THE INTRA-CRANIAL LYMPHATIC SYSTEMS.

by

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In a description of the Intra-cranial Lymphatic Systems, it is most convenient to divide the systems into two main groups.

(a) The Intra-Cerebral System, which is limited to the Lymph channels in the brain substance.

(b) The Lymph System of the Meninges including the Pia Arachnoid and the Dura.

It is easiest to begin with the Lymph at its origin when it diffuses through the capillary wall and to trace its course outwards until it reaches the Venous Circulation.

A. THE INTRA-CEREBRAL LYMPHATIC SYSTEM.

Lymph is usually brought to an organ by the arterial blood stream and hence all the lymph in the cranial cavity enters the cranium in the blood stream, through the arteries and then diffuses through the capillary wall to perform the different functions for which it is required. The path of exit is quite different and distinct from that of entrance, as there are no efferent lymphatics and the intra-cerebral veins have an entirely different arrangement from that of the arteries.

The object of the following is to show the possible ways by which the intra-cerebral lymph can escape from the meshes of the brain tissue and reach the main systemic circulation.

Fresh blood is supplied to the brain by

(a) Basal Arteries entering the brain substance in the intra-cerebral arteries.

(b) Arteries from the pia.

And the paths of exit from the cerebrum, cerebellum, etc., are by the veins which chiefly run to the cortex and open into the various sinuses. Hence it is necessary to study the vessels of the cortex to see what means of exit there is for the exuded lymph.

At the present time there are three chief theories:-

(1). Tuke, considers that there is a sheath to the capillaries derived from the pia which gives saccular prolongations to the nerve cells and so conveys lymph in which to bathe them.

(2). Bevan Lewis holds that the neuroglia fibres act as fine lymphatic tubes.

(3). Ford Robertson describes a basketlike network around the capillaries through which lymph filters and then lies free between the capillary loops bathing the nerve cells. These capillary

loops he has termed Intervascular Spaces.

It is my endeavour to give here a brief sketch of the latest researches bearing on these points and to indicate the most probable arrangement of the lymph system.

The pial vessels enter the cortex taking with them a prolongation of the pia in the form of a sheath. This does not appear to be of the nature of a cellular membrane, as described by Tuke, enclosing the vessel in a layer of cells thus forming an open channel for lymphatic fluid between the adventitia and the pial prolongation, but rather of the nature of a network of meshes of connective tissue which surrounds the vessel with layers of fibres capable of containing and permitting the flow of lymph through their interstices. Fig. 1.

The vessels as they enter from the pia, carry with them a sheath of pia which consists of a very close network of connective tissue fibres varying in density with the size of the vessel. Fig. 2.

These fibres are easily seen if stained by the Platinum Method of Ford Robertson and form a network of black lines often containing in its interstices, a few blood cells or leucocytes. There is no evidence of the distinct cellular structure of this sheath. Attached to the vessel, or rather to the

sheath of the vessel, are large numbers of fine fibres running more or less at right angles to the line of the vessel and apparently helping to keep the vessel in position in the brain substance.

These fibres are the processes of the neuroglia cells which form the supporting network of the brain substance. They originate from the cells and spread out on all sides, many ultimately reaching the capillary walls and being attached there. The method of attachment is worthy of note. When the fibre approaches a vessel, it usually breaks into two divisions which separate and are attached to the vessel wall by means of flattened expansions. Fig. 7.

In most stained sections of brain cortex however carefully prepared, there is usually a space to be seen between the vessel wall and the actual brain substance, but there is no evidence to show that it is any other than artificial and due to shrinkage. In carefully prepared sections, it is nearly absent in the white layer and numerous glia-fibres can be seen crossing it to find attachment to the vessel wall. (Occasionally a few leucocytes may be seen lying outside the vessel, probably having been extruded through the wall).

This sheath, described above, is always continuous with the vessel and gives no prolongations to any nerve cells. Clear spaces may be seen around the large nerve cells and they are due to shrinkage and there is no evidence of any distinct sheath or prolongation of the capillary sheath enclosing the nerve cells to be demonstrated by the Platinum or by the Methyl-Violet Methods. Fig.3.

In the Platinum method - in tissues stained deeply - the capillaries are shown with a dense black network around them, but strictly limited to the vessels and there is no sign of a similar structure round the nerve cells. Fig. 4.

Also, should such a sheath exist, it would be reasonable to expect to find glia-fibres attached to it or showing attachments similar to these on the vessel walls, but there is no evidence of any such fibres being attached to the cell wall.

The sheath above demonstrated is often found markedly thickened and containing a large amount of debris or leucocyte exudation distending it. The debris and leucocytes lie in the meshes of the perivascular sheath between the vessel wall and the brain substance outside and do not appear outside the perivascular sheath, except occasionally and in small numbers.

In general paralysis of insane, this sheath is increased in thickness and often distended with leucocytes and debris distinctly showing that there is means of passage for large quantities of material in the sheath of the vessel. There is also a marked proliferation and hypertrophy of the glia-fibres attached to the vessel wall. Fig.5.

The actual course of the lymph is as follows:- It exudes through the endothelial walls of the capillaries and lies in a space bounded by a capillary loop and traversed by numerous glia-fibres which are for the most part attached to the vessel wall. All these cells are kept in position by the surrounding network of glia-fibres attached to the vessel and are bathed in the lymph exudation from the capillary, there being no distinct lymph channels to the nerve cells or other cells.

According to one author, there is a system of fine channels in the nerve cells themselves through which the lymph passes.

The lymph having bathed the cells, etc., of the intervascular space passes into the adventitial channel or space of the vessels and travels along it towards the surface of the brain and ultimately passing into the perivascular spaces of the pial vessels.

In all probability there is a free exudation of lymph directly out of the intervascular spaces near the surface of the brain into the meshes of the pia arachnoid.

This adventitial channel is distended and often blocked with cells and debris in general paralysis and in cases where there has been localised areas of softening and destruction of brain substance, the adjacent adventitial channels around the capillaries are enormously distended with debris and cells. Fig.6.

The lymph leaves the brain substance by

(1). Adventitial channels of the capillaries and is poured into the arachnoid spaces and subdural space.

(2). or, direct from the intervascular spaces of the the first layer of the cortex into the arachnoid spaces.

From the arachnoid spaces, it returns to the systemic circulation

(1). Pacchionian bodies into the para-sinoidal spaces.

(2). By the sheaths of the pial veins which enter the superior longitudinal sinus and sinoidal spaces.

and from the subdural space

(1). Probably by the Pacchionian bodies to a small extent.

(2). By the perivascular canals of the dura. (see later).

(3). By the sheaths of the cranial nerves.

B. THE ARRANGEMENT AND STRUCTURE OF THE LYMPH CHANNELS & VESSELS OF THE DURA.

Until quite recently little or no attention has been paid to the structure and functions of the dura and it is only in the last two or three years that pathological changes in the dura have been studied at all.

In the ordinary English text-books there is very little to be found about the arrangements of the vessels and lymph channels and practically nothing about the functions of the dura except in so far as it acts as a periosteum to the inner surface of the calvarium.

The descriptions as a rule are limited to a few statements that there are two layers of fibres running more or less at right angles to one another, lined on the inner surface by an endothelial membrane and by a similar membrane on the outer surface in places.

Obersteiner however mentions that there are two layers of fibres,

(a) Visceral; (b) Parietal.

There is tessilated epithelium on both sides of the dura and the big blood vessels lie towards the parietal surface.

There is a space on each side of the arteries with numerous irregular branches which are connected with one another so as to form a network. These channels

(a) Can be injected from the Blood Vessels;

(b) Contain red blood corpuscles;

(c) Are not to be regarded as veins, as no blood normally circulates in them.

If they were filled with blood, the dura of a living animal would be a dark violet colour. They are supposed to communicate with the subdural space and to open into the blood vascular system.

The other views are - that the arteries of the dura cover veins, whose edges are perceived on each side of the artery, as suggested by Winslow - and a capillary system consisting of two sets of capillaries (a) Superficial (External) and (b) Deep (Internal) directly under the epithelium. There are oblique vessels connecting the arteries of the external layer with the inner network and the capillary system intercommunicates and connects with veins. Some of these capillaries unite, forming spaces transverse in direction to the capillaries and receive several on each side. These dip obliquely into the dura and ultimately open into veins. (Paschkiwcz).

The most recent account is by Ford.Robertson, who describes a capillary network under the endothelium in which the capillaries are of large size; they lie in grooves usually parallel to the fibres of the dura and forming a system of perivascular canals.

Methods used:

Various ways were used for examining the dura and the most suitable were:

(a) The dura was stripped from the calvarium in the ordinary manner, by tearing off the calvarium leaving the dura in situ;

(b) After being stripped, the vessels were injected with gelanthum and silver nitrate 10% solution. It was hardened in a mixture of Formalin 10 parts, spirit 90 parts, the object being that the formalin should reduce the silver while the spirit coagulated the gelanthum. It was only partially successful.

(c) The dura and calvarium were removed together so that the dura was still adherent to the bone.

The perivascular spaces on each side of the bigger branches of the meningeal arteries were injected with Indian Ink by means of a hypodermic needle, great care being taken not to open into the vessel itself.

The whole calvarium and dura were then hardened for two days in formalin 10%, after which the dura was stripped off the bone.

Naked Eye Appearances:

If the dura mater is examined carefully by the naked eye directly the calvarium has been torn off

in the usual manner, the bigger arteries will be seen lying on the outer surface and on each side is a clear space or canal; this canal is termed the Perivascular Canal. It follows closely the wall of the artery giving off accompanying canals to any branches of the main artery and also gives off independent canals, seen as clear spaces in the dural membrane, which form a network anastomosing with any adjacent canals. As a rule these spaces are clear and do not contain any visible matter, but in cases where death has been caused by, or accompanied by considerable cerebral congestion, they will be found to contain a small quantity of blood. These canals can be seen to follow the arteries from the foramen of entrance at the base to the vertex but when about one inch from the superior longitudinal sinus, they can sometimes be seen to leave the vessel and run as a wide independent channel into the upper wall of the sinus.

Relatively to the size of the artery, the canals are much bigger at the vertex than at the base, and when they leave the vessel near the vertex they communicate by lateral branches with many smaller canals in the neighbourhood, so as to form a close network. The above is best seen if

the perivascular canals have been injected with Indian Ink with the dura adherent to the bone and then hardened.

The appearances presented are very striking, the vessel is seen full of blood with the canal on each side and the independent network of canals filled with black ink.

I was never able to get the perivascular canal filled with injection by injecting the vessel or vice versa.

Inner Surface:

In a normal dura there is nothing to be seen naked eye on the inner surface, but if there has been cerebral hyperaemia ante mortem the endothelium is covered with fine parallel red lines usually running parallel to the long axis of the head and giving off small connecting branches. When the perivascular canals of the larger arteries were injected with ink some very interesting facts were obtained. A hypodermic needle was pushed into the dura, left adherent to the base of the skull, in the opposite direction to the blood flow, i.e. towards the base, and the perivascular space was injected. The ink flowed readily along the canal, spreading into all the branches, and dis-

tributing itself in channels on each side of the main perivascular canal so as to form a network of thin black lines mostly parallel to one another and at an angle to the main space: also entering the perivascular spaces of adjacent arteries. As the pressure increased a series of very fine parallel black lines appeared directly under the endothelium and then minute drops of ink oozed out of points on the inner surface of the endothelium; these were wiped away, but appeared again as the pressure continued.

This showed direct communication between the main perivascular canals and a system of finer spaces on the endothelium probably opening to the subdural space.

The ink could also be seen running into the cavernous sinus and appearing there and in the superior petrosal sinus.

After partially hardening the dura in situ it was removed and ink was found in the prolongation into the foramen ovale, but not accompanying the middle meningeal or into the foramen spinosum.

The canals were also injected towards the vertex with the dura adherent to the bone. The ink flowed as above forming a similar network, the

red blood in the vessel showing well between the two black lines on either side. The same appearances were seen here as before, e.g. fine parallel black lines under the endothelium and small drops of ink oozing out. Ultimately the superior longitudinal sinus became full of ink which escaped by entering the pial veins, which had been left attached to the sides of the sinus.

In the calvarium itself it appeared as if the injection had followed the capillaries into the bone, but no minute examination was made.

Microscopic Structure:

No attempt is being made in the following to describe the structure of the dura, except as regards the arrangement and structure of the Perivascular Canals and Vessels. For the purposes of description I have adhered to the usual accepted arrangement of fibres of the dura, viz. two layers running obliquely to one another and forming an inner and outer layer. The inner layer is lined internally by a membrane consisting of endothelial cells with large nuclei and in parts there is a similar lining to the outer surface, where it is not adherent to the bone.

Methods:

The methods used in the examination of the dura that were of special note were,

All the tissues were hardened in 10% formalin for two days or more.

In the case where the vessels were injected with Gelanthum with 10% silver nitrate solution, a mixture of spirit and formalin was used in the proportion of 10 parts of formalin to 90 parts of spirit, in order that the spirit should harden the gelanthum while the formalin reduced the silver nitrate. This was only partially successful, giving a dark brown stain throughout the vessels and capillaries.

All the sections were cut by the Swift Freezing Microtome.

In order to get good views of the actual arrangement it is necessary to cut sections in various planes.

(a) Horizontal Sections: Got by preparing a flat surface of frozen dextrin as described by Ford Robertson for surface sections and then freezing the piece of dura on to the flat surface.

(b) Surface Sections:

(c) Oblique Sections: The freezing plate was covered with dextrin and frozen. When hard the surface was pared obliquely with a plane or razor, so

that a smooth sloping surface was obtained which was higher on the side removed from the operator than on the near side. This enabled one to get fair sized sections showing sufficient of all the various layers of the dura at the same time, to enable a thorough study of the spaces and vessels to be made.

(d) Stripped Sections: These were made to enable one to study fully the appearances of the vessels on the surface of the endothelium and were prepared, viz.

Fold a piece of dura over the finger with the inner surface outwards - cut the surface lightly with a knife - teaze up the free edge thus formed with a small pair of forceps and carefully strip off as much endothelium as possible.

With a little practice it is quite easy to strip off fair sized pieces containing little else but the endothelium and blood vessels attached.

The stains used were chiefly haematoxylin, counterstained by eosin and then mounted in Xyol and Xyol Balsam.

Microscopic Structure:

The bigger arteries in the dura are similar in structure to any other arteries, except that the adventitia is very thick and has fibres of the dura

running parallel to the vessel.

On each side of the vessel lies a channel, called the perivascular canal, which follows the line of the vessel but does not follow closely any small bend or turn the vessel may have.

These spaces are lined by endothelial cells lying directly on the dural fibres, so as to form a fine membrane enclosing a space, (see Fig 1.) and there is no appearance of any wall proper other than endothelial cells.

These canals are crossed by branches of the main artery, which often carry prolongations from the canal with them on each side. As they cross the space or canal, the arterial branches appear to lie in it and do not cross over the canal as they would if it were a vein; sometimes the vessel may pass directly into fibrous tissue on the other side of the space without any accompanying canal and then acquire a perivascular canal from some adjacent one.

In size and number these perivascular canals are bigger and more numerous than the vessels. Usually there are two - one on each side of the artery, each of which is much wider and forms a network of numerous branches communicating with adjacent spaces independently of vessels. Fig. I. For the most part these spaces are empty, but may be found to contain red blood corpuscles in small amount. They can

readily be injected with any fluid medium by means of a hypodermic syringe. The needle being stuck into the canal on one side of any of the bigger arteries. The injection (Indian Ink) is confined to the spaces and enters their branches, but does not enter any artery or vein. (Fig 8) A. shows a complete system of spaces, in places independent of vessels, which branch and communicate with one another in a very free network.

Tracing the arteries and spaces inwards towards the endothelium, it is seen that they branch and break up in the usual manner until they reach the space between outer and inner layer when the artery turns at right angles to its original course and runs between the layers of the dura, giving off another set of finer branches parallel to the original direction. (see figs. 2, 5, 6)

For the present we shall describe the arrangement of the arteries briefly, returning to the perivascular spaces later.

Arteries:

From the arterial branches lying between the two layers of the dura, branches are given off at at right angles which run parallel to one another

between the fibres of the dura and are either small arterioles or large capillaries in structure. They form a complete system, but do not anastomose much except at the end next the endothelium, where they break up into fine capillaries. Structurally they present similar appearances to similar vessels elsewhere in the body, being composed of an intima formed of endothelial cells and a varying amount of adventitia only present in the bigger vessels. (Fig.3)

These straight vessels are very numerous in the inner layer and are not found elsewhere. They run in straight lines obliquely downwards to reach the endothelium and may be called the straight vessels of the inner layer.

When they reach the dural surface of the endothelium, they again break up to form a network of very fine capillaries lying in a loose connective tissue on the outer surface of the endothelium, in intimate relationship to it. The manner in which the straight vessels of the inner layer distribute themselves is similar to the above - branches being given off more or less at right angles to form a very complete capillary plexus on the surface of the endothelium.

This capillary plexus is very regular and is formed by numerous capillaries - relatively large in

size - with walls consisting of large endothelial cells with pale oval nuclei.

They are very well seen in stripped sections which often shew a small arteriole of the inner layer breaking up into capillaries which unite again to form a vein (fig.4)

The veins follow the capillaries of the inner layer closely, either running alongside them or parallel to them between the fibres of the dura. They unite into bigger trunks at right angles to their course in a similar manner to the arteries and then seem to have a separate course of their own between the two layers of the dura.

The Perivascular Canals:

A system of canals alongside the bigger arteries and forming a network between them, has already been described, but it is convenient now to begin at the capillary layer and trace these canals outwards to the bigger vessels. On close examination of the capillaries just described, it is quite easy to see a clear space on each side of a capillary lined by a single layer of flattened endothelial cells which run parallel to the capillary wall (Figs. 4 & 4a).

These spaces are seen around the smallest capillaries, lying directly on the endothelium and com-

municate with the subdural space, but whether by means of stomata or not, could not be ascertained. At any rate there is not more than a single layer of cells between the space and the subdural space through which diffusion of fluids could readily take place. In some cases the space may not be actually visible, but one can usually distinguish a line of extra nuclei closely apposed to the wall of the capillary, representing an empty or flattened perivascular space. *Fig. 7.*

The sheath of the capillaries of the endothelium is continued on to the capillaries of the inner layer and follows them throughout their whole length often enclosing both the arteriole and venule in a common sheath, but other arrangements are sometimes found.

(a) The perivascular space may lie at the side of an arteriole, Fig. *13*

(b) The perivascular space may enclose either arteriole or venule separately.

(c) The spaces may be distinct and separate without having any vessel in close proximity.

These spaces are formed by a single layer of endothelial cells following the vessel wall either lying close against the vessel or being separated by a clear space usually enclosing a venule and

arteriole in a common space or else showing any of the other arrangements mentioned above. Fig. 2

When the canals reach the junction of the inner and outer layers, they open into large spaces placed at right angles which receive often two or more smaller canals from either side. Figs. 8.16.

These bigger spaces are in many cases close to or surrounding the bigger arterioles, whose arrangment has been described, but they may also be quite independent of any vessel.

Canals are given off from these spaces to accompany the straight capillaries of the inner layer and also independent systems of straight canals running parallel to and between the capillaries of the inner layer. Branches are also given off to follow the arteriole in the outer layer as well as separate canal to communicate with the perivascular network around the more superficial arteries. Fig. 1.

Indian Ink injected into the perivascular canals of the larger vessels gives a beautiful view of all the small canals. The spaces between the two layers are distended with ink and branching off them are the smaller canals running parallel to the capillaries or around them. In some places the ink lies at one side of the vessel and then

crosses over it so as to partly cover it; in others, the vessel is seen surrounded by ink. Fig. 9.10.11.13.

The capillaries of the inner layer are surrounded and covered by the injection, the red blood corpuscles being seen through the gaps in the injection, showing that the vessel itself does not contain the ink, but that it lies in the perivascular sheath outside the vessel.

In the fine capillaries of the endothelium the black granules lie inside the nuclei of the perivascular sheath, but cover the nuclei of the vessel wall and in many places, the vessel is still full of red blood corpuscles which show through the gaps in the injection mass. Fig. 10.11.12.

THE VEINS.

The veins were described as following the arterioles and capillaries of the inner layer and then usually following a separate path.

They run between the two layers and have a separate and distinct perivascular sheath from which they are separated by a clear space. As the walls of the veins are very thin and consist only of a layer of cell and nuclei, it is not easy to distinguish them from perivascular canals, but they are usually full of red blood corpuscles and leucocytes and lie inside a perivascular canal. Fig. 14. 15.

MORBID APPEARANCES.

The morbid appearances of the perivascular system have not been especially studied except in so far as they have a bearing on the function and arrangement of the spaces.

It is interesting to note that in cases where there has been recent false membrane formation on the inner surface of the dura - as is found in large numbers of the insane - the perivascular spaces show several distinct changes. The canals in the inner layer especially towards the endothelial surface, are enormously dilated and are filled with leucocytes, large multinucleated cells similar to those seen in the false membrane formation, cells with deeply staining nuclei in a state of subdivision and large quantities of broken down red blood corpuscles with occasional granules of haematoidin. These cells are found blocking the canals and can be traced outwards towards the spaces surrounding large vessels. The perivascular canals of the large vessels on the outer surface are also dilated, but not so markedly as the smaller ones and are full of multinucleated cells of all kinds, leucocytes and red blood corpuscles. Fig. 17. 18. 16.

In many cases of Senile Insanity, especially if there has been a history of syphilis, the perivascular canals are found blocked with proliferated endothelial cells from the walls. These cells proliferate and form masses resembling cell nests which occlude the lymph channel and press on the adjacent vessels so as to interfere with their function, and may close them altogether. Fig.19, 20.

The effect is to cause damming up of the lymph stream, dilatation of the space behind the block, and the collection in this dilated space of large numbers of leucocytes and nucleated cells.

The proliferated endothelial cells are seen in the minute lymph channels of the inner layer, which may be entirely blocked, but they are not seen in the lumen of either arteries or veins.

Communication with Sinuses.

The perivascular canals of the main vessels communicate with the sinuses directly as has been shown by Indian Ink finding its way into the superior longitudinal sinus; the cavernous sinus and petrosal sinus, when injected in the perivascular canals of the larger arteries.

The canals themselves can also be seen with the naked eye, leaving the vessels and running into the wall of the superior longitudinal sinus and communicating with a system of smaller canals which also open either into the sinus or more probably into the parasinoidal space.

The exact method of communicating with the sinus is by means of canals in the wall of the sinus opening into the parasinoidal spaces. These canals are seen filled with ink in suitable injection and in cases where there has been much proliferation of endothelial cells in the other perivascular canals. These are often blocked with endothelial cells and can be traced in this way right through the wall of the sinus, into the sinoidal spaces. They are seen often full of blood corpuscles lying both inside the canal and in the looser fibres of the dura around the canal.
Fig. 21. 22.

There is no communication from the dura with the pacchonian bodies opening into the parasinoidal spaces. These bodies only communicating with the pia arachnoid and subdural spaces.

Pacchonian Bodies.

These bodies are projections of pia arachnoid which have pierced one layer of the dura and lie between the layers of the dura, at one side of the longitudinal sinus in the parasincidal space. They communicate directly with the subdural and sub-arachnoid spaces and serve as a channel by which fluid can pass out of these spaces directly into the sinoidal spaces and thence into the venous blood stream.

The Periosteal Vessels.

Besides the vascular arrangements described above, the dura supplies the bone with a large number of fine blood vessels.

These pierce the inner table, ramifying there and in the diploe and are all supplied with peri-vascular canals. In surface sections of dura, taken from the outer surface directly subjacent to the bone; there are no evidences of any distinct venous channels for the return of blood to the dura.

It is probable therefore that the venous blood returns to the heart by the diploic veins of which there is a large system opening for the most part into the facial, deep, temporal, and occipital veins. The lymph in the perivascular canals of these vessels may also escape through the diploe.

The conclusions arrived at with regard to the dura mater are:-

(a) That there is a fine, very complex and free system of lymphatic canals termed perivascular canals, closely associated with the vessels and communicating freely with the subdural space probably by means of small openings in the endothelium.

(c) That the perivascular canals of the meningeal arteries do not accompany them through the foramina, but communicate with neighbouring sinuses.

(d) That the perivascular canals may communicate with the extra cranial lymph systems through the sheaths of nerves.

(e) That these canals contain both lymph and blood in small amounts.

(f) That there is a stream flowing through them towards the sinuses which will carry with it exudation products from the inner surface of the dura.
There is thus a free and easy means of exit for lymph from the subdural spaces direct into the venous circulation.

(g) That there is communication with the veins of the face through the diploic veins and that probably lymph can find its way out of the cranial cavity ~~of~~ by similar paths.

The presence of a free lymph system in the brain substance and in the meninges is especially of interest with regard to its bearing on diseases of the brain and the insanities; also in relation to the question as to whether the cranium is to be considered as a practically closed box or not.

It is well known that in many insanities there is dilatation of the inter-adventitial lymph spaces which are filled with cells and debris often blocking the lymph flow and thus causing a lymph stasis around the nerve cells producing still further degenerative changes.

There is also blocking of the lymph channels (perivascular canals) of the dura which still further tends to increase the lymph stasis inside the cerebrum.

As regards the possibility and effects of hyperaemia of the brain, the presence of a free lymphatic system also has an important bearing.

The cranium being to all intents and purposes a closed box filled with fluid or semifluid contents, it is quite reasonable to expect that when hyperaemia (functional or otherwise) occurs, the cranial contents being practically incompressible, room must be made for the extra blood by means of some fluid being expressed into an extra cranial system.

The simplest explanation of what occurs seems to be this:- The blood vessels dilate and the first effect of the dilatation will be to press on the adventitial spaces and them them. This will cause an increased flow of lymph into the sub-arachnoid and pial spaces and also into the subdural space. This excess of lymph here will rapidly be removed and poured into the main venous system by the pacchonian bodies and by the perivascular canals and network of the dura mater, the pacchonian bodies removing the lymph from the sub-pial and arachnoid spaces while the perivascular system removes the lymph from the subdural space. In this way a hyperaemia of the brain may occur without actual increase in pressure in the cranial contents. The effects of any process which causes blocking of the lymph channels, can also readily be seen. A lymph stasis will be caused around the nerve cells which will cause auto-intoxication and poisoning of them, leading to total destruction and disintegration. The debris of these cells when disintegrated will be carried off and still further block the lymph channel and increase the morbid changes.

DESCRIPTION OF PLATES.

SERIES B.

1. Dura, stained by Haematoxylin and Eosin, Low Power.

Two arteries in transverse section, showing perivascular spaces lined by endothelial cells intercommunicating and giving off branches to other spaces.

The spaces contain red blood corpuscles in small number. Note small branch crossing the space.

Slide

2. Dura, oblique section, Haematoxylin & Eosin, Low Power.

An arteriole accompanied by two veins lying in a perivascular space. Branches are given off at right angles which again give off big capillaries running parallel to one another and communicating freely.

Venous capillaries are also seen containing blood in small amount

Slide 2.

3. Dura, Haematoxylin & Eosin, Low Power.
To show the straight vessels of the Inner layer running parallel to one another.

Slide 3.

4. Dura, Stripped section. Haematoxylin & Eosin, High Power.

Shows a capillary loop on the endothelium.
Note: Cells showing the perivascular canal around the capillary.

Slide 4.

4a. Dura, Stripped Section. Haematoxylin & Eosin, High Power.
Shows above as in 4.
Note arteriole with perivascular sheath.

Slide 5.

5. Dura, Stripped section, Haematoxylin & Eosin, High Power.
Artery and vein from inner layer, breaking up into capillaries and showing the arrangement of perivascular spaces.

Slide 6

6. Dura, Oblique section, Sinus, injected with Gelanthum and Silver, High Power.
Capillary of inner layer coming off a bigger branch surrounded by cells of the perivascular sheath.

Slide 7 F

7. Dura, Horizontal section, Haematoxylin & Eosin, High power.
A small vessel showing the perivascular space represented by dark stained nuclei.

Slide 8 F

8. Dura, Horizontal section. Haematoxylin & Eosin with Indian Ink injection, Low Power.
Perivascular spaces filled with ink.

Slide 9 F

9. Dura, Horizontal section, Haematoxylin & Eosin, with Indian Ink injection, High Power.
Injected perivascular space filled with Indian Ink lying alongside a capillary vessel.

Slide 9 F

10. Dura, Horizontal section. Haematoxylin & Eosin, with injected lymphatics, High power.
Note the capillary with ink in the sheath, the vessel still being full of red corpuscles.

Slide 10 F

11. Dura, Oblique Section. Haematoxylin & Eosin, with injected lymphatics.
Note parallel capillaries showing the perivascular space filled with ink.

Slide 11

12. Dura, Oblique Section. Haematoxylin & Eosin, Injected capillaries, High Power.
Note capillary with masses of Ink in the sheath.

Slide 10

13. Dura, Oblique Section. Haematoxylin & Eosin, with injected capillaries, High Power.
Note arteriole and branch, with adjacent Perivascular space and canal.

Slide 9 f

14. Dura, Oblique Section. Haematoxylin & Eosin, High Power.
Shows a vein with a perivascular canal on each side of adjacent arteriols.

Slide 8 F

15. Dura, Stripped Section. Haematoxylin & Eosin. High Power.
Shows a vein near the endothelium lying in a perivascular canal.

Slide 12 †

16. Dura, Oblique Section. Haematoxylin & Eosin. Low Power.
Shows perivascular canals dilated and filled with leucocytes, red blood corpuscles and debris from a subdural membrane.
Note canals opening into others at right angles.

Slide 13 †

17. Dura, Oblique Section at side of subdural false membrane. Haematoxylin & Eosin. High Power.
Shows a large artery with perivascular space, which is filled with leucocytes Multinucleated cells. Red corpuscles and debris brought from the subdural false membrane.

Slide 13 ‡

18. Dura, Oblique Section at side of subdural false membrane. Haematoxylin & Eosin. High Power.
Shows several perivascular canals near the endothelium dilated and filled with cells, which have been carried in from the false membrane.

Slide 14 †

19. Dura, Oblique Section. Haematoxylin & Eosin High Power.
Note arteriole with perivascular space. Vein on one side which has been obliterated by proliferated endothelial cells from the perivascular canal.

Slide 2 ‡

20. Dura, Oblique Section. Vessels injected with silver and gelanthum. Haematoxylin & Eosin. Medium Power.
Shows arteriole with space on either side which is blocked by proliferated endothelial cells, distended and filled with leucocytes, debris, etc.

Slide 14 +

21. Transverse Section of superior longitudinal sinus with injected and lymphatic spaces. Haematoxylin & Eosin. High Power.
Shows a part of the wall of the sinus with spaces filled with ink which had been injected into the perivascular space of a larger artery. In the fibres of the dura are many leucocytes and cells.

Slide 15. +

22. Transverse Section of the Superior longitudinal sinus in a case of General Paralysis. Haematoxylin & Eosin. High Power.
Shows a canal blocked at one end by proliferated endothelial cells, as seen in the other parts of the dura. Cells are arranged as cell nests.

Slide 16. +

SERIES A.

1. Brain of sheep. Platinum method. High Power. To show normal vessel with the fibres of sheath stained black. No distention.

Slide 17. +

2. Brain of cat. Pia adherent. Platinum method. High Power.
Shows vessel entering cortex from pia, taking with it a sheath of connective tissue fibres stained black.

Slide 18 +

3. Pons of sheep. Platinum Method. High Power.
Shows two large cells with adjacent vessels showing black fibres on their wall.
Note - no fibres going to cell and no trace of any envelope to cell.

Slide 19 +

4. Pons of dog. Platinum Method.
Show ditto.

Slide 20 +

5. Cortex of brain. Case of G. P. Platinum Method. High Power.
Shows vessels with the adventitial space distended with corpuscles and much thickened.

Slide 21 +

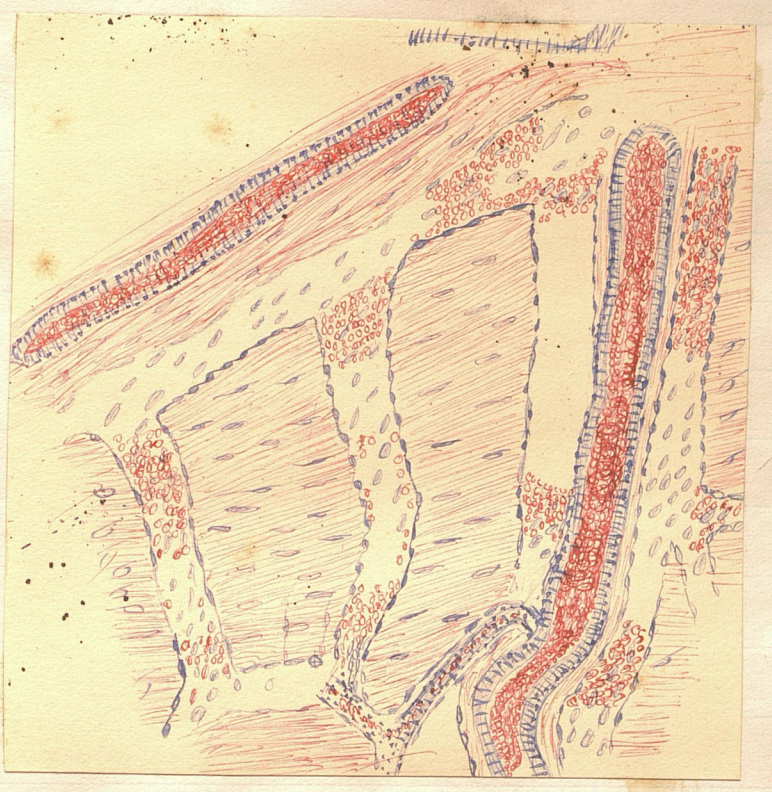
6. Cortex of brain, from near a small area of softening. Platinum Method. High Power.
Note distention of adventitial space with corpuscles and debris.

Slide 22. +

7. Cortex of brain of cat. Formalin hardened directly after death. Stained by the Methyl Violet Method. High Power.
Note - Glia fibres attached to the wall of the artery. White matter of brain surrounds the vessels closely.

Slide 23. +

Series. B.



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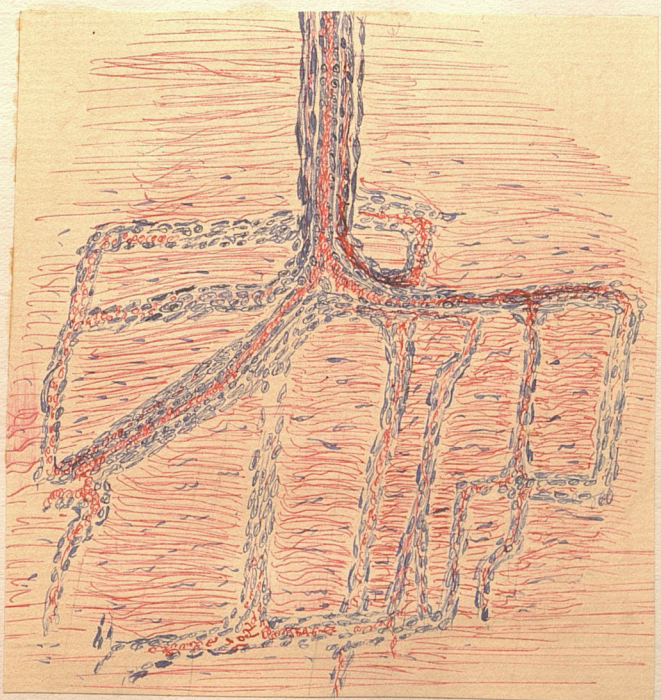

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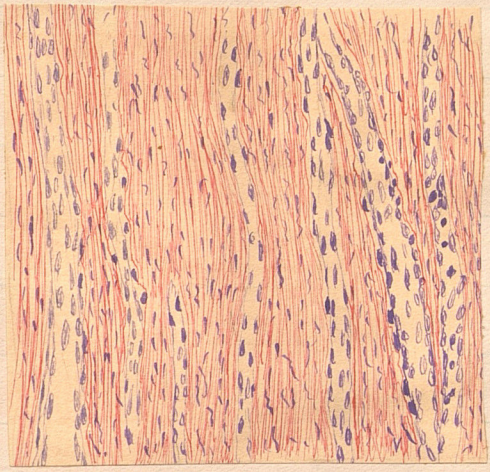

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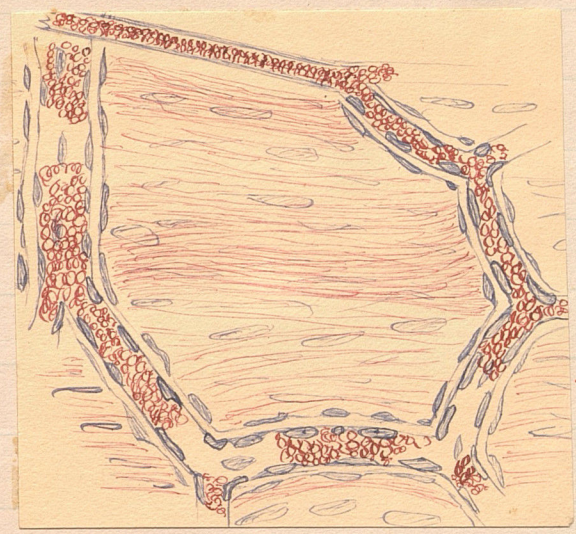

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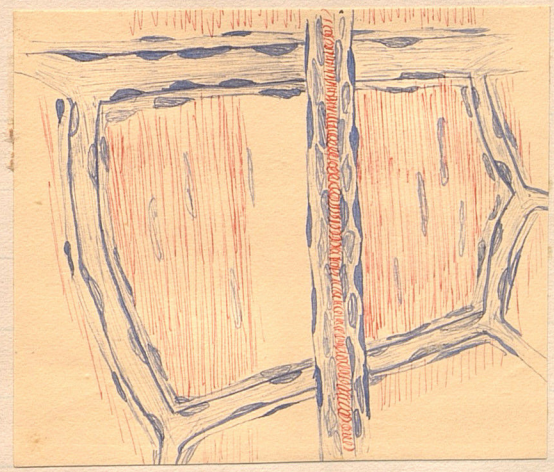

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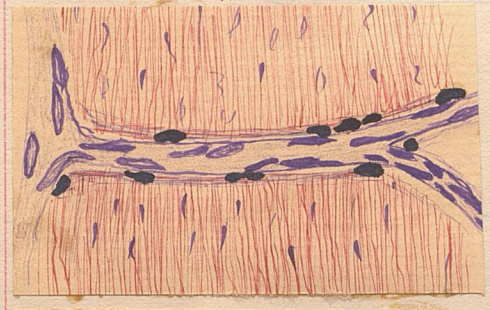

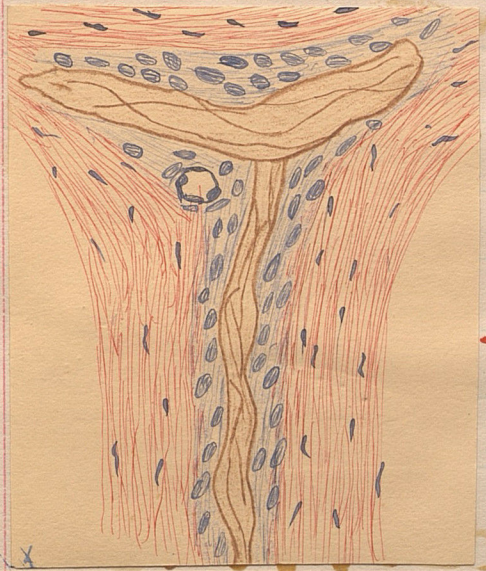

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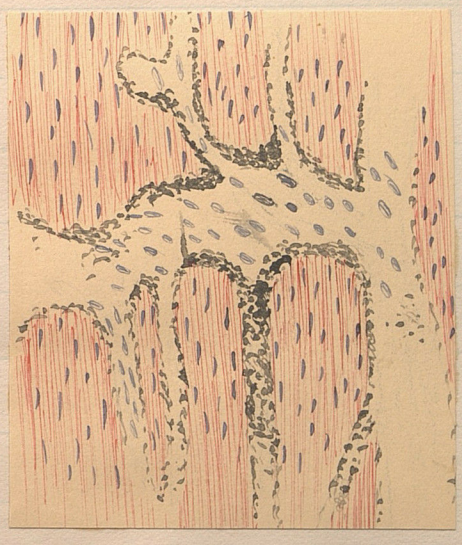

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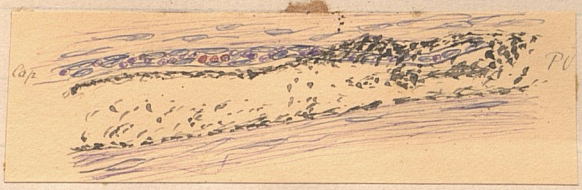

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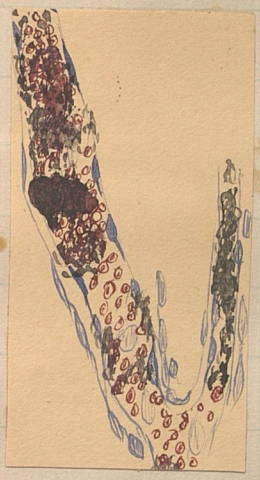

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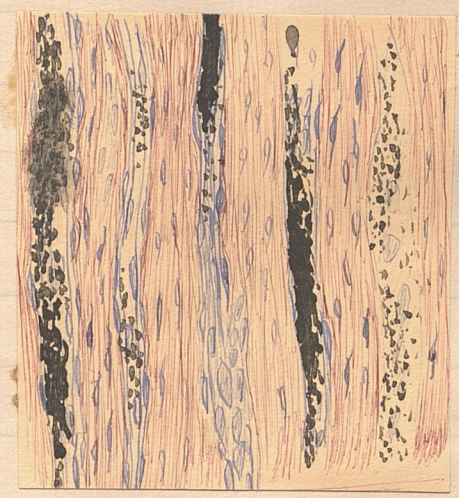

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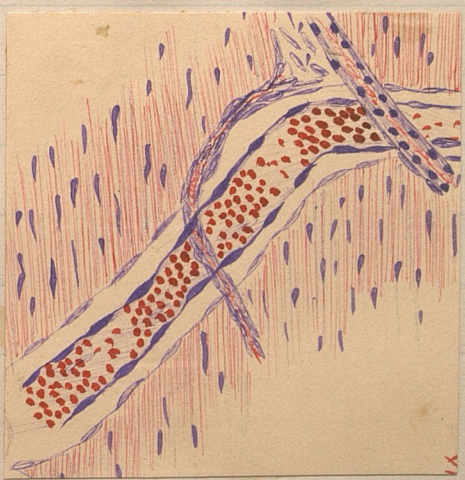

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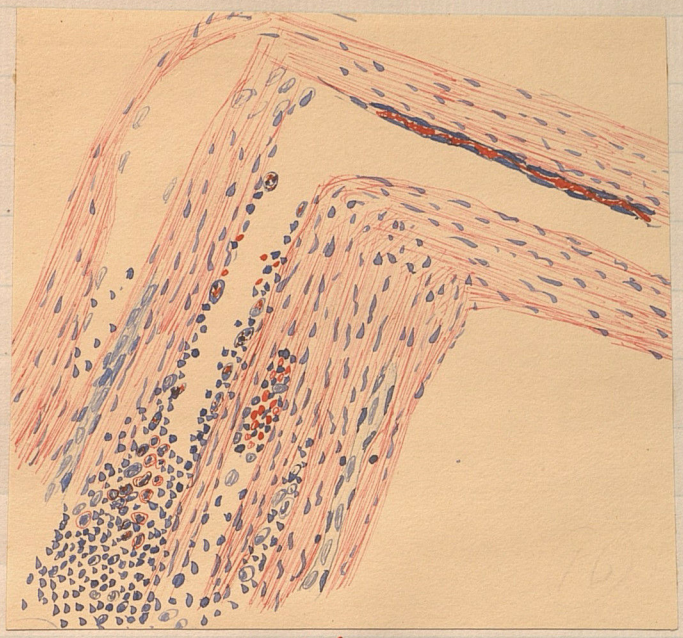

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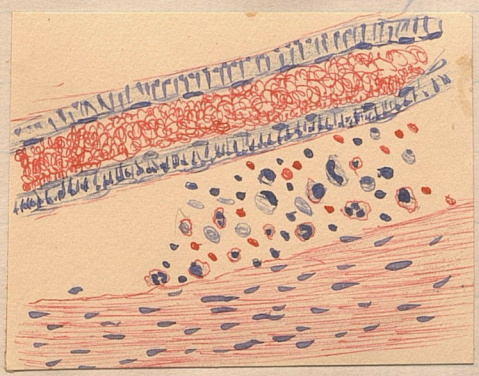

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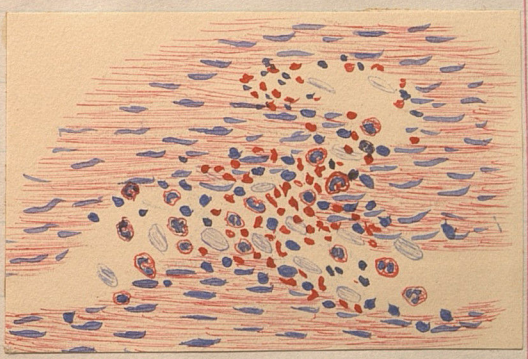

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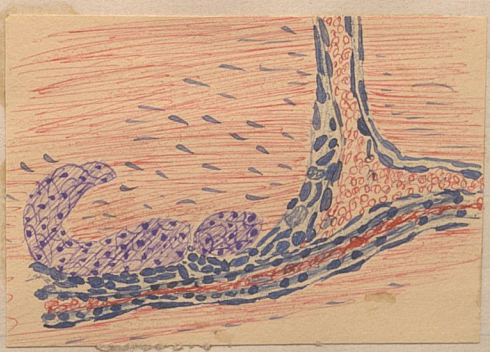

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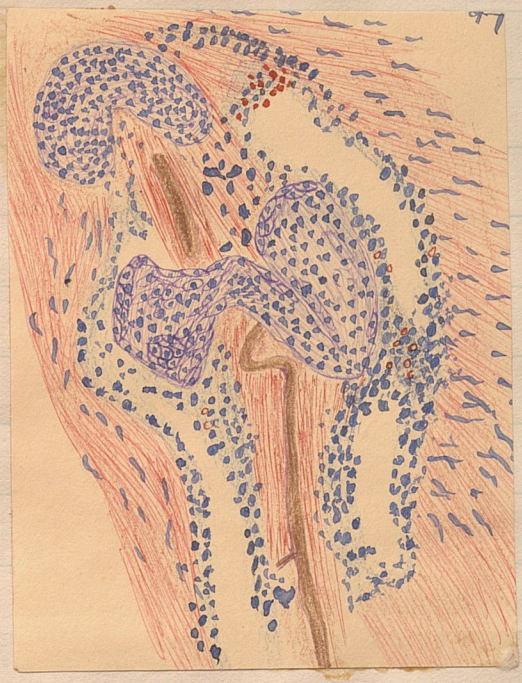

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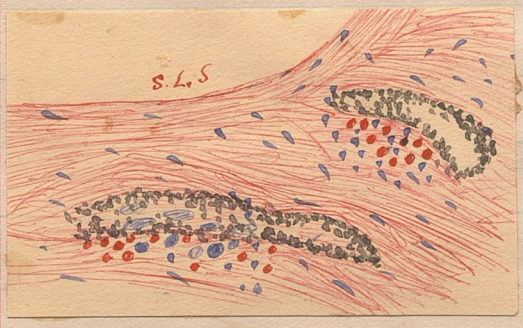

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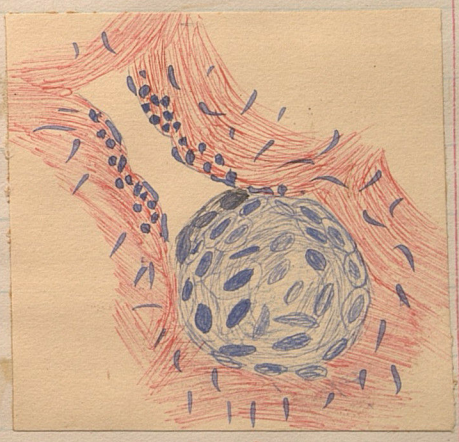

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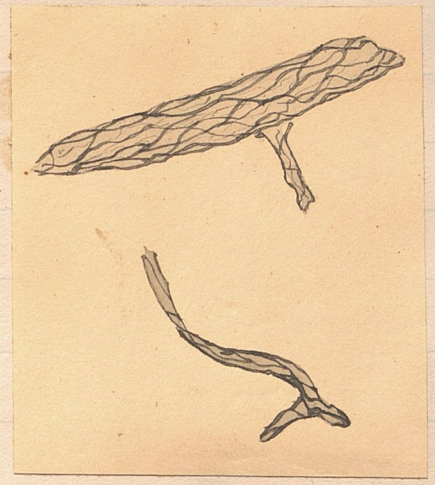
Series. A.



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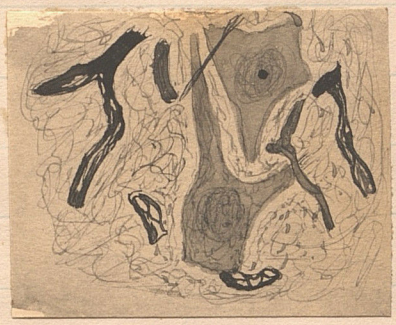

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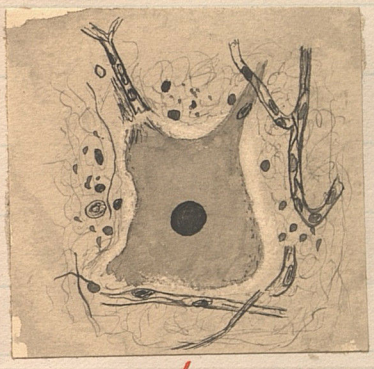

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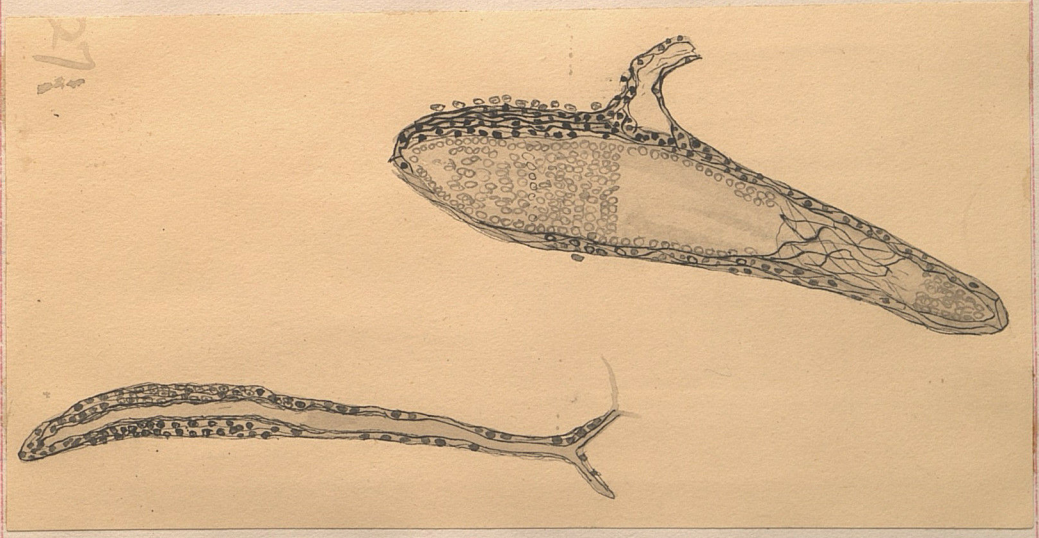

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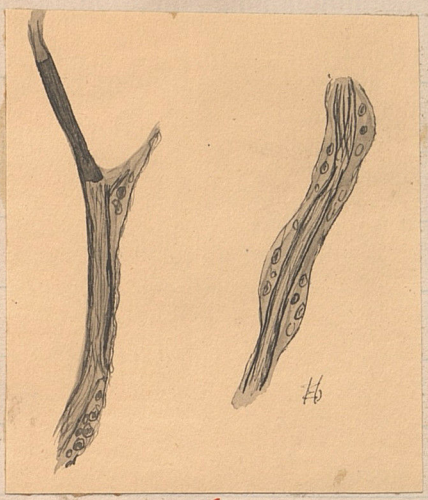

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