

Research Article

A Brief Historical Survey of Generation (From Hippocrates (469-399 B.C.) to the Controversy between “Spermatists” and “Ooists”)

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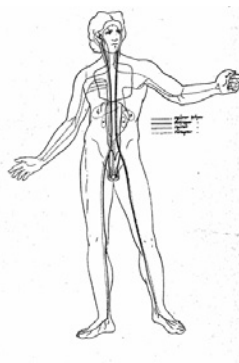
Abstract

The authors take into consideration the knowledge and the ideas about the male and female generation organs in mammals from Hippocrates (c. 469-c. 399) and Galen (129-c. 199 A.D.) to the discovery of both spermatozoa and oocytes and the consequent controversies between the so-called “spermatists” and the so-called “ooists” about the genesis and the formation of the foetus. They have recourse to a critical review of the passages dealing with these topics in Hippocrates', Aristotle's (384-322 B.C.), Celsus' (1st century B.C.-1st century A.D.), Galen's, Leeuwenhoek's (1632-1723), Malpighi's (1628-1694), De Graaf's (1641-1683) and von Baer's (1792-1876) works.

MATERIALS AND METHOD

A critical review of the pertinent passages in Hippocrates', Aristotle's (384-322 B.C.), Galen's, Leeuwenhoek's (1632-1723), Malpighi's (1628-1694), De Graaf's (1641-1683) and von Baer's (1792-1876) works dealing with both the anatomophysiology of the male and female generation organs in mammals and the formation of the foetus.

According to Aristotle¹ Polybos (Hippocrate's son in law² maintained that the veins' system³ consisted of 4 “zeúgē” (yokes, i.e. “pairs”), the second of which – whose veins were called by him “sphagítides” (jugular veins) – started from behind the ears and reached the testicles (Figure 1).



1 Cf. *Historia animalium* (Description of animals), 3, 3, 512b 12 ff. From now on we will use the abbreviation H.A.

2 This means that Hippocrates had at least one daughter!

3 In none of the treatises of the so-called *Corpus Hippocraticum* may be found even the faintest idea about the difference between veins and arteries, which was discovered by Praxagoras of Cos, who flourished in the 2nd half of the 4th century B.C. However he thought that the arteries (the pulse of which he pointed out clearly) contained air, an idea that was also advocated by his disciple Herophilus (1st half of 3rd century) and demolished by Galen (c. 129-199 A.D.) in his as brief as marvellous treatise *An in arteriis sanguis contineatur* (If the arteries contain blood) (cf. K, IV, 703-736). However this exceptional discovery was a real tragedy for Galen, who could not realize where the breathed in air could go and forced him to imagine that it was used by the heart auricles that acted as a sort of fan to limit the too exaggerated heat of the heart, whose task was to “cook”, or better to “concoct” the foods into the stomach, which, in its turn, was nothing else than a sort of cooking pot. Cf. note n. 46.

Figure 1: The blood vascular system and its “4 *zeúgē*” according to Polybos (after H. Aubert & Fr. Wimmer, *Aristoteles, Thierkunde*, Leipzig, 1868). In fact the same statement may be found in the 22nd chapter of the Hippocratic treatise *Peri aērōn, hydátōn kai tōpōn* (On the airs, the waters and the places). It reads as follows⁴:

“The great majority among the Scythians become impotent, do women’s work, live like women and converse accordingly. Such men they call “Anaries” (impotent persons)...The habit of riding causes swelling at the joints, because they are always astride their horses; in severe cases follow lameness and sores on the hips. They cure themselves in the following way. At the beginning of the disease they cut the vein behind each ear. When the blood has ceased to flow faintness comes over them and they sleep. Afterwards they get up, some cured and some not. Now, in my opinion, by this treatment the seed is destroyed. For by the side of the ears are veins, to cut which causes impotence, and I believe that these are the veins, which they cut”.

This exceptionally interesting passage poses a problem: as Aristotle maintains that the pair of veins starting from behind the ears were not hypothesized by Hippocrates, but by his son in law Polybos, we must conclude that either Aristotle made a fundamental mistake – that is literally impossible because he surely knew both Polybo’s and Hippocrates’ works much better than we do – or the author of the treatise *Peri aērōn, hydátōn kai tōpōn* (On the airs, the waters and the places) is not Hippocrates but Polybos himself or, finally and most probably, that Hippocrates is the real author of the treatise, in writing which – or at least in writing the 22nd chapter quoted above – he adhered to his son in law’s theories. However it is exceptionally worth observing that one can find the same theory about the four “pairs” of veins in the 11th chapter of the treatise “Nature of man” of the *Corpus hippocraticum*⁵ that reads as follows:

“The thickest of the veins have the following nature. There are four pairs in the body. One pair extends from behind the head through the neck, and on either side of the spine externally reaches to the loins and legs, and then stretches through the shanks to the outside of the ankles and to the feet. So bleeding for pains in the back and loins should be made on the outside, behind the knee or at the ankle. The other pair of veins extends from the head by the ears through the neck, and the veins are called “jugular veins”. They stretch right and left by the side of the spine internally along the loins to the testicles and the thighs, then on the inside through the hollow of the knee, and finally through the shanks to the ankles on the inside and to the feet.”. The rest of the passage deals with the other two pairs of veins and with the “very many veins of all sorts” that “extend from the belly over the body...by which nourishment comes to the body”. As the entire passage is quoted verbatim by Aristotle, who affirms that it is by Polybos⁶, and as Aristotole’s disciple Meno maintains in his *Iatriké sunagogé* (Medical collection)⁷ that the author of the treatise “Nature of man” is just Polybos, this confirms our opinion that, if the author of the treatise *Peri aērōn, hydátōn kai tōpōn* (On the airs, the waters and the places) is Hippocrates, he adhered to his son in law’s theories about the second “pair” of veins that starts from behind the ears and reaches the testicles and confirmed it not only by the statement of the impotence caused by bleeding these veins, but also by quoting Polybos’ theory of the 4 pairs of veins in chapter 11th of the treatise *Nature of man*. As the female womb was thought – as we shall emphasize later when dealing with Galen – to be “horned” and the female genital organs were considered as the turned out inside male ones⁸, those we know to be the “ovaries” were mistaken for “female testicles”. By consequence the female orgasmic emission was supposed to be the “female semen” and the menstrual blood – it too regularly emitted monthly unless the female is pregnant – as the necessary “matter” to give origin to the formation of a foetus⁹. On the basis of the theory of the “four qualities” (hot, cold, moist and dry) that characterized all the phenomena and that the formation and growth of a foetus was caused by the joining of both the male and the female semen, and that every right part (the right male and female “testicle” included) is hot and dry and the left one is always cold and moist, the anonymous author of chapters 26th-29th of the first book of the Hippocratic treatise *Regime*¹⁰ maintains that the development of the embryo derives from the male semen (inclining to fire, i.e. to hot and dry) and the female one (inclining to water, i.e. to cold and moist). This being the supposed fact, the joining of the two “semens” gave origin to the generation of offspring that are male or female according to the predominance of the male or the female element. By consequence the idea of the anonymous author may be summarized as follows:

- 1) Male from man and male from woman > brilliant man;
- 2) Male from man mastering female from woman > brave man;
- 3) Male from woman mastering female from man > androgyne;
- 4) Female from both man and woman > lovely woman;
- 5) Female from woman mastering male from man > bold but modest woman;

4 Cf. Hippocrates with an English translation by W. H. S. Jones, London, William Heinemann LTD – Cambridge, Massachusetts, Harvard University Press, 1957, I, p. 126 ff.

5 Cf. Hippocrates with an English translation, etc, IV, p. 30 ff.

6 Cf. note n. 3.

7 Cf. Anonimi Londiniensis Iatrica, (edited by H. Diels in 1893), XIX, p. 33ff.

8 We shall discuss at length this rather erroneous idea when dealing with Galen

9 We shall clarify the concepts of “matter” and “form” when dealing with Aristotle

10 Cf. Hippocrates etc. (cf. note n. 4), IV, p. XII.

6) Female from man mastering male from woman > brazen woman.

As for the problem of the origin and the task¹¹ of both the male and the female “semen” none of the treatises of the *Corpus Hippocraticum* deals with it.

The first who fronted it was Aristotle.

However let us start by taking into consideration chapters 189th and 190th of the pseudo-galenic treatise *Definitiones medicae* (Medical definitions), which may be considered as a brief summary of the main opinions about both semen and generation¹².

The first reads as follows:

“The semen – as Plato (428/27- 348 B.C.) and Diocles <of Carystus> (contemporary of Aristotle) maintain¹³ – is secreted by the brain and the spinal cord; according to Praxagoras, Democritus (c.460-c.370 B.C.) and Hippocrates himself it emanates from the whole body. However Democritus writes “a man is all men and all men are one man”. As for Hippocrates, he maintains that the semen derives from all the parts of the body, a healthy generation derives from healthy semen and an unhealthy generation derives from unhealthy semen... According to Asclepiades <of Prusa> († c. 40 B.C.), semen is the humour ejaculated during sexual intercourse”.

The second reads as follows:

“A debate arose whether women emit semen like males ejaculate it. Indeed a female enjoys the same pleasure as a male during sexual intercourse and suffers from the same diseases; moreover dissection clearly shows that she too is provided with seminal ducts. However the fact that offspring that look like their mothers are born is the clearest proof that females too produce semen”.

We shall deal with the alleged “female semen” later.

Now let us pass to Aristotle’s theories about the parts of the human body, whose “task”¹⁴ is generation, about semen and generation itself, although no allusion – let alone any quotation – to him may be found in the “Medical definitions”¹⁵. He deals with or alludes to semen and generation in nearly numberless passages¹⁶. However the most extensive treatments of this argument can be found in the 1st book of H.A. (mainly in chapters 12th and 13th), in the 4th book of the treatise “*Peri zōiōn moriōn*”¹⁷ (On the parts of animals) and in the 1st and 2nd book of the treatise *Peri zōiōn genéseōs* (On the generation of animals)¹⁸

About the male and female genital organs Aristotle points out¹⁹

1) That: “A part peculiar to the female is the womb, while the penis is peculiar to the man. The penis is situated externally, at the base of the trunk, and consists of two parts: the extremity is fleshy, and always, one may say, equal in size; it is called the glans. The skin round it (which has no special name) if cut does not grow together (nor does the jaw or the eyelid). Common to this part and the glans is the frenum. The remaining part consists of gristle; it enlarges easily, and protrudes and retracts in the reverse way to that which occurs in cats. The testicles are not the same thing as flesh, yet they do not substantially differ from it...The privy parts of the female is opposite in structure to that of the male: the part below the pubes is receding and does not protrude as in the male. Further there is a urethra outside the womb; it serves as a passage for the semen of the male: in both sexes the urethra serves as an outlet for the liquid residue”. He deals with the nature and the task of the penis also in P.A., IV, 10, 689a22 ff. After having dealt at length with “the parts that have to do with the discharge of the residue, both solid and fluid” (ibid., 689a4 ff.) and having pointed out that “Nature employs one and the same part for the discharge

11 We must use the term “task” instead of “function” because no ancient author prior to the anatomists and physiologists of at least the second half of the 17th century had even the faintest idea of the modern concept of “function”. They have always recourse either to the Greek term “*khreîa*” or to the Latin term “*usus*” that mean “usefulness”, i.e. the particular task Nature endowed each “part” of a living body with. As for the meaning of “part” it is worth pointing out that no ancient author till at least the second half of the 18th century had even the faintest idea of the difference between “organs” and “tissues” and confined themselves to speaking of “similar” and “dissimilar” parts. The “similar” ones were the parts of a living body, whose infinitesimal components had the same nature and the same substance of the whole (like is the case of a vein or of an artery), whilst the “dissimilar” ones were those, the nature and substance of whose infinitesimal components were different (like is the case of the heart, the components whose infinitesimal parts are veins, arteries, muscles, nerves etc.) This is why we constantly translate simply “parts”, although the “similar” and “dissimilar” ones seem a faint intuition of our “tissues” and “organs”. The modern concept of “tissue” was only inaugurated by Xavier Bichat (1771-1802).

12 We shall find later a more ample summary in Aristotle’s “*De generatione animalium*” (On generation of animals).

13 He was considered as the second physician in time and fame after Hippocrates.

14 Cf. note n. 9.

15 This is the clearest proof that Galen was not the author of the treatise, because – as we shall point out later – the great physician of Pergamum literally adored Aristotle, whose perspectives and theories are present, emphasized, summarized, accepted – and sometimes even criticized and disproved – in nearly all his more or less ample works. Suffice it to observe that the entry “Aristoteles” occupies two columns and a half in the General Index of Kühn’s edition of Galen’s *Opera omnia* (Officina Libraria Car. Cnoblochii, Lipsiae, 1821 ff.)

16 Suffice it to observe that the entry “spërma” in H. Bonitz’s “Index Aristotelicus” (cf. Aristotelis Opera, Berolini apud W. De Gruyter et socios, 1961, V, p.690 ff.) occupies more than 8 folio columns in 8-point body. As for generation, the term “*gènesis*” occupies more than 2 columns and a half in 8-point body in the same Index.

17 From now on we shall use the abbreviation P.A...

18 From now on we will use the abbreviation Z.G.

19 Cf. H.A., I, 13-14, 493a, 25 ff.

of the fluid residue and copulation in all blooded animals (with a few exceptions), male and female alike, and in all Vivipara without exception" and that "the reason is that the semen is a fluid and a residue" and that "The same applies to the catamenia in females and the part where they emit semen", he concludes that "it is clear that the actual form of these parts is determined of necessity by the task they have to perform. The male organ, however, exhibits differences corresponding to those of the body as a whole, for some animals are more sinewy, some less. Further, this part is the only one, which increases and subsides apart from any change due to disease. Its increasing in size is useful for copulation, whilst its contraction for the employment of the rest of the body, since it would be a nuisance to the other parts if it were always extended. And so it consists of substances, which make both conditions possible: it contains both sinew and cartilage; and so it can contract and expand and admits air into itself:"

2) That (cf. H.A., III, 1, 510a14 ff.): "The following description may be given of the testicles themselves in all footed viviparous animals. From the Aorta passages of blood-vessel character run to the head of each testicle, and two more from the kidneys: the latter contain blood, the former two contain none. From the head of the testicle alongside it there is a passage stouter and more sinewy than the others, which bends back again at the end of the testicle towards the head of it; and again from the head of each testicle the two passages continue until they converge in front at the penis. The passages that bend back and those which lie alongside the testicle are enveloped in one and the same membrane, so that they appear to be just one passage, unless the membrane is cut open. Further the liquid contained in the passage which lies alongside the testicle is still blood like, though less so than in the passages higher up which are connected with the Aorta; whereas in the passages which bend back towards the canal of the penis the liquid is white in colour. Also from the bladder there runs a passage, which leads into the upper part of the canal; and around this, like a sheath, is which is called the penis. These details we have mentioned should be studied in the accompanying diagram²⁰:

A indicates the starting point of the passages, which run from the Aorta;

K indicates the heads of the testicles and the passages, which come down into them;

Ω indicates the passages running from the preceding alongside the testicle;

BB indicates the passages, which turn back, containing the white-coloured fluid;

Δ indicates the penis;

E the bladder;

$\Psi\Psi$ the testicle"

Although the original "Atlas of anatomy" went lost, Aristotle's description lets us represent at least something like the original plate as follows (Figure 2)

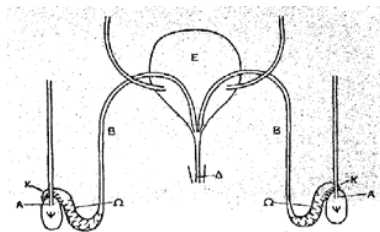


Figure 2: Diagram illustrating Aristotle's description of the testicles (after Aristotle, *Historia Animalium* with an English translation by A. L. Peck, London, William Heinemann LTD – Cambridge Massachusetts, Harvard University pres. 1965, I, p. 236)²¹.

Everyone may realize that – apart from the mistakes concerning the arterial and venous ducts that reach the testicles – with which we shall deal later – in Aristotle's description of the male genital apparatus the prostate gland, the "pampiniform plexus", the seminal vesicles and the "ampullae ductus deferentis" are missing. By contrast the description of the epididymis is really perfect, although he erroneously maintains that it consists of capillaries of the spermatic vessels. As for the task of the testicles Aristotle could not avoid making his greatest mistake caused by the fact that he ignored – and could not avoid ignoring! – not only the difference between veins and arteries, but also both the "body of Highmore" and the "rete testis", which was observed and correctly described for the first time by Albrecht von Haller (1708-1777)²². These being the facts, he obviously thought that the testicles did not take any part in generation and their task was simply to keep bent the course of the deferent ducts so that the blood could front the complicated transformation into semen by passing first through the subtlest and tortuous capillaries of the epididymis, then through the sinuous path of the deferent

²⁰ Most probably Aristotle is referring to a now lost "Atlas of anatomy".

²¹ We have corrected and modified Peck's plate because it adds the prostate gland, the seminal vesicles and the "ampullae" absolutely ignored by Aristotle!

²² Haller reported his discovery in the article "Observationes de viis seminariis" published in the *Philosophical transactions* of the Royal Society, p. 340 ff. However – as we shall see later – also Galen had observed both the inner vascularization of the testicles and the "ductus Higmorianus".

ducts. In brief, the task of the testicles is as perfectly as erroneously described by Aristotle in G.A, I, 4, 717b2 ff. The passage reads as follows:

“Those...which have to be more sober...in the case of copulation have passages, which are twisted, so that their desire shall not be violent or speedy. This then is the object, for which the testicles have been contrived: they make the movement of the seminal residue²³ steadier. In the Vivipara, as for instance in horses and such animals, and also in man, they do this by maintaining in position the doubling-back of the passages...since the testicles are no integral part of the passages: they are merely attached thereto, just like the stone weights which women hang on their looms when they are weaving²⁴. When the testicles are removed, the passages are drawn up within and this is why castrated animals cannot generate, whereas if the passages were not so drawn up they would be able to do.” As for the blood vessels that reach the testicles Aristotle’s description²⁵ is quite wrong and will be corrected – as we shall see later – by Galen. Indeed he maintains that *“from the Aorta passages of blood-vessels character run to the head of each testicle, and two more from the kidneys: the latter contain blood; the former two contain none”²⁶*. Aristotle’s description of the blood vessels reaching the testicles may be represented by the following diagram (Figure 3)

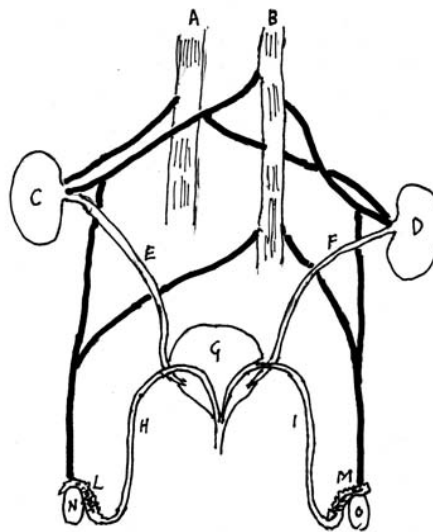


Figure 3: The vascular system reaching the testicles according to Aristotle: A, B: vena cava and aorta respectively; C, D: right and left kidney respectively; E, F: ureters; G: the urinary bladder; H, I: ductus deferentes; L, M: epididymides; N, O: testicles.

At this point let us pass to Aristotle’s description and interpretation of the female genital organs. In G.A. I, 3, 716b33 ff., after having dealt with the position of the testicles in the Vivipara, Aristotle states that *“The uteri²⁷ are always double without exception, just as in males there are always two testicles without exception. In some animals they are placed by the pudenda (as it is in women and in all animals that are viviparous internally as well as externally, and such of the fishes as lay their eggs visibly); in other animals the uteri are up towards the diaphragm (as is in all birds and the viviparous fishes)”*. He deals with the same argument in H.A., III, 1, 510b7 ff. and writes: *“The uteri are not of identical formation in those animals, which possess one, nor it is similar in all; differences are found both among the Vivipara and among the Ovipara. In all animals which have the uteri close to the generative organs they are forked, one fork being towards the right side and the other towards the left; their starting point, however, is single, and so is their opening, as it were a tube consisting of much flesh and cartilage in most animals and in the largest. One of these parts is called “hystera” or “delphys”...the other part, the tube or opening of the uteri is called “mētra”*.

As for the position of the “uteri”, Aristotle observes (G.A., I, 12, 719a30 ff.): *“We have seen...that while all animals have their uteri inside, some have their testicles inside and others outside. The reason why the “uteri” are always inside is that they are the container for the young creature while it is being formed, and this needs protection, shelter, and concoction²⁸, which the outer parts of the body cannot*

23 We shall see later that, according to Aristotle, the semen is the “final residue” of the “concoction” (elaboration) of the blood.

24 The same statement may be found in G.A., V, 7, 787b26 ff.

25 Cf. H.A., III, 1, 510a29 ff.

26 The alleged “two more blood vessels” are referring to the renal veins, only one of whose branches reaches the left testicle. This is why – as everyone knows – only the left testicle generally suffers from varicocele.

27 It is worth noting once for all that the term “uterus” includes what we now know to be the “oviducts”. Moreover we must emphasize that Aristotle (as well as Hippocrates and all the subsequent authors till at least the 16th century) constantly use the plural term “hysterai/hystérōn” (= “uteri/uterorum”). because of their idea that the “uterus” – as we have pointed out above – was “horned” so that they deal always with both “uteri” and call them “right” and “left” uterus.

28 We shall deal with the term “kḗma” (concoction) later.

provide, being easily injured and cold"²⁹.

After having observed (G.A., I, 12, 719a, 30 ff.) that "the testicles...are inside in some animals, but outside in others: since, however, they also need shelter and covering to keep them safe and to secure concoction for the semen (for if they have been exposed to cold and rendered stiff they cannot be drawn up and emit the semen), those animals whose testicles are in the open have a covering of skin over them known as the scrotum; while those animals the nature of whose skin is so hard that it is not amenable to this arrangement, and cannot be used for a wrapping and is not soft or like ordinary skin...they must of necessity have their testicles inside" and having dealt at length with this argument in connection with a lot of animals (Crustacea, Cephalopods, Insects, etc.), he concludes (ibid., 16, 721a 27ff.): "Such is the manner of animals' instrumental parts connected with generation, which I had not dealt with in my previous treatise"³⁰, he fronts the problem of the origin, the nature and the substance of the "semen". However, before exposing his own theory, he reviews a length and slates stubbornly the theories of his predecessors (mainly Empedocles', whose theory he judges to be "impossible" and Anaxagora's) (ibid., I, 17, 721b7 ff.), he, at last, begins exposing his own theory (ibid., I, 18, 724a24 ff.) and writes: "We must begin this investigation and those, which are to follow by discovering first of all what semen is; this will enable us to consider more easily its task and everything connected with it. Now the aim of semen is to be, in its nature, the sort of stuff, from which the things that take their rise in the realm of Nature are originally formed"³¹. There are, however, numerous senses, in which one thing is formed or comes into being "from" another, as we say that "from day comes night" and goes on quoting the different senses of "from" and concludes (ibid., I, 18, 724a36 -20,729a21): "Now it is clear that the case of the semen falls under one or other of these two senses: the offspring is formed "from" either (a) as "from" material, or (b) as "from" a proximate motive cause"³²Thus we now have to discover in which of the two classes semen is to be placed: is it to be regarded as matter, i.e. as something, which is acted upon, or as a form, i.e. as something, which acts of itself - or even as both?... Now every substance, whatever it may be, that we find in the body, must be of necessity one of the following: 1) one of the parts, which are there in accordance with nature, in which case it will be one of the similar or dissimilar parts"³³; 2) one, which is there contrary to nature, e.g. a tumour; 3) residue; 4) colliquescence; 6) nourishment. By "residue" I mean that, which is left over as surplus from the nourishment; by "colliquescence that, which is given off as an abscession from the material that supplies growth, as the result of decomposition proceeding contrary to nature". As it is impossible that the semen may be "one of the parts" (either "similar" or "dissimilar"), "it must be either a colliquescence or a residue". The conclusion is that "the semen must of necessity be a residue" and, as "every residue results either from useful or from useless nourishment", the semen "is a part of a useful residue". These being the facts, Aristotle summarizes the whole matter as follows (ibid., 18, 726a26 ff.): "the foregoing discussion makes it clear that, whether all animals discharge semen or not, semen is a residue derived from useful nourishment, and not only that, but from useful nourishment in its final form". After having dealt at length with the male semen, he passes to front the problem concerning "the menstrual discharge...because this occurs in some of the Vivipara". He summarizes the problem as follows (ibid., 19, 726a29 ff.): "Does the female discharge semen as the male does, which would mean that the object formed is a single mixture produced from two semens; or is there no discharge from the female? And if there is none, then does the female contribute nothing whatever to generation, merely providing a place where generation may happen; or does it contribute something else, and if so, how and in what manner does it so?". After having most correctly observed that (ibid., 20, 727b34 ff) "There are some, who think that the female contributes semen during sexual intercourse because women sometimes derive pleasure from it comparable to that of the male and so produce a fluid secretion. This fluid, however, is not seminal; it is peculiar to the part, from which it comes in each several individual; there is a discharge from the uteri, which though it happens in some women, does not in others. Speaking generally, this happens in fair-skinned women of a masculine appearance. When it occurs, this discharge is sometimes on quite a different scale from the semen discharged by the male, and greatly exceeds it in bulk"³⁴.

The obvious conclusion is that the male semen is the "formal cause" and the "menstrual discharge" is the "material cause". As "form" cannot be without "matter" and "matter" cannot be without "form" so that everything is a "synolon" (= "all together"), generation is nothing else than the joining of both male semen (which gives "movement" to the matter) and female menstrual discharge, and gave origin first to the embryo, which later becomes a foetus and finally a baby. It is really astonishing that Aristotle had even recourse to the dissection of fecundated eggs at different times after fecundation in order to discover the different stages of the formation of a chick.

The result of his studies may be represented by the following simplified diagram (longitudinal section) (Figure 4)

29 This statement arises from Aristotle's fundamental principle that "Nature does nothing in vain".

30 He is alluding to P.A.

31 At this point some unintelligible phrases follow, which must be eliminated, all the more so because Aristotle's definition is the simplest and basic one, from which he builds up his final definition, as the argument, which immediately follows abundantly proves.

32 One must have present that according to Aristotle there are four "causes": 1) material cause, 2) formal cause, 3) motive (or "efficient") cause and 4) final cause.

33 Cf. note n. 11.

34 The first part of this passage (from "there are some" to "in others") is clearly referring to the so-called "vaginal orgasmic emission", whilst the second part seems describing cases of "leucorrhoea", which is pathological. Aristotle seems to have confused the two. We shall point out later that Galen did not accept the correct opinion of Aristotle about the "vaginal emission" and maintained that it was the "female semen" and concurred with the male semen to the formation of the embryo, although the contribution of this alleged "female semen" to generation was, in his opinion, only marginal

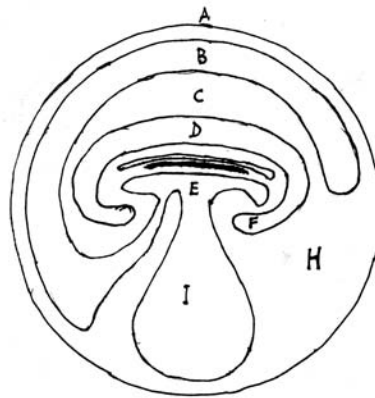


Figure 4: (after Aristotle, *Generation of Animals*, with an English translation by A. L. Peck, London, William Heinemann LTD. – Cambridge Massachusetts, Harvard University Press, 1953, p.369).

The diagram – that we have partly corrected – shows the state of development after about ten days. The embryo itself is in the central part of the diagram (black horizontal thick line): A. chorion; B: allantoic cavity; C: extra-embryonic coelom; D: amniotic cavity; E: gut; F: amnion; H: extra-embryonic coelom; I: yolk sac.

In order to let the reader fully understand the calibre of Aristotle's genius – in spite of the many mistakes that one can easily point out in his anatomo-physiological and biological system – we think it is worth emphasizing that this procedure to realize how the chick forms into the egg was readopted only about 2.000 years later by Marcello Malpighi (1628-1694) in his *De formatione pulli in ovo* (On the formation of the chick into the egg) (1672) and *Appendix repetitas auctasque de ovo incubato observationes continens* (Appendix containing repeated and improved observations of the incubated egg) (1672) both published in the *Transactions of the Royal Society*³⁵ and that the anatomo-physiological (or better anatomo-biological) procedure, to which Aristotle had recourse – as well as a lot of other exceptionally outstanding observations – are the first and, for nearly 20 centuries, the only evidences of modern “comparative anatomy” and “comparative biology”, for which he laid the basis. However we must also regret that Aristotle's outstanding achievements were completely forgotten – as said above – for nearly 2 millennia!

All the works of the great Hellenistic anatomists Herophilus and Erasistratus (flourished in the 1st half of the 3rd century B.C.) went regrettably lost and only few fragments were preserved. However Galen lets us know some of their most important achievements concerning their anatomical observations and descriptions, which we shall emphasize a little later when dealing with Galen. In fact although Aulus Cornelius Celsus (1st century B.C. – 1st A.D.) surely derived the whole matter of his *De medicina* from Hellenistic sources, nonetheless, as his main interest concerns pathology and therapy, all the passages dealing with anatomy and physiology are exceptionally schematic and summary so that reading and analysing them would be more trouble than they are worth. Suffice it reading a brief passage that proves what we have pointed out: in *De medicina*, IV, 12, 2, after having described the male and female genitourinary organs, he writes: “Having made a sort of survey as it were of these organs, so far as it is necessary for the practitioner to know them, I shall follow out the remedies for the several parts when diseased”, obviously “starting with the head” according to the usual and traditional pattern “from head to feet”. As the works of the subsequent great Hellenistic anatomists like Marinus (flourished in the 1st century A.D., Quintus (flourished in the second half of the 2nd century), Satyros (flourished at the half of the 2nd century A.D.), Lycos and Noumisianos (flourished in the same centuries) went lost as well as Herophilus' and Erasistratus' ones, we must wait Galen³⁶ to find a more complete and more interesting description³⁷ of the male and female genital apparatus. Although he deals with the argument in nearly numberless chapters and passages, nonetheless we shall confine ourselves to quoting the most accurate and most significant ones in order to avoid annoying the reader and offending his intelligence.

Well then., Galen starts from a comparison of the male and the female genital organs and writes³⁸: “Although we cannot succeed in explaining clearly all the works of Nature...nonetheless we must at least try to understand all of them and, first of all, discover the cause why the uteri are associated with the mammae and then explain why the males stay into their right cavity and the females into the left one... and first of all these things which is the nature of the male and that of the female. Aristotle pointed out correctly that the female is more imperfect than the male, but did not conclude his treatment, or rather it seems to me that he neglected the main question, which I shall try to deal with according to Aristotle's and Hippocrates' correct statements and to add what is still missing. The female is less perfect than the male owing to one main cause, i.e. because she is colder³⁹. Indeed if it is true that in the animals hot is more active than cold, what is colder

35 Cf. Opere scelte di Marcello Malpighi, edited by Luigi Belloni, Unione Tipografico-Editrice Torinese, Turin, 1967, p. 223 ff.

36 Who repeatedly quotes either endorsing or censuring their opinions and, by consequence, lets us know at least some fragments of their works.

37 In spite of his many and sometimes literally absurd anatomical and physiological mistakes we shall emphasize in due time.

38 Cf. *De usu partium corporis humani* (On the usefulness of the parts of the human body), XIV, 5 ff. (= K, IV, 157 ff.).

39 Obviously Galen's physiology relies on the “four qualities”, i.e. hot, cold, moist and dry. Cf.

will be more imperfect than the hotter. Autopsy reveals the second cause... All the parts the males are provided with are also present in the females and the only difference is that...the female ones are inner whilst the male ones are outer and emerge from the region of the so-called perineum. First of all consider the parts you prefer: should you turn the female parts inside out and the male ones outside inwards, you will find that they are quite the same. Imagine first the male ones turned inwards together with the tracts between the rectum and the urinary bladder. Should this occur, the scrotum will necessarily occupy the place of the uteri and the testicles will lay outwards at both their side whilst the male penis will be the neck of the uteri and the skin at the top of the penis, which is now called "prepuce" will become the vagina. At this point imagine the contrary occurrence, i.e. that the uteri be turned and prominent outwards. Will it not be necessary that the testicles transfer outwards and that the uteri themselves become a sort of scrotum around them and that the neck, which was earlier bidden into the perineum and now hangs outwards, become the male member and the vagina, which is an epiphysis similar to the skin of this neck, transforms into the so-called prepuce?

By consequence it is obvious that also the position of the arteries, of the veins and of the seminal ducts will change. One cannot find any exceeding part in the males. Only the position changes: the inner female parts are the same as the outer male ones". As for the blood vessels that reach the testicles Galen maintains against Aristotle that⁴⁰ "A characteristic that is common to all the animals is that from the venous branch that inserts into the left kidney departs a branch that reaches the left testicle. A particular and proper characteristic is the following: sometimes this branch that reaches the left testicle proceeds from two branches, one of which starts from the left kidney vein, whilst the other starts directly from the vena cava after having forked. Finally sometimes one may even observe one only branch, which proceeds from the left femoral vein. By contrast the vein that reaches the right testicle branches out from the vena cava". We shall deal later with Galen's description of the seminal vesicles, the ampullae ductus deferentis and the prostate gland. For the moment let us underline some of Galen's contradictions, which prove that he was not absolutely sure about the blood vessels that reach the testicles. Indeed he maintains⁴¹:

1) That "the blood vessels that run towards the genital parts, those, which reach the right testicle start from the big vessels that run along the vertebral column, the vein from the vena cava and the artery from the aorta, whilst those, which reach the left testicle they too are two, i.e. a vein and an artery, however they do not start from the big vessels but from the renal ones"⁴².

1) Finally he seems coming to a compromise and writes⁴³: "It is worth pointing out that after the branches that reach the kidneys, there are those that reach the testicles: the left one receives always and anyway a branch of the renal vein and sometimes uses only this, whilst the right one starts always from the aorta and sometimes receives in addition a branch of the renal artery".

However the legitimate suspicion arises that Galen had the misfortune – so to say – of dissecting some corpses characterized by the so-called "situs viscerorum inversus", although this "inversion" occurs only very seldom (1 time out of 10 thousand people).

These being the facts his description may be represented by the following diagram (Figure 5)

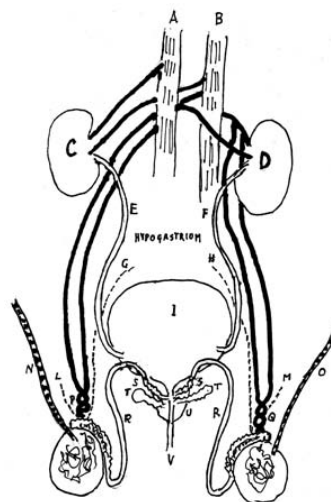


Figure 5: Galen's vascular system concerning the arteries, veins muscles and nerves reaching the testicles⁴⁴. A B: vena cava and

40 Cf. *Anatonikāi egkeiréseis* (= Anatomicae administrationes = Anatomical procedures), I, 2, K. II, 219 ff.

41 Cf. U.P., XIV, 7, K. IV, 170.

42 Galen is repeating here Aristotle's mistake!

43 Cf. U.P. XVI, 10, K. IV, 321.

44 We write "reaching" because Galen maintained that the flow of the blood through the veins was not centripetal but centrifugal. Indeed according to him the "venal blood" produced by the liver reached the left ventricle of the heart, passed through the riddled interventricular septum, transformed into "arterial blood" and flowed into the aorta. A branch of the aorta reached the cerebellum where the supposed "rete mirabile" (the "admirable network" that does not exist in the human brain, but only in the brain of the unguulate) transformed it into "spirif".

aorta respectively; C D: right and left kidney respectively; E F: ureters; G H: muscular bodies; I: urinary bladder; L M: nerve; N O: muscles; P Q: pampiniform plexuses; S S: ampullae ductus deferentis; T T: seminal vesicles; R R seminal ducts; U: prostate gland; V: urethra. Obviously the figure represents Galen's erroneous statement that the blood ducts of the pampiniform plexuses insert directly into the epididymides.

As for the testicles themselves, Galen thinks that their complex structure was created by Nature in order to perform the laborious transformation of blood into sperm – which is due to the most complex vascular convolutions of the epididymis and the sinuous pathway of the deferent ducts – and does not recognize – in opposition to Aristotle – the mere task of “weights” to the mass of the testicles, but an active participation to the realization of sperm thanks to his observation of a vascular structure into the testicles themselves. Indeed he writes⁴⁵: “the testicles are a “lax flesh”⁴⁶ ...and very conspicuous veins and arteries insert into them and from each of these veins and arteries other ducts start, into which there is the liquid generated by them. Although the liquid generated by the testicles is white in all the animals and is provided with a particular virtue, nonetheless it is not the same in all the animals”. Moreover it is clear that Galen – as well as other previous anatomists – had already observed the “ductus Highmorianus”. Indeed he writes⁴⁷: “You can also dissect the testicle itself and will see that in its middle there is body as hard as the membranes. Some authors believe that this body is the “belly” of the testicle.”

The allusion to “some authors” confirms that Galen was not the first anatomist to observe the “ductus Highmorianus”.

Let us pass, now, to the prostate gland, the “seminal vesicles”, the “ampullae ductus deferentis”.

First of all we must take into consideration three passages of A.A.⁴⁸.

The first reads as follows: “I never observed in female animals either the “lax flesh” that in male animals lies at the base of the penis, or the ducts arising from it, which someone calls “glandular assistants” (= seminal vesicles), whilst I have found both this “lax flesh” and the two ducts very big and exceptionally conspicuous in male animals, and mainly in stud-ones...it is useful ...observing that the veins, which reach and nourish both the testicle and the other part, the so-called epididymis, just from which starts the deferent duct, run through this duct (i.e. the spermatic funicle). You may observe that the veins that nourish both the testicle and the epididymis, after having inserted into them roll up in manifold and overlapping convolutions and you may also observe that the blood changes its colour and becomes white just into these complicated meanders, because such convolutions prepare it to change into semen. Should you eliminate the covering of the nourishing veins, you will find that the major veins insert into the head of the testicle, whilst the smaller ones insert into the so-called epididymis”. As “lax flesh” in the galenic anatomical terminology means “gland”⁴⁹, and as he clearly distinguishes here between this “lax flesh” and both the “varicose assistants” (i.e. the ampullae ductus deferentis) and “glandular assistants” (i.e. the seminal vesicles) as we shall see later, there cannot be any doubt that this “lax flesh” is the prostate gland.

The second passage – which repeats partly what one reads in U.P., XIV, 1 – is no less clearly alluding to the prostate gland and reads as follows:

“The seminal ducts (= ductus deferentes) insert into this region (i.e. near the sphincter) of the neck of the bladder after having swollen exactly like varicose veins. This is why Herophilus called them “varicose assistants”, and I too shall call them so in order to save the tradition of the ancient names. Herophilus called them “varicose” because of their peculiar shape: indeed near their insertion into the neck of the bladder they swell like varicose veins. Near these varicose assistants and at both their sides there are two more ducts that Herophilus called “glandular assistants” and gave them this name because they start from the “lax flesh”, which in this point adheres to the neck of the bladder exactly in the same point where the other two ducts also insert into it. Should one dissect the “glandular assistants” and observe carefully their inner shape, he will find that they consist of a peculiar substance, very similar to the peculiar substance of the bodies, whence they originate. And the same happens with regard to the “varicose assistants”. Moreover we have already said that the “varicose ducts” start from the so-called “epididymis”, whilst the “glandular ducts” start from the glands lying at the sides of the neck of the bladder”.

The most important and most revealing fact to be observed in these two passages is that Galen does no longer use the term “glandular bodies” as he did in U.P., but “lax flesh” and “the bodies whence they originate” and therefore he is clearly alluding to the prostate gland.

The cause of such an important new perception and, by consequence, of such a fundamental lexical change could be only one: in 192 A.D. a violent fire destroyed the Temple of the Peace and a lot of nearby houses and warehouses in Rome and – as Galen himself states – all the copies of his works preserved in the warehouses near the temple were destroyed. He regrets this tragic event in a final passage of A.A.⁵⁰ that reads as follows:

45 Cf. A.A., XII, 1. Although the only Greek parts of this fundamental treatise preserved are the books I-IX, 5, nonetheless we can read the lost part (IX, 6-XV) thanks to the Arab translation made by Hunain's (9th century E.V.) disciples Hubaish and 'Isā .

46 The galenic term “lax flesh” means “gland”.

47 Cf. A.A., XII, 8).

48 The first in A.A., XII, 7; the second in A.A. XII, 8.

49 Cf. note n. 46.

50 Cf. XI, 12.

"I had already written the books of A.A. and was just on the point of putting an end to them. It happened that a violent fire broke out... and destroyed the warehouses where my A.A. were preserved together with all my other works. By consequence none of them were saved, with the only exception of the books I had already published. At that time I had already published only eleven books of A.A., so that I am now forced to rewrite all the subsequent books".

Importantly, in order to rewrite the lost books XII-XV, he states to have carried out a lot of further autopsies. These being the facts, it is likely that he observed the genital organs more carefully, and realized that the "glandular bodies" were nothing but "lax flesh", i.e. a "gland", although he considered it as consisting of two glands⁵¹. At any rate a passage of Galen's treatise "On the semen"⁵² proves that he – and Herophilus before him – had observed both the seminal vesicles and the ampullae ductus deferentis and, by consequence, could not avoid observing also the prostate gland. After having maintained that to assert that the ducts, which are provided with a common mouth, must necessarily refer to the same task is a mistake, he writes: "this statement may be clearly proven by the urethra, which is just the same trough which urine flows and to which the "four assistants" are connected in males". The word "four assistants" can only refer to both the seminal vesicles and the ampullae ductus deferentis. Therefore we can do nothing else than confirm our opinion that should one (be he either Herophilus or Galen or any else anatomist makes no difference) observe these "four assistants" could not avoid also observing the prostate gland!

As for the particular task of the prostate and the "four assistants" Galen fronts it in two different chapters, the first in U.P., XIV, 11, K., IV, 189 ff.; the second in chapter 6th of the II book of *De semine*.

The first reads as follows: "the liquid that forms into the glandular bodies flows in the males into the urethra together with the semen. Its usefulness consists in exciting the man to have sexual intercourse, in causing pleasure and in moistening the urethra just during copulation...Its natural characteristics were already a clear proof that it moistens and softens the urethra. Indeed as it is rather viscous and thick like oil, it greases the urethra and prevents it from drying up and subsiding and, by consequence, from preventing an easy flow of both urine and semen through it...I have shown that also other glands exist, which were created to perform the same usefulness, like those of the pharynx, of the glottis as well as those of the windpipe and of the bowel".

In the second, after having repeated – agreeing with Marinus – that to assert that the ducts, which are provided with a common mouth, must necessarily refer to the same task is a mistake, Galen writes: "Perhaps Nature prepared this humour (contained into the prostate gland and the "four assistants") also as a salve for the urethra, fearing the caustic action of the urine...However, if one considers the facts more carefully, he could also pinpoint a third task" that would be either the production or the elaboration of semen. However this third task is absolutely unconceivable because – he adds – "should semen be produced by these glandular bodies also the eunuchs would be stimulated to ejaculate. But it is clear that they do not feel such an impulse. Therefore it is also clear that the glandular bodies do not produce semen". Let us now pass to dealing with Galen's statements concerning the origin of the semen.

First of all we must emphasize that he agrees with Aristotle theory that the semen is the last and most perfect "concoction" of the blood⁵³, but rejects – as we shall see a little later – his idea that the testicles have the simple task of keeping the deferent ducts bent (as we have emphasized above). The most sweeping passage is chapter 12th of the treatise *De semine*⁵⁴, which reads as follows: "One may see that both artery and vein reach both the testicles not through a straight pathway as all the other arteries and veins, but through twisted like ivy or tendrils ones and this is why – I suppose – some experts of dissections called their shape "ivy-like" and some others "tendrils-like"⁵⁵. One can easily see that the blood whitens little by little into these "tendrils-like" and these anfractuosities they realize before reaching the testicles and that when, at last, it reaches the testicles the substance of semen clearly appears. Let us skip at the moment pointing out whether the semen receives some alteration by the testicles and could not absolutely be prepared otherwise or not and follow – if you like – Aristotle's pinion and agree with him that the testicles take not any part in the generation of the semen so that the artery and the vein produce not a great part, but the whole substance of the serous humour. Should the matter be so, there is no doubt that both the arteries and the veins are provided with the nature of generating semen. But they produce semen from the blood that stays into them for a long time and just the anfractuosities have this task, i.e. they transform the concocted blood into semen. Indeed, everything changes anything transforms into its own nature the changed thing, a fact that may also be observed in this case. In fact the semen is white and thick and suitable for the nourishment of the substance of the veins and the arteries".

In brief: as the "anfractuosities" are white, they perform the final and most perfect "concoction" of the blood transforming it into semen and endowing it with their own colour!

Suffice it to read a brief passage of chapter 9th of the XIV book of U.P. (= K., IV, 185): "I suppose that he, who has read what I have

51 This is why he and all the subsequent anatomists constantly speak of "glands". Vesalius (1514-1564) and Giovanni Battista Morgagni (1682-1721) were the firsts to maintain that the prostate is one and one only gland. Cf. S. Musitelli & I. Bossi, Ampullae ductus deferentis, seminal vesicles and prostate gland in the Hellenistic anatomists and Galen, in *De Historia Urologiae Europaeae*, 18, 2011, p. 97 ff. Cf. also S. Musitelli, P. Marandola, H. Jallous: La prostata sconosciuta (The unknown prostate), *La Goliardica Pavese*, Pavia, 2001, p.39 ff.

52 Cf. II, 6, K. IV, 645. We shall deal with the problems concerning the semen a little later.

53 Cf. note n. 25.

54 K., IV, 512 ff.

55 He is clearly describing the "pampiniform plexus".

proven in the treatise "On the natural faculties"⁵⁶, will easily discover why the blood becomes white while lingering into the ducts. I have proven in that treatise that every part makes its nourishment like itself. This being the fact, why would one wonder if the tunics of the vessels, which are white, modify the blood and give it a colour like their own? Perhaps someone will ask why we do not succeed in observing this occurrence in any of the other vessels. However we can easily answer: because in none of the other vessels the blood lingers for such a long time. Indeed none of the other blood vessels are endowed with I do not say so many and overlapping twists, but even with only one... Therefore no wonder if the seminal humour accumulates because of the blood standing – so to say – into the above mentioned twists". As the females too are provided with "testicles"⁵⁷ – as pointed out above – they must have also "semen". However Galen maintains⁵⁸ that "as the male testicles are porous and cavernous receive the liquid already concocted onto the vessels an concoct it again so that they make it perfect for the generation of an animal because they are bigger and hotter and because the semen that flows into them has been already elaborated more accurately thanks to the distance and the strength of the vessels that concoct it; the female semen is less perfect because the female testicles are littler and cooler and, by consequence, they receive a less accurately concocted semen". Moreover he succeeded – as we have pointed out above – in finding a "liquid" in the seminal vesicles, the ampullae ductus deferentis and the prostate gland itself and writes⁵⁹: "the liquid that forms into the gland-like bodies flows onto the urethra in males together with the semen. Its usefulness consists in stimulating sexual intercourse, causing pleasure and moistening the urethra during copulation". At any rate the joining of both the male and the female semen gives origin to the formation of an embryo, which will be nourished by the menstrual blood and develop into a complete foetus⁶⁰. By conclusion we cannot avoid emphasizing that in spite of his many anatomical doubts⁶¹ and even his many absurd statements – mainly under the physiological point of view – nonetheless Galen's skilfulness in performing anatomical procedures and his consequent descriptions are still really astonishing, all the more so if we consider that he did not have and could not have any magnifying instrument at his disposal and therefore he performed all his anatomical observations with the naked eye. None of the subsequent authors at least till Andreas Vesalius (1514-1564) published his *De humani corporis fabrica libri septem* (Seven books on the shape of the human body) (Basel, 1543)⁶² added anything to what Galen had already discovered and described.

We confine ourselves to quoting a passage of the anonymous *Demonstratio anatomica* preserved in pp. 175-177 of the manuscript Q.2 of the Mary Magdalene Library in Breslau⁶³. It reads as follows: "...from the branches (of the Aorta) that proceed from a lower point of the renal arteries and veins two other branches start, each of which reach one of the two testicles. The branches of the vein that runs at both the sides of the vertebral column (vena cava) descend still further and from this lower tract two other braches start, each of which reaches one of the testicles... You will see that the testicles, which are the instruments of the semen, consist of a white, soft and loose glandular flesh⁶⁴. This was done (by Nature) with the aim that the semen my form into them... The substance of the semen gathers into a follicle, which changes it partly and make it white before reaching the testicles. This follicle lies under the kidneys and above the testicles and... – as I have shown – from both the sides of these follicles start two ducts, through which that substance (of the semen) flows into the testicles. In their lower part you find two ducts that are called "seminal", through which the semen flows from the testicles to the penis. These ducts are long, wide and hard just like the hard and muscular fleshes. They are long so that the semen that flows from the testicles may undergo a better concoction along the path, and are wide so that the semen, which flows from these ducts, may be received into the penis and from the penis into the female pudenda".

We may clearly realize that:

1) The anonymous author was making a rather incorrect summary of what he found in Galen's treatises, most probably deriving from more or less correct previous summaries;

2) The mainly deriving from Arab sources, as the presence of terms like "sifac", i.e. the peritoneum parietale, and "zirbus", i.e. greater omentum prove. The only important fact is that the Anonymous "Magister Salernitanus" endorses Galen's opinion about the

56 Cf. II, 20 ff. (= K., II, 20 ff.).

57 Obviously Galen mistook the "ovaries" for "testicles" and, by consequence, he also mistook the "female orgasmic emission" for ejaculation of "female semen", an error that Aristotle did not fall into, as pointed out above...

58 Cf. U.P., XIV, 10, K., IV, 184.

59 Cf. U.P., XIV, 11, K., IV, 189.

60 Obviously the foetus will be male if the male semen (as well as the female one) starts from the right male and female "testicle" and reaches the right "horn" of the "uteri", whilst it will be female if both the semens start from and reach the left parts as we have already emphasized when dealing with Hippocrates' theories.

61 For instance those concerning the blood ducts reaching the testicles as we have pointed out above.

62 It is worth observing that he is still speaking of "fabrica" (= shape / construction / building). We shall see at due time that the term "fabrica" will be replaced by "machina" (mechanism) only in the 17th century after Galileo Galilei's (1564-1642) "scientific revolution", which demolished once and for all the "qualitative", and therefore "animistic" and "finalistic" perception of the phenomena and inaugurated their "quantitative" and therefore mathematically expressible description. This new and revolutionary perspective, which laid the foundation of modern Science, was transferred into medicine and mainly into anatomy and physiology by Giovanni Alfonso Borelli (1608-1679) – the founder of the "iatromechanic school" – and chiefly by his most renowned disciple Marcello Malpighi. Cf. S. Musitelli, The Galilean revolution, in *Europe – The cradle of Urology*, History Office of the European Association of Urology, Arnhem, 2010, p. 40 ff.

63 Cf. S. De Renzi, *Collectio Salernitana*, Naples, 1853, II, p. 392 ff.

64 There is no doubt that all the authors, who maintain that the substance of the testicles is white, mistook the "albuginea" for the substance of the testicle itself!

cooperation of the testicles to the realization of the semen against Aristotle's statements⁶⁵.

Nothing better may be found in the anatomical treatises of subsequent authors like Mundinus de' Liuzzi (1270/75-1326), Matteo Ferrari da Gradi († 1472), Giovanni da Vigo (1460-1525) and Berengarius of Carpi (1470-1530)⁶⁶.

However – all these anatomists apart – Leonardo da Vinci (1452-1519) is worth a particular although brief consideration. After having contacted the great anatomist Marcantonio Della Torre in 1510 (most probably in Pavia, where Della Torre held the chair of Anatomy), he planned, but never realized a complete "Atlas of Human Anatomy" in order – as he writes – "to provide (everyone) with a complete and correct anatomical knowledge". As he ignored both Latin and Greek his "primary literary source was the first Italian edition of Johannes de Ketham Fasciculo di Medicina (Collection of Medicine) printed in 1493⁶⁷. This anatomical textbook is a collection of works from classical authors that have been filtered through Arab translations made during the Middle Ages. Furthermore, it contains the first translation of the...work "Anothomia" of Mondino de' Liuzzi (1270-1326)"⁶⁸. Tradition reports that Leonardo had dissected more

65 Cf. S. Musitelli: Avicenna: The Prince of Physicians.; Copho the Younger, William of Saliceto, Lenfrancus of Milan, and Guy de Chauliac: The Great Surgeons and Anatomists of the Middle ages, in D. Schultheiss, S. Musitelli, Ch. G. Stief, U. Jonas (eds), Classical Writings on Erectile Dysfunction – An Annotated Collection of Original Texts from Three Millennia, E.A.U History Office, European Society of Andrological Urology, ABW • Wissenschaftsverlag, 2005, p.67 and p. 75 respectively

66 Cf. S. Musitelli – P. Marandola – H. Jallous: Struttura e funzione del testicolo da Aristotele al "Testis examinatus" di Claudius Aubry (Structure and function of the testicle from Aristotle to Claudius Aubry's "Testis examinatus"), La Goliardica Pavese, Pavia, 2001, p. 15 ff. It is really astonishing that Berengarius of Carpi neither corrected nor added anything new to what he read in Galen about the structure of the testicles, all the more so if one considers his really revolutionary description of the human kidney, dissecting which not from the convex side – as made by all the previous and subsequent anatomists, Vesalius included – but from the concave side he succeeded in observing and describing the multipapillar structure of the human kidney (Figure A),



Figure A: It represents the kidney of a pig we have dissected from the concave side, as Berengarius and after him Gabriele Falloppio did. Vesalius, in his turn, feared the fat of other kidneys, dissected the monopapillary kidneys of dogs from the convex side, scarified the kidneys' substance, mistook the "offshoots of the membranous bodies" for both Berengarius' and Falloppio's "calices" and "papillae", ignored Barengarius and entered into a groundless debate with Falloppio (Figure B, Figure C).

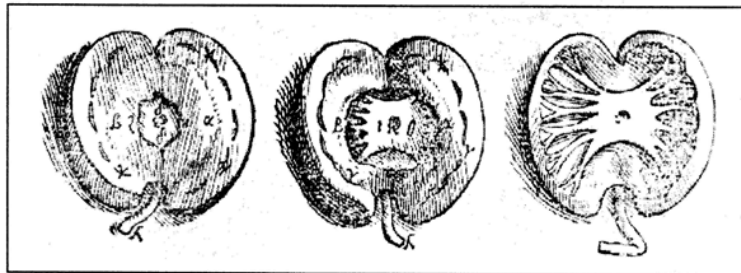


Figure B: The monopapillary kidney of a dog described and illustrated by Vesalius in De humani corporis fabrica, V, fig. XXI, p. 371. Cf. S. Musitelli, P. Marandola, H. Jallous: Il rene dalle origini al Malpighi (The kidney from the origins to Malpighi), La Goliardica Pavese, Pavia, 2001, p. 93 ff.



Figure C: We have incised from the convex side and scarified the monopapillary kidney of a kid: the three photos represent Vesalius' figures perfectly.

67 In Venice by Gregorius de Gregoriis.

68 Cf. D. Schultheiss, Leonardo da Vinci: The Birth of Medical illustration, in Classical Writings on Erectile Dysfunction – An Annotated Collection of Original Texts from Three Millennia, E.A.U History Office, European Society of Andrological Urology, ABW • Wissenschaftsverlag, 2005, p. 81 ff.

than thirty human bodies, but this is a rather overestimate and may be accepted only if this exceptional number refers to dissections of both humans and animals.

In fact many of Leonardo's masterful anatomical drawings reveal that:

- 1) The dissected surely animals and referred his observations to humans;
- 2) The succeeded in making some original observation;
- 3) However he generally confined himself to illustrating – as masterly as one wants – what he read in the texts mentioned above.

Indeed one can agree with our – perhaps desecrating but surely correct statement – if he only observes carefully and unbiasedly at least some of his anatomical drawings like, for instance, either that of the section of the human head (Figure 6)



Figure 6: Lonardo's mistaken drawing.

Figure 6: As one may easily realize, the retina, the choroid, the sclera and the cornea are connected to the meninges, a mistake already made by Galen and by all the subsequent anatomists till at least the 17th century. Moreover Leonardo did not distinguish the "dura mater", the "pia mater" and the "aracnoid", although Galen had already observed and described them nearly perfectly. It is clear that Leonardo was simply illustrating the scanty descriptions of the medieval texts, mainly Mondinus' ones or that of the inner parts of the human body (Figure 7).

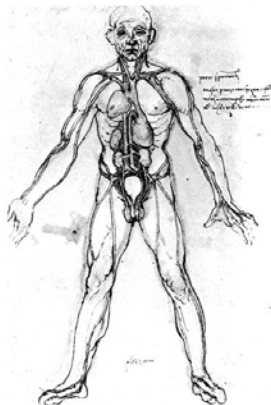


Figure 7: Although the genito-urinary apparatus seems perfectly drawn, nonetheless one may easily realize that neither the prostate gland, nor the seminal vesicles, nor the ampullae ductus deferentis are present, only because – in spite of Galen's nearly perfect description, which we have dealt with above – none of the subsequent anatomists described them, let alone Mondinus. In one only drawing Leonardo represents the seminal vesicles, but neither the ampullae ductus deferentis nor the prostate gland (Figure 8)



Figure 8: Observe mainly the right drawing below (the upper parts show the lungs (left) and the iliac vessels (middle and right)).

Even the perhaps most famous drawing, which represents a foetus contained into the placenta seems to be nothing else than an as masterly as incorrect illustration of what he found in the previous anatomical treatises (Figure 9).



Figure 9: Leonardo's drawing representing the foetus into the placenta.

As one may easily observe, the position of the foetus seems to be mistaken, unless Leonardo had the misfortune of dissecting a case of "breech presentation" (*partus agrippinus*). In fact it is sure that he dissected a dead pregnant woman (at about the 9th month of pregnancy) because a "breech presentation" was generally deadly at his times. Should we not be wrong, Leonardo's drawing is a real masterpiece mainly if compared with the previous medieval figures of foetuses in the same position (Figure 10, Figure11).



Figure 10: The illustration of "breech presentation" in a medieval manuscript of Soranus of Ephesus' (contemporary of Galen) *Gynaecia* (Gynaecology) preserved in the National Library of Paris.



Figure 11: The same position represented in Eucharius Rösslin's († 1526) "*Rosengarten*", Leipzig, 1513.

Another drawing (Figure 12) represents a coitus (right) and the human penis (below left)



Figure 12: The coitus and the human penis (below left).

As one may see, the penis is represented as provided with two superposed longitudinal ducts: the lower represents the urethra; the upper originates from the spinal cord and carries the “*spiritual power*” into the female uterus. There is no doubt that in this drawing Leonardo confined himself to illustrating what he read in the anatomical treatises of his time. Should one need a further proof, we invite him to considering a drawing representing the human brain (Figure 13)

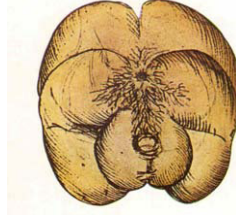


Figure 13: The back side of the human brain.

As one may clearly realize Leonardo drew the inexistent “*rete mirabile*”, into which, according to Galen and all the subsequent anatomists till at least the 17th century, the arterial blood changed into “*spirit*”⁶⁹!

However, in spite of the many mistakes and gaps, some of Leonardo’s observations – generally written in marginal notes⁷⁰ – are worth a particular appreciation, like, for instance, that dealing with the erection of the penis, which he correctly refers to the blood flow, against the general opinion that it was caused by the “*pneuma*”⁷¹: “*it would be necessary – he writes - an exceptional amount of air to enlarge and elongate the penis and make it as hard as wood, so that even a great amount of air in the nerves⁷² would not be sufficient for reduction to such a hardness. Not only the air of the nerves, but even if the whole body were filled with it, it would not be enough*” and again in another marginal note he writes: “*On the virile member: when it is hard, it is thick and long, dense and heavy, and when it is loose it is thin, short and soft, that is limp and weak. This should not be adjudged due to addition of flesh or wind, but to arterial blood. I have seen this in the dead, who had this member erected. For many die thus, especially those hanged, of whom I have performed an autopsy, and found it having great density and hardness, and these are full of a large amount of blood, which has made the flesh very read within, and in others, without as well as within. And again, one may observe that the erected penis has a red glans, which is a sign of an abundance of blood, and when it is not erected it appears whitish*”. Unfortunately Leonardo did not publish any of his many anatomical drawings and of his sometimes astonishing captions⁷³, so that, even if he made exceptional discoveries – that is a rather doubtful statement – and did not confine himself to illustrating what he found in the anatomical treatises available in his time, none of his alleged anatomical and physiological discoveries did improve an inch the knowledge of human anatomy and physiology. There is no doubt that Andreas Vesalius (1514-1564) is worth the merit of a real “*innovation*” in the history of anatomy rather than of a real “*revolution*” as we shall point out later.

In fact he really revolutionized only the method of teaching anatomy.

We do not know how either Aristotle or Galen lectured anatomy, but know very well how a medieval master did (Figure 14).



Figure 14: A medieval lesson of anatomy (after Ketham’s *Fasciculo di medicina*, plate VI, p. 64).

69 Cf. note n. 46.

70 Should one want to read them, he must have recourse to a mirror because Leonardo was left-handed and wrote from right to left.

71 Advocated by Galen and repeated by all the subsequent authors at least till the 17th century.

72 To Aristotle, Galen and all the subsequent authors till William Harvey (1578-1657) the nerves were a third vascular system containing the “*spirits*”!

73 The so called “*Quaderni d’anatomia*” (Anatomical quaternions) were only rediscovered in the second half of the 19th century. They were hidden into a forgotten wooden case in Windsor Castle.

As one may easily realize, the “master” is sitting on his high and preciously decorated “cathedra” and is “reading”⁷⁴ a text; at the feet of the “cathedra” five disciples are observing a corpse lying upon a table while the “dissector” (at left) is dissecting the corpse and the “ostensor” (the “demonstrator”) (at right) is indicating by a little rod the part (or the parts) the “master” is reading and explaining. By contrast, if one observes the front page of Vesalius’ treatise (Figure 15),



Figure 15: The front page of Vesalius’ *De humani corporis fabrica libri septem*, Basel, 1543, he cannot avoid realizing that Vesalius himself is dissecting the corpse!

In few words, Vesalius descended from the “cathedra” and began performing autopsies with his own hands, and his “assistants” confined themselves to staying under the “anatomical bench” and sharpening and preparing the necessary instruments that Vesalius illustrated in a particular plate (Figure 16).

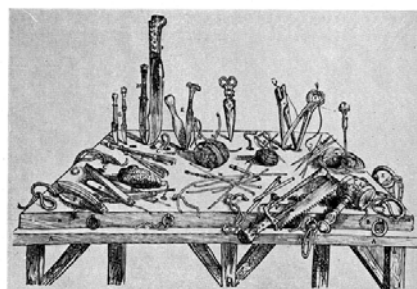
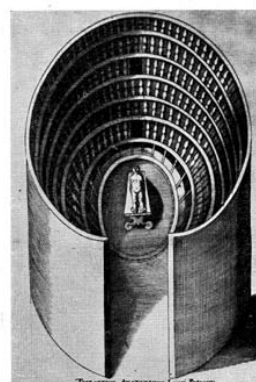


Figure 16: The necessary instruments to perform autopsies (the border of the table is provided with rings to tie up living animals for vivisections (*De humani corporis fabrica*, V, plate III, fig. XX). There cannot be any doubt that just this innovation was so fundamental as to be considered as the real Vesalius’ “anatomical revolution”, which was the premise of the creation of the “anatomical theatres” like that of the University of Padua, devised, paid and illustrated by Gerolamo Fabrizi di Aquapendente (15377-1619) (Figure 17).



⁷⁴ One must remember that the terms “lesson”, Italian “lezione”, French “leçon”, Spanish “lección”, German “Lektion” derive from the Latin “legere” that means “to read”!

Figure 17: Fabricius of Aquapendente's "anatomical theatre".

As for anatomy and physiology, Vesalius is generally still a faithful "galenist".

First of all he still follows faithfully Galen's pattern in dealing with each "part": 1) substance (i.e. "quality"), 2) size, 3) Number (i.e. single, double or even triple), 4) shape, 5) form (in the case of composite parts), 6) position, 7) connection with other parts. Second, although he argues with certain Galen's descriptions and opinions, nonetheless he accepts and repeats even the most clearly mistaken ones.

Suffice it to consider that he is still maintaining – with Galen – that the right kidney is higher than the left (Figure 18)⁷⁵

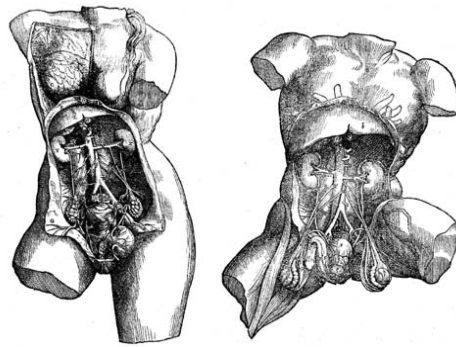


Figure 18: The position of the kidneys according to Vesalius.

Moreover, in spite of observing that no "rete mirabile"⁷⁶ can be found in the human brain, he still maintains that the nerves are a third vascular system, through which the "spirits" flow.

However he refuses and corrects some of Galen's statements about the testicles and their "task".

Suffice it to read what he writes at p. 527 of his treatise: after having correctly described the prostate gland (but not the seminal vesicles and the ampullae ductus deferentis) and having censured the passage of Galen's *De semine* quoted above, he concludes: "The dissection proves that it is absolutely certain that between the deferent duct and the veins end arteries of the testicles there is not any direct connection thanks to which the glandular bodies (the prostate gland) could draw semen without the help of the testicles. And even if such a connection existed – as I myself once thought together with many other anatomists – that is to say should it be true that both the spermatic vein and artery change into the nature of the deferent duct and, by consequence, should it consist of the vein and the artery, Galen's proof would be valid only about the animals, on which a castration wizard could succeed in eliminating the testicles ad letting the deferent ducts undamaged, a thing that, in fact, is absolutely impossible". Nonetheless he makes – together with Galen and all the subsequent anatomists – the mistake of not observing that the spermatic veins and arteries are extraperitoneal. As for the generation of a foetus, although he does not deal with this argument at length, he agrees with Galen and against Aristotle that it is caused by the joining of the male and the female semen and not by the joining of the male semen with the catamenia.

In few words:

1) the quoted passages prove that Vesalius does not tell us much newer and much more than what we have read in Galen's works and is still a "galenist" in about 90 % of his treatise; in fact his physiology is still "vitalistic" and therefore "animistic" and "finalistic" and has still recourse to the galenic "qualities", "virtues", "spirits", "temperaments" etc.;

2) He is still considering the nerves as a third vascular system;

3) He has not yet even the faintest idea of "blood circulation" and is still maintaining – in accordance with Galen – that the venal blood reaches the right ventricle and passes to the left one through the pervious interventricular septum to change into arterial blood. Suffice it to read the following passage: "The septum of the ventricles of the heart is very dense. It abounds with pits on both sides. Of these pits none, so far as the senses can perceive, penetrate from the right to the left ventricle. We are thus forced to wonder at the art of the Creator, by which the blood passes from the right to the left ventricle through pores, which elude the sight"⁷⁷.

⁷⁵ The mistake will be only corrected by Realdus Colombo in the 9th chapter of his *De re anatomica libri XV* (Fifteen books on anatomy), Venice, 1559): "Our good Galen – he writes – investigated this fact too much carefully, non to say in vain, because everyone may very easily observe, on the basis of experience, that the things are exactly the contrary". Cf. the above quoted S. Musitelli, P. Marandola, H. Jallous: *Il rene dalle origini al Malpighi* (The kidney from the origins to Malpighi), La Goliardica Pavese, Pavia, 2001, p. 89 ff.

⁷⁶ Cf. note n. 46.

⁷⁷ However he partly revised his statement in the second edition of his treatise and wrote: "Although sometimes these pits are conspicuous, yet none, so far as the senses can perceive, passes from the right to the left ventricle. I have not come across even the most hidden channels by which the septum of the ventricles is pierced. Yet, such channels are described by teachers of anatomy, who have absolutely decided that the blood is taken from the right to the left ventricle. I, however, am in great doubt as to the action of the heart in this part" and adds an exceptionally interesting passage that proves both his faithful "galenism" and his well founded

By contrast some of Vesalius' observations, descriptions and illustrations are worth particular appreciation, namely:

7) He describes and illustrates – at last! – the uterus without “horns”, although is still describing and illustrating the alleged “female testicles” (Figure 19).

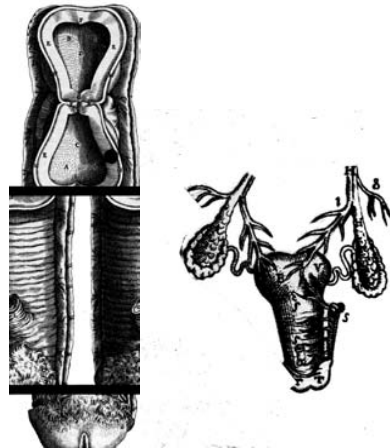


Figure 19: (left) Vesalius' Figure of the uterus; and (right) the alleged “female testicles” (*De humani corporis fabrica*, III, plate n. V, Figure. XXVIII and XXVIII respectively):

8) he observes and describes more carefully and cleverly than Galen the inner vascularization of the testicle, although he does not observe the “*ductus Highmorianus*” exactly described by Galen;

9) he describes and illustrates more clearly the prostate gland;

10) finally – and chiefly – he asserts peremptorily against Galen that there is no direct continuity between the spermatic vessels and the epididymides and these are surely fundamental contributions to the understanding of the formation of the semen, although not to the solution of the problems concerning generation.

As we are mainly dealing just with them, we think that it will be better to spare the reader the further more or less important improvements to the knowledge of the anatomical structure of the male and female genital organs contributed by Realdus Colombo (c. 1520-after 1559)⁷⁸, Gabriele Falloppio (or Falloppia) (1523-1562), Nicola Massa (c. 1504-1589), Guido Guidi (c. 1500-1569), Bartolomeo Eustachi (c. 1510-1574), Caspar Bauhin (1560-1624), Caspar Bartolin (1585-1629), Joannes Riolan (1538-1605)⁷⁹ and his son Jean (1580-1657), Johannes Vesling (1598-1649), André du Laurens (c. 1550-1609) and many other not at all despicable anatomists, and to pass to dealing with William Harvey (1578-1657), whose discovery of the complete blood circulation⁸⁰ and ideas concerning the “generation of animals” paved the way for the final solution of all the problems.

He was one of Galileo Galilei's disciples at the University of Padua, understood immediately the importance of the “Galilean scientific revolution”⁸¹ and applied a “*quantitative*” perspective to the study of the blood movements. His thinking may be summarized as follows: the average total amount of blood contained into the veins and arteries is about 5/6 litres; should it be the result of the transformation of foods into venal blood performed by the liver⁸² and should it be transformed into arterial blood by the heart and should it be finally transformed into “*spirit*” by the alleged “*rete mirabile*” and, by consequence, should it be constantly – so to say – consumed, i.e. disappear into “*spirit*”, one ought to eat about 150 kilos of food daily in order to survive; by contrast one survives even eating only few grams of food. This means that the total amount of blood is nearly always the same and that, by consequence, it must “*circulate*”! The proof of this hypothesis were the valves of the veins, which prevent reflux of blood towards the heart (Figure 20)

doubts: “*In considering the “fabrica” of the heart, I bring my words for the most part into agreement with the teachings of Galen; not because I think these on every point in harmony with the truth, but because, in referring at times to new uses and purposes for the parts, I still distrust myself. Not long ago I would not have dared to diverge a hair's breadth from Galen's opinion. But the septum is as thick, dense and compact as the rest of the heart. Therefore I do not see how even the smallest particle can be transferred from the right to the left ventricle through it. When these and other facts are considered, many doubtful matters arise concerning the blood vessels.*”

78 Although his discovery of the lesser circulation paved the way for William Harvey's discovery of the complete blood circulation.

79 Who was a relentless adversary of Harvey!

80 After the discovery of the “*lesser circulation*” made by Realdus Colombo.

81 Cf. note n. 64.

82 As maintained by Galen and all the subsequent physiologists. Cf. note n. 46.

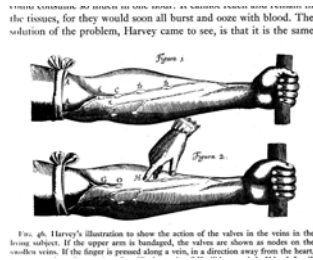


Figure 20: Should the upper arm be bandaged, the valves appear like nodes. Should the finger be pressed along a vein, in a direction away from the heart, from one node to the next, e.g. from O to H, the section OH will be emptied of blood and will remain empty because the valve O does not allow the blood to flow away from the heart.

In fact, after a brief and partial description by Giovanni Battista Canano (1515-1579), the valves of the veins were discovered, described and illustrated by Gerolamo Fabizi (or "Fabrici") of Aquapendente in his *Exercitatio anatomica de venarum ostiis* (An anatomical research on the valves of the veins) (Padua, 1603), from whose first illustration (Figure 21) Harvey derived his one.

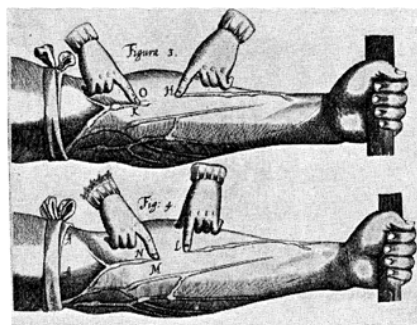


Figure 21: Aquapendente's illustration of the valves of the veins.

However Aquapendente, who was still a "galenist", did not understand the real function of the valves and thought that they were endowed with the task of preventing a too quick centrifugal flow of the blood as if they were a sort of "natural brakes". By contrast Harvey understood perfectly that the valves prevented blood just from centrifugal flow!

But it is not enough: Harvey was the first, who guessed – before Francesco Redi's (1626-1698) discovery that the insects (namely flies) did not generate "spontaneously"⁸³ – that all the living animals develop from an egg, and illustrated his idea just in the front page of his treatise *Exercitationes de generatione animalium* (Studies on the generation of animals) (London, 1651) (Figure 22)



Figure 22: The most important particular of the front page of Harvey's *De generatione animalium*: it represents Jupiter's hands that are opening an egg bearing the inscription "Ex ovo omnia" (Everything from an egg), from which all animals (man included) come out.

Although we must agree with F. Alessio⁸⁴ that "All the animals generate in the same way from an identical principle, whose shape is that of an egg: I say "whose shape is that of an egg" not in the sense that it has the shape, but in the sense that I is provided with the same

⁸³ As maintained by Aristotle and all the subsequent biologists not only till Redi, but till Lazzaro Spallanzani (1729-1790), who proved – against John Turbeville Needham (1713-1781) – that not only insects – as proven by Redi in his *Esperienze intorno alla generazione degli insetti* (Experiments about the generation of insects) (Florence, 1668) – but even micro-organisms (the so-called "infusoria" = "hatched from the infusion of herbs in water") did not generate "spontaneously". However it is worth observing that according to Aristotle some insects generated "spontaneously" but reproduced by copulation, a fact that he called "equivocal generation".

⁸⁴ Cf. Harvey W., *Trattato sulla generazione degli animali*, Turin, 1963, p. 555. Cf. also the really interesting C. Castellani's, *La Storia della generazione* (The history of generation), Longanesi, Milan, 1965, p. 65 ff. in particular.

nature, because in the generation of all animals it is normal that there must be in advance a “primordium” – similar to the nature of an egg and corresponding to the semen of the plants – from which the foetus originates”, nonetheless we think that there cannot be any doubt that Harvey’s intuition supported – as we shall see later – the thesis of the “ooists”.

Suffice it to read a brief passage of his *De generatione animalium*: “The process of generation is only one and always the same...The viviparous keep the conceived child into the uterus like the oviparous do while incubating”. As for the task of the male semen he writes that the ejaculated sperm does not fecundate by direct contact with the egg but because it contains a “creative virtue” that acts like “the spark originated by the flint lights the fire”⁸⁵.

A further step towards the final solution of the problems was made by the Danish anatomist Niels Steensen (Latinized “Nicolaus Stenonius”)⁸⁶ (1638-1686), a follower of Galileo’s “scientific revolution”, who published his treatise *Elementorum myologiae specimen* (Essay on elements of myology) in Florence in 1667. The book contains the brief but exceptionally important appendix *Dissectus piscis ex canum genere* (Dissection of a fish of the shark genus). One may read the following fundamental passage at p.117: “I followed the general opinion in dissecting a ray, have dealt with the uterus and said that it performs the same function of the ovarium in the oviparous. By consequence, as I observed that the testicles of the viviparous contain eggs and that their uterus opens into the abdomen like a sort of oviduct, I have no doubt that the female testicles are analogous to the ovaria and that either the eggs themselves or their content is transferred, one way or another, from the testicles to the uterus, as I shall prove purposely elsewhere if only I shall succeed in exposing the analogy of the genital parts and eliminating the mistake of considering the female genital organs to be analogous to the male ones”⁸⁷. Although unfortunately Steno could not write the devised treatise and confined himself to publishing the article *Observationes anatomicae spectantes ova viviparorum* (Anatomical observations concerning the eggs of the viviparous)⁸⁸, nonetheless his ideas surely paved the way for the subsequent studies and discoveries – mainly those of Antony (or Antoni) van Leeuwenhoek (1632-1723) and Regnier de Graaf – and to the final statement that also the Mammalians reproduce from eggs.

Let us start from Leeuwenhoek (Figure 23).



Figure 23: Leeuwenhoek portrait.

82 Cf. *De generatione animalium*, De conceptione, p. 376 ff. It is worth observing that, as Harvey had not any microscope at his disposal and moreover had not even the faintest idea of “cells” in our modern sense of the term (cf. note n. 97), he could not avoid having still recourse to the “virtues” of “galenic” memory!

86 However “Steno” is a mistake! He signed his letters either “Nicolaus Stenonis”, or “Nicolaus Stenonius”: “Stenonis” was erroneously supposed to be the genitive case of a hypothetical “Steno-Stenonis” and therefore it was changed into “Steno”! In fact “Stenonis/Stenonius” mean simply “son of Steen” (van Steensen = “Stenonis [filius] in Latin”); in fact the name of his father was “Steen Pedersen”. Indeed in his portrait he is called “NICOLAUS STENONIUS” (Figure D)



Figure D: Steno’s portrait.

87 He is surely alluding to Galen and the “galenists”.

88 Cf. *Acta medica Hafniensia*, 1673, 2, 210.

First of all, it is absolutely not right that he was equipped with “*magnifying instruments that were exceptional for his times*”⁸⁹. In fact his alleged “*exceptional magnifying instruments*” were not only rather rudimental but also very difficult to use (Figure 24)

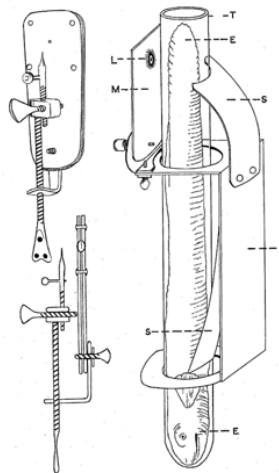


Figure 24: Leeuwenhoek microscopes. The right one was used for examining living animals (after A short History of Medicine, by Ch. Singer and E. Ashworth Underwood (second edition), Oxford, at the Clarendon Press, 1962).

As everyone can see, it is not at all a “*compound microscope*”, but a simple magnifying glass, or better a very tinny (\varnothing 2 mm) glass sphere inserted into a littlest hole near the upper end of two either wood or metal plates rivetted together. Opposite to this glass sphere – of very small focal length – a needle-pointed rod is supported vertically behind the lens and the object to be observed was fixed to its point. Thanks to a horizontal rod the object could be focused.

Although Leeuwenhoek was probably able to obtain a magnification of nearly 300 diameters, it may be clear that to observe an object with this alleged “*exceptional magnifying instrument*” forced him to scratch literally his eyes out!

However he succeeded in observing

However he succeeded in observing

- 11) the blood circulation in the fin of an eel and in the web of frog’s foot;
- 12) the red blood corpuscles and the capillary anastomosis between arteries and veins (Figure 25)

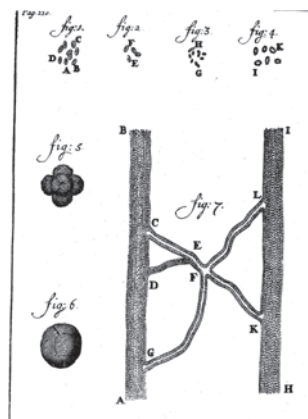


Figure 25: Leeuwenhoek’s illustration of red blood corpuscles 1) in a salmon; 2-4) in an eel; 5-6) several eel red blood corpuscles gathered into globes; 7) anastomotic capillaries between an artery (HI) and a vein (BA) (after A short History of Medicine, by Ch. Singer and E. Ashworth Underwood², Oxford, at the Clarendon Press, 1962)⁹⁰.

But his most important and fundamental discoveries were:

⁸⁹ Cf. C. Castellani, *La Storia della generazione* (The history of generation), Longanesi, Milan, 1965, p. 107.

⁹⁰ However the complete network of the anastomoses between veins and arteries was only finally discovered and proven by Marcello Malpighi in the frog’s lungs and perfectly described by him in his two *Epistulae de pulmonibus* (Letters on the lungs) (*De pulmonibus observationes anatomicae* and *De pulmonibus epistola altera* respectively) sent to his master Giovanni Alfonso Borelli and printed in Bologna in 1661.

1) that of the structure of the voluntary muscles, which consists of bundles of muscle fibres and that individual fibres present a characteristic striated appearance (Figure 26)

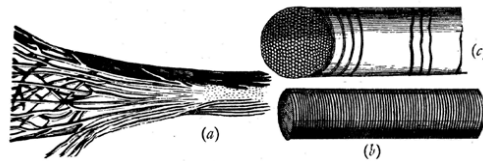


Figure 26: Leeuwenhoek's illustration of the structure of voluntary muscles (after a short History of Medicine, by Ch. Singer and E. Ashworth Underwood², Oxford, at the Clarendon Press, 1962).

2) That of the "spermatozoa" (Figure 27), although he mistook them for micro-organisms like the "animalcula" (little animals), mainly the so-called "infusoria"⁹¹, a lot of which he had already succeeded in observing.

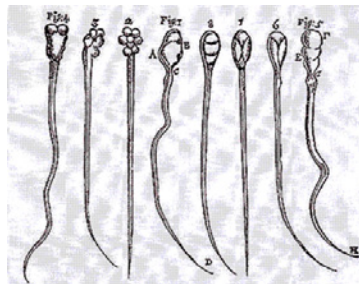


Figure 27: The different kinds of spermatozoa Leeuwenhoek supposed to have seen.

Leeuwenhoek had already observed the spermatozoa and had described them in a letter sent to the Royal Society on November 1677⁹², but had considered them as meaningless "little globes" and therefore he did not improve his observations. However, when the young biologist Jan Ham succeeded in meeting him and invited him to observe a sperm sample – that he had brought just for this purpose – and informed him that he had observed "some living and tailed animals, which did not live for more than 24 hours", Leeuwenhoek felt encouraged to improve his own observations and – as usual – informed the Royal Society about their results⁹³: "I often observed – he writes – the semen and found such an amount of animals that a million of them moved into a drop of sperm as little as a grain of sand... These animals were littler than the globules of blood. Their bodies were round, their anterior part was blunt whilst the rear one ended in a sort of spine and their thin and pellucid tail was five or six times longer than the body and was as thick as the twenty-fifth part of it. They proceeded with a snake-like movement as eels do in water"

These fundamental discovery together with Regnier de Graaf's (Figure 28) ones – we are going to deal with – gave origin to the relentless controversy between the so-called "spermatists" and the so-called "ooists". In fact, de Graaf not only corrected and improved the knowledge of the male reproductive system in his treatise *De virorum organis generationi inservientibus* (On the male reproductive organs) (Leyden, 1668), but also discovered in his *De mulierum organis generationi inservientibus* (On the female reproductive organs) (Leyden, 1672) that the alleged "female testicles" were not at all "testicles", but "ovaries" into which – as we shall point out – he identified the so-called "graafian follicles" that he mistook for "female eags"⁹⁴.



91 Cf. note n. 83.

92 Cf. *Observationes de natis e semine genitali animalculis* (Observations of little animals born in the genital semen), in *Philosophical Transactions*, 1679, 12, 1050:

93 Cf. Leeuwenhoek's letter sent on November 1677.

94 The real "oocyte" will be discovered only in 1827 by Karl Ernst von Baer (1792-1876), who described it perfectly in his *Epistola de ovi mammalium et hominis genesi* (Letter on the mammals' egg and human generation). However Marcello Malpighi had already supposed that the "graafian follicles" were not "eggs", but "contained" them. Cf. chapter 4th of Malpighi's *Letter to Jacob Spon* (1647-1685) sent on 01/11/1681.

Figure 28: Regnier de Graaf's portrait.

There is no doubt that Steno's work *Dissectus piscis ex canum genere* quoted above encouraged him to improve his studies on the female generation organs as he himself states: "I am sure that eggs may be found in animals of every kind, because one can clearly see them not only in all birds and in both oviparous and viviparous fishes, but also in quadrupeds and even in the man himself. As everyone knows that eggs may be found in fishes and birds, it is not necessary to give any proof; in rabbits, hares, dogs, pigs, sheep, cows, and other animals I dissected, such eggs appear to the dissector like vesicles similar to the germs of the birds' eggs...As I supposed that these things could be also found in the animals I had not yet dissected, I asked the most illustrious Steno to design to inform me about what he observed in the female testicles of different animals that I could not dissect and he did not disappoint my expectations. Indeed he kindly informed me that he had found eggs of different size in does, cavies, female badgers, she-wolves, she-asses, even in mules and in many other female animals. These statement – if compared with my own observations – clearly confirms that eggs can be found in females of every kind ... Until they (the eggs of birds) are still little, they do not contain anything else than a thin liquid, and one may see that such an albumen also exists into the eggs (of the viviparous) if only one boils them. Indeed the liquid contained into the boiled eggs of the female testicles acquires the same taste and consistency of the eggs of birds"⁹⁵.

It is really astonishing that a so keen observer as Graaf did not realize that the follicles he had discovered and mistaken for eggs corresponded exactly to the shell of the bird's egg!

However he correctly observed that "the common function of the female testicles is to generate, nourish and bring to maturation the eggs. Therefore they perform in females the same function of the bird's ovaries so that they ought to be called "female ovaries" instead of "female testicles" (Figure 29).

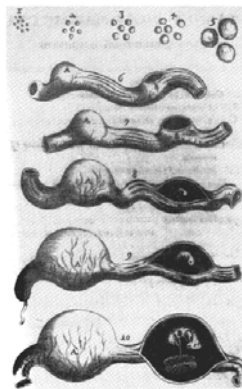


Figure 29: De Graaf's plate illustrating the ovaries and the "graafian follicles"

Graaf's mistake was due to the fact that he had still not even the faintest idea of "cells" in the modern sense of the term⁹⁶. However, the discoveries of both the "spermatozoa" (Han-Leeuwenhoek) and the "graafian follicles" – although mistaken for "oocytes" as we have pointed out above – gave origin to the relentless controversy between "spermatists" and "ooists". The ones maintained so fiercely that the embryo was already "preformed" into the head of the spermatozoa as to illustrate their alleged observation of a "preformed" foetus into it (Figure 30)

95 Cf. *De mulierum organis generationi inservientibus*, p.159 ff.

96 The real "cells" were only discovered, correctly described and illustrated for the first time by the Italian biologist Felice Fontana (1720-1805) in 1781. He succeeded in observing and describing even both their "nucleus" and the "nucleolus". It is worth emphasizing that when Robert Hooke (1635-11703) in his *Micrographia* and even the great Marcello Malpighi in many occasions use the term "cellula", it does not mean "cell" in the modern sense, but simply "little room" like the cells of the honeycombs. In fact Hooke did not discover the vegetal cell, but only succeeded in observing the outer and withered cellulose membrane in a thinnest cork slide (Figure E)

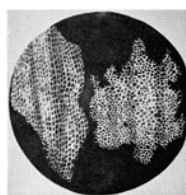


Figure E: Hooke's illustration of the cork "cells" cut longitudinally (left) and transversally (right).

As for Malpighi, he called them "utriculi", i.e. "little bags" (which contained "air" in his opinion) that have nothing at all to do with our "cells"!



Figure 30: The alleged foetus curdled into the head of a spermatozoon described and illustrated by Nicolas Hartsoeker (1656-1725) in his *Essais de Dioptrique*, Paris, 1694. Whilst the others asserted that the foetus was “preformed” into the “female eggs”. Although both the “spermatists” and the “ooists” were obviously and absolutely – if not absurdly – wrong⁹⁷, nonetheless their controversy had at least the fundamental merit of putting into shadow once and for all the millenary and preposterous theories on generation and of paving the way for the modern anatomico-physiological and biological achievements. This proves that in the history of science in general and of medicine in particular the mistakes are always more fecund than the more or less alleged truths, so that the history of science could be considered as “the endless correction of the former mistakes”.

⁹⁷ Although the “ooists” seem to be unconsciously nearer the truth than the “spermatists”, all the more so in the light of the latest developments of our knowledge of the mitochondrial DNA. The legitimate suspicion arises that the theory of the “spermatists” was deriving from the still prevailing male-chauvinistic culture. However it is worth observing that during the 5th and the 4th century B.C. the enslavement of women was already dramatically declared in the first Medea’s monologue in the homonymous tragedy of Euripides (484/480-406 B.C.) played in 431 B.C. and that in the same period a long and hard feminist movement exploded in Athens and was ridiculed by Aristophanes (445-385B.C.) in the comedy “*Ecclesiazusa*” (Women in constituent assembly) played in 391 B.C.. The final and successful feminist movement started only in 1903, when the *Women’s Social and Political Union* was founded in England and headed by Emmeline Panchurst (1858-1928).

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