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## HISTORY OF MORPHOLOGY

# The genitourinary and reproductive systems: Interpretation of Avicenna's (980–1037 AD) treatise in the Canon of Medicine



*Interprétation du traité d'Avicenne (980–1037 après J.-C) dans le Canon de Médecine sur l'anatomie des systèmes reproducteur et uro-génital*

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Kidney;  
Urinary bladder;  
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**Abstract** Avicenna (also known as Ibn Sina 980–1037 AD) was the most influential Persian physician and scholar in the medieval times (9–12<sup>th</sup> century AD). Avicenna contributed to various fields of medicine, astronomy and metaphysics during his time. In the field of basic medical sciences, Avicenna systematically described the anatomy and pathology of various organs of the human body and devised surgical interventions towards the treatment of disorders associated with them. Avicenna compiled his famous book the Canon of Medicine which went on to become a reference textbook of medicine in the region and the West. Although neither formal human cadaveric dissection nor surgical training was recorded during his time, the anatomical and surgical information presented in the Canon of Medicine is comparable to modern literature. In the current vignette, we present an analysis of the basic structural anatomy and functional aspects of the genitourinary and reproductive systems and some reproductive concepts presented in the Canon of Medicine textbook and compare their relevance in modern medical literature. We found Avicenna's information on these systems to be congruent to modern anatomy and physiology literature. The only differences are attributed to the differences in the experimental approaches with Avicenna's information being derived in an era with less technological advances especially on the histology of organs. However, Avicenna's information in this treaty can be regarded as pioneering in the fields of urology and gynaecology.

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**Résumé** Avicenne (également connu sous le nom d'Ibn Sina, de 980 à 1037 après. J.-C) était le médecin et savant perse le plus érudit de l'époque médiévale (9<sup>e</sup>–12<sup>e</sup> siècle de notre ère). Avicenne a contribué à divers domaines de la médecine, de l'astronomie et de la métaphysique de son siècle. Dans le domaine des sciences médicales de base, Avicenne a systématiquement décrit l'anatomie, la pathologie et les troubles liés à de divers organes du corps humain et mis au point des interventions chirurgicales visant à les traiter. Avicenne a compilé son célèbre livre, Le Canon de la Médecine, qui est devenu le manuel de référence sur la médecine, dans la région et dans l'ouest. Bien qu'aucune dissection cadavérique humaine ou formation chirurgicale n'ait été officiellement transcrites à son époque, les informations anatomiques et chirurgicales présentées dans le Canon de la Médecine sont comparables aux écrits de la littérature moderne. Dans le traité actuel, nous présentons une analyse de l'anatomie topographique de base et fonctionnelle des systèmes reproducteur et uro-génital, ainsi que certains concepts de procréation présentés dans le Canon de Médecine, en les comparant à ceux de la littérature médicale moderne. Nous avons estimé que les informations d'Avicenne sur ces systèmes étaient cohérentes avec celles trouvées dans la littérature actuelle. Les seules différences sont attribuables aux contrastes entre les approches expérimentales, celles d'Avicenne étant dérivées d'une époque définie par des développements technologiques moindres, notamment concernant l'histologie des organes. Cependant, les informations d'Avicenne dans ce traité peuvent être considérées comme innovatrices dans les domaines de l'urologie et de la gynécologie.

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## Introduction

Ibn Sina (Avicenna in the West), was a Persian Muslim scientist and one of the greatest physicians and philosophers in the medieval era (Fig. 1) [1–3]. He was born in 980 AD in old Persia in Boukhara (in present-day Uzbekistan) and died and buried in 1037 AD in Hamedan, Iran [4–6]. Avicenna became famous through his medical textbook the Canon of Medicine [7]. The textbook was adopted as the main referral book in Western and Arabic universities for centuries [1,7]. The medical principles presented in the Canon of Medicine were based on traditional Greek (Unani), Roman and Chinese medicine [5]. Avicenna emphasised on integrative, holistic treatment and examination approaches to his patients [8,9]. In addition, he emphasised on the importance of the subject of anatomy and regarded it as being pivotal to the practise of medicine [1,10]. To support the importance of anatomy in medical practise, Avicenna in his book the Canon of medicine devoted the early chapters of the book to anatomy of the human body and also the anatomy of the various regions was described at the beginning of each section on any disease condition, particularly information related to that disease [11]. To date numerous research articles analysing the Avicenna's anatomical concepts in the Canon of Medicine have been and continues to be published. Although there is lack of conclusive evidence on the source of his anatomical information since there is no record of formal human cadaver dissection training in his treatises. Some evidence suggests that Avicenna acquired his information from animal cadaver dissection and vivisection on live animals [1].

Avicenna's information on the genital and urinary organs, although it was presented about 1000 years ago still compares with modern information in anatomy and associated literature. Avicenna described the anatomy and pathology of the urinary tract and reproductive system in both males and females. In other discoveries and advances related to the genitourinary systems, he advised on urine analysis in



**Figure 1** Drawing of Ibn Sina on a Polish postage stamp. Image obtained from the Muslim Heritage site <http://www.muslimheritage.com/article/ibn-sinas-canon-medicine>. Downloaded 20th of March 2018.

health and disease, whereby he suggested the timing of urine collection and the urine characteristics such as colour, turbidity, consistency, odour, sediments, volume and foaminess [4,11–14]. Avicenna expounded on obstructive diseases of the urinary tract and suggested on herbal and surgical

treatment of these disorders [13]. He mentioned the use of grasping forceps and mechanical litholopaxy in the managements of urinary bladder stones [15]. He characterized the pain from kidney and urinary bladder stones and suggested that the former was more painful than the latter [11,16]. Avicenna cautioned on the importance of the knowledge of anatomy in conducting cystolithotomy thereby minimizing the risks of sterilising the patient [11,12,14,16]. Herein, we analysed the functional anatomy of the genitourinary and reproductive systems as viewed by Avicenna in the Canon of Medicine textbook and compared their relevance to modern anatomy and physiology literature, particularly to the extant textbooks used in medical schools.

## The kidney (pages 1061 – 1062)

The descriptions of the anatomy and functional correlates of the kidney were derived from the Galenic (200 AD) principles where Avicenna erroneously described the right kidney as located at a plane higher than the left kidney. This description originated from the misconception that there was a communication channel between the liver and the right kidney. Avicenna stated that:

“The right kidney is located above the left one in order to be closer to the liver. It receives more matter from the liver. The right kidney has a direct connection with the liver and it attaches to the livers accessory part that is on its side” [16].

The left kidney was described as occupying a lower position to the right kidney because of its relationship to the spleen and hence it was pressed down by it [11,12,16]. Instead, modern anatomy literature shows that the right kidney is located below the liver at a lower level than the left kidney [17]. With regards to the position and relationship of the left kidney and the spleen, Avicenna stated:

“The left kidney is located lower and there are two reasons for this: The left kidneys might make trouble for the spleen...” [16].

Avicenna mentioned that the kidneys were designed for the excretion of excess water and waste substances from the blood. He also deliberated on the compensatory mechanisms of having two kidneys in case one fails due to disease [11,16,18]. The compensatory mechanism in kidney function was further developed to allow for kidney transplantation and donation, a technique, which was first implemented by surgeon Yurii Voronoy (1895–1961) in the year 1933 [19]. On the functions and number of kidneys, Avicenna stated that:

“Now we can say in the description of the kidney that the kidney sends that watery matter out of the body. Since this watery matter is a great amount, the organ that sends it out needs to be large enough to hold it, or else there should be a pair of these organs. If there were just one large one, it might at some point become narrowed and if there were too much water, this would cause difficulties. This is why God made the kidneys in a pair, and there are some benefits in this...” [16].

Avicenna described the origin and course of renal vessels and their relationship to gonadal vessels [11,12,16], but

did not clearly expound on their respective. He assumed that both renal arteries and veins bring blood and nutrition respectively to the kidney [11,12,16]. Avicenna described the renal pelvis within the kidney; how it fills with urine and the subsequent transport of urine to the urinary bladder through the ureters. Avicenna stated that:

“There are spaces inside each of the kidneys to which the watery matter drops from a short canal or duct. It goes from those spaces to the bladder through another canal or duct. The carrier canal to the bladder receives the water little by little and sends it to the bladder” [16].

He also acknowledged the role played by the kidney in the filtration of blood and slowly releasing the excess water as urine into the bladder. He described the filtration process and excretion of urine as a very slow process. He stated that:

“Why does the water go little by little from the kidney to the bladder? Because the water that comes to the kidneys directly has not been completely refined. It still has a part of the bloody matter (sanguinous humour) with it. The kidney has to filter this water mixed with blood and feed from the blood that it receives from this water. It then sends the extra refined water—that is completely separated from the blood—towards the bladder...” [16].

He also described the innervation of the kidney through sensory nerves found in the covering capsule and devoid in the kidney parenchyma.

“There is a small nerve in the kidney from which the kidneys covering is made” [16].

## Urinary Bladder (pages 1109 – 1110)

Avicenna described the function of the urinary bladder based on a two phase dogma which still stands in modern physiology principles. According to Yoshimura [20] the urinary bladder functions in two separate phases: first the storage phase whereby the urinary bladder fills with urine and second the voiding or emptying phase whereby urine is excreted to the external environment. Avicenna stated that:

“... Also, God made a small reservoir-like thing for waste and useless water, so that it accumulates there little by little and all comes out at the proper time. The person does not need to urinate every minute and hour like a strangury patient.” [16].

Avicenna described the bladder wall as made up of elastic tissue and tendons because of its capacity to expand in volume and diameter during filling. He stated that:

“It is made from tendons, and there are two reasons for this: 1. To make it as tight and hard as possible to avoid rupture. 2. To make it elastic so that it can be extended and filled with water while remaining stable” [16].

Instead, modern histology literature describes the muscular wall of the urinary bladder as consisting of smooth muscle tissue which is distensible on filling and contracts during emptying [21]. In addition, he described the urinary bladder wall as having only two layers.

“The bladder has two layers, the external layer and the internal layer. The internal layer stays at the bottom and is twice as strong as the external comes into contact with it” [16].

Instead, microscopically the urinary bladder wall consists of three layers that include the urothelium, muscular layer and the adventitia [21]. The latter two layers were described as one by Avicenna [4,13]. Avicenna ascribed the firmness of the internal wall of the urinary bladder to adaptation towards contact with astringent urine [11,12,16]. Avicenna described the anatomical course of ureters transporting urine from the renal pelvis to the urinary bladder. Interestingly, he described the anti-reflux mechanism located at the termination of the ureters into the urinary bladder wall. Avicenna stated that:

“There are two vessels ducts that carry water and the bladder, it opens both its layers to receive them. First both ducts pass through the hole in the first layer; then they pass through both layers as needed; then they open the covering layer and penetrate into the space inside the bladder and drop the waste water matter into it until it is full. As soon as the bladder becomes full with water matter the internal layer becomes attached to the external layer and it looks like they are just one layer. Because of this attaching and coming together of the layers, the watery matter will not return to the vessel ducts...” [16].

Modern anatomy literature indicates that the ureters enter the urinary bladder at an angle and pierce the fibromuscular layers (adventitia and muscular layers) first; they then traverse about 2 cm in the submucosa of the urothelium before piercing and opening in the urothelium [17]. When the bladder fills with urine the urothelium becomes closely applied to the muscular wall thereby closing the orifices of the ureters and preventing reflux of urine into the ureters [22]. Surprisingly, Avicenna described these mechanisms of urinary bladder filling and anti-reflux before the advent of cystometrograms, a device used to measure the change in the intravesicular pressure and the tone of the bladder wall muscles during filling. The mechanism of filling of the urinary bladder obeys the Laplace's law, which was coined by Pierre-Simon Laplace (1779-127) [4]. The law stipulates that when the urinary bladder is filling with urine, its diameter increases but the intravesicular pressure remains almost constant. This allows for the urinary bladder to collect as much urine until the micturition reflex is initiated which allows for emptying of the bladder [22].

Avicenna identified the prostate gland, muscle and connective tissue fibers surrounding the proximal urethra at the region of the neck of the urinary bladder in males. He affirmed that the glandular and fibromuscular structures were sensitive implying that they were highly innervated. He stated that:

“There is fleshy and sensitive matter in the bladder neck that is the neighbor of the muscle to the bladder. A muscle covers this neck-like thing at its origination at the upper portion. This muscle compresses and blocks the urine so that it will not come out when the bladder does not want it to come out. When the person wants to urinate, this muscle becomes relaxed, and, as you understand already,

this muscle is helped by the abdominal muscles. Therefore, this process works in an orderly way unless this muscle or the muscles that help it are damaged” [16].

Avicenna also described the functional anatomy of the external urethral sphincter at the neck of the urinary bladder. He affirmed that this voluntary sphincter is assisted by the abdominal muscles during normal voiding of urine. Avicenna described the curvatures of the urethra and suggested that they help in preventing involuntary voiding of urine. He described three curves in the male urethra and only one in the female. He stated that:

“God made a neck-shaped thing for the secretion of waste watery matter into the urethra to be evacuated out of the body. This neck shaped structure goes from the bladder to the external reproductive system, and it has some turns in it. These turns prevent urine from being evacuated. There are more of these turnings in men. There are three turns in men but there is just one in women. Because the bladder is close to the uterus in women” [16].

Consistent with Avicenna, in modern anatomical discourse, the male urethra consists of five different parts and along its length they are three curvatures (prostatic, bulbar and penile) and these help to trap urine and avoid involuntary voiding [4,17]. On the other hand, the female urethra contains a single curve, which is located between the neck of the urinary bladder and the beginning of the urethra that assists the external urethral sphincter in preventing involuntary voiding [4,17].

### **The morphology of the genitalia and some reproductive concepts (pages 1169 – 1170; 1221 – 1224)**

Avicenna's descriptions of the anatomy of male and female reproductive systems was based on Galen's (200 AD) description of the “one sex model” that depicted the female and male reproductive organs as homologous anatomical structures, with differences only in the location, size and complexity [23]. The female organs were regarded as less complex than male organs and were also viewed as an inverted form of the male's reproductive organs [23]. Avicenna mentioned that the male organs (penis, testes and the scrotum) were located outside the body and that the testes were responsible for the production of semen. He stated that:

“The difference between the penis and the uterus is that the penis is outside the body, but the reproductive organ in the female is inside the body. It is like an inverted penis. There is the thin-layered uterus inside of the scrotum. The uterine neck looks like the penis, but here it is inverted and hidden. Female ovaries are instead of male testicles. They are located at the end of the uterus and on each side of it. They are separated from each other, and a membrane covers each of them. This indicates that each of them has its private sac and they are not in one sac. The covering layer for each one of these ovaries is a membrane with nerves” [16].

Avicenna described the production and transportation of semen from the testes through a long and twisted epididymis and the ductus deferens to the prostatic urethra at the neck of the urinary bladder. He stated that:

“When food enters the fourth stage of digestion and it is to be distributed to the organs, an extra amount of it that has passed through the third digestion leaks from the vessels. This leakage is from the radical moisture that has recently been coagulated. The arteries, vessels and other things feed from the radical moisture. A large amount of this radical moisture might pass the fourth stage of digestion. It then has the ability to feed the vessels and other organs of the same nature without needing to be changed. This is how the semen enters the vessels: the sexual fluid (semen) in the male is in the seminal duct between the two testicles on one side, and the root of the penis is on the other side. The ducts or tubes for the female egg are in between the ovaries. The only difference is in the way they are used. Semen in the male starts moving from the testicles, comes up and drops into a cavity that the testicles hang from that is very hard. Then it comes back from it and comes down and goes through a twisting way. It becomes completely matured in this movement and comes to both ducts on both sides of the penis root” [16]

### Uterus and ovaries (pages 1221 – 1224)

As mentioned earlier, Avicenna subscribed to the Galenic dogma of the inverted female genitalia. He described the uterus as inverted penis, whereby the scrotum represents the body of the uterus, the shaft of the penis making the neck (cervix) and the foreskin (prepuce) forming the vagina [16]. Avicenna mentioned that the uterine wall is capable of stretching and contraction. In addition, he stated that the uterus is small in girls than in married women and that during pregnancy the uterus and the breasts grow continuously until the foetus reaches maturity [11,12,16]. He stated that:

“Why is the uterus made from nerves, and why are so many nerves collected in it? It is to make the uterus completely ready for stretching, contracting and squeezing. When the uterus covers the fetus, it needs to stretch a great deal to provide a wide space for the fetus. When the baby is born, it comes together and becomes very small. This widening of the uterus grows to the maximum when the fetus is completely developed. The uterus is like a breast in this regard, and the breast receives the largest mass when the fetus is completely developed because the breast is nonfunctional until the fetus is completely developed. That is why the uterus of girls is smaller than the uterus of married women” [16].

Avicenna described a two layered uterine wall consisting of the thick inner lining and the outer covering layer contradicting the modern anatomical descriptions of the three layered uterus including the perimetrium (fibrous), myometrium (smooth muscle) and endometrium (mucosa). He however correctly described the menstrual cycle by pointing out that the uterine wall thickens during the menstrual cycle and the menstrual blood comes from the inner lining of the uterus. He stated that:

“The uterus consists of two layers. The hardness of the lining layer is closer to the hardness of the vessels than it is to that of the covering layer. It is in closer contact with the vessels than with the covering layer. These vessels are the ones hidden inside the uterus. The fetus membranes are attached to the uterus through these vessels. Menstrual blood comes from two layers—the outer layer—is closer to the sensory nerves. Any of these two layers can open and close depending on temperament and the needs of the uterus.” [16].

Furthermore, Avicenna mentioned that the inner uterine wall shrinks on cessation of the menstrual blood flow. During pregnancy, he observed that the wall of the uterus decreases in thickness as the pregnancy progresses and that the foetal membranes, particularly the placenta attaches to the inner lining of the uterus through blood vessels. Avicenna stated that:

“The uterus looks thick and puffy during the menstrual cycle. It looks like it has become fat, but after menstrual bleeding, this fattiness and puffiness goes away and the uterus shrinks and shrivels. As the fetus grows larger, the uterus becomes thinner and thinner. The uterus expands with the fetus” [16].

Avicenna described the uterine position and relations as lying behind and on top (postero-superior) of the urinary bladder with its body resting on the superior surface of the bladder. He also mentioned that rectum lies behind (posterior) to the uterus. He described the “uterosacral ligaments” as ligamentous attachments of the uterus to the sacrum. Avicenna described the innervation and blood vessels to the uterus and suggested that blood vessels can be seen during the examination of the uterus in pregnant females. Avicenna mentioned the opening of the uterine tubes into the cavity of the uterus on both sides and described the cervix by confirming that its folds increase during pregnancy. He stated that:

“The uterus is attached to the posterior area with strong tendons, and it tends towards the umbilicus, the bladder, the flat bone and the area above the flat bone. These tendons are elastic. . . . If it is said that the uterus is nerve-sensory, it does not mean that it is made from the brains nerves. It means that the nature of the uterus looks like nerves. It is white in colour. It does not have blood. It is elastic. There are a few nerves from the brain to the uterus. They can be seen by examination. If there were more sensory nerves than this, there would be more connections with the brain. The neck of the uterus has folds. It looks like there is fold upon fold. There are more folds and greater stiffness of the uterus in fat women. The folds are also more numerous during pregnancy” [16].

He also described the vagina and its functions as a conduit for semen, menstrual blood flow and as a birth canal. In addition, he mentioned the presence of a hymen in the vagina during virginity. Within the perineum, he described the location of the urethral meatus as being located above the vaginal orifice in the vulvar. He stated that:

“There is a tube in the uterus that is located exactly in front of the vulva orifice from the outside. Semen enters from that tube and menstrual blood comes from this tube.

The passageway for delivery of a baby is this tube. When a woman is pregnant, this tube is very narrow so that it is difficult to insert a surgery rod into the tube... A girl who is a virgin has membranes in the uterus neck that are made from thin vessels and tendons. When she has sexual intercourse for the first time, she loses her hymen, rupturing these thin membranes and releasing the blood that is in those membranes” [16].

Consistent with modern anatomical descriptions, Avicenna suggested that the female ovaries are equivalent to the male testis and they produce female eggs (ova) for reproduction. He mentioned that each ovary was enclosed in a membrane with sensory nerves and was located on each side of the uterus at the end of uterine horns. He affirmed that the female eggs were transported by uterine horns towards the uterus [11,16].

## Reproductive concepts

Avicenna explained the reproduction process, particularly that of fertilisation based on the principles from his predecessors including Aristotle, Hippocrates and Galen. He expounded on Aristotle's concepts of males contributing more than females towards the development of the fetus [24]. Concurrently, he acknowledged the contribution of females towards fertilisation in a similar manner to Hippocrates and Galen's [23] assertions. He emphasized that the male semen was vital for fertilisation and considered the female eggs for only providing the necessary environment for the development of the conceptus [11,12]. Avicenna also described penile erection and the mechanisms around the process. He cited blood pressure increases and engorgement in the penis as major factors contributing towards penile erection. In addition, he cited the sexual intercourse and thoughts particularly during sleep as factors that contribute to the stimulation and maintenance of penile erection [16].

In conclusion, studies on the genitalia and reproductive system were hampered by religious beliefs during the medieval era and very few scholars, if they attempted did not carry out thorough examination of the differences between the male and female genitalia. However, Avicenna described the anatomy of this region and offered guidelines to the surgical procedures such as perineal urethrostomy (perineostomy) [4] to treat common conditions such as obstruction of the urinary tracts. Avicenna's information on this region is comparable to modern literature although numerous research developments are continuously being added.

## Disclosure of interest

The authors declare that they have no competing interest.

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