Historic Considerations in Male Reproduction

Michael K Skinner, Center for Reproductive Biology, School of Biological Sciences, Washington State University Pullman, Pullman, WA, United States

This is an update of Michael K. Skinner, Bernard Jégou, Historic Considerations in Male Reproduction, Editor(s): Michael K. Skinner, Encyclopedia of Reproduction (Second Edition), Academic Press, 2018, Pages 3–9, ISBN 9780128151457, https://doi.org/10.1016/B978-0-12-801238-3.64554-3.

Abstract

This chapter will present a number of critical early historic considerations and theories starting in 500 yr BCE and progressing through the 1800's and early 1900's. One of the first physiological procedures involved ancient man's castration of animals for domestication and then later observations by early societies and Aristotle on the impacts of the testis on human male characteristics. These observations impacted the theories of sex differences, sex determination and fertilization for over 2000 years. Understanding these early theories and speculations clarifies the historic steps in the development of modern male reproductive biology. A number of these historic considerations are presented.

Key Points

- History of male reproduction biology.

Introduction

The objective of this chapter is to provide a number of early historic observations and theories that influenced the development of the field of Male Reproductive Biology (Skinner and Jegou, 2018). The use of castration by ancient man to domesticate animals indicate the testis was the first organ studied in regards to its impact on male reproductive physiology. The differences between males and females also lead to the first biological theories on why these differences exist. One of the first uses of the microscope was the examination of sperm and the initial theories developed that impeded the initial theory of fertilization. The basis for sex determination was also one of the first biological considerations of Aristotle which impacted the biological sciences for over two thousand years. Although the focus of Volume 1 is to present the current state of the art understanding in Male Reproduction, this chapter will present a number of historic considerations (**Table 1**) that were for the most part inaccurate and misleading, but have significantly impacted the progression of the field of reproductive biology.

Historic Castration (Testis) Considerations

Ancient civilizations used the removal of testis (i.e., castration) to domesticate animals including pigs, cattle, and sheep. The origins of castration, most likely developed at the time of the emergence of farming (i.e., neolitic period ~10,000 BCE), either accidentally or intentionally, but had a significant impact on ancient civilizations (Diamandopoulos *et al.*, 2005). Therefore, this biological manipulation is the first documented physiological observation on the impacts of a specific organ on the biology of an organism. The first writings on castration was around 1500 BCE by Assyrians in a tablet relating castration as punishment for sexual crimes. Then, the Greek medical writer Hippocrates in the 5th–4th century BCE elaborated on the concept requiring the two parents. Physical traits on voice and feminization in eunuchs (i.e., human castrations) were documented by Aristotle in the 4th–3rd centuries BCE (Hippocrates 1915 Prorrheticum, 1915). He commented on the effects of castration in the rooster and man and gave a detailed description of the genital tract in mammals. Aristotle also developed early theories or speculations on the role of the testis in male biology (Hippocrates 1962 Aphorismi, 1962). Over the next thousand years debates and theories on the

Table 1 Historic considerations impacting male reproduction

Reproductive topic	*Observation*	*Period*
Castration	Testis first organ interest Domestication animals	Prehistoric/neolitic
	Eunuch characteristics	Assyrian/Egyptian/ Greek societies
Reproduction theory	Theory male provides seed (testis involved) active role and female provide soil passive role (prevailing theory 2000 years)	Aristotle (384–322 BCE)
Environmental sex determination	Theory environmental factors such as heat (fire) and cold (water) promotes sex determination for male or female	Aristotle (384–322 BCE)
Spermist theory/ animalculism	One of two theory of preformationism for which sperm head contained preformed offspring (homunculus) and female provide passive environment for development	Nicolaas Hartsoeker 1600s
Ovism	The other theory of preformation for which the embryo is preformed in the ovum (egg) while the sperm only provides an "aura seminalis", that is a vital essence	1600s–1700s
Female ovary & egg role reproduction	Egg produced in ovary and has active role reproduction with sperm	William Harvey and Bishop Niels Stenson 1600s
Male reproductive tract organs anatomy	Detailed anatomy of male reproductive tract organs and specialized roles	Vesale 1543s and De Graaf 1600s
Genetic sex determination theory	The role of genetics followed by gonadal followed by phenotypic sex in mammals	Alfred Jost (1940s & 1950s)
Male reproduction endocrine theory	The role of endocrine hormones in male reproduction integrating the testis, brain and other reproductive organs	Berthold 1879 Alfered Jost (1940s & 1950s) McCullagh (1930s & 1940s)

impacts of the testis on male biology developed ranging from the impact of temperature on the testis to the effects of the testis on the heart, brain and muscle development (Diamandopoulos *et al.*, 2005). One of the more interesting speculations was the role of a testis derived liquid on the males biology (Diamandopoulos *et al.*, 2005; Galen, 1964). Although the majority of these theories and speculations were neither accurate or based on specific observations, Aristotle's concepts had significant impacts for centuries on our approach and progress of scientific advances (**Table 1**).

The use of castrations in ancient societies in humans to create eunuchs was reported in Assyrian, Egyptian and Greek cultures. Observations of the physiological impacts of castration were documented in all these societies. This included infertility, brain behavioral effects, voice changes, weight and metabolism alterations and more. These observations led to a variety of early theories and speculations. A prominent link between the testis and the brain was discussed by Aristotle and others throughout history, which was the first speculations of the brain and gonadal axis today known to be endocrine based. Although these early speculations and theories were not completely accurate, they laid the foundation for much of the early male reproduction research in the last century.

Reproduction and Sperm Theory

One of the first recorded reproduction theories or speculations was proposed by Aristotle (**Table 1**). Observations with castration and role of the testis to create semen Aristotle proposed the male provided the seed having an active role in reproduction and the female provided the soil having a passive role in reproduction. Although this reproduction theory was based on observations at the time, this Aristotle concept persisted for nearly 2000 years and impacted the majority of reproductive biology research and society. A classic example involving one of the first observations following the development of the single lens microscope in the 1600s by Leewenhock was made on his own sperm which lead him to describe the presence and vigor of "animalcules", the name that he gave to spermatozoa. Under the name of "homunculus" the speculation was made by Nicolaas Hartsoeker (1694) that the spermatozoon contained the entire preformed human (homunculus)/animal (animalcules) with a number of supporting microscopic observations (Hartsoeker, 1696). The concept named "animalculism" was that the sperm provided the seed that contained the preformed animal (**Fig. 1**) and that the female provided the soil to allow its growth. Therefore, Aristotle's reproduction theory was supported.

This preformation sperm theory was debated for the next 100 years. The work of the Reverend Lazzaro Spallanzani (1717, 1780) lead to the description of the mobility of spermatozoa (the "small worms" as he wrote) and he also provided the first artificial insemination using a dog (Inza, 1964). Although all of Spallanzani's work supported the role of the sperm in reproduction, he believed in ovism and the role of a preformed person in the egg. The very long standing controversy about the role of spermatozoa in reproduction really ended with Prevost and Dumas in 1824 who re-discovered after Spallanzani the relationship between the male gamete and reproductive abilities. The named "spermatozoa" was first coined by Van Baer soon after (1827), and it was van Kolliker in 1841 who introduced the fact that spermatozoa derive from germ cells in the testis.

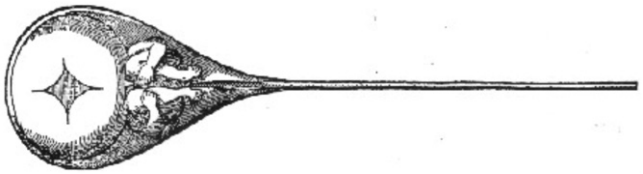

Fig. 1. Homunculus involving preformed human/animal in the head of the sperm to then allow growth in the female (Hartsoeker, 1696).

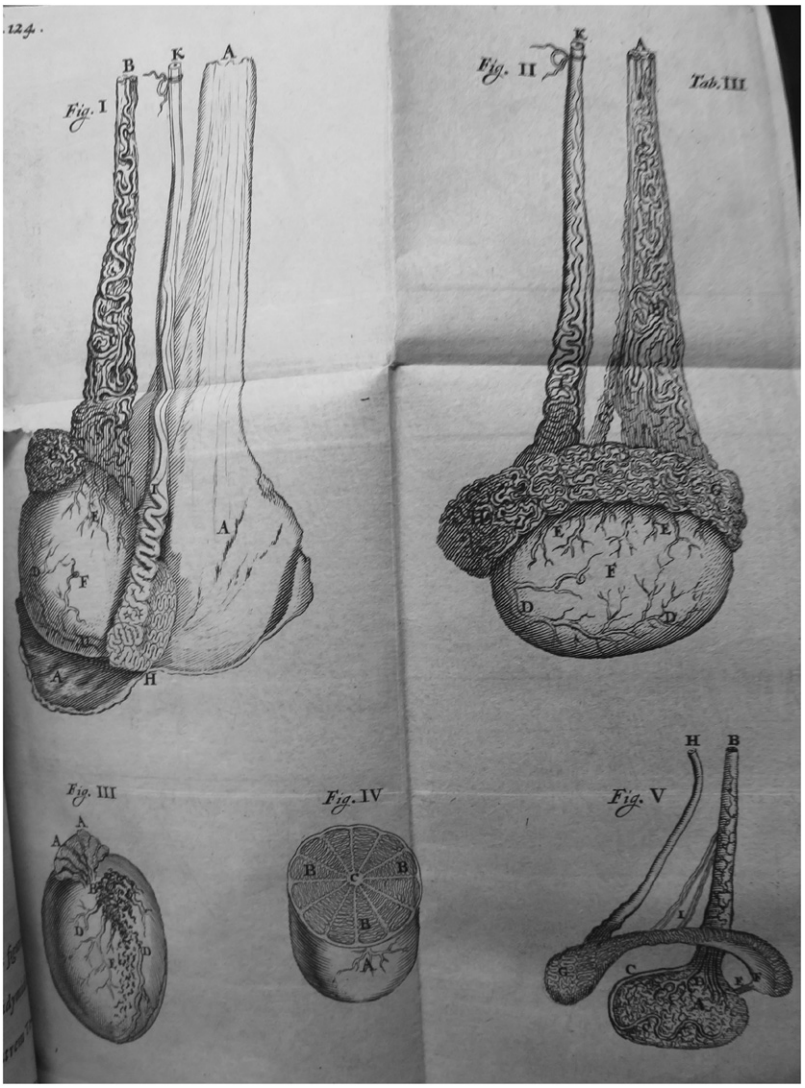

Fig. 2. Testis and epididymis male reproductive tract anatomy drawing (DeGraaf, 1677).

During the same period, it was William Harvey (1578–1657), who discovered circulation of blood, but he also studied the ovary anatomy making major observations on the histology of the ovary and anatomy of the female reproductive system. Observations led Harvey to the proposal that ovulation and the ovary had a critical role in reproduction (Harvey, 1651). Harvey did not discover the egg as during the same period Bishop Niels Stensen (1638–1686) using fish ovaries to discover the egg and later using the mule, horse and donkey described the role of the egg in reproduction (Volker, 1989). The debate that the female and egg played an active role in reproduction was contested during the 1600s and 1700s period due in part to the predominant influence of the early Aristotle concepts. The active role of the female in reproduction slowly became accepted, however, this provides an example of how early scientific theories can develop into dogma and paradigms that can persist and sometimes impair the progression of science.

Male Reproductive Tract Organs and Anatomy

Anatomy was one of the first biological fields to develop and was documented by artists and scientists from early Egyptian, Greek and Roman periods through the modern era. All those societies had documentation of testis and ovary which suggested their understanding of the link with reproduction. Later artists such as Leonardo Di Vinci (1452–1519) created drawings of reproductive systems and organs such as the male reproductive tract. This included an anatomical representation of coitum of a hemisected man and women, and is best known for his analysis of fetal developmental anatomy (O'Malley, 2003). Many artists and scientists documented the anatomy of many reproductive organs, such as the work of Vesale in 1513, but one of the most influential and informative scientists was Regneri de Graaf in the 1600's (De Graaf, 1677). The most complete and insightful male and female reproductive tract anatomy was provided by de Graaf and detailed the specific organs, connections and hypothetical functions. An example of his detailed drawings of male reproductive tract anatomy is presented in **Figs. 2** and **3**. In addition to the testis, rete testis and epididymis, seminal vesical, vas deferens and penis are presented in detail (De Graaf, 1677). The work of early anatomists such as de Graaf set the ground work for our modern understanding of male reproduction. The development of the microscope in the late 1600s allowed more detailed anatomy and histology to be performed of male reproductive tract tissues. This analysis advanced the concepts of the "Cell Theory" which suggested tissues and organs had specific cells that allowed them to function. One of the first tissues studied was the testis due to its importance for reproduction and having more understanding than most tissues. Following the understanding sperm was produced within the seminiferous tubules, the first somatic cell identified at this level was the Sertoli cell. Enrico Sertoli was an Italian physician that used the early microscope to describe the structure and histology of this critical cell type. Sertoli elaborated the crucial concept that Sertoli cells are the "nurse cells" of germ cells (Anon, 1987). His early diagrams of these cells that now have his name are shown in **Fig. 4** (Sertoli, 1865). The various structures of the Sertoli cell and its role in the development of the seminiferous tubule are described from this 1865 observation (Sertoli, 1865). This is simply the first of many different observations by many scientists to describe specific cell types in various male reproductive tract organs. Clearly the organ anatomy and cellular histology of the 1600s–1800s helped establish the initial building blocks for current reproduction research.

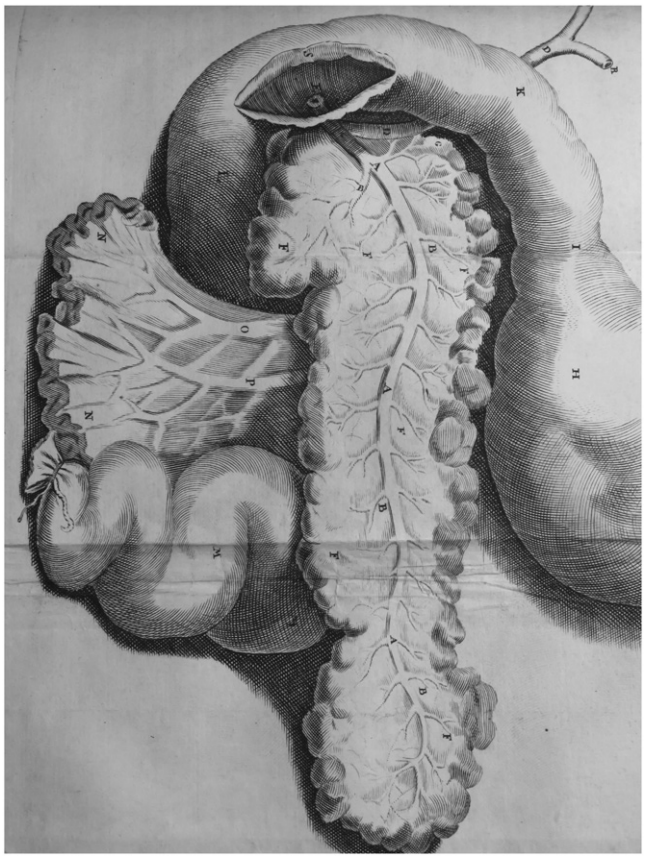

Fig. 3. Seminal vesicle and male reproductive tract anatomy drawing (DeGraaf, 1677).

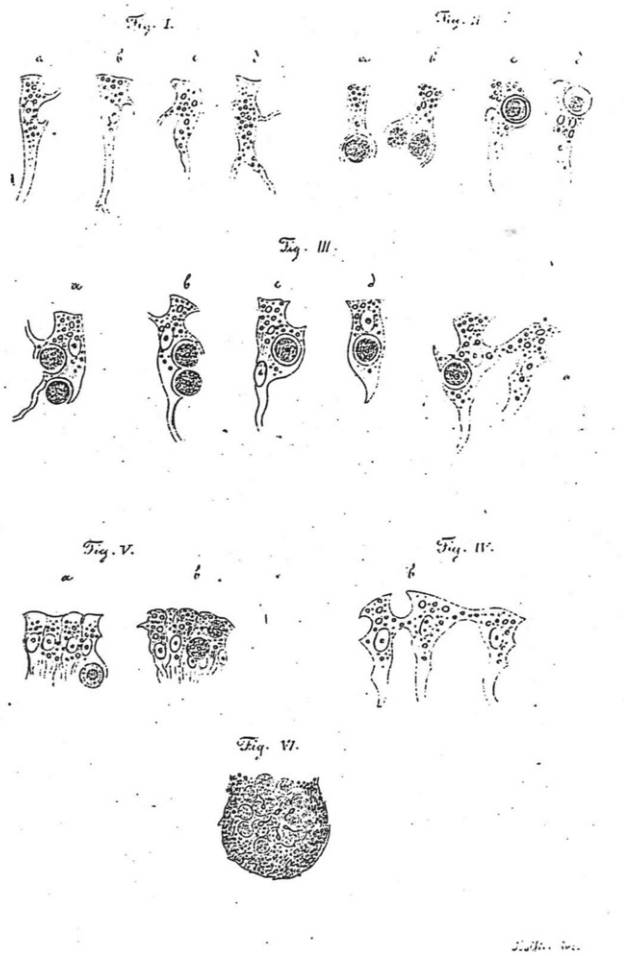

Fig. 4. Aristotle sex determination theory. The relative preponderances of the four elements and their qualities in males and females. The greater innate heat of the male allows for a greater degree of concoction of the nourishment and hence a more concentrated white semen is formed.

Early Sex Determination Theory

The origins of males versus females through the process of sex determination was also considered in early societies, but the first documented theory or speculation was provided by Aristotle (**Table 1**). The concept was that environment promoted sex determination and Aristotle suggested heat initiated male development and cold initiated female development (**Fig. 5**). Although this does exist in some organisms such as turtles (Volume 6 Chapter 23–31), this is now known not to be a factor in mammals and most organisms (Volume 3 Chapters 47–52). This theory has persisted even into the modern era. An example is in the 1980s when the prince of England was about to have a child the fact he had been a helicopter pilot was determined by the popular press to indicate he would have a male child. Therefore, even today the concept environment can impact sex determination persists from these early Aristotle concepts.

This environmental impact on sex determination persisted until the mid-1900s. The first modern theory of sex determination was provided by Alfred Jost, University of Paris in the 1940s and 1950s (Jost, 1945; Jost, 1970). The development of genetics in the early 1900s led to the identification of sex chromosomes that then through experiments by Jost on early fetal sex determination led to his theory for sex determination (**Table 1**). This involved the theory that genetic sex (sex chromosomes) promotes gonadal sex (testis or ovary) that then promotes phenotypic sex (male or female) (Jost, 1945; Jost, 1970), **Fig. 6**. This sex determination theory displaced the early Aristotle concept of environmental sex determination, but surprisingly Aristotle's theory was predominant for nearly 2000 years. Another example of how early historic concepts can impede the progression of science by development of strong dogma or paradigms.

Early Endocrine Observations

The development of early anatomy and cell histology in the 1600s and 1700s established an understanding of the complexities of male reproduction in a number of different species. The first major advance to the next level was made by Claude Bernard in the

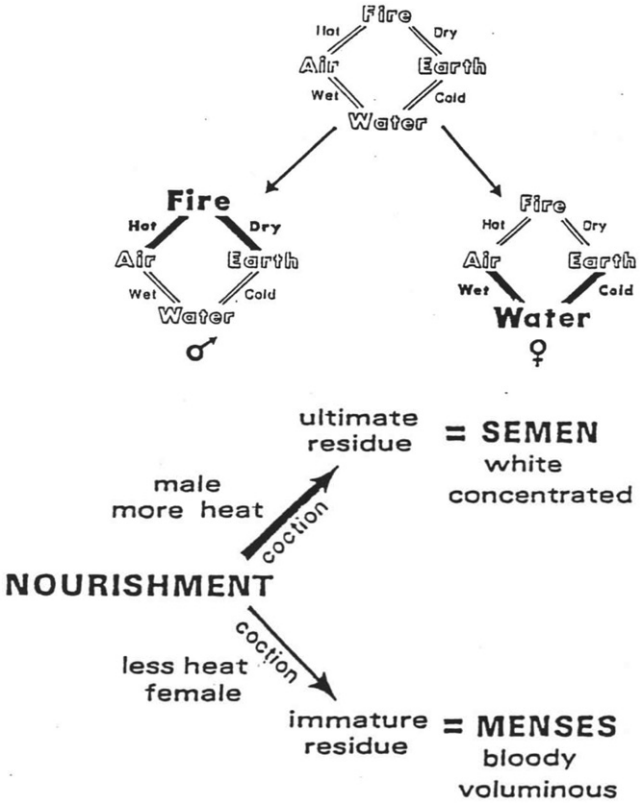

Fig. 5. Aristotle sex determination theory. Role of heat in promoting sex (testis or ovary) that promote male or female phenotypic sex characteristics.

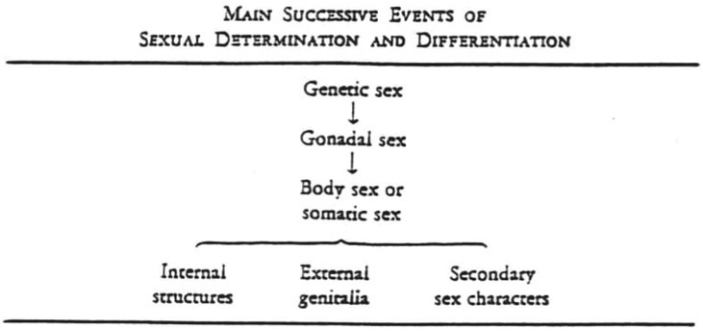

Fig. 6. Sex determination theory. From Jost, A., 1970. Hormonal factors in the sex differentiation of the mammalian foetus. Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences 259, 119–130. Jost, A., 1945. Sur l'action de divers androgenes dans la differenciation embryonnaire du sexe. Comptes Rendus des Seances de la Societe de Biologie et de SesFiliales 139, 670–672.

1850s with the advent of the field of physiology. He is considered the father of the field through his insight and experiments that different organ systems interact to influence their functions. He described the concept of cybernetic systems between organs and tissues through the internal milieu as the basis of how the organism functions (Bernard, 1872). Although he did not focus on reproduction, the concepts and theory initiated the fields of physiology, endocrinology and cell biology. One of the systems he did consider was the brain-gonadal interaction. Therefore, Bernard set the ground work for reproduction physiology and indirectly led to the field of endocrinology.

With this in mind and the summary of the main milestones concerning the testis itself, the seminiferous tubules and spermatozoa (see above) it is interesting to note that the first demonstration of the role of a "gland", was provided by Berthold in 1849 when he showed that while castration was followed by regression of the cockscomb, transplantation of the testes to the castrated cocks restored its size. Very soon afterward Leydig (in 1850) provided the first microscopic description of the interstitial cells of the testis which were named the Leydig cells and are now known to produce the hormones named androgens, and Insulin-like factor 3 the latter being responsible for testicular descent in mammals.

The early 1900s involved a large number of physiology experiments to examine how organ systems influence each other and identified substances that mediate those interactions. Some of the first hormones identified were shown to be produced by the gonads and impact a wide variety of tissues (**Table 1**). This involved the identification of testosterone being produced by the testis (McCullagh, 1948). In addition, one of the first protein hormones inhibin being produced by the testis and impacting the brain hypothalamus (McCullagh, 1948). One of the prominent scientists involved was E. Perry Mc Cullagh (McCullagh, 1948). This initiated in the following decades an increasing number of endocrine focused experiments to help understand male reproduction. Another example is related to the work of Alfred Jost, **Fig. 6**, who during his work on sex determination identified a Testis Determining Factor that we now know is a specific gene (SRY), as well as a hormone Müllerian inhibiting substance (MIS) which is critical in both male and female fetal sex determination and in the adult (Jost, 1945; Jost, 1970). Over the past 100 years the advances have been far more rapid than in previous centuries.

Summary

The review of ancient and early history has revealed that early history concepts for science are often not completely accurate, but they do have an important role in the progression of science. The advantage is that a theory is developed that can be tested through experiment and during that process new observations can be made to progress science. The disadvantage is that the theory developed can turn into dogma and a strong paradigm that becomes so ingrained that it can impede the progression of science. In considering the history and concepts of male reproduction, there have been good examples of both. Although the insight and theories of Aristotle were surprising, the development of dogma around these concepts clearly impeded the progression of science in subsequent centuries. We have displaced many of these concepts, but even today we have our paradigms (e.g., genetic determinism). The future will need to assess these paradigms and not resist the paradigm shifts required to advance science.

Considering the male reproduction historic concepts can assist in our understanding of the origins of current science and theories. Perhaps the biggest value of this historic understanding is to put the current activities in perspective, which will only help the advances of male reproductive sciences, and all sciences, in the future.

References

Anon, 1987. Historical tribute: On the existence of specialized branching cells in the seminiferous canaliculi of the human testis. By Enrico Sertoli. 1865. Hum. Reprod. 2, 83–84.
Bernard, C., 1872. De La Physiologie Generale. Paris: Librairie Hachette Et Cie.
De Graaf, R., 1677. Opera Omnia, Lugd. Batav. Ex Officina Hackiana.
Diamandopoulos, A., Goudas, P., Patsy, D., 2005. The ancient and medieval Greek writer's perceptions concerning the relationship between sexual characteristics and testicular volume. Hormones (Athens) 4, 117–120.
Galen, 1964. Chapter 4 – De semine libri ii. In: Claudii Galeni Opera Omnia, 583. Hildesheim, Olms.
Hartsoeker, N., 1696. Anisson (Ed.), Principes de Physique. Imprimerie Royale, Paris.
Harvey, W., 1651. Exercitationes de Generatione Animalium. Auibus Accedunt Quaedam de Partu; de Membranis ac Humoribus Uteri; & de Conceptione, Londini, Typid Du-Gardianis. Impensis O. Pulleyn.
Hippocrates 1915 Prorrheticum, 1915. Chapter 16 – Galeni in Hippocratis Prorrheticum I Commentaria III. Leipzig: Corpus medicorum Graecorum, p. 608.
Hippocrates, 1962. Chapter 6 – Oeuvres Completes D'Hippocrate. In: Section, 28. Publication Hakkert, Amsterdam.
Inza, R., 1964. Monography on Lazaro Spallanzani. Sem. Med. 124, 622–630.
Jost, A., 1945. Sur l'action de divers androgenes dans la differenciation embryonnaire du sexe. C R Seances Soc. Biol. Fil. 139, 670–672.
Jost, A., 1970. Hormonal factors in the sex differentiation of the mammalian foetus. Philos. Trans. R. Soc. Lond. B Biol. Sci. 259, 119–130.
Mccullagh, E., 1948. Testicular dysfunction. Bull. N. Y. Acad. Med. 24, 341–363.
O'malley, C.D., 2003. Leonardo da Vinci on the Human Body: The Anatomical, Physiological, and Embryological Drawings of Leonardo da Vinci, Gramercy.
Sertoli, E., 1865. Dell'esistenza di particolari cellule ramificate nei canalicoli seminiferi del testicolo umano. Morgagni 7, 31–40.
Skinner, M.K., Jegou, B., 2018. Historic considerations in male reproduction. In: Skinner, M.K. (Ed.), Encyclopedia of Reproduction,, second ed., vol. 1. Elsevier, pp. 3–9.
Volker, A., 1989. [Neils Stensen (1638-1686) in the medicine of his era]. Z. Gesamte Inn. Med. 44, 215–221.