18. MALE GENITAL DEVELOPMENT:

Male urogenital development: (4-8 weeks)

The *urorectal septum* (URS) divides the cloaca into the dorsal anorectal canal and the ventral primitive urogenital sinus (UGS). At 4 weeks the URS and perineal plates have separated the cloacal membrane into the circular anal membrane, and elliptical urogenital membrane. The anal membrane forms the floor of the anal pit and is surrounded by the anal fold. The urogenital membrane forms the floor of the urogenital groove and is surrounded by the urogenital fold.

The *sinus tubercle* (Müllerian eminence*),* projects into the posterior wall of the UGS*.*

The *upper border of the sinus tubercle* divides the primitive urogenital sinus into the vesicourethral canal above, and the definitive urogenital sinus or vestibule below.

The upper segment of the vesicourethral canal develops the allantois/urachus. The middle segment develops the urinary bladder, and the lower segment develops the prostatic urethra and membranous urethra.

The sinus tubercle develops the vagina masculinus. The distal ends of the mesonephric ducts (ejaculatory ducts), run superolateral to the vagina masculinus, in the sinus tubercle, and open superolateral to the introitus of the vagina masculinus.

The sinus tubercle will form the colliculus seminalis, which projects into the lower end of the prostatic urethra. Since the *membranous urethra* receives urine from the urinary tract and semen from the genital tract, it functions as the *pelvic part of the vestibule*.

When the *urogenital membrane disintegrates*, around 7-8weeks, the urogenital fold, now called the vestibular/ urethral fold, surrounds the opening of the *vestibule/urethra.* Disappearance of the urogenital membrane causes *mucosa (endoderm),* at the elliptical opening of the vestibule/urethra, to meet *epithelium (ectoderm)* of the inner layer of the vestibular/urethral fold, at *Hart's line*.

Male genital development (8-16 weeks):

Indifferent stage of male development:
Elongated masses of cavernous/erectile tissue, vestibular bulbs, develop on the lateral sides of the vestibule/urethra. The elliptical opening of the vestibule/urethra is surrounded by the vestibular/urethral fold. At 8 weeks, male/female genital development is indistinguishable. Male genital differentiation proceeds due to testosterone secreted by the fetal testes, and is completed by 16 weeks.

Genital development in the perineum:

Formation of corpus spongiosum:
In the perineum, mucosa (endoderm) of the *vestibule/urethra*, undergoes postero-anterior folding and ventral midline fusion to form the *bulbar urethra*. The *bulbs of the vestibule*, join posteriorly, and fuse dorsally and ventrally around the bulbar urethra, to form the *corpus spongiosum* of the bulbar urethra.

Formation of the scrotum and scrotal raphe:
The *vestibular/urethral folds* fuse in the ventral midline to form the *bulbar raphe* and a median septum, *the bulbar septum. The bulbar sep*tum attaches the bulbar raphe to the tendinous raphe between the bulbocavernosus muscles and the median sulcus of the corpus spongiosum of the bulbar urethra.
The *scrotal folds* merge in the midline, to form dual *scrotal sacs* that constitute the *scrotum*. With the merging of the scrotal folds, median bulbar septum becomes the *scrotal septum*. The inferior borders of the scrotal sacs *(ectoderm of the scrotal folds),* reflect on the lateral borders of the *bulbar raphe,* now called the *scrotal raphe, (ectoderm of fused vestibular/urethral folds).*

Formation of the bicavernosal body of the penis:
The crura of the corpora cavernosa, are attached to the flattened medial surfaces of the of the ischiopubic rami. The tapered distal ends of *the crura,* leave their bony attachment, as they converge towards the midline. A dense layer of fibrous tissue, the *tunica albuginea*, develops around the corpora cavernosa. Under the pubic symphysis, the (tunica albuginea of the) medial surfaces of the *corpora cavernosa*, fuse in the midline. The corpora cavernosa have formed a *bicavernosal body*

Development of the phallus/penis:
The genital swelling (genital fold, genital tubercle, and urogenital fold) grows forwards of the body of the embryo, to form the *phallus/clitoris/penis.* Testosterone secreted by the fetal testes, cause *the genital swelling, now called the phallus or penis, to* elongate.
The phallus contains the phallic segment of the bicavernosal body and corpus spongiosum, the dorsal plate (of fossa navicularis) and open phallic segments of the vestibule/urethra (future penile urethra, and fossa navicularis, and phallic segments of the urogenital/vestibular/urethral fold (future penile raphe, preputial raphe, frenulum, labia, and dorsal commissure of the labia, of the glans penis).

Formation of the penile urethra, corpus spongiosum and penile raphe:
The open vestibule/urethra (endoderm), ventral to the bicavernosal body, undergoes postero-anterior folding and midline ventral fusion to form the mucosa (endoderm) of the *penile urethra*. Continuation of the process of tubularization (dorsal and ventral fusion) of the *vestibular bodies*, which started in the perineum, forms the *corpus* spongiosum around the penile urethra. Postero-anterior fusion the vestibular/urethral folds (ectoderm) forms the *penile raphe.*

Formation of the prepuce:
The *prepuce* originates as a *fold of penile skin* (epidermis of genital fold/ectoderm and a layer of underlying mesoderm), with the penile raphe (fused related fused vestibular/urethral folds) attached to the ventral borders of the fold of penile skin. The base of the fold originates just proximal to the *coronal sulcus*. The fold grows distally to cover the developing glans penis. The skin of the return/inner layer of the fold joins the skin of the coronal sulcus. The penile raphe on the outer and inner layers of the prepuce is called the *preputial raphe*. The preputial raphe joins the frenulum in the coronal sulcus.
Development of the prepuce is independent of development of the glans penis.

Development in the coronal sulcus:
The coronal sulcus is the part of the phallus, that develops between the origin of the inner layer of the fold of the prepuce, and the corona of the glans penis.
The coronal sulcus is covered by *penile skin*, derived from the *genital fold* and underlying mesoderm. The bicavernosal body of the penis runs through the coronal sulcus, and enters the body of the glans penis, through the roof section of the corona of the glans penis.
The *penile urethra,* surrounded by *corpus spongiosum* is ventral to the bicavernosal body. The mucosa of the penile urethra joins mucosa of the fossa navicularis, at the apex of the V-shaped gap between the wing sections of the corona of the glans penis. At the apex of the V-shaped gap between the wing sections of the corona of the glans penis, the corpus spongiosum becomes the dorsal plate of fossa navicularis.

Development of the frenulum:
Ventral to the penile urethra in the coronal sulcus, midline fusion of the vestibular/urethral folds, forms the quadrilaminar frenulum. Epithelium of the lateral surfaces of the frenulum (vestibular/urethral folds), reflects on epithelium of the coronal sulcus (genital fold). The frenulum joins the preputial raphe to the navicular raphe.

DEVELOPMENT OF FOSSA NAVICULARIS, DORSAL PLATE OF FOSSA NAVICULARIS, GLANS PENIS, BODY OF THE GLANS PENIS AND EXTERNAL URETHRAL MEATUS:

Development of the dorsal plate of fossa navicularis:
The dorsal plate of fossa navicularis, is a narrow plate of tissue adherent to the roof of fossa navicularis.
Origin: The corpus spongiosum that surrounds the penile urethra, is reduced to a plate of tissue on the roof of the fossa navicularis. The roof section of corpus spongiosum of the penile urethra, continues as a narrow plate, which is adherent to the *mucosal roof of fossa navicularis.*
The tunica albuginea of the roof section of the corpus spongiosum of the penile urethra, continues as a layer of tunica albuginea, adherent to the *dorsal surface of the dorsal plate* of fossa navicularis. The tunica albuginea of the dorsal plate of fossa navicularis, adheres to the ventral groove of tunica albuginea of the bicavernosal body of the penis.

The dorsal plate of fossa navicularis, consists of a *pair of side-to-side laminas*, divided in the midsagittal plane by a fine septum. The origin of the laminas is traced to the bulbs of the vestibule which fuse on the ventral and dorsal aspects of the bulbar section of the vestibule/urethra, to form the corpus spongiosum of the bulbar urethra and penile urethra.

The sides and distal end of the dorsal plate of fossa navicularis, generate spongy tissue, which forms the (spongy tissue of) the glans penis.

Development of fossa navicularis:
Origin: Distal end of the vestibule/urethra.
The ventral borders of the distal end of the vestibule/urethra (endoderm), fold ventrally and fuse from posterior to anterior.

The *dorsal plate of fossa navicularis*, derived from the roof of the corpus spongiosum of the penile urethra, adheres to the mucosal roof of fossa navicularis

The *wings of the glans penis*, generated by the lateral borders of the dorsal plate of fossa navicularis, drape over the lateral wall and ventral aspect of the fossa navicularis. In the *ventral midline* the wings of the glans penis, contact the small amount of *areolar tissue*, that separates the floor of fossa navicularis from the navicular raphe.

Development of the navicular raphe:
Origin: Fused vestibular urethral folds.
The vestibular/urethral folds ventral to fossa navicularis, undergo postero-anterior fusion, to form the midline the *quadrilinear navicular raphe.*
The navicular raphe runs in the midline gap between the ventral borders of the wings of the glans penis.
Epithelium (ectoderm) of the lateral borders of the navicular raphe, reflects on the epithelium (ectoderm of the genital fold), covering the wings of the glans penis.
The *lateral and medial* borders of the quadrilinear navicular raphe, (fused vestibular/urethral folds), join the ipsilateral *outer and inner* borders of the labia of the glans penis (unfused vestibular/urethral folds).

Glans penis:
The *glans penis* consists of the *body of the glans penis*, and the *external urethral meatus.*
The *body of the glans* is composed of spongy tissue, generated by the *dorsal plate of fossa navicularis*.
The *external urethral meatus*, formed by the *labia and dorsal commissure of the labia* of the glans penis, is formed by the *unfused vestibular/urethral folds*.

Epithelium covering of the body of the glans, is derived from the *genital fold* (ectoderm). The ventral borders of the genital fold, reflect on the lateral borders of the *navicular raphe* (ectoderm), derived from the *fused* vestibular/urethral folds, ventral to the fossa navicularis.

Development of the glans penis:
The body of the glans penis can be divided into a *cap, roof, and wings.*

Development of the cap of the glans penis:
Spongy tissue generated at the *distal end of the dorsal plate of fossa navicularis,* flows forwards and dorsally, under the genital fold, and molds over the *conical end of the bicavernosal body*, to form the *crescentic cap of the glans* penis.
The *rounded tip of the cap* is the *tip of the penis*. The *point of the (short) ventral horn* of the crescentic cap, is *just ventral to the tip* of the penis. The circumferential *proximal border* of *the cap* joins the circumferential *distal border of the roof* of the glans penis.

Development of the roof of the glans penis:
Spongy tissue generated by the *lateral borders of the dorsal plate* of fossa navicularis, flows dorsally, under the genital fold, and covers the *lateral and dorsal surfaces* of the bicavernosal body.
The distal end of the roof is naturally continuous with the proximal end of the cap.
The *prominent posterior border of the roof* of the glans penis, forms the *roof segment of the corona of the glans penis.*
The *ventral borders* of the roof of the glans penis, are level with the *ventral surface* of the dorsal plate of fossa navicularis.

Development of the wings of the glans penis:
Spongy tissue generated by the lateral borders of the dorsal plate of fossa navicularis, enters the ventral ends, of the genital fold.
The spongy tissue, with a covering of epithelium of the genital fold, flows ventrally, and drapes around the mucosa of the lateral and ventral surfaces of the fossa navicularis, to form the wings of the glans penis. The ventral borders of the wings of the glans do not meet in the midline.
In the *ventral midline, spongy tissue* of the wings of the glans penis, contacts a thin band of areolar tissue that separates the floor of the fossa navicularis, from the navicular raphe.
In the *ventral midline, epithelium (ectoderm),* of the *genital fold*, reflects on the *lateral borders* (ectoderm) *of the navicular raphe.*
The wings of the body of the glans penis, drape around the mucosa of the walls and ventral surfaces (except the ventral midline), of the fossa navicularis. In development spongy tissue generated by the lateral borders of the dorsal plate of fossa navicularis, forms the wings of the glans penis. The spongy tissue flows ventrally, under the genital fold, to drape around the lateral and ventral surfaces (except the ventral midline), of the fossa navicularis. In the midline, the ventral borders of the wings of the glans penis, contact the thin band of areolar tissue that separates the navicular raphe from the floor of fossa navicularis.
The prominent *posterior borders of the wings*, curve forwards/distally, to form the *wing segments of the corona* of the glans penis.
The *dorsal borders of the wings* of the glans penis, are *level with the ventral surface* of the *dorsal plate of fossa navicularis*.

External urethral meatus:

The *external urethral meatus* is formed by the *labia of the glans penis* and *dorsal commissure of the labia* of the glans penis. Epithelium (ectoderm) of the inner borders of the labia of the glans, meets mucosa (endoderm), at *Hart's line.*

Development of the external urethral meatus:
The external urethral meatus is unique to male genital development. However, at the outset, male and female genital development is indistinguishable.

In *female development*, the elliptical vestibular/labial fold, surrounds the opening of the vestibule. The *inner border* (ectoderm) of the vestibular/labial fold meets *mucosa (endoderm)* of the vestibule, at *Hart's line.*

In the perineum, the *outer borders* (ectoderm) of the vestibular/labial folds, reflect on epithelium (ectoderm) of the *labial folds/labia majora. The inner borders* of the vestibular/ labial folds, meet mucosa (endoderm), of the vestibule*, at Hart's line.*

In the phallus, the bicavernosal body of the clitoris, is covered on its dorsal and lateral aspects, by the *dorsal hood* of the clitoris, and spongy tissue of the *roof of the glans clitoris*. The *outer borders* of the vestibular/labial folds/frenulum (ectoderm) reflect on epithelium (ectoderm of the genital fold) of the dorsal hood, and *roof of the glans clitoris*. *There are no wings in the glans clitoris.* The *inner border*s of the vestibular/labial folds/frenulum, (ectoderm), meet *mucosa* (endoderm) of the lateral borders of the *flat roof of the anterior section of the vestibule*, at *Hart's line.*

*At the anterior commissure of the vestibular/labial fold/frenulum, t*he *outer border* (ectoderm) of the anterior *commissure* (ectoderm), reflects on epithelium (ectoderm) of the ventral end of the *crescentic cap of the glans clitoris.* The *inner border* (ectoderm) of the *anterior commissure*, meets the mucosa (endoderm) of the anterior/distal border of the *flat roof of the anterior section of the vestibule*, at *Hart's line.*

In male development, postero-anterior ventral folding and midline fusion of the mucosa (endoderm), of the vestibule/ urethra, forms the bulbar urethra, penile urethra, and fossa navicularis.

<u>*Fused vestibular/urethral folds*</u>:

In the perineum, postero-anterior fusion of the vestibular/ urethral folds, (ectoderm), forms the scrotal/bulbar raphe. The lateral borders of the of the scrotal/bulbar raphe (ectoderm), reflect on epithelium (ectoderm) of the scrotal folds/scrotum.

In the phallus, proximal to the body of the glans penis, postero-anterior fusion of the vestibular/ urethral folds, form the penile (and preputial raphe). *In the penile segment of the phallus,* the lateral borders of the penile (and preputial raphe (ectoderm), reflect on epithelium (ectoderm of the genital fold) of the penis and prepuce. *In the coronal sulcus segment of the phallus,* the outer layers of the frenulum (ectoderm), reflect on epithelium (ectoderm of the genital fold) of the coronal sulcus. *Ventral to the body of the glans penis*, postero-anterior fusion of the vestibular/urethral folds form the quadrilinear, navicular raphe. The lateral borders of the navicular raphe (ectoderm), reflect on epithelium (ectoderm of the genital fold), of the wings of the glans penis.

<u>*Unfused vestibular/urethral folds*</u>: Distal to the navicular raphe, the vestibular/urethral folds remain unfused, and form the *labia, dorsal commissure of the labia, of the glans penis* (external urethral meatus).

DEVELOPMENT OF THE WINGS OF THE GLANS PENIS, DIRECTS THE DISTAL UNFUSED SEGMENT OF THE VESTIBULAR/URETHRAL FOLD AND ITS ANTERIOR COMMISSURE, TO FORM THE LABIAL FOLDS AND DORSAL COMMISSURE OF THE LABIAL FOLDS OF THE GLANS PENIS (EXTERNAL URETHRAL MEATUS).

The anterior commissure of the vestibular/urethral folds is *attached* to the *ventral end of the crescentic cap of the glans penis*. The *anterior and ventral borders of the developing wings* of the glans penis, push the *proximal ends of the unfused vestibular/urethral folds*, forwards/ distally. *Differential growth of the wings of the glans penis and fossa navicularis, causes the*

unfused vestibular/urethral folds and anterior commissure of the vestibular/urethral folds, to line up vertically along the elliptical opening of the fossa navicularis.

The *unfused vestibular/urethral folds* and anterior commissure of the vestibular/urethral folds are now the *labia of the glans penis and dorsal commissure of the labia of the glans penis, which form the external urethral meatus*.

The extant opening of the vestibule/urethra is preserved at the external urethral meatus:

At the outset of genital development, the *vestibule/urethra, had a wide ventral elliptical opening.* Mucosa (endoderm) *of the opening of the vestibule/urethra*, joined the *inner layers of the* vestibular/urethral fold and *anterior commissure* of the vestibular/ urethral fold.

At the end of genital development, the vestibule/urethra, has narrower vertical elliptical opening.

Mucosal epithelial junction of the external urethral meatus (Hart's line):

Mucosa (endoderm) at the opening of the fossa navicularis, joins epithelium (ectoderm) of the inner layers of the labia and dorsal commissure of the labia, of the glans penis (external urethral meatus), at *Hart's line.*

Epithelial reflections of the external urethral meatus:

Epithelium (ectoderm) of the *outer border of the dorsal commissure* of the labia of the glans penis, reflects on epithelium (ectoderm of the genital fold), at the *ventral end of the crescentic cap of the glans penis*. Epithelium (ectoderm), of the *outer layer of the labia* of the glans penis, reflects on epithelium (ectoderm of the genital fold), at the *anterior/distal borders of the wings of the glans penis*.

In the *ventral angle of the external urethral meatus*, the *outer borders (ectoderm) of the labia* of the glans penis, join the *lateral borders (ectoderm) of the quadrilinear navicular raphe*. The *ventral ends of the inner borders of the labia* of the glans penis, are *fused in the midline*. The *fused inner borders* (ectoderm) *of the labia*, join the *fused medial borders* (ectoderm) of the *quadrilinear navicular raphe*.

Spongy tissue and areolar tissue contacts in the external urethral meatus:

Spongy tissue (mesoderm) of the body of the glans penis, is enclosed by the *genital fold* (ectoderm).
Areolar tissue (mesoderm) of the external urethral meatus is contained in the *folds of the labia and dorsal commissure of the labia,* of the glans penis.

Spongy tissue (generated by the distal end of the dorsal plate of fossa navicularis) in the *ventral end of the crescentic cap* of the glans penis, contacts *areolar tissue* in *the dorsal commissure* of the labia of the glans penis.

Spongy tissue of the *anterior/distal borders of the wings* of the glans penis, contacts *areolar tissue* in the *labia of the glans penis*.

Spongy tissue of the *ventral borders of the wings* of the glans penis, contacts a thin strip of *areolar tissue* that lies between the floor of the fossa navicularis and the *navicular raphe*.

Distal migration of Hart's line in male genital development:
At the start of the male genital development, the wide elliptical opening of the vestibule/ urethra is oriented horizontally. Mucosa (endoderm) of the vestibule/urethra (endoderm), meets epithelium (ectoderm) of the inner border of the vestibular/urethral fold, at Hart's line.

During m*ale genital development,* postero-anterior ventral midline fusion of the vestibule/ urethra forms the tubular bulbar urethra, penile urethra, and the fossa navicularis. Postero-anterior ventral midline fusion of the vestibular/urethral folds forms the scrotal/bulbar raphe, penile raphe, the frenulum, and navicular raphe.

Distal to the fused vestibular/urethral folds of the navicular raphe, the *unfused vestibular/ urethral folds,* and its *anterior commissure*, are pressed into alignment with the elliptical opening of fossa navicularis.

At the completion of male genital development, the narrowed elliptical opening of the vestibule/ urethra is oriented vertically. Mucosa (endoderm) of the fossa navicularis, meets epithelium (ectoderm), of the inner borders of the labia and dorsal commissure of the labia of the glans penis, at Hart's line.

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