

Citation:

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Anatomy. — “*About the development of the urogenital canal (urethra in man.*” By A. J. P. v. D. BROEK. (Communicated by Prof. L. BOLK).

In the following communication I am going to give a description of the way in which ontogenetically the closure of the urogenital canal comes about in man; next I intend trying to throw some light upon the composition of this canal from a comparative point of view.

The youngest stage that I examined was a male(?) embryo of a length of 30 m.m. from crown to coccyx; a stage which is a little younger than the oldest female embryo (l.c. Embryo Lo) described by KEIBEL¹⁾.

The urodaeum (entodermal cloaca) is divided into rectum and sinus urogenitalis; there is a primitive perinaeum. The anal membrane no longer lies near the surface of the body, but forms the bottom of a short proctodaeum. Sinus urogenitalis and proctodaeum combine into a short (200 μ) ectodaeum (ectodermal cloaca), in whose walls the two component parts are easy to recognize. If we follow the part of the wall proceeding from the sinus urogenitalis, it appears that this at the basis of the penis contributes to the limitation of the short genital groove (“Geschlechtsrinne”); before this it continues in the beginning of the penis as an epithelial double lamella, phallusframe (“Urogenitalplatte”, “Urethralplatte”, “lame cloacale” etc.). There is not yet a fossa navicularis.

In an embryo of 4 c.m. the apertures of proctodaeum (anus) and sinus urogenitalis are separated by a definitive perinaeum.

The sinus urogenitalis mouths on the perineal penis-surface with an aperture about lozenge-shaped, situated immediately behind a circular furrow on the penis. This furrow denotes the limit between the glans and the corpus of the penis.

Following the transverse sections, starting from the apex of the penis, it appears how in the part before the navicular aperture (fossa navicularis) the phallus-frame as double-lamella penetrates into the tissue of the penis (fig. 1 a). In the sphere of the fossa navicularis the lamellae of the phallus-frame partly deviate (fig. 1. b.), by which on the perineal surface a groove becomes visible. The angle between the two leaves becomes gradually larger, till at last, in the widest part of the aperture, one is the continua-

¹⁾ KEIBEL (K.). Zur Entwicklungsgeschichte des menschlichen Urogenitalapparates. Archiv f. Anatomie und Physiologie. Anat. Abth. 1896. pag. 55

tion of the other (figure 1 c. and d.). The upper part of the phallus frame stands like a crest upon the cornerplace of the deviating lamellae. (fig. 1 b-d.).

If we look more closely at the wall of the fossa navicularis, it appears that it is only partially formed by the lamellae of the phallus-frame; the rest originates from the penisectoderm, which by the side of the phallus-frame bends like a fold over its edge (marked in fig. 1 b and c. with g.p.). If this fold is to be called sexual-fold, it must be borne in mind that it does not represent the transition-edge of the phallus-frame into the penisectoderm, but entirely originates from this ectoderm. In figure 1 b the two sexual folds are situated close to each other, in figure 1 c, corresponding to the middle of the fossa navicularis they are farther distant.

Towards the base of the penis the two lamellae of the phallus-frame remain each other's continuation; likewise the median crest remains present; the two sexual folds, on the other hand, keep bending to one another till they reach each other in the median line and close the urogenital canal. Accordingly the wall of this canal consists of two parts, originating from the phallus-frame and from the sexual folds (penisectoderm) (fig. 1 d.). At the nature of the epithelium they are to be recognized microscopically.

In the discussion of the older embryos I shall restrict myself to that place, where comes about the closure of the urogenital canal. I mention in passing that the part already closed, grows in length during the following time of development and contributes to the growth of the perinaeum.

In an embryo of 5 cm. the place where the two sexual folds meet in the median line, is situated somewhat behind the broadest part of the fossa navicularis. Here, too, the two wall-parts of the urogenital canal, originating from the phallus-frame and from the sexual folds are clearly to be distinguished from each other. The part of the phallus-frame not separated lies like a crest on the ventral wall of the urogenital canal; before the fossa navicularis the phallus-frame forms an epithelial double-lamella. In this embryo a praeputium has appeared which has not yet entirely grown about the penis. The closure of the urogenital canal now goes on in apical direction, so that the orificum externum urethrae is removed to the point of the penis. This removal runs almost parallel to the growing of the praeputium round the glans penis.

In the closed part of the urogenital canal the wall every time consists of the two parts described higher up, which are microscopically sharply to be distinguished. Differences appear only in the

proportions in which the two epithelia contribute in the formation of the wall. In an embryo of a length of 8.5 cm the praeputium has grown round the whole glans. The orificium externum urethrae finds itself not far behind the apex of the penis on the perineal surface of the glans.

The first sections, beginning at the apex of the penis, still show the solid phallus-frame (fig. 2 a.). The aperture of the urogenital canal is to be seen in fig. 2 a as a groove in the thick mass of epithelium, having arisen by the meeting of the two edges of the praeputium. Through this the urogenital canal runs in an oblique direction and after some sections it reaches the surface of the glans. In that place the two lamellae of the phallus-frame have partly deviated a little from each other (fig. 2 b.). The adjoining penisectoderm forms at the edges of the phallus-frame two small sexual folds (marked in fig. 2 b with *g p*). By the meeting of these two folds, some sections further on, the closure of the urogenital canal is brought about (fig. 2 c). In contradistinction to what we saw in the sphere of the fossa navicularis, the phallus-frame has by far the greatest part in the formation of the wall of the urethra; only a very small part proceeds from the sexual folds (penisectoderm).

That here, also, the two wall-parts are easy to distinguish from each other, is taught by fig. 3, in which a part of fig. 2c under high power is sketched.

The epithelium of the phallus-frame is to be recognized in a very distinct stratum germinativum of high cylindrical cells; between the stratum germinativum on either side there are a number of big, little coloured, polygonal cells with large round nuclei. The cell-boundaries are very clear. The groove between the deviated parts of the phallus-frame possesses a smooth surface.

The epithelium proceeding from the penisectoderm and covering the foremost part of the canal, has quite a different appearance.

It has a much darker colour, probably partially a consequence of the much closer arrangement of the nuclei. A clear stratum germinativum is not to be recognized, no more are the cell-boundaries visible; the limitation of the lumen is not so smooth and sharp as in the phallus-frame.

If we follow the urethra towards the fossa navicularis, we see two kinds of changes taking place. First in the wall-formation a place getting larger and larger is given to the penisectoderm; secondly the two lamellae of the phallus-frame deviate more and more, only a small part remaining in the shape of a crest on the urethra (fig. 2e). The epithelium of the phallus-frame is gradually replaced by an

epithelium having the character of the penisectoderm. In the section from which fig. 2*g* has been borrowed, the two components which are ontogenetically contained in it, are no more to be recognized. I cannot omit directing attention in this figure to the epithelial knob lying dorsally with respect to the urethra. It represents the "Anlage" of one of the so-called para-urethral passages and is to be considered as a separated part of the phallus-frame or as a cell-cord grown inside from this frame.

Finally I give in fig. 4 a series of sections through the urethra of an embryo 13 cm. long (\pm at the end of the 5th month) in which embryo the state of the full-grown man has been reached.

The urethra mouths at the end of the penis with a vertical aperture. Where the urethra is vertical, accordingly before the fossa navicularis, its wall, as is shown in fig. 4*a*, consists principally of the epithelium of the phallus-frame; only an exceedingly small part proceeds from the penisectoderm, resp. the sexual folds. The lamellae of the phallus-frame are almost entirely separated, not because they are deviated, but because the central mass has disappeared.

In the direction to the fossa navicularis also here the composition of the wall changes and the part proceeding from the phallus-frame becomes smaller, the part originating from the sexual folds becomes larger. In fig. 4*c* the vertical part of the canal certainly answers to the phallus-frame, the rest is for the greater part a production of the sexual folds. Also in this preparation the difference between the two kinds of epithelium disappears in the sphere of the fossa navicularis; in the sections from which fig. 4*d-g* has been borrowed the boundaries between the two components are no more to be seen.

In different places separated cell-cords and tubes are present which must be considered as the "Anlagen" of paraurethral passages; the tube in fig. 4*f* marked *s. g.* is the "Anlage" of the sinus of Guérin.

The series fig. 4, like fig. 2, shows the cause of the change in the position of the urethra, which, as is well-known, stands vertical before the fossa navicularis, behind it mostly horizontal. The difference is based upon the difference in composition. For before the fossa navicularis it is the phallus-frame, which has a vertical position, that forms the greatest part in the wall-formation of the urethra, only a small part proceeds from the sexual folds. Behind this fossa, on the other hand, the wall of the urethra is for the greater part the production of the united sexual folds, only a small part proceeding ontogenetically from the phallus-frame. The deviation of the two lamellae of the phallus-frame is in this transformation an important factor.

Considering the ontogenetical processes which contribute to the closure of the urogenital canal, as they have been described before, I have to join the group of investigators (REITTERER, REICHEL, HERZOG) who assume a closure in consequence of the combination of two folds (sexual folds) in the median line. I deviate from their opinion as to the origin of the sexual folds, which are not the edges of the phallus-frame, but which represent folds of the penisectoderm.

In connection with the processes described above I finally wish to give some ideas about the value and the importance of the urethra from a comparative ontogenetical point of view. For this purpose I have to remind of the state, as it occurs in *Echidna*, one of the *Monotremata*. In this animal, as KEIBEL's¹⁾ investigation taught us, a couple of tubes, the so-called "Samenurethra" and the "Harnurethra" are developed caudally from the glands of Cowper. The former runs like a canal through the penis and is a production of the phallus-frame; the latter goes from the urogenital canal oblique caudally to the ectodaeum (ectodermal cloaca). Genetically this tube is formed, because the original single ectodaeum is divided by means of two folds which come together and unite, into two halves, the proctodaeum and the "Harnurethra". For the group of the *Marsupialia I*²⁾ have proved that the urogenital canal must not be considered as a homologon to the "Samenurethra" of *Echidna* (as is generally done for the urethra of placental mammals on the ground of its topography with respect to the corpus cavernosum), but that it must be considered as a combination-product of "Samenurethra" and "Harnurethra", which placed themselves against each other and formed one canal. In *Perameles* there exists a transition between *Echidna* and placental mammals (man).

Applying the explanation given for the marsupialia about the genetical composition of the urogenital canal to the urethra of man, I come to the conclusion that here, too, a real "Samenharnurethra" exists, homologous to the "Samenurethra" + "Harnurethra" of *Echidna*. To be compared with the "Samenurethra" is that part of the urethra which owes its origin to the phallus-frame. The homologa of the two folds of the ectodaeum are the two folds which I described as sexual folds, by whose meeting the closure of the urogenital canal is brought about. The part bounded by these folds thereby becomes homologous to the "Harnurethra."

¹⁾ KEIBEL (F.). Zur Entwicklungsgeschichte des Urogenitalapparates von *Echidna aculeata* var. *typica*. Semon. zööl. Forschungsreisen. Lieferung 22. pg. 153—206.

²⁾ v. D. BROEK (A. J. P.) Zur Entwicklungsgeschichte des Urogenitalkanales bei Beutlern. Verhandl. der Anat. Gesellschaft. 22. Berlin 1908, pg. 104—120.

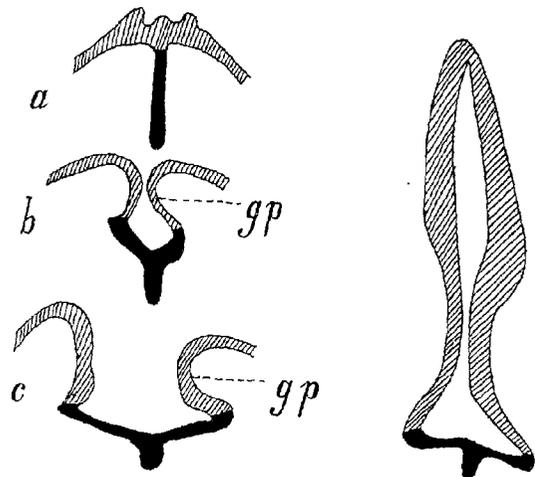


Fig. 1.

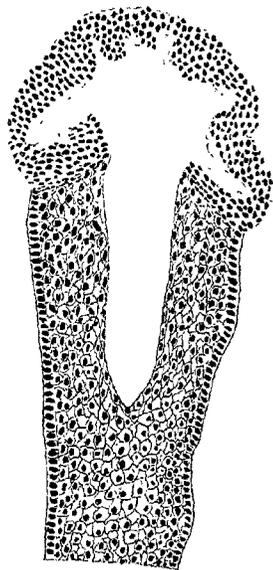


Fig. 3.

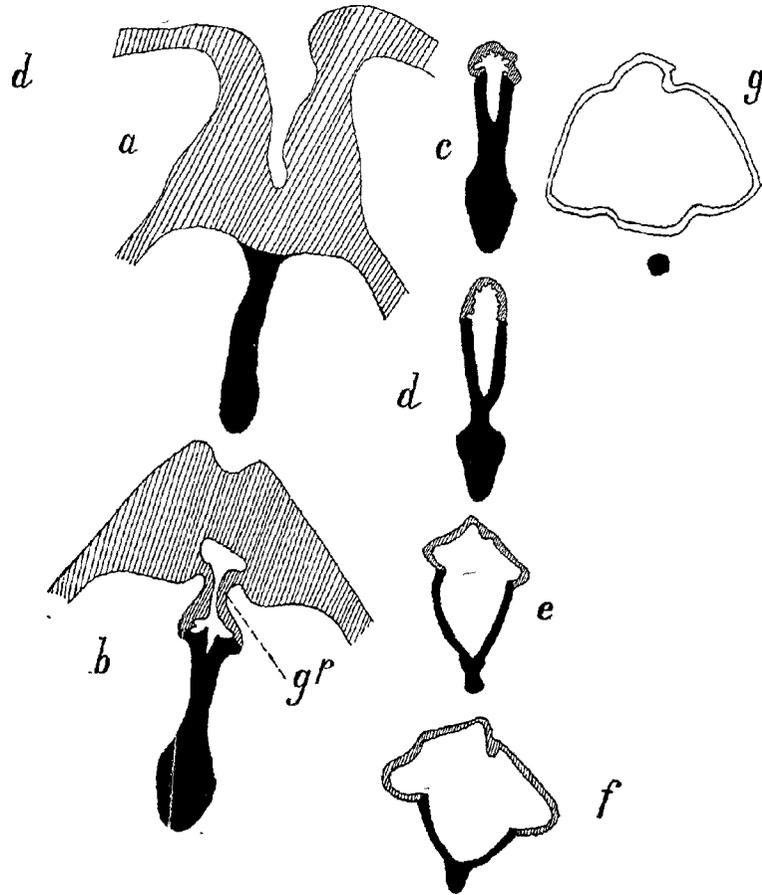


Fig. 2.

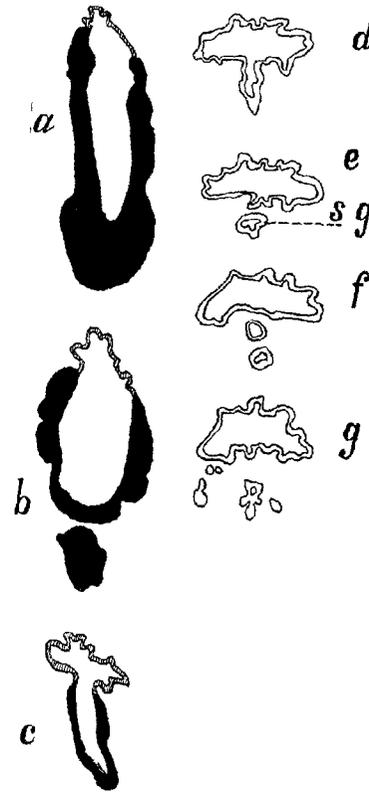


Fig. 4.

In the figures 1, 2 and 4 the phallus-frame is black, the penisectoderm marked with transverse lines. g. p. sexual fold.

From a comparative ontogenetical point of view, therefore, also the value of the urethra before and behind the fossa navicularis is different. For, whereas behind the fossa navicularis only a very small portion of the wall can be considered as a production of the phallus-frame, perhaps the vertical part of the lumen as it is found in the urethra of man, this changes before the fossa navicularis in such a way that there the greater part of the wall originates from that frame; therefore behind this fossa the urethra is principally homologous to the "Harnurethra", before it to the "Samenurethra".

Mathematics. — "On bicuspidal curves of order four." By Prof. JAN DE VRIES.

1. It is easy to see, that each curve of order four, C_4 , with two cusps can be represented by the equation

$$x_1^2 x_2^2 + 2x_1 x_2 x_3^2 + 2b_1 x_1 x_3^3 + 2b_2 x_2 x_3^3 + c x_3^4 = 0.$$

The triangle of reference has then the cusps O_1, O_2 and the point of intersection O_3 of the cuspidal tangents as vertices.

From the equation

$$(x_1 x_2 + x_3^2)^2 + 2(b_1 x_1 + b_2 x_2 + b_3 x_3) x_3^3 = 0,$$

where $2b_3 = c - 1$, is evident that

$$b_x \equiv b_1 x_1 + b_2 x_2 + b_3 x_3 = 0$$

represents the *double tangent* d of C_4 and that the conic

$$u \equiv x_1 x_2 + x_3^2 = 0$$

passes through the tangential points D_1, D_2 of d and *osculates* C_4 in the cusps O_1 and O_2 .

By combining the equations

$$u^2 + 2b_1 x_3^3 = 0 \quad \text{and} \quad u = \lambda b_x x_3$$

we understand that the conics A_λ through O_1, O_2, D_1 and D_2 generate a system of pairs of points on C_4 , which are lying in pairs on the rays

$$2x_3 + \lambda^2 b_x = 0$$

of the pencil, having the point of intersection H of $k \equiv O_1 O_2$ and d as vertex.

As this system of points with the curve is given we shall denote it as the *fundamental involution* F_2 .

If we put $\lambda^2 = \mu$, it follows from

$$2x_3 + \mu b_x = 0 \quad , \quad u^2 = \mu b_x^2 x_3^3,$$

that C_4 can be generated by a pencil of conics ($O_1 O_2 D_1 D_2$) arranged in the pairs of an involution and a pencil of lines (H) between which