlargement of male sex organs during puberty
  - Development of male secondary sex characteristics
  - Development of sexual function
  - Stimulation of anabolism (the building of larger molecules from smaller ones)
- **Testosterone operates under negative feedback**



Sperm is Transported and Stored in Ducts

- **Sperm is produced in the testis and then moves through a series of ducts on its way out of the body**
  - As it travels along the ducts, fluid secretions from several structures mix with the sperm to form semen
  - **The Sertoli cells** - create a fluid that fills the seminiferous tubule lumen and pushes the developing spermatozoa along the epididymis
  - **The epididymis** - serves as a storage area and final maturation center for the spermatozoa
  - **The vas deferens** - transports and stores sperm for as long as several months
    - If there is no ejaculation during that time, the sperm are broken down and reabsorbed
  - **Ejaculatory duct** - short duct that passes through prostate gland and empties into the urethra
  - **The urethra** - transports semen (and urine) through the length of the penis to the external urethral orifice

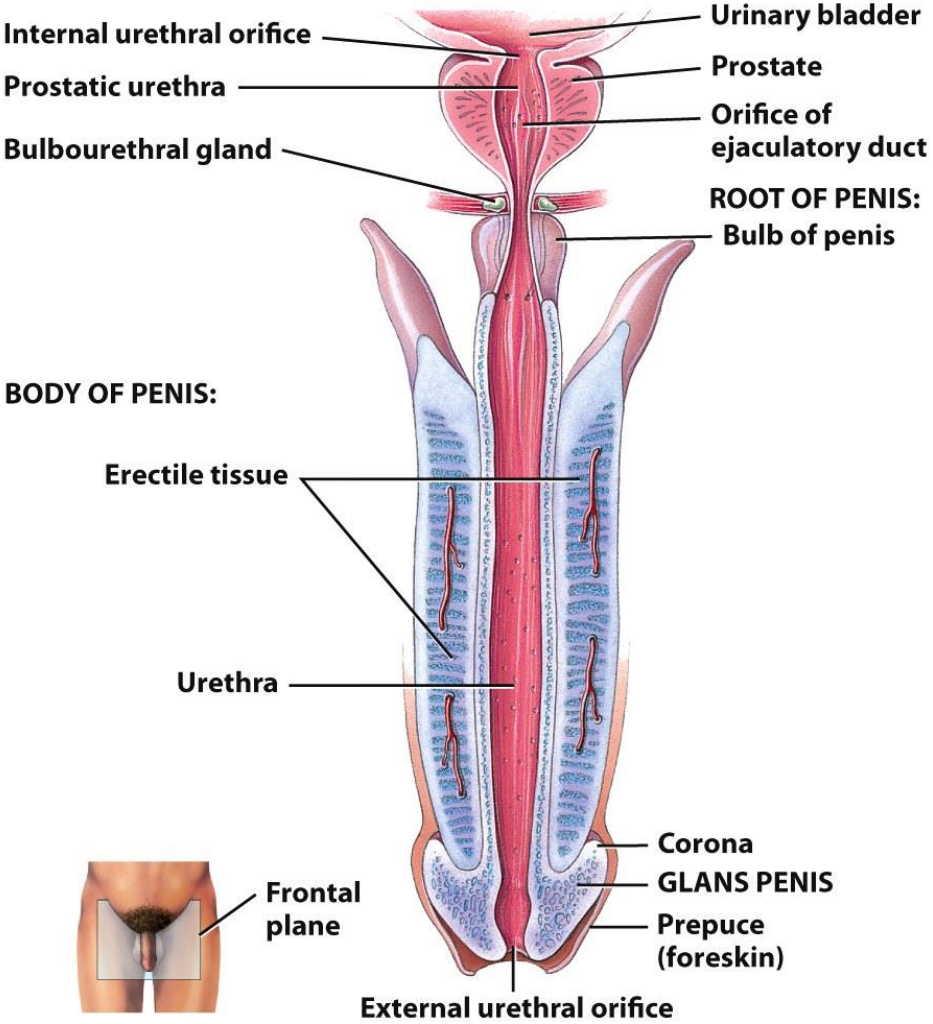
Three Sets of Glands

- **Seminal vesicles**
  - Pair of glands attached to the vas deferens near base of the urinary bladder
  - Secrete alkaline fluid – and fructose and prostaglandins
  - Contents empty into the ejaculatory duct
  - Forms 60% of semen
- **Prostate gland**
  - Surrounds urethra and ejaculatory duct
  - Alkaline secretion activates sperm and reduces acidity of male & female reproductive tracts
  - Forms 30% of semen
- **Bulbourethral glands**
  - Pair of glands near bulb of penis
  - Protects sperm by neutralizing the acidity of residual urine in the urethra

– Male Sexual Response

- Orgasm propels sperm from the epididymis through the vas deferens, the ejaculatory duct, and the urethra, releasing it from the male body

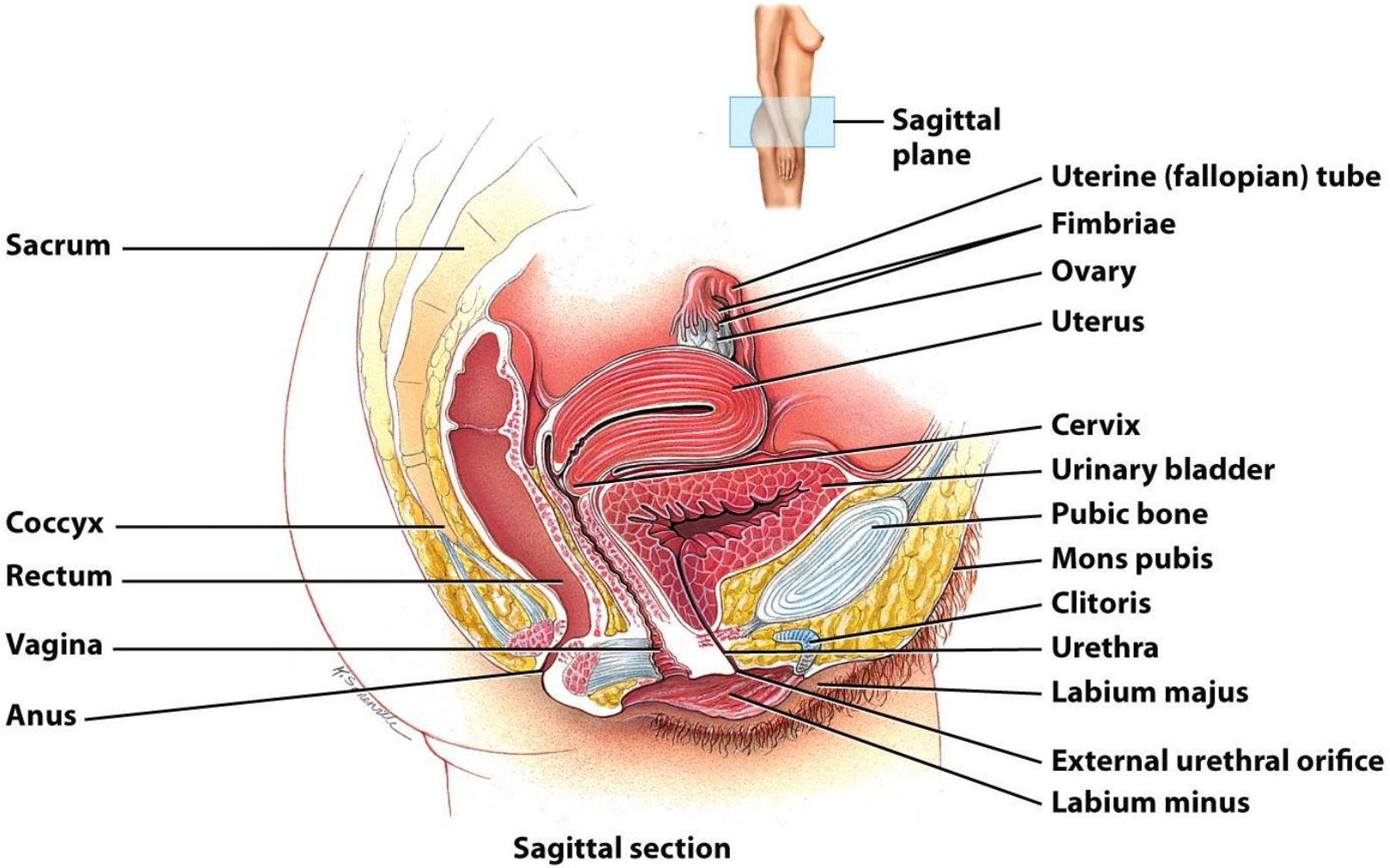
The Prostatic Urethra and Penis



The Female Reproductive System

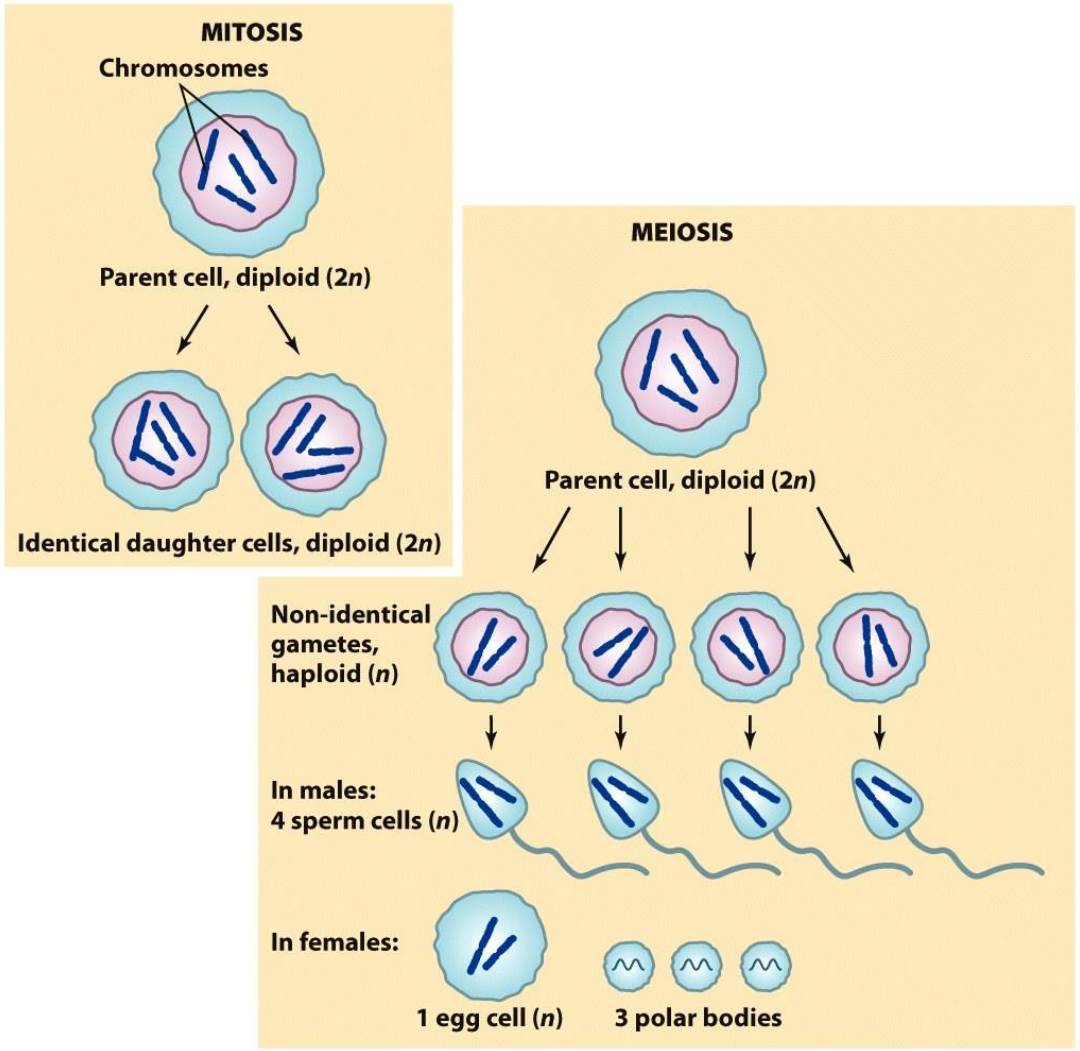
- **The main functions of the female reproductive system are to**
  - Receive sperm
  - Produce and maintain egg cells (oocytes) = gametes
  - Transport oocytes to the site of fertilization
  - Provide nutrition and safe environment for fetal development
  - Give birth – expel offspring to outside
  - Produce female sex hormones
- **Primary female sex organs - gonads – <u>two ovaries</u>**
  - Produce eggs (gametes) through a process called <u>oogenesis</u>
  - Produce the hormones <u>estrogen</u> and <u>progesterone</u>
- **Accessory sex organs – internal and external**
  - Uterine tubes, uterus, vagina, labia majora and minora, clitoris, vestibule

The Female Reproductive System - Structures



Sagittal section

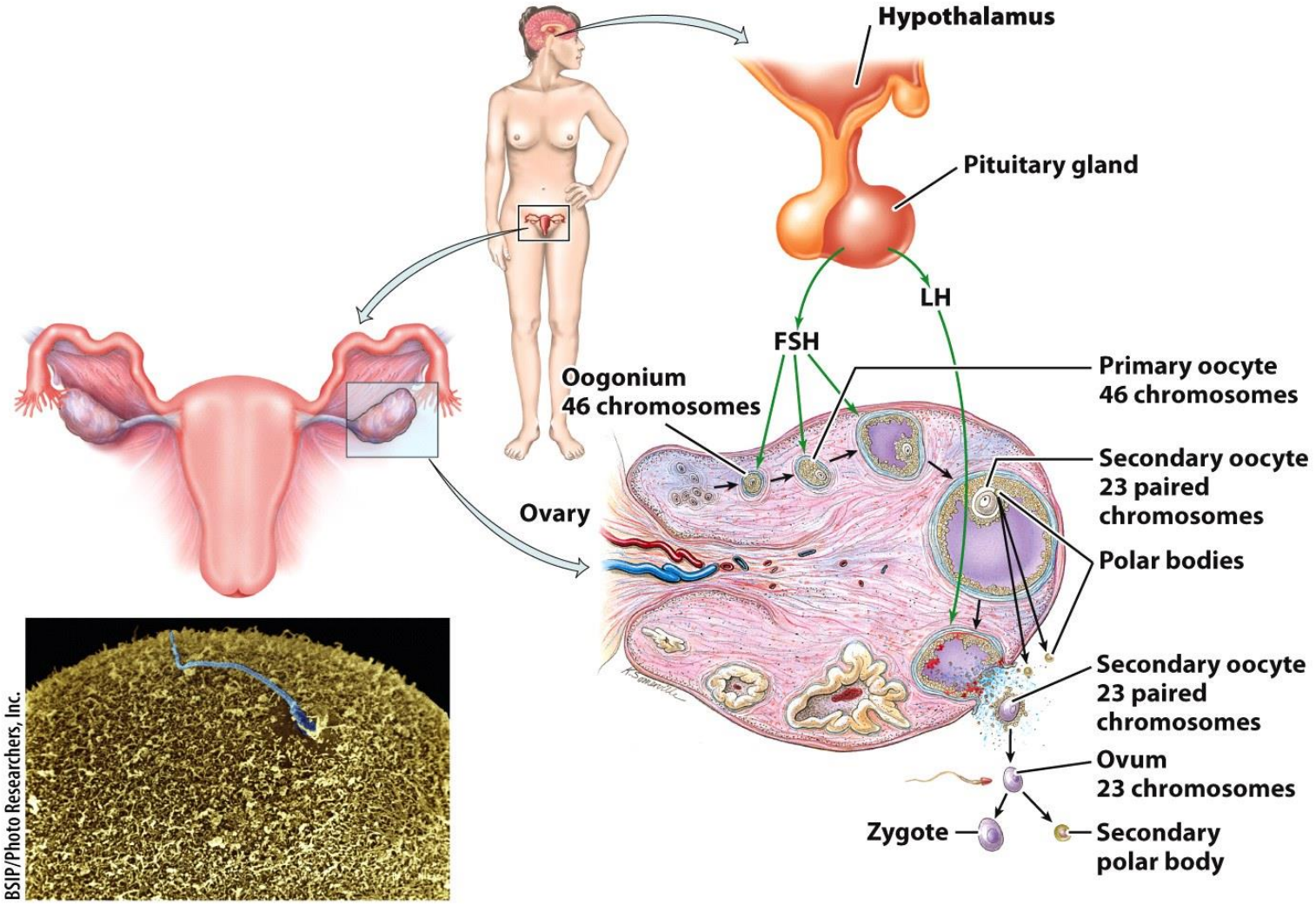
Gametes and Meiosis



Oogenesis

- **Oogenesis occurs via meiosis – and produces only one viable ovum per meiotic event**
  - **Oogonia begin meiosis *in utero*, but are arrested in meiosis I until puberty**
    - Cells remain as diploid primary oocytes until puberty
    - After which, they start to complete meiosis I, one-by-one, in monthly cycles, to become haploid secondary oocytes
  - **After puberty**
    - One haploid secondary oocyte is released from the ovary (though the process of ovulation), passes into the fallopian (uterine) tube, and travels toward the uterus
    - If the haploid secondary oocyte is fertilized within 24 hours after ovulation, it will complete meiosis II - and will become a zygote, the first cell of the new individual
    - If it isn't fertilized, it will degenerate
  - **At birth, each ovary may contain from 200,000 to 2 million such cells**
    - About 400 of these will actually mature to the point of ovulation during a woman's reproductive lifetime

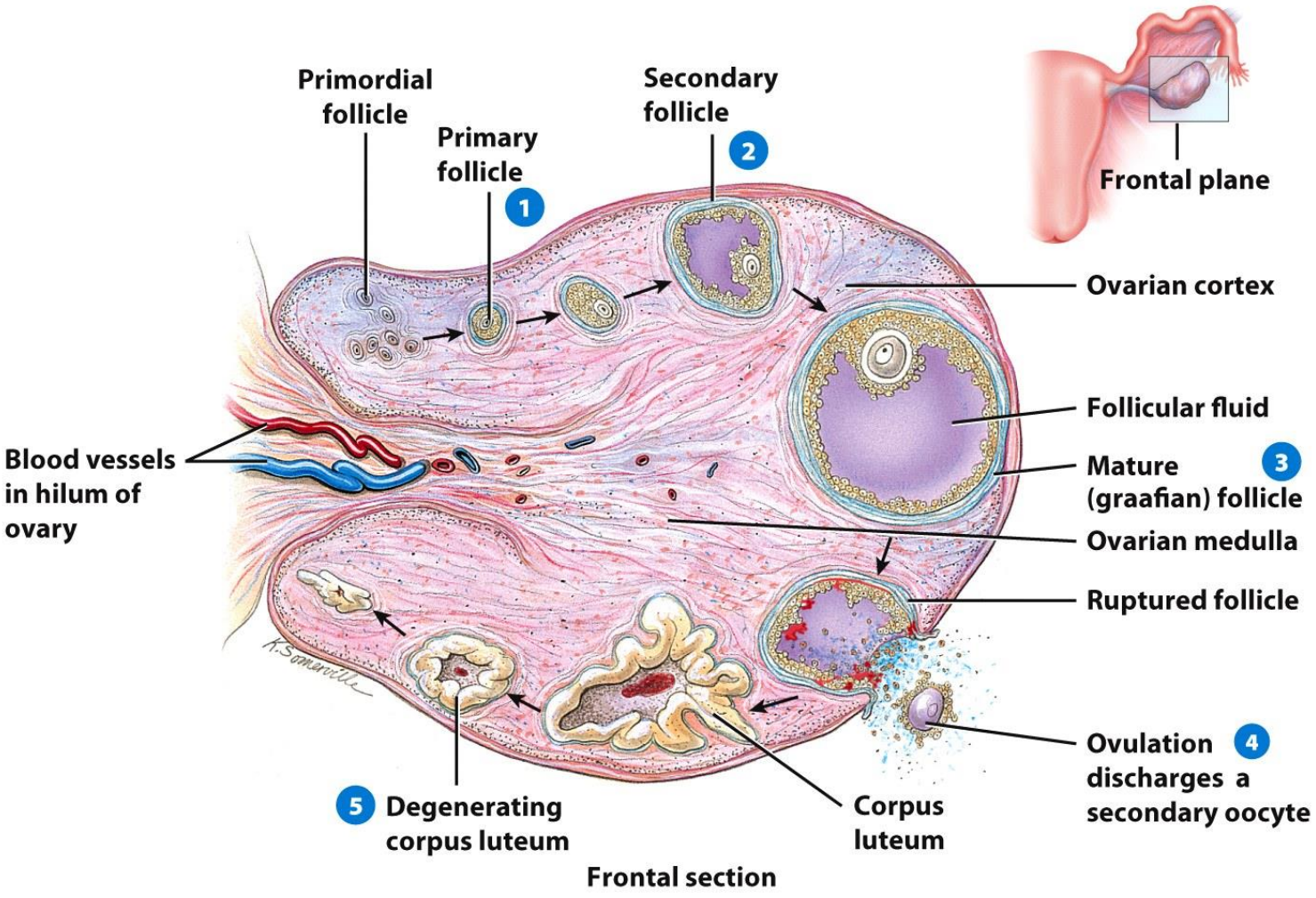
Oogenesis



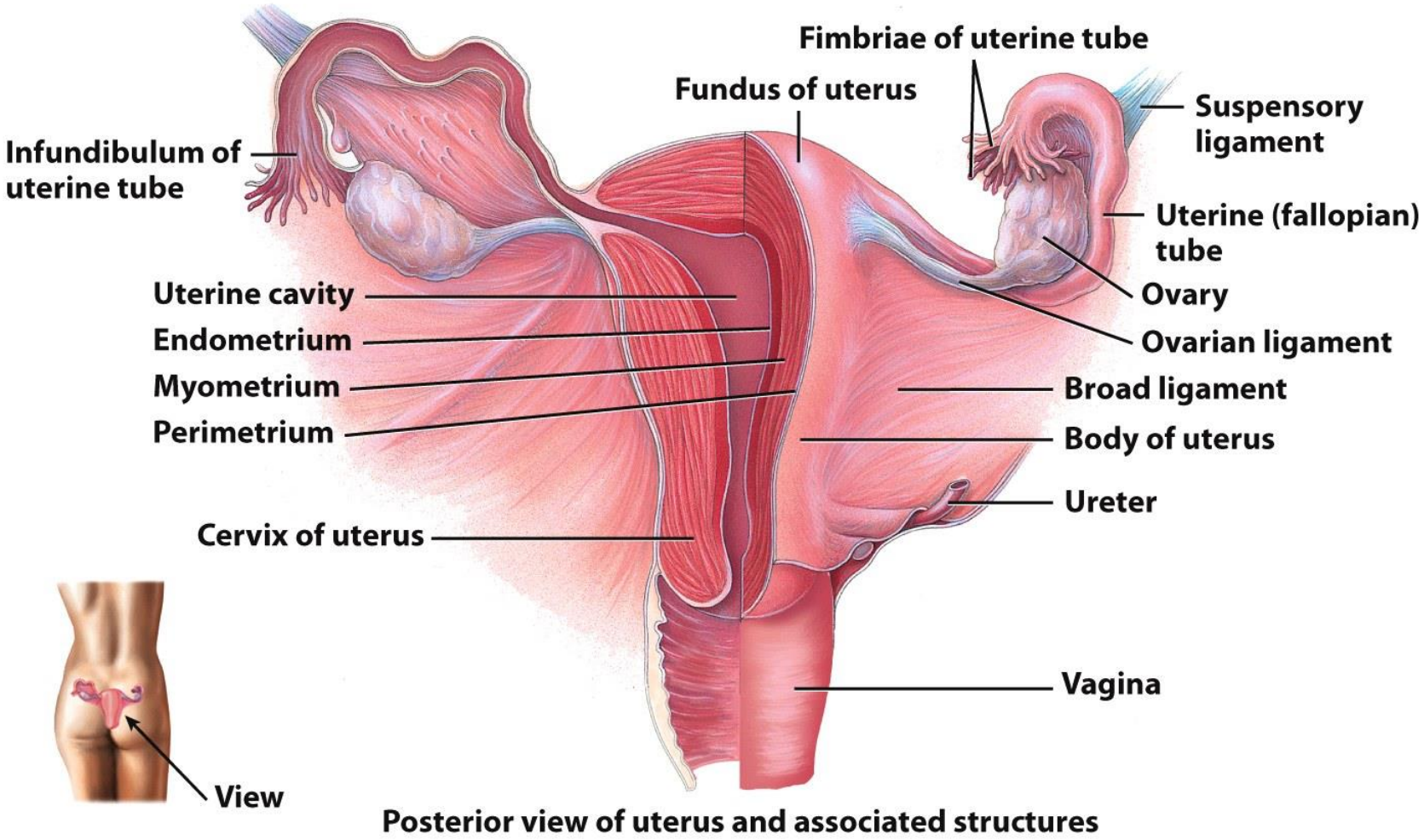
Follicles

- **Each primary oocyte sits in the center of a group of follicular cells, which are stimulated to develop alongside the oocyte**
  - A primary follicle has one to seven layers of follicular cells surrounding the oocyte
  - These follicular cells produce a clear gel-like layer that surrounds the maturing oocyte
- **Follicle-stimulating hormone (FSH)**
  - Released by the anterior pituitary gland - stimulates the diploid primary oocyte to mature into a secondary follicle, and finally into a mature, blister-like graafian follicle
- **Luteinizing hormone (LH)**
  - Causes the graafian follicle to ovulate – thus releasing the haploid secondary oocyte from the ovary

The Ovary – Follicle Maturation and Ovulation



The Uterus, Ovaries, and Fallopian Tubes



Posterior view of uterus and associated structures

The Fallopian Tubes and Uterus

- **The open ends of the fallopian tubes**
  - Are located near the ovaries - but are not physically connected
  - Are expanded into finger-like fimbriae
  - The fimbriae collect the ovulated oocyte and sweep it into the infundibulum
- **Fertilization must occur within 24 hours of ovulation**
  - The oocyte takes 6 to 7 days to reach the uterus
  - It will degenerate if it is not fertilized
- **The uterus is where fetal development occurs**
  - This organ has
    - An outer covering, the perimetrium
    - A middle layer of smooth muscle, the myometrium
    - And, an inner layer, the endometrium

Implantation and the Endometrium

- **Implantation of the embryo**
  - Occurs in the uterine endometrium, which is built up every month in anticipation of receiving an embryo
- **The endometrium thickens and sheds every 28 days or so**
  - In response to hormone levels
  - If there is no successful fertilization, the endometrium is shed, resulting in most of the menstrual flow.

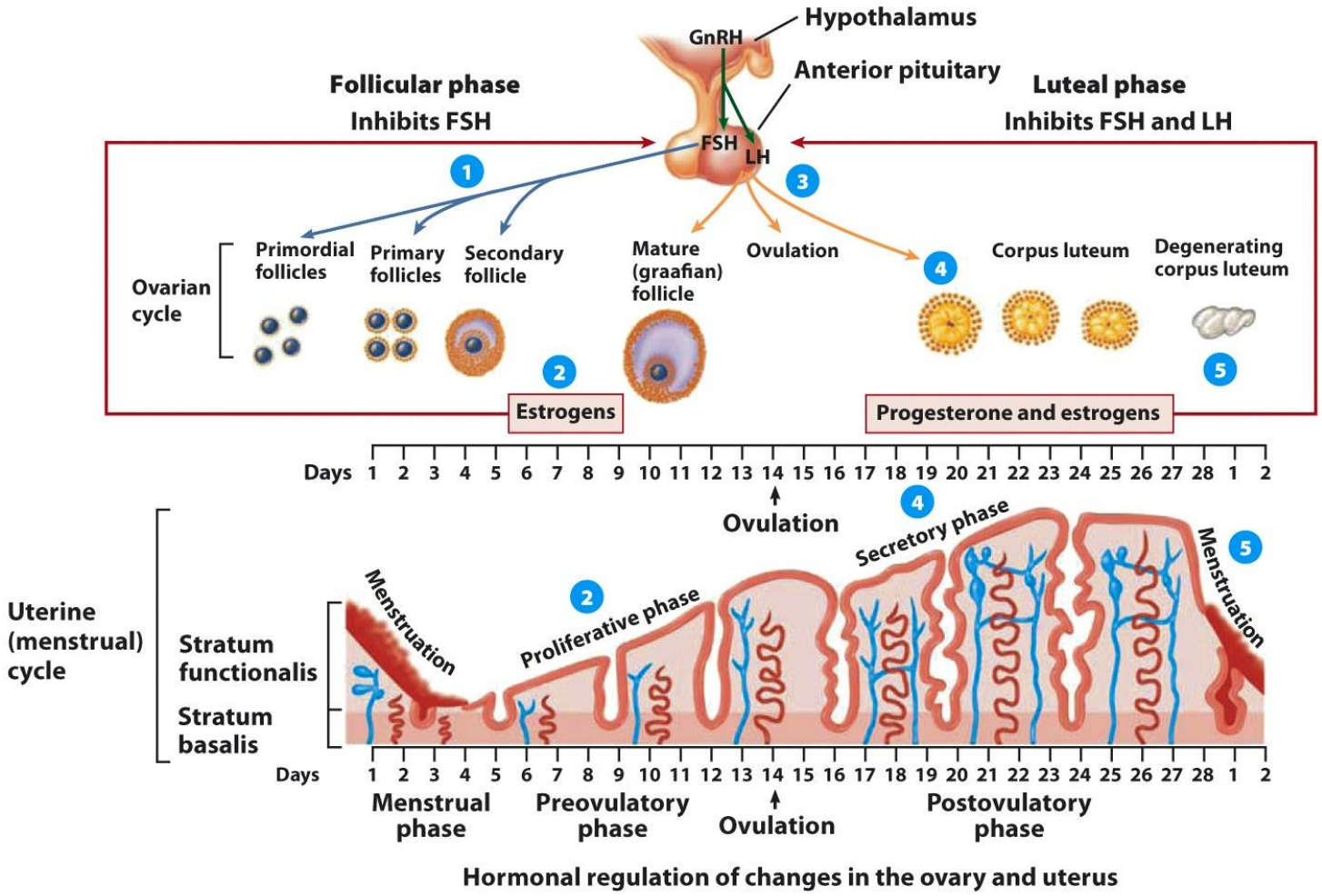
The Uterine and Ovarian Cycles

- **Two separate cycles occur at once in the nonpregnant female**
  - Each affects the other, and together they cause the cyclic menstrual flow
  - **The ovarian cycle**
    - The events that occur in the ovary as eggs mature and ovulate
    - Governed by FSH and LH, from the anterior pituitary gland
    - Cause the release of ovarian hormones
      - Which, in turn, cause changes to the endometrium of the uterus
  - **The uterine cycle**
    - Caused by the ovarian hormones – estrogen and progesterone
    - Which, in turn, cause changes to the endometrium of the uterus and the appearance of the menstrual flow

Hormonal Control of the Female Reproductive Cycle

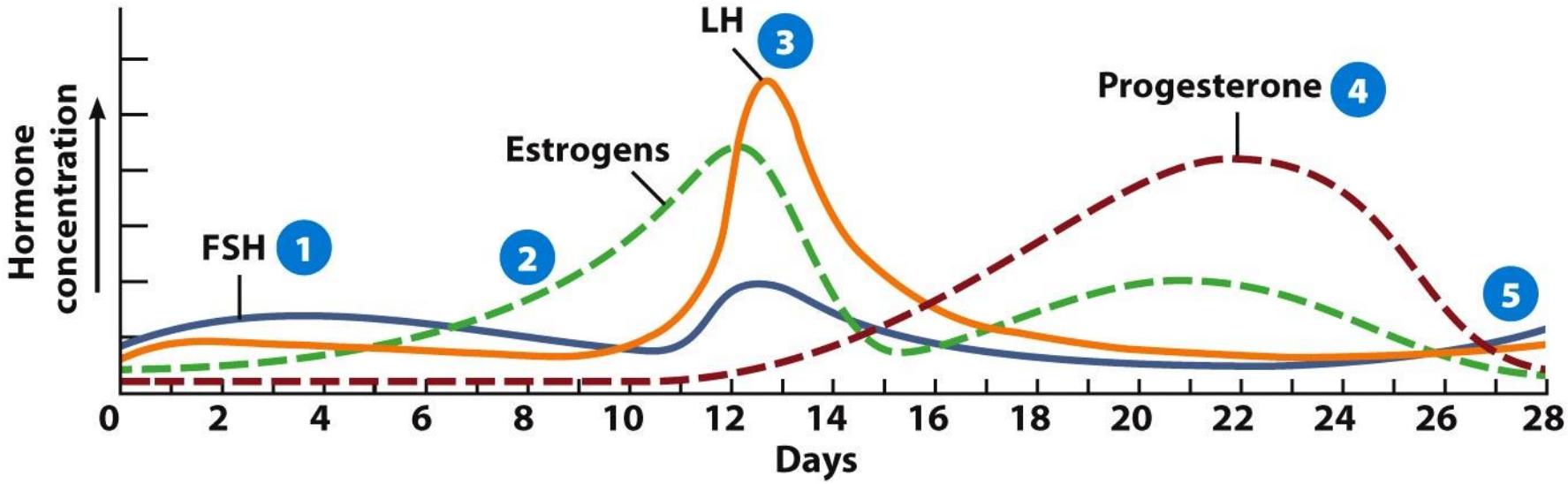
- **The female reproductive cycle is ultimately regulated by gonadotropin-releasing hormone (GnRH) from the hypothalamus**
  - Through its effects, FSH and LH are produced in the anterior pituitary
    - Follicle-stimulating hormone (FSH)
      - Stimulates follicle cell growth in the ovaries, maturing the follicles and associated ova, hence the name
    - Luteinizing hormone (LH)
      - Causes the most mature follicle to burst (ovulate), leaving a yellow body of spent follicular cells (corpus luteum) on the ovary
      - The maturing follicle cells secrete estrogen into the bloodstream
- **Ovarian hormones**
    - Estrogen
      - Regulates development of the female secondary sex characteristics
    - Progesterone
      - Affects the development of the endometrium

The Female Reproductive Cycle



Hormonal regulation of changes in the ovary and uterus

The Female Reproductive Cycle



Changes in concentration of anterior pituitary and ovarian hormones