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Topographic Anatomy and its development in Urology in the 20th Century. The work of Salvador Gil Vernet

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SUMMARY

Salvador Gil Vernet was a mid-twentieth-century Spanish anatomist and urologist who made highly significant advances in the field of urological anatomy with his studies on the topographic anatomy of the male pelvis and perineum. He was the first author in the twentieth century to precisely and accurately describe the anatomy of the external urethral sphincter, detrusor, posterior urethra and prostato-urethral musculature. In addition, his contributions to pelvic plexus neuroanatomy, with the description of the cavernous nerves and autonomic innervation of the external urethral sphincter, were used to develop a modern and less invasive surgical technique for treating urogenital disease. His research on the embryology and topographical anatomy of the prostate gland also helped him to define the first regional anatomical model of the prostate, which would act as the cornerstone for the development of current zonal anatomy. In this paper we present a summary of his most important discoveries, which have led him to be considered one of the pioneers of urological anatomy of the previous century.

Key words: Bladder – Detrusor – Perineum – Prostate regional anatomy – Pelvic plexus – Cavernous nerves – Posterior urethra – External urethral sphincter – Rectourethralis complex – Urethral crest – Pubovesical ligaments – Detrusor posterior longitudinal fascia – Detrusor apron – Prostate neurovascular bundles – Salvador Gil Vernet – Urology

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INTRODUCTION

At the beginning of the twentieth century, descriptive macroscopic anatomy of the male urogenital apparatus appeared to be fully developed. However, the topographic anatomy of the male pelvis and perineum had yet to be explored in depth, and a number of questions remained on the arrangement of the perineal muscles and aponeuroses, the pelvic nerve plexus, the arrangement of the detrusor muscle fibres, the bladder neck and posterior urethra, and the anatomy of the prostate gland. The anatomy textbooks and atlases of the period contained contradictory descriptions and did not provide an accurate representation of what surgeons saw in their daily surgical practice. The new morphological challenges were met by urologists, some of them also anatomists, who approached the study of anatomy from a clinical and functional perspective.

Salvador Gil Vernet (SGV), Spanish anatomist and urologist (Fig. 1), intended to bring to life the vesico-prostato-urethral neuromuscular system, using structural knowledge of the pelvic and perineal regions and disentangling the complexity of the pelvic neural plexus to explain the physiologic process of urination, erection and ejaculation. SGV's work also provided surgeons with new insights into topographic anatomy, leading to the development of more precise and scientific surgical techniques.

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Fig. 1. Salvador Gil-Vernet on the stairs of the Medical Faculty of Barcelona (1965).

BIOGRAPHY

Salvador Gil Vernet was born in Vandellós, a small village in the province of Tarragona (Spain) on August 10th, 1892. In 1909 he entered the Medical School at the University of Barcelona, graduating on June 30th, 1915. In 1928 he became a Professor in the Anatomy Department at the University of Barcelona, also performing functions as Director of the Professional School of Urology at the Hospital Clinic of Barcelona. He was elected president of the International Society of Urology (SIU) from 1967 to 1973, Honorary President of the Spanish Association of Urology in 1967 and Honorary member of the of the Spanish Royal Academy of Medicine in 1977. He was elected Honorary Member of the Societies of Urology of France, Italy, Greece, Mexico and Colombia. He was a visiting lecturer at Columbia University (New York), and at the Universities of Chicago, Buenos Aires, Bogotá, Toulouse, Tokyo, Amsterdam, Johannesburg, Mexico and Munich. Salvador died in Barcelona on October 24th, 1987.

SCIENTIFIC WORK

Beginning in the 1920s, his research was focused on the topographic anatomy, surgical techniques and pathological anatomy of the male urogenital system, except for the kidney and proximal ureter, and specially centered on the prostate gland. By using the histotopographic method of serial anatomical sections (whole mount sections) as described by Kalischer (1900), he achieved outstanding new perspectives on the morphological study of the urogenital system (Gil-Vernet, 2015). All this passion was rewarded with the publication of four books dedicated to the study of the Urogenital Anatomy and Pathology. On the one hand, *Urogenital Pathology*, a three-volume work composed by "Prostate Cancer" (Gil Vernet, 1944), "Biology and Pathology of the Prostate" (Gil Vernet, 1953) and " Diseases of the Prostate " (Gil Vernet, 1955), focused on the study of the prostate, its embryology, regional anatomy, topographic anatomy, pathology and surgical techniques. This volume was followed by Morphology and Function of Vesico-Prostato-Urethral Musculature (Gil Vernet, 1968), a work dedicated to the study of the topographic and microscopic anatomy of the detrusor, trigone, vesical neck, posterior urethra, urogenital striated musculature and the vesicourethral musculature in woman.

The chapter entitled "Prostatoperineal Surgical Anatomy" in “Prostate Cancer" studies the topographical anatomy of the male pelvis and perineum, describing the external urethral sphincter, the superficial and deep perineal muscles, and rectourethral complex and the central tendon of perineum (perineal body). A full study was conducted on the neural pelvic plexus, describing the innervation of the seminal vesicles, prostate, external urethral sphincter and the most caudal extension of the plexus which supplies the nerves of the corpus spongiosum urethra, the cavernous nerves and haemorrhoidal nerves.

In “Biology and Pathology of the Prostate” (Gil Vernet, 1953), SGV clearly demostrated that the prostate is not an homogeneous gland and that it consists of three main areas: a cranial gland, a caudal gland and the intermediate gland.

Male perineal topographic anatomy

At the beginning of the twentieth century, knowledge of surgical anatomy of the perineum was essential for performing many surgical procedures on prostate adenomas and cancers in a precise and minimally invasive manner, by the perineal access. From 1933, the arrangement of the perineal musculature and its relationship with the adjacent organs was analysed using both macroscopic and microscopic dissection, the latter through histotopographic anatomical sections.

Transverse superficial perineal muscle

In classical descriptions of this muscle, which are somewhat inconsistent, it originates on the ischiopubic ramus and inserts on the central tendon of the perineum. But SGV proved that the superficial transverse muscle is made up of fibres that anastomose from the superficial external sphincter of the anus with fibres of the bulbospongiosus muscle, and which never insert into the ischiopubic rami (Figs. 2 and 3).

Rectourethralis muscle

SGV demonstrated that this is not actually a muscle but rather a complex formed by smooth longitudinal muscle fibres of the anterior surface of the anal canal and the anterior surface of the rectum, which join the fibroconnective tissue of the perineal body, as well as some dorsocaudal striated fibres of the external urethral sphincter, but

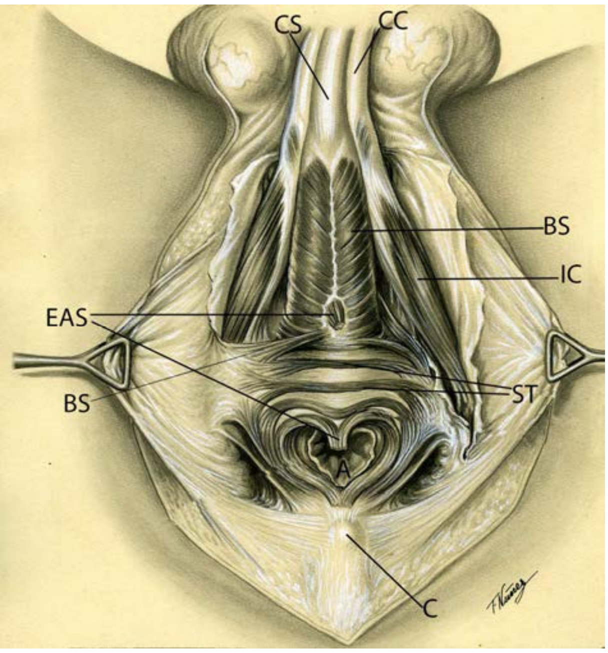


Fig. 2. Male perineal muscles. Drawing (ca. 1943). ST: transverse superficial perineal muscle; CS: corpus spongiosum; BS: bulbospongiosus muscle; CC: corpus cavernosum; IC: ischiocavernosus muscle; A: anus; AES: external anal sphincter; C: coccyx.

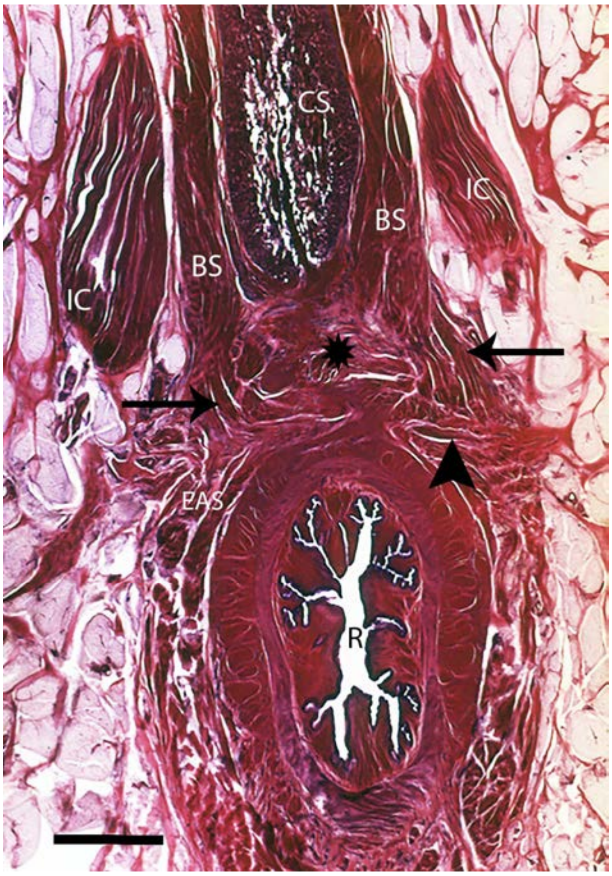


Fig. 3. Transverse perineal muscle. Male newborn. Transverse section, 40 µm. Haematoxylin and eosin stain (HE). Scale bar: 1 mm. Abbreviations as in Fig. 2 and R: rectum; Perineal body (asterisk). Anastomosis between fibres of the bulbospongiosus muscle and superficial fibres of the external anal sphincter. Transverse superficial perineal muscle fibres (arrowhead).

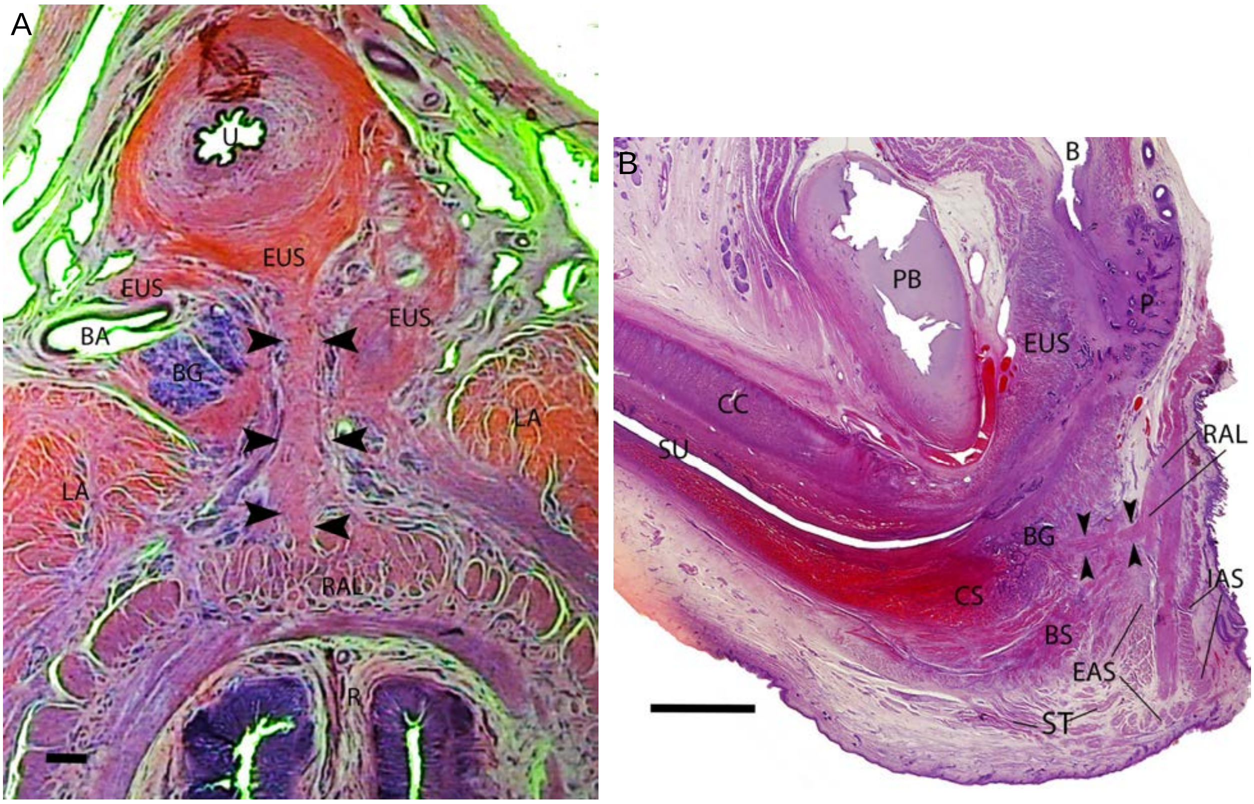
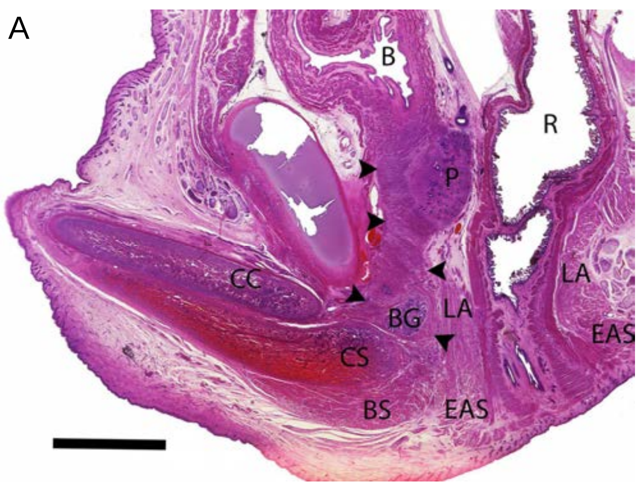


Fig. 4. Rectourethralis complex. Male newborn, 40 µm. HE. (**A**) Transverse section. Scale bar: 1 mm. U: membranous urethra; EUS: striated fibres of the external urethral sphincter. BA: bulbar artery; BG: bulbourethral gland; LA: levator ani muscles; RAL: anterior longitudinal muscular layer of the rectum; R: rectum; Rectourethralis complex (arrowheads). (**B**) Midsagittal section. Scale bar: 1 cm. Abbreviations as in Figs. 2 and 3 and PB: pubic bone; B: bladder; SU: spongy urethra; BG: bulbourethral gland; CS: penile bulb; P: prostate; EUS: external urethral sphincter (striated fibres); IAS: internal anal sphincter; RAL: anterior longitudinal muscular layer of the rectum; ST: transverse superficial perineal muscle. Rectourethralis complex (arrowheads).



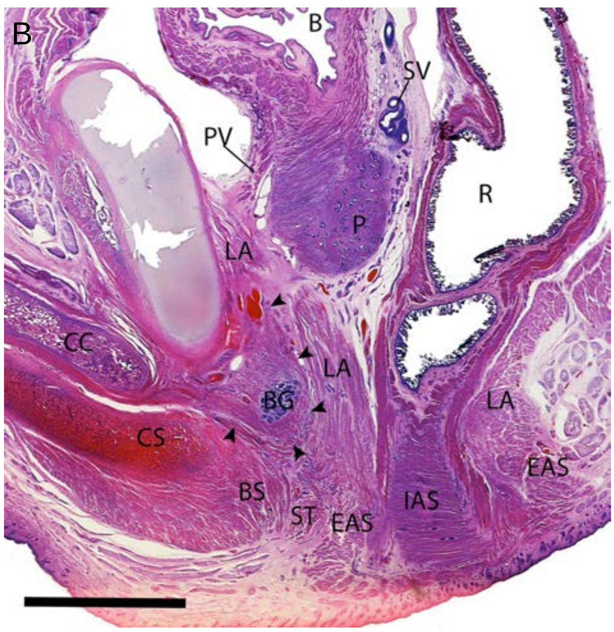


Fig. 5. External urethral sphincter. Male newborn, 40 µm. HE. (**A**) Parasagittal section. Scale bar: 1 cm. Abbreviations as in Fig. 4 and external urethral sphincter (arrowheads). (**B**) Parasagittal section lateral to (A). Scale bar: 1 cm. Abbreviations as in Fig. 4 and PV: pubovesical ligament; SV: seminal vesicle; ST: transverse superficial perineal muscle. Caudal portion of the external urethral sphincter (arrowheads) wrapping the bulbourethral gland.

without ever reaching the urethra (Figs. 4A and 4B), suggesting that the term rectourethralis is a misnomer. SGV (Gil Vernet, 1944) named it the “rectourethral system” and it is currently known as the "rectourethralis complex" (Myers, 2001).

External urethral sphincter

With the aim of improving urinary incontinence in radical prostate surgery, SGV studied the urethral sphincter extensively. What he observed in his dissections and perineal radical prostatectomy of the prostate did not match the descriptions offered in textbooks. In the 1940s, SGV provided the first description of the sphincter as a vertically-arranged tubular structure, refuting the existence of a plate of muscle arranged transversely between the two ischiopubic rami, an error that was established in atlases and anatomy textbooks until the end of the twentieth century (Gil Vernet, 1944; Gil Vernet, 1953).

He divided the external urethral sphincter into three areas: cranial, medial and caudal, with the latter extending dorsally to envelop the bulbourethral glands (Figs. 5A and 5B). The external urethral sphincter consists of two layers, an internal layer made of circularly- and longitudinally-arranged smooth muscle and an external layer made of circular striated fibres (Figs. 6A and 6B). He also demonstrated that the deep transverse muscle of the perineum does not exist and that the structures surrounding the bulbourethral glands

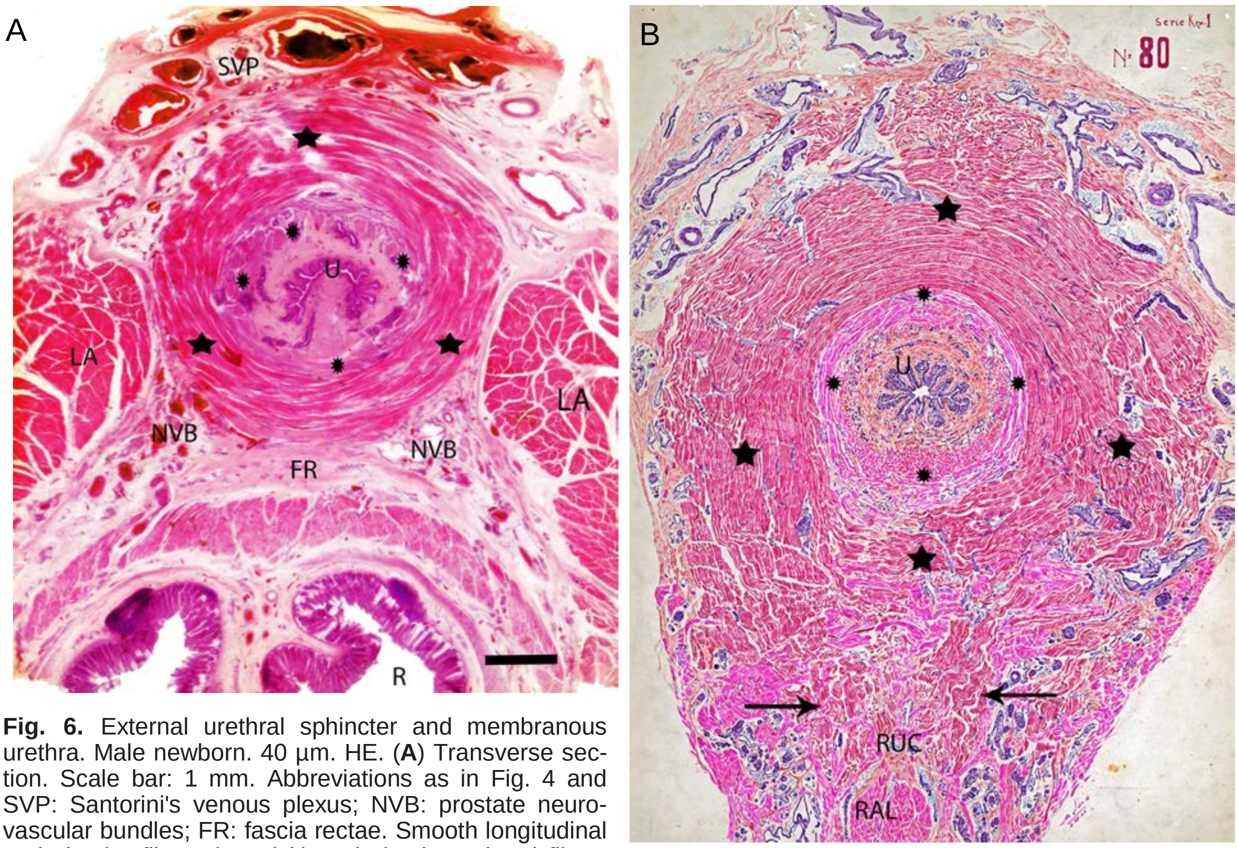


Fig. 6. External urethral sphincter and membranous urethra. Male newborn. 40 µm. HE. (**A**) Transverse section. Scale bar: 1 mm. Abbreviations as in Fig. 4 and SVP: Santorini's venous plexus; NVB: prostate neurovascular bundles; FR: fascia rectae. Smooth longitudinal and circular fibres (asterisk) and circular striated fibres (stars) of the external urethral sphincter. (**B**) Transverse section caudal to (A). Drawing (1945). Abbreviations as in Figs. 2-4 and RAL: rectal anterior longitudinal layer; RUC: rectourethralis complex. Smooth longitudinal and circular fibres (asterisks) and circular striated fibres (stars) of the external urethral sphincter with some of them (arrows) running dorsally and forming the rectourethralis complex.

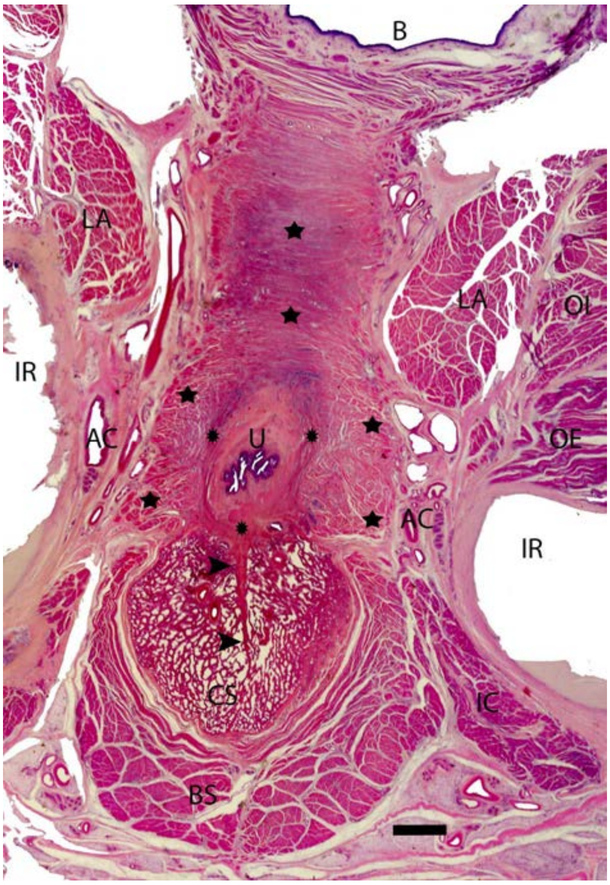


Fig. 7. External urethral sphincter and membranous urethra. Male newborn. Coronal section, 50 µm. HE. Scale bar: 1 mm. Abbreviations as in Figs. 4-5 and OI: internal obturator muscle; OE: external obturator muscle; AC: Alcock's canal with internal pudendal nerve and vessels; CS: penile bulb; IR: ischiopubic rami. Smooth fibres of the external urethral sphincter (asterisks) with dorsal fibers tapering caudally ending at the corpus spongiosum of the penile bulb (arrowheads). Circular striated fibres (stars) of the external urethral sphincter.

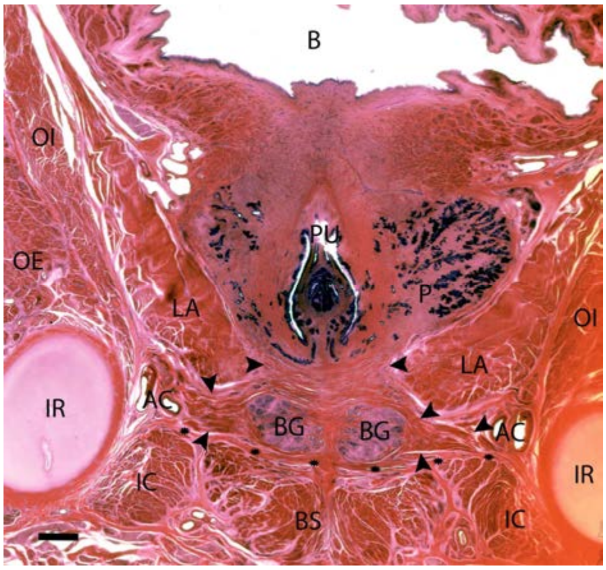


Fig. 8. External urethral sphincter and bulbourethtral glands. Male newborn. Coronal section dorsal to the penile bulb. 50 µm. HE. Scale bar: 1 mm. Abbreviations as in Figs. 4-7 and PU: prostatic urethra. Perineal membrane (asterisks). Striated fibres of the external urethral sphincter (arrowheads) wrapping the bulbourethral glands and ending laterally at the medial wall of the Alcock's canal.

are the dorsocaudal fibres of the external urethral sphincter, which do not insert into the ischiopubic rami (Figs. 7 and 8). This publication was cited by the anatomist Oelrich in his classic work describing the anatomy of the external urethral sphincter (Oelrich, 1980).

Urethral crest. The posterior prostato-urethral muscular bundle

In 1953, SGV (Gil Vernet, 1953) described a group of dorsal longitudinal smooth urethral musculature which he called the posterior prostato-urethral muscular bundle, and which forms the relief of the mucosal fold in the infracollicular urethra known as the crista urethralis (Fig. 9). This smooth muscular bundle originates below the ejaculatory ducts at the lower pole of the colliculus seminalis, and runs dorsally and downwards ending into the penile bulb. This dorsal prostato-urethral column originates from the confluence of fibers from the fibromuscular sheath that wraps the ejaculatory ducts and the utricule. Several tenuous fibrils are sent out, incorporating in the posterior prostato-urethral column at the level of the colliculus seminalis. Some series of prostate collecting ducts are linearly arranged on each side. (Figs. 10 and 11).

The function of this muscle, as was later shown in the per-ejaculatory ultrasonographic studies (Gil -Vernet, 1989) is to shorten and dilate the infracollicular urethra during ejaculation. Dorschner and Stolzengurg (1994) renamed this posterior prostato-urethral muscle bundle "musculus ejaculatorius".

SGV denied the existence of a superior urethral crest above the colliculus seminalis, known as Bell's muscle or musculus retractor uvulae and described as a muscle bundle that runs from the bladder trigone to the colliculus seminalis.

Topographic anatomy of the bladder

With a clear functional goal, trying to determine the role of the different muscle bundles of the detrusor and their relationship with the bladder neck and the prostate in urination and urinary continence, SGV performed detailed dissections and microscopic studies of the bladder. Through this research he was able to describe new elements in the anatomy of the detrusor.

The transverse precervical arc and the retro-symphysial vesico-urethral system

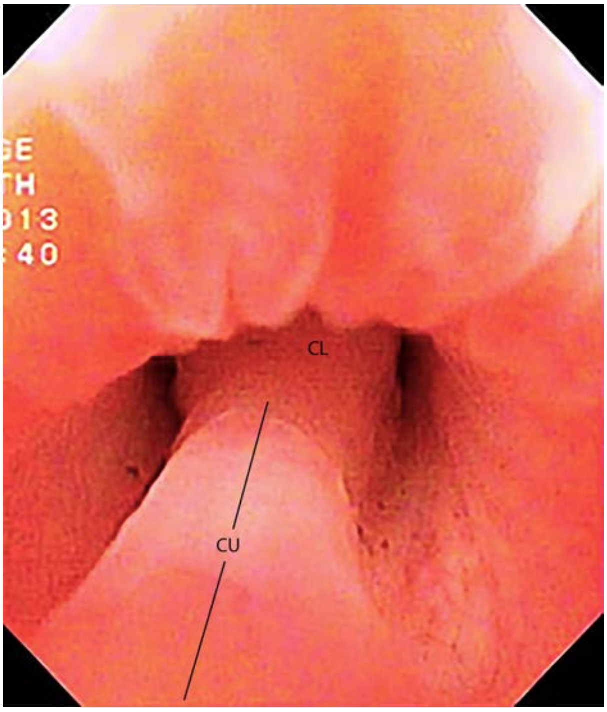


Fig. 9. Endoscopic view of the crista urethralis, 35-year-old male. CL: colliculus seminalis; CU: crista urethralis.

The outer, anterior and posterior longitudinal fibres of the detrusor intersect in the caudal part of the bladder's anterior surface, forming a structure that SGV called the transverse precervical arc (Figs. 12A, 12B and 13). He said: "A considerable part of the bundles of the anterior longitudinal fascia arrives in the compound of muscular fibres placed transversally in front of the vesico-prostate angle and forms a sort of muscular cross-road and corresponds to what we called the pre-cervical transverse arc. The lateral walls of this triangle are formed by some posterior longitudinal fibres of the detrusor; these fibres insert into the dense fibrous tissue situated on the sides an anterior portion of the prostate which is the continuation of the lateral aponeurosis (endopelvic fascia). The central part of this muscular triangle is mainly occupied by fibres with a vertical direction that come from the anterior wall of the detrusor. This muscular compound is called the vesico-urethral retro-symphysial system" (Gil Vernet, 1953). The transverse precervical arc and the vesico-urethral retro-symphysial system form what Myers described as the detrusor apron, an important anatomical landmark in radical prostatectomy (Myers, 2002). Dorschner et al. (1994) would later these describe these structures as *collare vesicae* and *nodus vesicae.*

Fig. 10. Posterior prostato-urethral muscle bundle. Male newborn. Coronal section. 50 µm. HE. Scale bar: 1 mm. Abbreviations as in Figs. 2-9 and striated (stars) and smooth (asterisks) fibres of the external urethral sphincter. Prostate collecting ducts (filled circle). Posterior prostato-urethral muscular bundle (arrows).

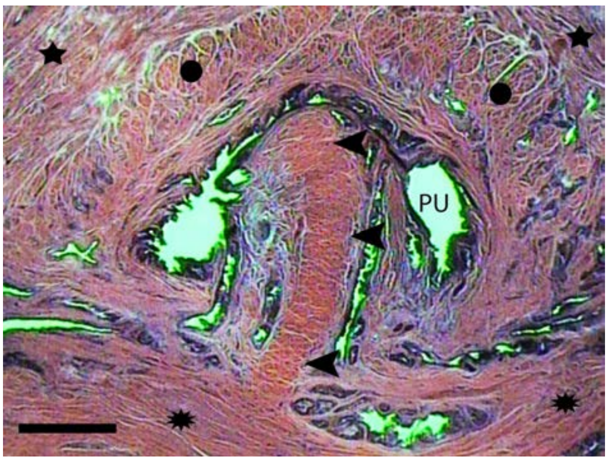
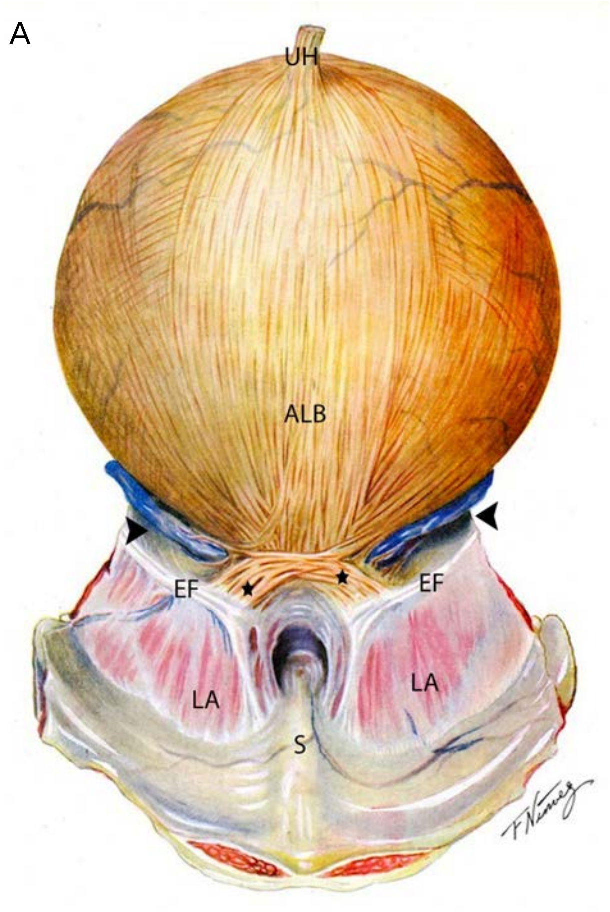


Fig. 11. Posterior prostato-urethral muscle bundle. Male newborn. Transverse section. 50 µm. HE. Scale bar: 1 mm. Abbreviations as in Figs. 8-10. Striated (stars) and smooth circular (asterisks) and longitudinal (filled circle) fibres of the external urethral sphincter. Posterior prostato-urethral muscular bundle (arrowheads).



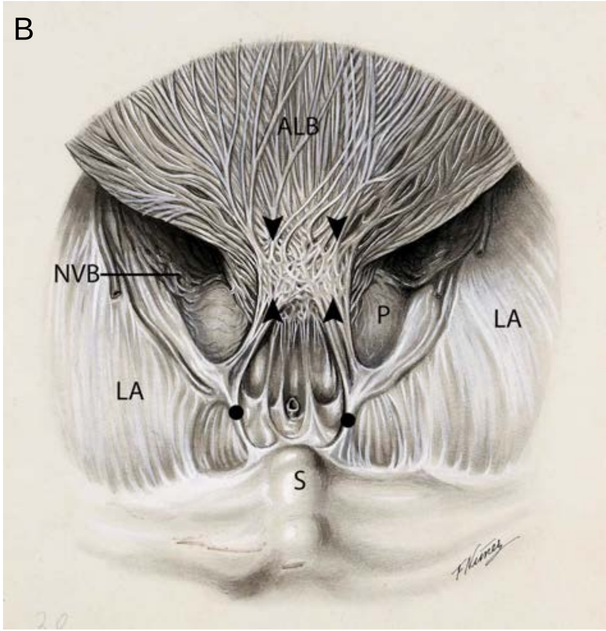


Fig. 12. Transverse precervical arc. Drawing (ca. 1951). (**A**) Abbreviations as in Figs. 4-8 and UH: urachus; ALB: Detrusor anterior longitudinal bundle; Vesico-prostatic sulcus with vasculo-nervous bundle (arrowheads); EF: endopelvic fascia; S: pubic symphisis. Transverse precervical arc (stars). (**B**) Abbreviations as in Fig. 4-8 and ALB: Detrusor anterior longitudinal bundle; NVB: prostate neurovascular bundle. Transverse precervical arc (arrowheads). Pubovesical ligaments (filled circles).

The pubovesical ligaments

He observed that the so-called puboprostatic ligaments are not really ligaments but rather a pair of muscular bundles bundles formed by smooth muscle fibres of the anterior longitudinal muscle layer of the detrusor and covered by the endopelvic fascia. They are present in both men and women and are arranged dorsoventrally and craniocaudally, running over the prostate and inserting into the lower edge of the pubic bone, ventral to the external urethral sphincter (Figs. 12B, 14A and 14B).

The posterior longitudinal fascia of the detrusor

In 1953 SGV described the detrusor posterior longitudinal bundle or posterior longitudinal fascia, formed by smooth muscle fibres that form a strong muscular tunic (Gil Vernet, 1953). It descends uninterrupted from the urachus, running caudally between the ureters and covering the trigone and the rear wall of the internal vesical sphincter (Figs. 14 B, 15A and 15B) and some medial bundles penetrate deep into the prostate, tapering, to terminate near the opening of the ejaculatory ducts at the colliculus seminalis (Figs. 16A and 16B). In the same year, Uhlenhuth (1953) also described this bundle but did not find its caudal extension through the prostate. Recently, several laparoscopic surgeons erroneously identified this structure as the anterior layer of Denonvilliers' fascia, but Secin et al. (2007) demonstrated that it was really the muscle described by SGV. Dorschner et al. (2001) later renamed this muscle "musculus vesicoprostaticus".

Pelvic plexus neuroanatomy

Since his youth, under the influence of Santiago Ramón y Cajal, SGV showed great interest in the study of the vegetative nervous system. In 1918 he described the inferior mesenteric ganglion for the first time in humans (Gallart and Gil Vernet, 1918). From 1940 he began to study the embryology and neuroanatomy of the pelvic plexus and, specifically, the innervation of the bladder, seminal vesicles, prostate and external urethral sphincter (Gil Vernet, 1944).

Prostate neurovascular bundles and external urethral sphincter nerves

SGV described in great detail the arrangement of the ganglia and nerves of the pelvic plexus and its relationship with the rectum, bladder, seminal vesicles, prostate and membranous urethra (Figs. 17, 18 and 19).

Using the histotopographic method, SGV showed

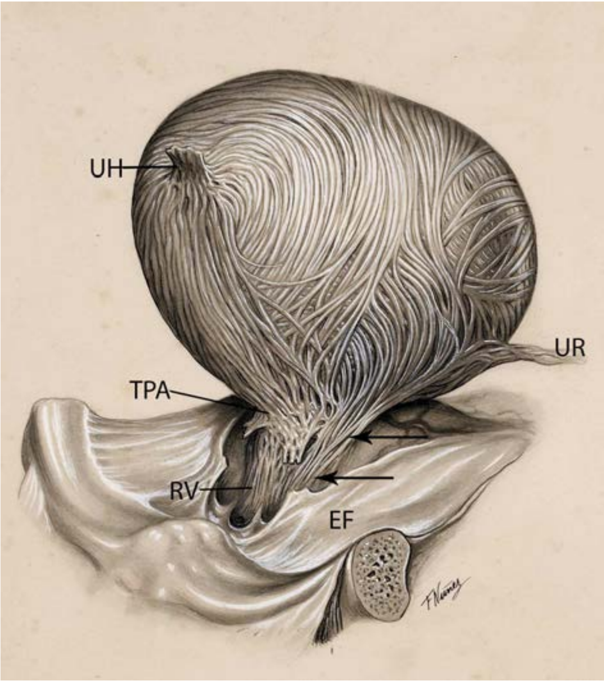


Fig. 13. Transverse precervical arc and retrosymphisial vesico-urethral system (pubovesical ligaments sectioned). Drawing (ca. 1940). Abbreviations as in fig. 12 and UR: ureter; TPA: transverse precervical arc; RV: retrosymphisial vesico-urethral system both forming the detrusor apron. Detrusor posterior longitudinal bundles (arrows) incorporating into the detrusor apron.

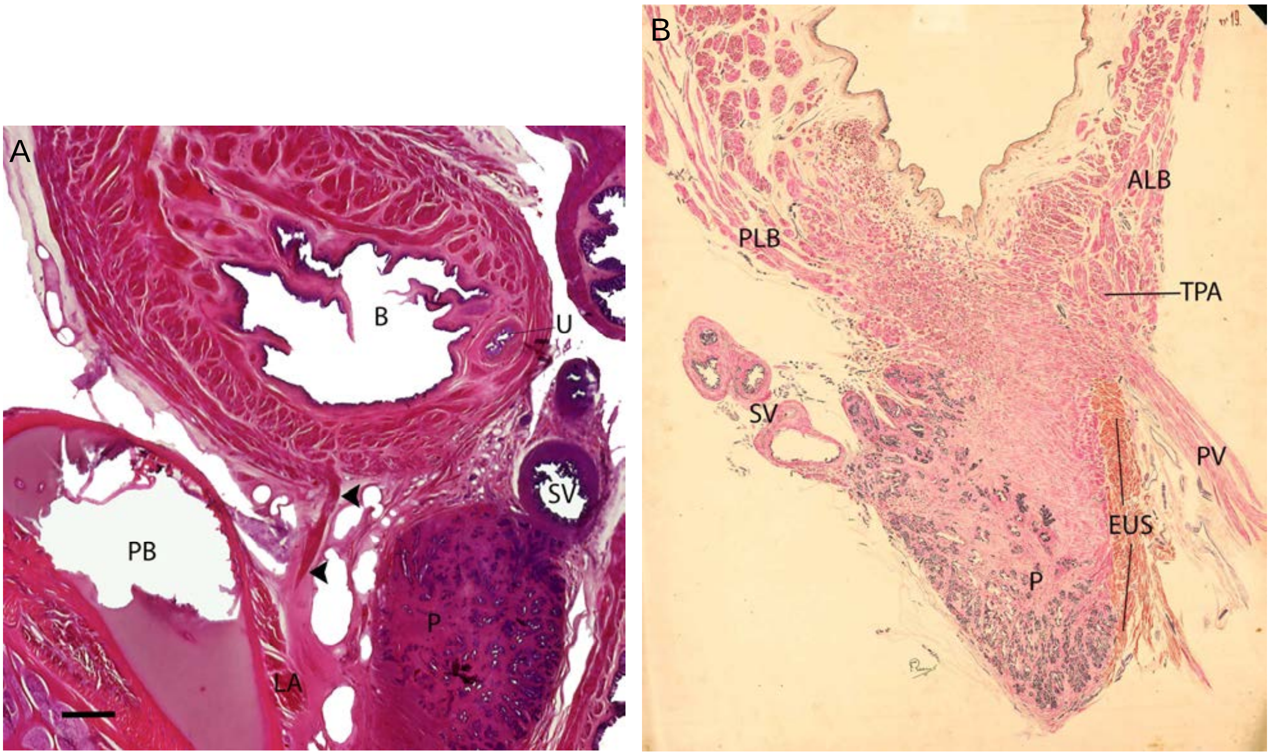
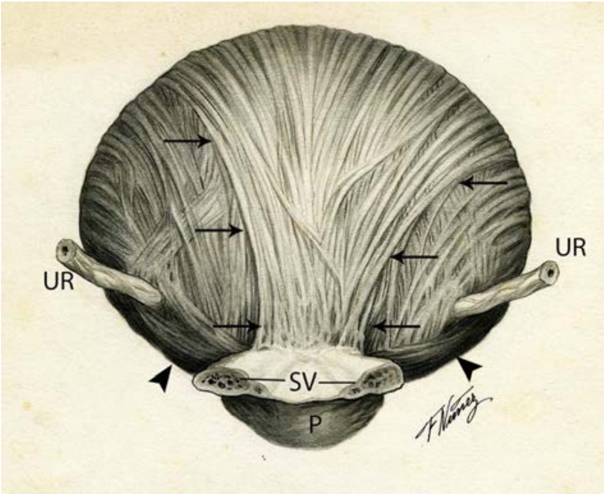


Fig. 14. Pubovesical ligaments. (**A**) Eight-month-old male foetus. Parasagittal section, 40 µm. HE stain. Scale bar: 1 mm. Abbreviations as in Figs. 8-13 and PB: pubic bone. Pubovesical ligament (arrowheads) covered by the endopelvic fascia. (**B**) Male newborn. Drawing (1945). Parasagittal section. Abbreviations as in Figs. 8-14 and PLB: detrusor posterior longitudinal bundle; PV: pubovesical ligament.



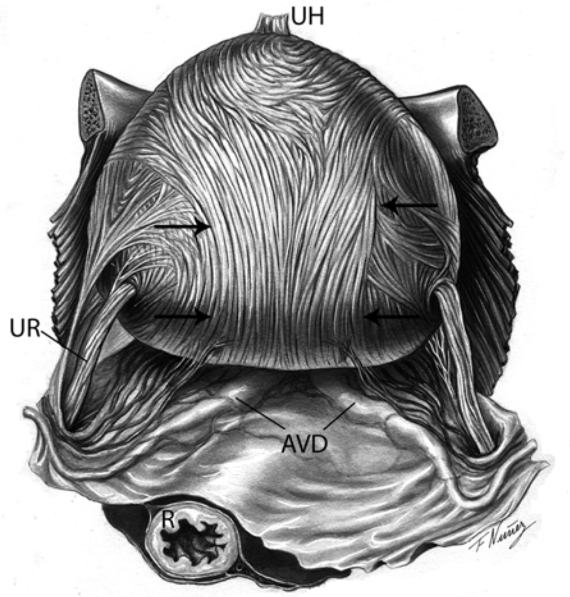
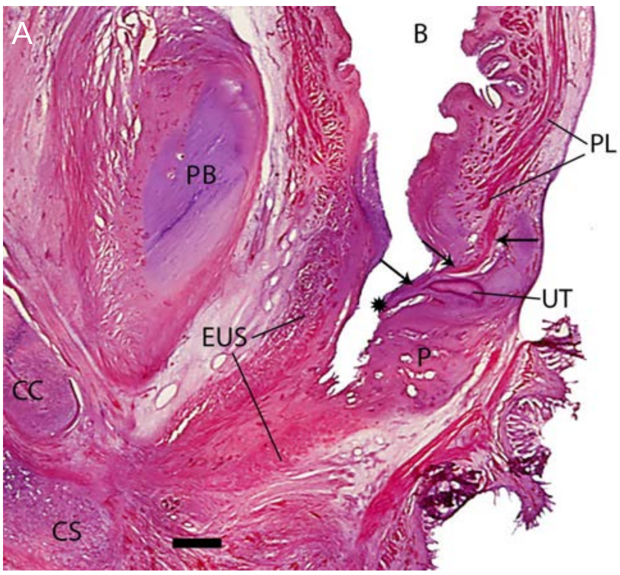


Fig. 15. Detrusor posterior longitudinal fascia. (**A**) Posterior view. Drawing (ca. 1945). Abbreviations as in Figs. 8-14. Detrusor posterolateral longitudinal bundle (arrowheads). Detrusor posterior longitudinal fascia (arrows). (**B**) Superoposterior view. Drawing (ca. 1940). Abbreviations as in Figs. 8-14 and AVD: Ampulla vas deferens. Detrusor posterior longitudinal fascia (arrows).



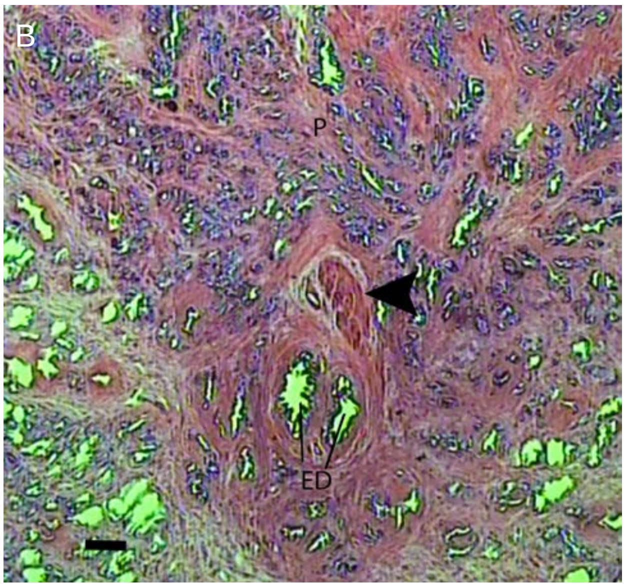


Fig. 16. Detrusor posterior longitudinal fascia. (**A**) Six-month-old male foetus. Midsagittal section. 40 µm. HE stain. Scale bar: 1 mm. Abbreviations as in Figs. 8-14. Colliculus seminalis (asterisk). UT: prostate utricule; PL: detrusor posterior longitudinal fascia with its medial and inferior bundles (arrows) penetrating into the prostate an ending very close to the colliculus seminalis. (**B**) Newborn. Coronal section. 40 µm. HE stain. Scale bar: 1 mm. Abbreviations as in Figs. 8-14 and ED: ejaculatory ducts; Tapered ending of the detrusor posterior longitudinal fascia (arrowhead).

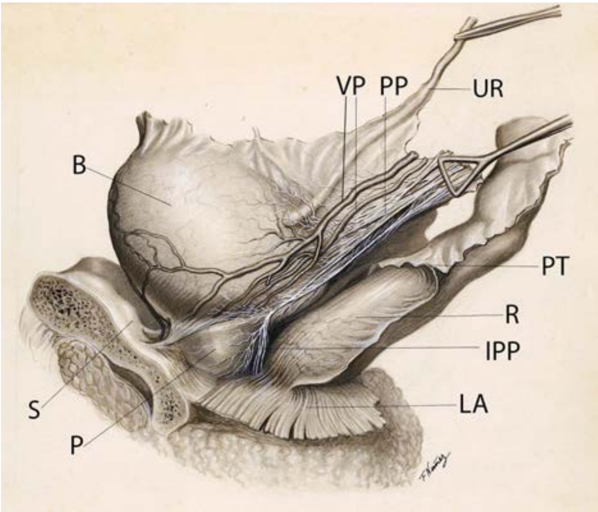


Fig. 17. Pelvic plexus (Drawing, 1944). Abbreviations as in Figs. 8-14 and VP: vesicoprostatic vessels; PT: peritoneum; PP: pelvic plexus; IPP: inferior prolongation of the pelvic plexus giving off the nerves of the seminal vesicles, prostate, membranous urethra, external urethral sphincter, corpus spongiosum and corpora cavernosa.

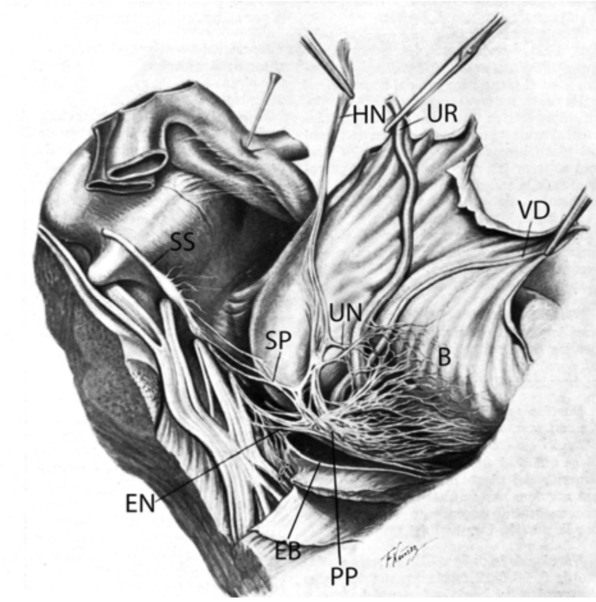


Fig. 18. Pelvic plexus (Drawing, 1953). Abbreviations as in Figs. 8-14 and VD: Vas deferens; HN: hypogastric nerve; SS: sacral sympathetic chain; PP: pelvic plexus SP: anastomotic branches between SS and PP; UN: Ureteral nerves; EN: erectile nerves; EB: abnormal branch of the erectile nerves not connected to the pelvic plexus.

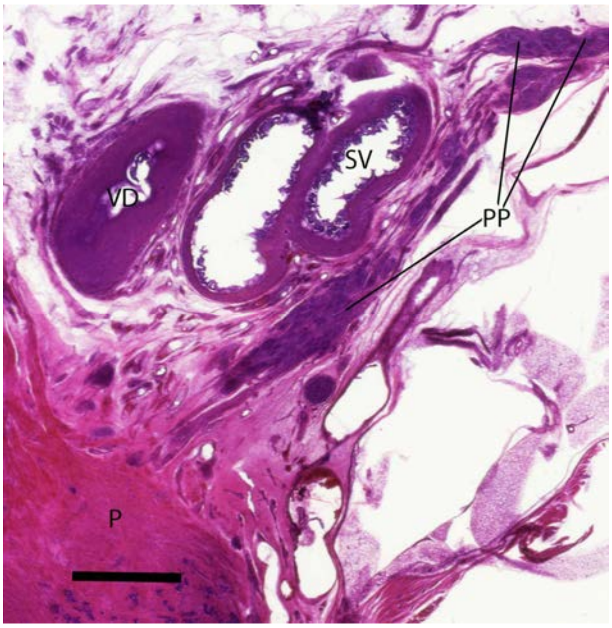


Fig. 19. Pelvic plexus. Male newborn. Coronal section, 40 µm. HE stain. Scale bar: 1 mm. Abbreviations as in Figs. 8-14.

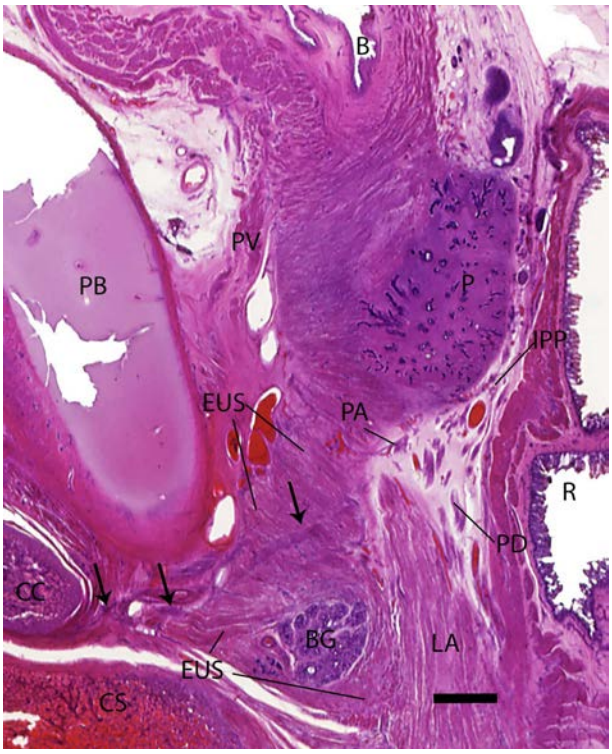


Fig. 20. Pelvic plexus. Male newborn. Parasagittal section, 40 µm. HE stain. Scale bar: 1 mm. Abbreviations as in Figs. 8-14 and PD: dorsocaudal division of the inferior pelvic plexus forming the haemorrhoidal nerves; PA: Pelvic plexus nerves running ventrocaudally to innervate the external urethral sphincter and the bulbourethral glands. Cavernous nerves (arrows).

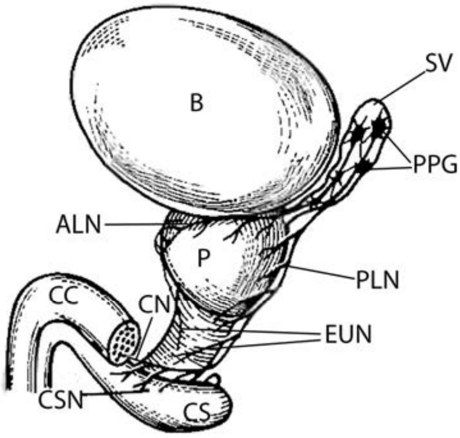


Fig. 21. Diagram of the pelvic plexus. Posterolateral view. Abbreviations as in Figs. 8-14 and PPG: pelvic plexus ganglia; ALN: anterolateral nerves; PLN: posterolateral nerves; EUN: external urethral sphincter nerves; CN: cavernous nerves; CSN: corpus spongiosum nerves.

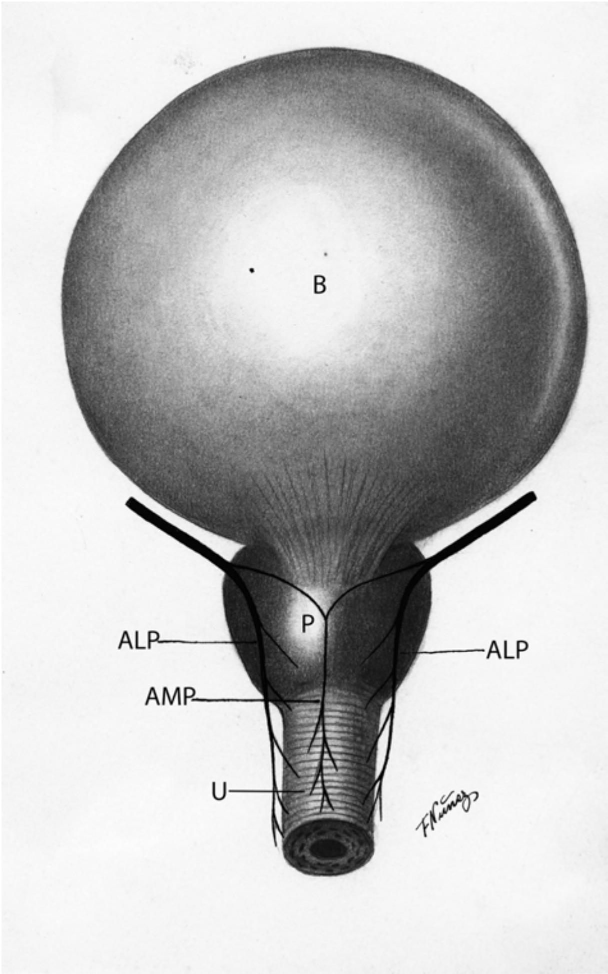


Fig. 22. Diagram of the pelvic plexus. Anterior view. Abbreviations as in Figs. 8-14 and ALP: anterolateral neural pedicle; AMP: anteromedial neural pedicle.

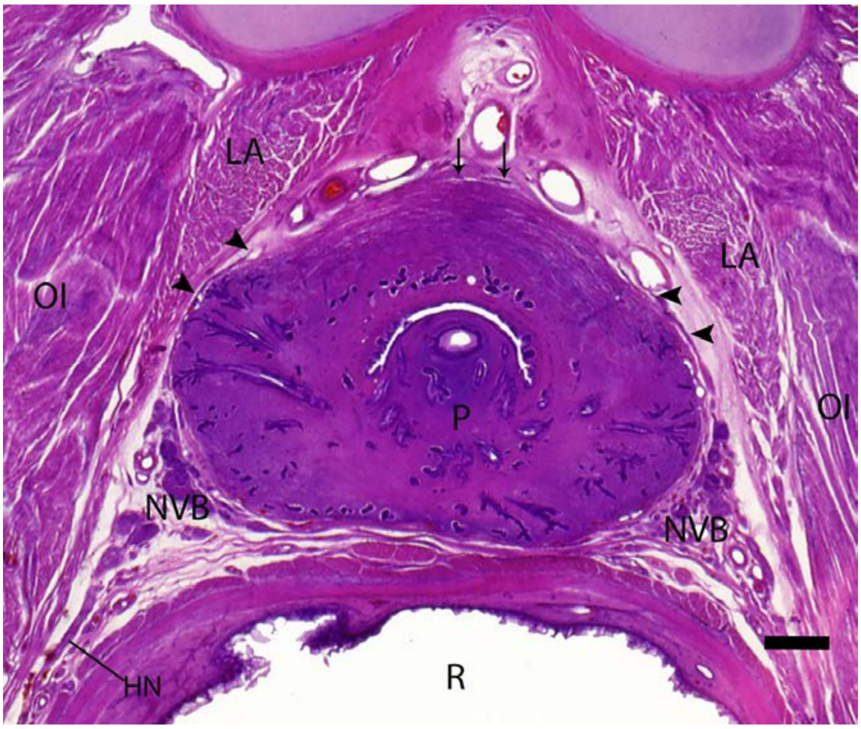


Fig. 23. Pelvic plexus and prostate. Male newborn Transverse section, 40 µm. HE. Scale bar: 1 mm. Abbreviations as in Figs. 8-14 and anterolateral neurovascular pedicle (arrowheads). Anteromedial neurovascular pedicle (arrows).

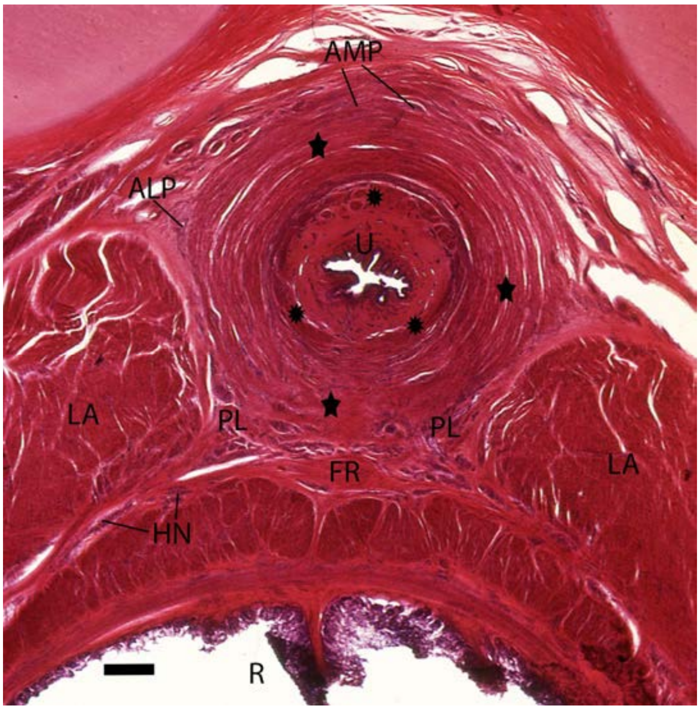


Fig. 24. Pelvic plexus and membranous urethra. Male newborn Transverse section, 40 µm. HE stain. Scale bar: 1 mm. Abbreviations as in Figs. 8-23 and PL: Posterolateral neurovascular pedicle; Smooth longitudinal and circular fibres (asterisk) and circular striated fibres (stars) of the external urethral sphincter.

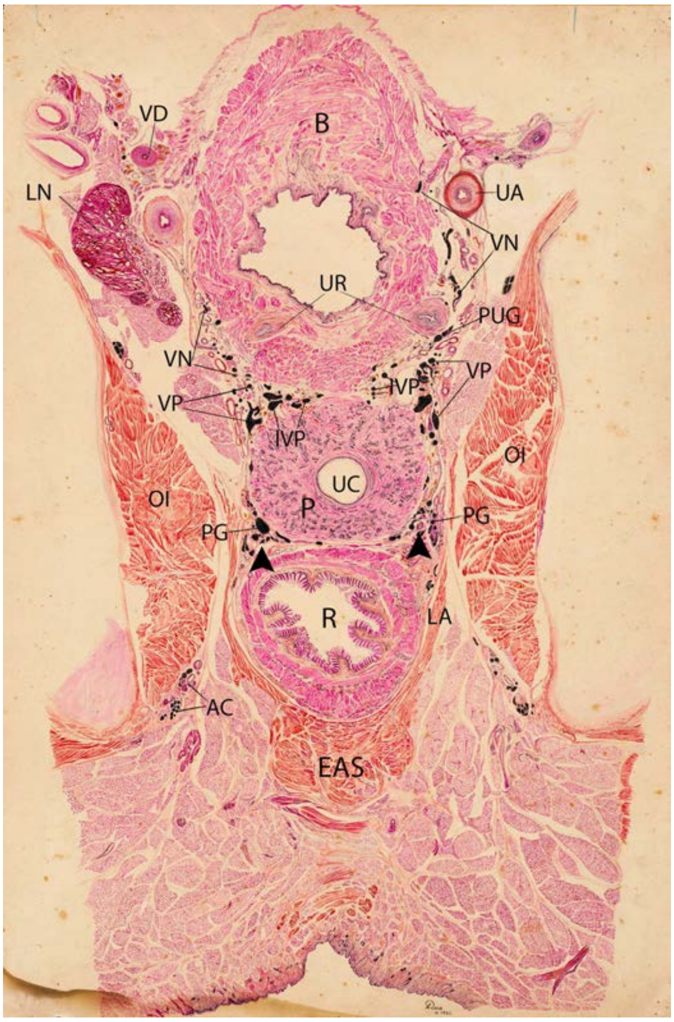


Fig. 25. Pelvic plexus. Six-month-old male foetus. Drawing (1942). Coronal section. HE stain. Abbreviations as in Figs. 8-23 and LN: lymphatic node; UA: umbilical artery; VN: vesical nerves; PU: periureteral nerves ; UC: utricular cyst; PG: periprostatic ganglia; IVP: intervesicoprostatic ganglia; VP: vesical and superior prostatic ganglia; PG: inferior periprostatic ganglia. Cavernous nerves (arrowheads).

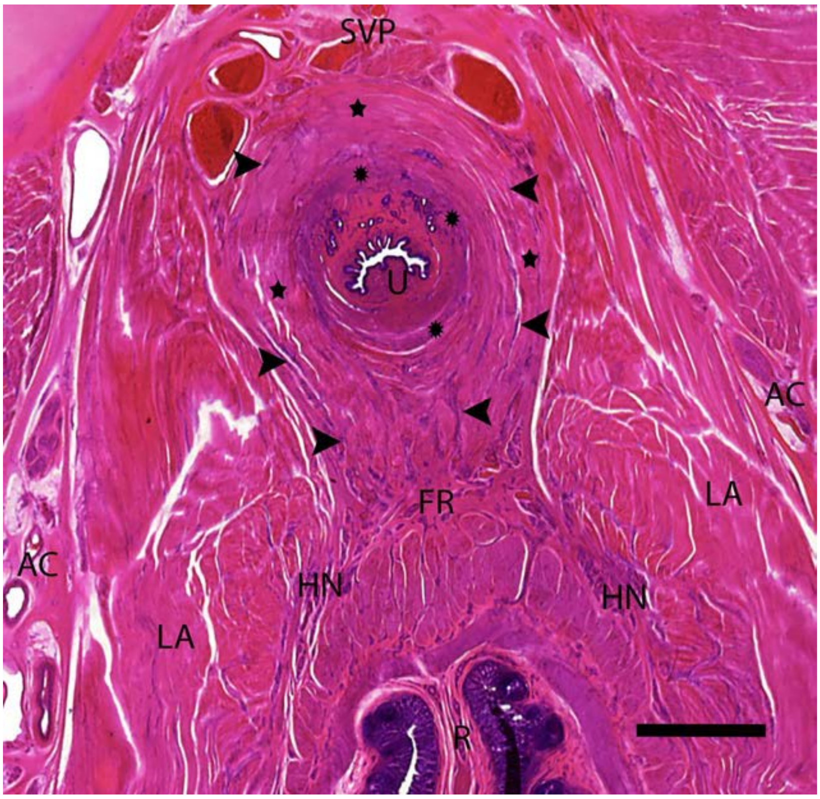


Fig. 26. Pelvic plexus and nerves of the external urethral sphincter. Male newborn Transverse section, 40 µm. HE stain. Scale bar: 1 cm. Abbreviations as in Figs. 8-23. Smooth circular fibres (asterisk) and striated circular fibres (stars) of the external urethral sphincter. Nerves of the external urethral sphincter (arrowheads).

that the vertical extension of the pelvic plexus follows the posterolateral border of the prostate, forming, together with the accompanying vessels, what we now refer to as the neurovascular bundle of the prostate. In the descending portion, it gives off nerve branches that penetrate the prostate gland, membranous urethra and external urethral sphincter, with the terminal branches forming the nerves of the corpus spongiosum and the cavernous nerves (Figs. 20 and 21). He also described a ventral prolongation of the pelvic plexus that forms what he called the anterolateral and anteromedial neurovascular pedicles (Fig. 22), which run downwards, giving off branches to the membranous urethra (Figs. 23 and 24). He wrote: "At every one of the four corners of the rectangle that makes up the prostatic cell, a neurovascular bundle is observed, and those are the bundles which carry the vessels and nerves intended for innervation and irrigation of the prostate, membranous urethra and the cavernous nerves, enabling erection" (Fig. 25). This description of the prostate neurovascular bundles was corroborated by the superb work of Walsh and Donker (1982), which served as the anatomical basis for the development of nerve sparing radical prostatectomy. The arrangement of the membranous urethra and inferior branches of the pelvic plexus along the ventral surface of the prostate was also corroborated many years later (Iwata et al., 2001; Eichelberg et al., 2007).

In his studies on the membranous urethra and the external urethral sphincter, he described the presence of microscopic periurethral nerve ganglia and tiny nerve branches, a continuation of the pelvic plexus, which penetrate the mass of the external urethral sphincter (Figs. 26 and 27). He thus assumed that autonomous nerves innervate the striated fibres of the urethral sphincter, contradicting the classical conception of the external urethral sphincter receiving only somatic innervation through the internal pudendal nerve. In addition, he assumed that some fibres of the internal pudendal nerve, following an intrapelvic pathway, join the hypogastric ganglion very close to the entry of the

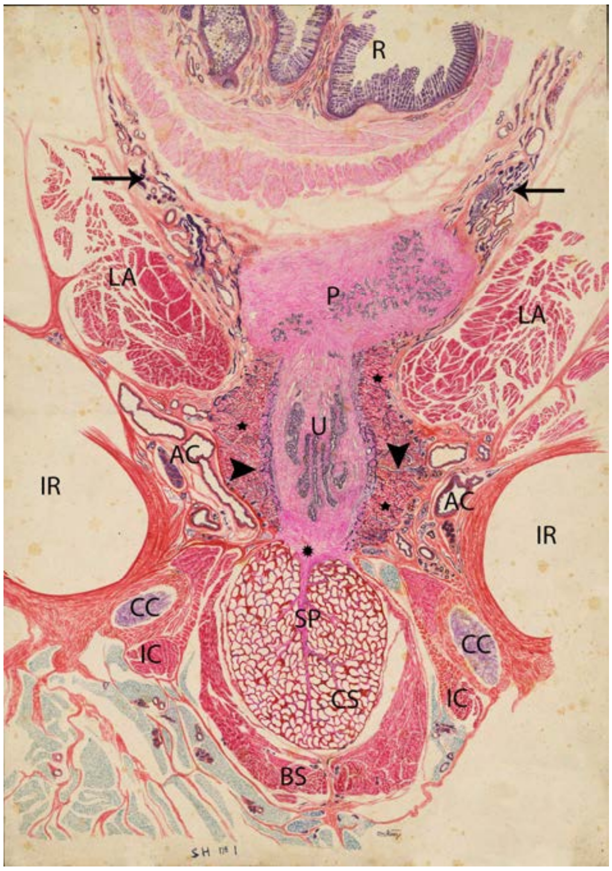


Fig. 27. Pelvic plexus and nerves of the external urethral sphincter. Six-month-old foetus. Drawing (1942). Coronal section. HE stain. Abbreviations as in Figs. 8-23 and pelvic plexus (arrows); SP: septum penile bulb; Smooth fibers (asterisk) and striated fibers (stars) of the external urethral sphincter; Nerves of the external urethral sphincter (arrowheads).

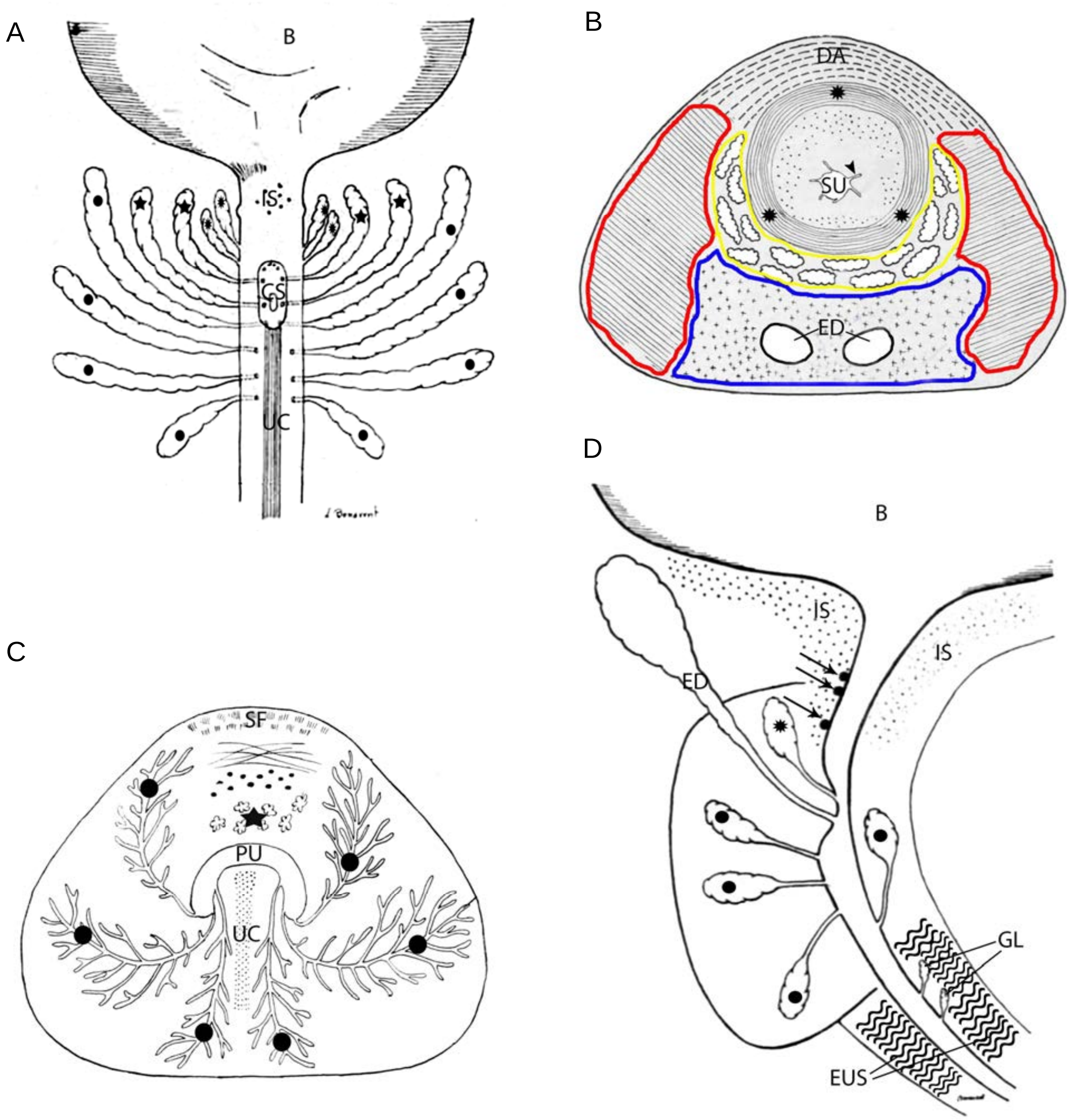


Fig. 28. Prostate regional model of Gil Vernet. Diagram. (**A**) Frontal section. Abbreviations as in Figs. 8-23 and UC: christa urethralis. Cranial gland with the intrasphincteric (IS) and subsphincteric glands (asterisk). Intermediate gland acini (stars). Caudal gland acini (filled circle). (**B**) Transverse section (supracollicular level). Abbreviations as in Figs. 8-23 and SU: supracollicular urethra. Internal vesical sphincter (asterisks). Intrasphincteric gland (arrowhead). Cranial gland with subsphincteric acini (yellow). Intermediate gland (blue) and caudal gland (red). (**C**) Transverse section (infracollicular level). Abbreviations as in Figs. 8-23. and external urethral sphincter with striated fibers (SF). Posterolateral (filled circles) and anterior acini (star) of the caudal gland. (**D**) Medial sagittal section. Abbreviations as in Figs. 8-23 and IS: internal vesical sphincter. LG: Littre glands. Cranial gland with intrasphincteric (arrows) and subsphincteric (asterisk) acinii. Caudal gland acini (filled circles).

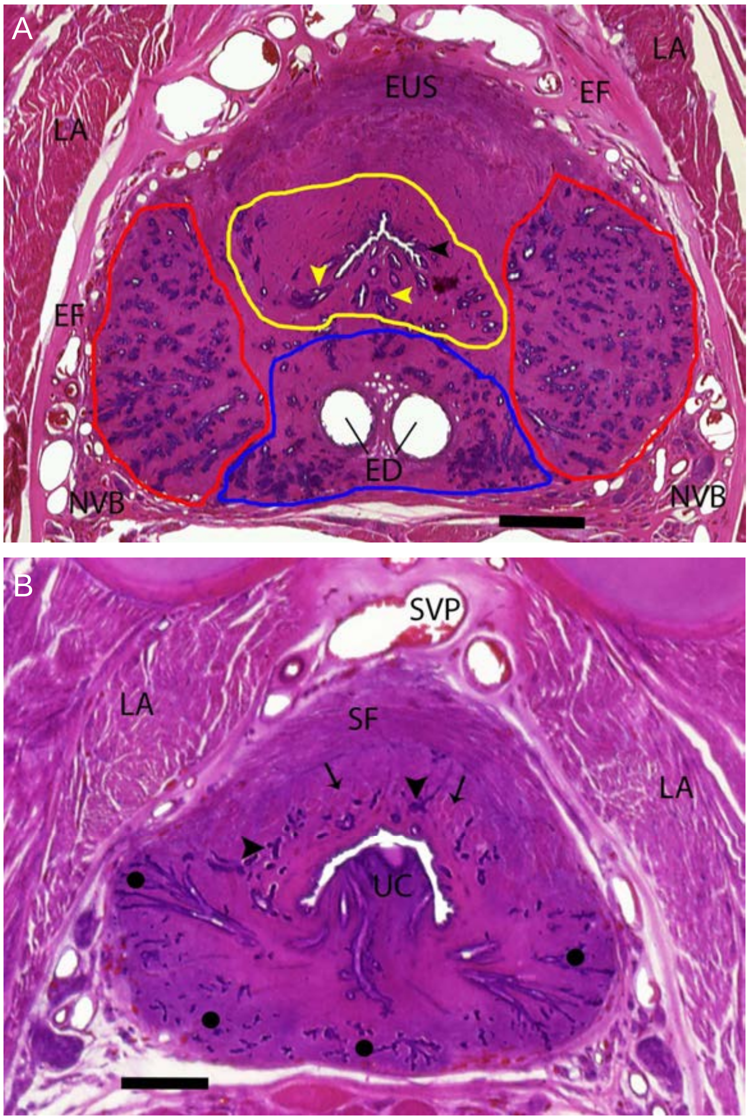


Fig. 29. Prostate regional anatomy. Gil Vernet's model. Newborn prostate, 40 µm. HE stain. Scale bar: 1 mm. (**A**) Supracollicular transverse section. Abbreviations as in Figs. 8-23. Cranial gland (yellow) with submucosal (black arowhead) and intrasphincteric glands (yellow arrowheads). Caudal gland with posterolateral acini (red). Intermediate gland (blue). (**B**) Infracollicular transverse section. Abbreviations as in Figs. 8-23 and caudal gland with posterolateral (filled circle) and anterior acini (arrowheads) and smooth anterior longitudinal prostato-urethral fibres (arrows).

pelvic nerves and innervate the striated urethral sphincter through the most caudal efferent branches of the pelvic plexus (Gil Vernet, 1953). More than 50 years later, several authors (Narayan et al., 1995; Hollabaugh et al., 1997; Arango and Domenech, 2000; Carlson and Nitti, 2001) confirmed in their publications this double innervation, somatic and autonomic, bilaterally entering the external urethral sphincter.

In his works on surgical technique, mainly those focusing on radical perineal prostatectomy, he highlighted the significant impact of preserving the nerves of the pelvic plexus on the incidence of postoperative urinary incontinence (Gil Vernet, 1944).

Regional anatomy of the prostate

In 1953, SGV described the first regional anatomical model of the prostate gland. He considered that the prostate was divided into three regions: the cranial, caudal and intermediate glands (Gil Vernet, 1953; Gil Vernet, 1975). This model was urethrocentric, with areas defined according to the location of their collecting ducts opening into the urethra (Figs. 28A, 28B, 28C and 28D) and was later used by McNeal, with very small variations, as the foundation of his zonal anatomy model (McNeal, 1968).

The cranial gland is formed by intersphincteric glands, located within the internal vesical sphincter (Albarran's periurethral glands) and two subsphincteric lateral lobes which correspond to the transition zone in McNeal's model.

The part so called by McNeal anterior fibromuscular stroma have the collecting ducts opening into the urethra and the prostate gland is formed by the dorsolateral, inferior and ventrocaudal surfaces of the prostate, the collecting ducts of which open distally into the colliculus seminalis, on both sides of the urethral crest. This region is identical to the area described as the peripheral gland in McNeal's model, although this author ignores the glands located on the ventral and apical surfaces of the gland, in what he calls the anterior fibromuscular stroma. The collecting ducts of the intermediate gland drain into the colliculus seminalis at the opening of the ejaculatory ducts. The glandular acini are located dorsolateral to the pathway of the ejaculatory ducts forming the craniodorsal surface of the prostate. This intermediate gland is identical to McNeal's central zone (Figs. 29A and 29B).

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