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THE VISIONARY VIEW OF PAULESCU ABOUT THE STRUCTURE AND FUNCTION OF THE SPLEEN

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Nicolae Paulescu
(1869–1931)

In a paper published 67 years ago by Theodore Snook (Am. J. Anat. 83:31, 1950), this mentioned a paper published by Robinson (Am. J. Path. 2:341, 1926) who justify his interest for the anatomic study of the spleen such as: "*This study was undertaken with the hope of obtaining more minute detail of structure and a better understanding of the blood flow through the spleen*." At his turn, in 1950 Snook mentioned in the introduction that his work has the same: "*the purpose*". The PhD thesis of Paulesco (Ed. Doin, Paris, 1897) has been not mentioned in their publication either for French language or by the low spreading of this work in the older time. For instance the PhD degree thesis of Paul Langerhans (1847–1880) published in 1869 has been only occasionally discovered by the French anatomist Edouard Laguesse in 1893, *i.e.* 24 years later in Lyon at the University from this town not very far from Berlin, where Paul Langerhans works under the supervision of the repute anatomo-histoloist Rudolph Virchow (1821–1902). Already in 1858 he published his master work: "Cellular pathology as fundamental theory about histological and pathological histology", in Berlin.

If for Langerhans the delay was only for 24 years, now when we rediscovered the Paulescu's thesis has past 120 years. If we look as a data from Paulescu's thesis we must recognise that the anatomical and histological description remain valid until our days.

It is quite clear for me that the optic microscopy has some advantages to electronic microscopy,

which in turn has other advantages *versus* optical microscopy. The last one offers a larger area for analysis, giving a better appreciation to the cellular assembly, whereas, electronic microscopy offers the possibility of a better knowledge of the subcellular structures: nucleus, endoplasmic reticulum, lysosomes, etc.

Coming back to the papers published in the last century, they exult a greater determination than that present in our times. Now, when the "time is money" and in the mad rush to obtain rapid recognition, it sometimes happens, what the Romanian wisdom say that "*haste makes waste*". I discovered, with great satisfaction, the first doctorate thesis (from the three obtained by Paulescu in Paris). I read it carefully and I have been impressed by the manner in which he approached this subject which is still even today a hot topic. The thesis of Paulescu entitled "***The structure of the spleen***" (translated for the first time in Romanian and also in English), will be printed soon. Here we present the English translation of the chapter "***The spleen***", from the "*Traité de Physiologie Médicale*" published in 1920, showing that his interest from these "forgotten" organ remained alive. In a subchapter ("*Personal investigations*") Paulescu invalidate the supposed influence of the spleen on the bile secretion. Instead he gives a summary of his view of the internal structure of the spleen starting with lobes, lobules and finally with a great number of "functional units" where take place the two main functions of the spleen: the "filtration" function of the "***red pulp***" and "immune" function (and maybe a secretory function) of the "***white pulp***".

There are strong arguments for sustaining that by his numerous priorities published in many international publications Paulescu was one of the greatest European physiologists from the first part of the 20th century. All who will be patient enough to read all his scientific state-of art papers and textbooks, will agree that my appreciation was not exaggerated.

THE SPLEEN

N.C. PAULESCO –
"TRAITE DE PHYSIOLOGIE MEDICALE"

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Embriology. The development of the spleen is not well known. According to some authors, the spleen derives from the gastric epithelium, from which certain cells migrate and reach inside the mesogastrium (MAURER). Other authors state that the spleen derives from the mesenchyme (mesoderm), whose cells proliferate around the branches of the future portal vein (LAGUESSE). This last hypothesis holds the highest probability, for the spleen acts as a connective-vascular organ and not as an epithelial organ. The spleen is not present in the invertebrates; but it exists in all vertebrates. Whilst underdeveloped in fish, batrachia and birds, it is relatively voluminous in mammals, especially in carnivores, more so than in herbivores.

Anatomy. The spleen is situated in the superior and posterior part of the abdominal cavity, in the left hypocondrium. It is shaped like a large croissant, whose long axis is directed almost horizontally, slightly oblique, back to front and above to below.

The spleen presents:

1. an external surface, convex in relation to the diaphragm, which separates it from the pleural cavity, from the left lung and from the inferior part of the rib cage (ribs 9, 10, 11);
2. an internal surface, that is concave, in the back of which the vessels (the hilum) make their passage, and which is, in the front, in relation to the great gastric curvature, to the tail of the pancreas and, also, sometimes, to the left colonic flexure;
3. an inferior border, very thick, which is in relation, in the back, with the adrenal gland and kidney on the left side, from which it is separated only by the peritoneum;
4. a superior margin, thinner, often divided by indentations of various depths;
5. a posterior extremity, very voluminous, situated in the anterior region of the vertebral column (corresponding to the thoracic vertebrae 9, 10, 11);
6. an anterior extremity, often very thin, which extends towards the hypocondrium but never, in a normal state, passes beyond the inferior border of the floating ribs; it is relative to the great gastric curvature and the colonic flexure.

The spleen is, on average, in an adult, 12 cm long by 8 cm wide and 3–4 cm thick; it weighs approximately 150 g. It is relatively more voluminous in children than in adults. It swells after every meal, which seems to indicate it has some

role in food assimilation. In the elderly, it is always more or less atrophied, sometimes even indurated, retracted and takes the shape and volume of an egg. These transformations are similar to those that take place in the lymphatic nodes.

The spleen is of a dark-red or purplish color, resembling that of concentrated red wine. It has a rather soft consistency, it is friable, becomes easily crushed or even torn. When subjected to putrefaction, it becomes fluid.

Seen on a magnifying glass, or with the naked eye, the spleen presents a multitude of small whitish dots, named *Malpighi corpuscles*, which are grouped around an arteriole and spread around the parenchyma, with a homogeneous distribution, that make out the *splenic pulp*.

The lobulated spleen and multiple spleens. The spleen, whose margins are usually smooth, sometimes present grooves or even very deep indentations, especially affecting its superior margin or the vecinity of its anterior extremity.

In some cases, the transversal grooves, more or less deep, range across the entire external surface of the organ. This way they divide the spleen into several *lobes* which are called *accesory spleens*.

Usually, there are no more than 2 excess spleens, but, sometimes, their number can go up to 23. These accesory spleens are round, and their volume varies from the size of a pea to that of a pigeon egg. They are often located alongside the vessels, in the gastrosplenic ligament. The structure of these multiple spleens is not different from that of the main spleen.

These pathological lesions of a general cause affect, in the same way and equally, all the spleens belonging to the same individual.

Histology. The histology of the spleen is not well known. For this I was compelled to undertake investigations in order to specify it.

PERSONAL INVESTIGATIONS[1]

The structure of the spleen

The spleen, like any other gland, is composed of glandular cells and a coat of connective and vascular tissue.

1. The cells of the spleen, placed in a network of splenic reticulum, are *lymphoid* cells, with a voluminous nucleus and a small amount of protoplasm. There are also much larger cells, with more abundant protoplasm, voluminous and round nuclei and other cells, less frequently, with a lobulated nucleus.

The protoplasm of these cells is coloured by hemoglobin and it occasionally contains a brown pigment.[2022]

Contrary to the oppinion of the classic authors, we haven't found any red blood cells in the splenic tissue other than inside the blood vessels, if indeed their extravasation occurs for another reason than the rupture of the vascular walls.

2. The coat of connective and vascular tissue of the spleen[3] includes the coats of the organ, the sheats of the vessels and the connective tissue of the parenchyma.

There are 2 layers coating the spleen.

a) The most superficial layer is nothing else than the visceral coat of the *peritoneal serous* coat. After enveloping the entire gland, it reinsert on the vessels which go through the hilum, and forms: the pancreatic-splenic ligament (around the splenic vessels) and the gastro-splenic ligament, around the short vessels and the left gastro-epiploic vessels which, from the splenic vessels, goes to the great gastric curvature.

The splenic peritoneum is composed out of a layer of endothelial cells and a thin layer of connective tissue which is adherent to the deep layer of the spleen.

b) The spleen's deep layer, located underneath the previous one, to which it is intimately connected, is made of fibrous bundles, elastic fibers and smooth muscle fibers. These form a thin, but elastic and relatively resistent, thin membrane.

The big splenic vessels (arteries and veins) follow the route inside the spleen together and they are surrounded by the same layer of connective tissue, which forms a common sheath. At the point when, following successive divisions, the diameters

[1] PAULESCU: La Strucutre de la Rate, Paris : O. Doin, 1897.

[2] In some pathological cases, a certain number of splenic cells are observable that contain vacuoles. Most of these cells are contained by the capillary veins and originate, undoubtedly, from the desquamation of the endothelium belonging to these veins, have been considered by some authors as being phagocytes engulfing red blood cells.

[3] The description of the connective-vascular coat, which we reproduce here, is different from that of the classic authors; it is the summary of the research we have enterprised on various occasions over this matter (PAULESCU, Structure de la Rate, Paris, 1897).

of the arteries become small, they then separate from the veins. The fibrous tissue, part of their common sheath, also separates:

– a part follows the artery, until it divides into capillaries

– a part follows the veins until they receive the capillaries.

The connective tissue of the splenic parenchyma is made of the trabeculae of the fibrous sheaths and the splenic reticulum.

From the inner surface of the deep layer of the spleen, numerous fibrous sheaths are emitted which divide, subdivide and form anastomoses thereby creating a complex *network* which serves as a splenic framework.

Contrary to the classic opinion, we have demonstrated that these trabeculae do not have a random distribution; they have a special distribution, always the same: *they are located in the middle of the space between 2 arterioles*[202] and are in immediate contact with the venous capillary network. The more voluminous veins, which arise from this network, are placed inside this connective sheath.

The spleen is thus divided by these trabeculae, in a multitude of *similar regions*, each with an arteriole in the centre, with its own Malpighi corpuscle and a peripheral venous network. These similar regions are in fact the *splenic lobules,* whose respective limits are marked by connective sheaths.

Arising from the capsule of the spleen, these connective sheaths, as well as the vascular sheaths, split into numerous very thin fibers, which form a tight network (reticulum) with spaces that contain the splenic cells.

The vessels. The vascular system is, in the spleen's economy, of capital importance.

The splenic artery, the most voluminous of the branches of the celiac trunk, is directed from right to left, towards the hilum of the spleen, following the superior margin of the pancreas. After giving branches to the pancreas and to the stomach (the short vessels and the left gastro-epiploic artery), it divides into 4 large branches which enter the spleen through its hilum.

Each arterial branch has a specific distribution to a distinct territory without forming anastomoses with the neighbouring arteries, and these various arterial territories may be considered to be, by analogy, the lobes of this gland.[4]

After they have entered the spleen, each of these arterial branches divides into decreasingly smaller branches and, when their caliber reaches no more than 0.5 mm, they separate from the veins (with which they have shared a common sheath).

From this moment forward, these arterioles, following further divisions and subdivisions, emit, at certain distances, like crowns of fine capillaries with splenic cells around them, thus forming the Malpighi corpuscles. These corpuscles have 0.3 mm in diameter.

The last arterial ramifications end in capillaries.

All *splenic capillaries* (intracorpuscular and terminal) have a continual connection with the veins[5]. We could not identify them on normal spleen sections, and even less so on pathological spleens. On a portion of their tract, variable in length, the splenic capillaries (which measure 6 to 11 μm in diameter), become suddenly dilated (20–40 μm) and form structures that are like sanguine sinuses, analogous to the lymphatic sinuses of the ganglia. In this way they become venules, whose walls have a specific structure *that is not found anywhere else in the body.* These venules (the capillary veins of BILLROTH) do not have their own walls, they are coated with a type of endothelium, made of a single layer of spindle-shaped cells, very elongated, that have a paralel position to the long axis of the vessel. As they distance themselves from the capillaries, these venules join with one another and, finally, they drain into *veins that have their own wall* which are situated in the thickness of the fibrous trabeculae that form the capsule of the spleen.

When they reach a certain caliber, these last veins join the arteries that are situated inside a common fibrous sheath until they arrive at the hilum of the spleen. At this level, duzens of venous branches are visible; they follow the tract of corresponding arterial branches and finally join to form the trunk of the splenic vein.

The splenic vein, very voluminous, follows a left to right trajectory, after having received numerous venules (the short vessels, the left gastro-epiploic vein), joins to form the small mesenteric vein, which then drains into the large mesenteric vein thus forming the trunk of the portal vein.

[4] PAULESCU. La Strucutre de la Rate, Paris : O. Doin, 1897, p. 30.

In fact, the supplementary spleens are similar to these lobes.

[5] PAULESCU. La Strucutre de la Rate, Paris : O. Doin, 1897, p. 47.

Some authors (STIEDA, W. MULLER, FREY, LEGROS, ROBIN) claimed that between the arterial capillaries and the venous capillaries there is an intermediate system made of a network of lacunae.

The origin of the *lymphatics* of the spleen is practically unknown and is barely mentioned by the classic authors. The research we have enterprised on this subject had allowed us to conclude that there is a radicular lymphatic system in the spleen, situated around the sanguine capillaries, in the pulp and in the Malpighi corpuscles, and that it is part of the net of the splenic reticulum.[6]

This radicular system is considered, by some authors (FREY, LEGROS, ROBIN) to establish the connection between the arteries and the veins.

From here, lymphatic capillaries emerge, the ones from the Malpighi corpuscles follow the trajectory of the arteries, the ones from the pulp follow the trajectory of the veins. They reunite to form 4–5 small trunks, [7] passing through the lymphatic ganglia situated at the tail of the pancreas.

The splenic lymph is clear and possesses all the characteristics of the lymph from other organs. But if one should rub the spleen, the lymph coming out of the organ takes a reddish colour and contains red blood cells, fact that is attributed to vascular ruptures.

In summary, the spleen is composed of a multitude of elementary units, each containing an arterial capillary, surounded by a layer, of variable thickness, of splenic cells, and floats in a sort of sanguine lake representing the capillary veins.

The splenic lobules result from the joining of a certain number of these elementary units.

In the centre of the lobule, around the arteriole, there is a considerable accumulation of splenic cells, in the spaces between the arterial capillaries. It is what we denominated as the Malpighi corpuscles.

Outside these corpuscles, the arterial capillaries are less frequent; the layer of splenic cells, which surrounds them is of variable thickness and sometimes very thin.

There, these elementary units of the spleen (the trabeculae of the spleen) are situated between the capillary veins, increasingly numerous and voluminous as they distance themselves from the central artery and which approach the fibrous sheaths that demarcate the periphery of the lobule.

The nerves. The nerves of the spleen come from the solar plexus (the great sympathetic). These are fibers that form anastomoses, which follow the splenic artery (without following its ondulations) and enter inside the organ. Their final terminations are not precisely known. They are surely distributed to the walls of the vessels as well as to the smooth muscle fibers, contained by the fibrous capsule of the organ.

KOLLICKER also describes sensitive fibers.

PHYSIOLOGY

Our research on the structure of the spleen shows that this organ is a lymphatic-sanguine gland, analogous to, but not identical to the lymphatic ganglia.

Indeed, the lymphatic sinuses which represent the pathways followed by the lymph inside the ganglia are replaced in the spleen by sanguine sinuses, namely capillary veins.

The products of the activity of the ganglia (plasma and globules) are drained into the lymph, on the contrary, the products of the activity of the spleen (plasma and globules) are taken by the blood, testimony of this, so to say, is the enormous size of the splenic vein, in contrast with the small size and number of lymphatic trunks possessed by this organ.

Among others, the fact that the blood of the splenic vein (mixed with pancreatic blood) drains in the portal vein, namely the tract of the blood that comes from the intestine (which contains a great part of the alimentary principles absorbed at the level of the intestinal villi) makes us consider the spleen's role in assimilation. Otherwise, it is known that the spleen undergoes considerable congestion and tumefaction 5–6 hours following meals. Furthermore, it loses a great part of its weight during periods of fasting.[8] And finally, as well as with the lymphatic ganglia, it atrophies at an old age.

The blood of the splenic vein contains a great proportion of leukocytes than the blood of other veins.

The stimulation of the nerves of the spleen (solar plexus, splachnic nerves, medulla oblongata) decreases the volume of this organ, probably as a result of the contraction of the smooth muscle fibers

[6] PAULESCU: La Strucutre de la Rate, Paris : O. Doin, 1897, pag. 37 si urmatoarele.

[7] The small number and caliber of the lymphatic trunks, which emerge from the spleen constitute, as KOLLIKER remarks, a less favourable argument of the existence of numerous lymphatic tracks in the splenic tissue. However, the special structure of the capillary veins and their presumably low blood pressure lead to the question whether there is a particular disposition, favourable to absorbtion, and intended to take over, at least partially, through the veins, the plasma coming from the arterial capillaries and that is spread across the splenic parenchyma.

[8] Research on the role of the spleen are taking place in this moment in my laboratory.

of the vessels, as well as of the fibrous capsule and of its inward extensions. The same effect is produced in a reflex manner, by stimulating the superior part of the vagus and of other sensitive fibers.

The removal of the spleen, in humans and in animals, is not followed by any measurable pathological phenomenon.

The splenectomy, performed on young animals, does not induce any growth disturbances in their bodies (DASTRE).

The chemical analysis of the splenic tissue shows that it contains amino acids (leucin, tyrosine), xanthine, hypoxanthine, especially uric acid and also iron, in considerable quantities (1%).

Hypothetical functions

I. It has been attributed to the spleen a role in *the production of pancreatic ferments.*

SCHIFF and HERZEN have claimed that, in animals on which splenectomies where performed, the pancreas loses its digestive propreties. According to HERZEN, the trypsinogen transforms into trypsin under the influence of a ferment secreted by the spleen. However, these statements are not yet demonstrated.

II. It has been assumed that the spleen has a hematopoietic function. However, likewise, the assertion is imaginary and does not rely on specific facts.

PERSONAL INVESTIGATIONS

The splenectomy does not modify the biliary secretion[9]

Some authors (PUGLIESE, CHARRIN şi MOUSSU) claim that the spleen plays an important role in the *production of bile.*

They have produced, in dogs, *a fistula of the gallbladder*, and have analysed the leaking bile. Then, they have removed the spleen and reanalysed the bile.

They found that the *bile* partially loses colour and changes its composition following the splenectomy.

However, the bile, collected through a fistula of the gallbladder, is not normal, due to the ligature of the choledoch, which supresses the biliary intraintestinal resorbtion.

Furthermore, the digestios become abnormal, in the absence of the bile.

Finally, frequently, as a result of the communication of the biliary tracts with the exterior, a suppurative inflammation of the gallbladder develops, where mucopurulent exudate is secreted, which mixes with the bile.

We were subsequently compelled to abandon the method of the biliary fistula and proceeded as follows:

1. In a series of experiments, we used dogs of different sizes (weight between 7 to 20 kg), and analysed the bile contained by their gallbladder[10] (27 measurements).

2. In a second series of experiments, we used dogs of different sizes, weight between 7 and 19 kg, and we have *removed their spleen*. Then, after 17–158 days we analysed the bile contained by their gallbladder.

3. And finally, in a third series of experiments, performed on 3 dogs, with approximately the same size (weight between 7–8 kg) and fed exclusively with corn bread, we analysed, **in the same animal**, on multiple rounds, the bile (obtained through a puncture in the gallbladder, after laparotomy) *before splenectomy and after splenectomy*, at time intervals varying between 18 and 66 days following the intervention.

Results. In the dogs on which a splenectomy was performed, the gallbladder is not notably different, regarding the colour and the composition from that of the dogs' with a spleen.

In the same dog, no notable and constant differences where found between *the colour and the composition of the spleen* before and after the splenectomy.

There is not, in conclusion, any manifest relation between the function of the spleen and the secretion of bile produced by the liver.

[9] PAULESCU, La splenectomy ne modifie pas la secretion de la bile, *Journal de physiologie et de pathologie generale*, Paris, 1906, p. 22.

[10] The techinique used in these analyses is described in detail on page 27 of the previous memoir.