1842

Memoir on the Synapte of Duvernoy (Synapta Duvernæa A. de Q.): A translation of *de Quatrefages, A. 1842. Mémoire sur la Synapte de Duvernoy (Synapta Duvernæa A. de Q.)*

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ANNALES
DES
SCIENCES NATURELLES

COMPRENANT

LA ZOOLOGIE, LA BOTANIQUE,
L'ANATOMIE ET LA PHYSIOLOGIE COMPARÉES DES DEUX RÈGNES,
ET L'HISTOIRE DES CORPS ORGANISÉS FOSSILES;

RÉDIGÉES

POUR LA ZOOLOGIE

PAR M. MILNE EDWARDS

ET POUR LA BOTANIQUE

PAR MM. BRONGNIART ET GUILLEMIN.

Seconde Série.

TOME DIX-SEPTIÈME. — ZOOLOGIE.

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Memoir on the Synapte of Duvernoy (Synapta Duvernæa A. de. Q.). A translation of *de Quatrefages, A. 1842. Mémoire sur la Synapte de Duvernoy (Synapta Duvernæa A. de Q.), Annales des sciences naturelles. Zoology. Ser. 2. Vol. 17. Pp. 19–93.* (J. M. Lawrence, Trans.).

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Jean Louis Armand de Quatrefages de Bréau (10 February 1810 – 12 January 1892) was born at Berthézène, in the commune of Valleraugue (Gard), the son of a Protestant farmer. He studied science and then medicine at the University of Strasbourg, where he took the degrees of M.D. and D.Sc. He was a student of Duvernoy. He was professor of natural history at the Lycée Napoléon in 1850. In 1852, he became a member of the French Academy of Sciences. In 1855 he was appointed to the chair of anthropology and ethnography at the Museum National d'Histoire Naturelle. He was an honorary member of the Royal Society of London (June 1879), member of the Institute and of the Académie de médecine, and commander of the Legion of Honor (1881).

Jean Louis Armand de Quatrefages de Bréau

Georges Louis Duvernoy (6 August 1777 – 1 March 1855)

He studied in Stuttgart, Strasbourg, and Paris.

In 1805, Duvernoy went to Montbéliard, where he worked as a practitioner of medicine. In 1827 he was elected professor to the Faculty of Sciences at Strasbourg, and during the next ten years published a number of treatises on anatomical subjects. In 1837 he became a professor of natural history at the Collège de France.

He was elected a member of the French Academy of Sciences in 1847 and a foreign member of the Royal Swedish Academy of Sciences in 1851.

Georges Louis Duvernoy

Translator's notes:

According to WoRMS (accessed 2 April 2021) *Synapta duvernaea* Quatrefages, 1842 is unaccepted because of synonymy with *Holothuria inhaerens* O. F. Müller, 1776. It was placed into the genus *Leptosynapta*, 1867, created by Verrill, 1867. The accepted name is *Leptosynapta inhaerens* (O.F. Müller, 1776).

de Quatrefages refers to the *Synapta* of Besel. This is *Synapta Beselii* Jæger. According to WoRMS (accessed 3 April 2021) this is unaccepted. The accepted name is *Synapta maculata* (Chamisso & Eysenhardt, 1821).

In measurements of length, de Quatrefages uses “pouce”, “thumb”, which is an inch, and “lignes”, which is 0.09 inches. I have translated lignes literally as lines.

I have not changed common or obsolete taxonomic names.

I have not changed errors or typos. E.g., there are two plate captions numbered sequentially “3”. The second one should be “4”. In the caption to Plate 5, there is no fig. 2. But two fig. 3's. The first one should be “2”.

de Quatrefages used “laudanum of Rousseau” as a tranquilizer. This is a fermented aqueous solution of opium, to which is added very weak alcohol: seven drops contain about one grain of opium.

de Quatrefages called one of the organs he described “ventouses”. Ventouse is translated as sucker. The organ de Quatrefages described is the ciliated urn (J.-P. Féral, pers. comm.). Cuénot (1948, p. 98) called them “urns”. Hyman (1955, p. 145) called them “ciliated urns” or “funnels”. de Quatrefages referred to the “suçoirs ou pied” (i.e., suckers or foot) of holothurians. de Quatrefages apparently called the organs in the synaptid suckers because he refers to the role of the tentacles in locomotion and thought these organs were responsible, like the tube feet of holothurians. I have called them ciliated urns.

de Quatrefages quotes Eschscholtz who compared the attachment of the anchors of *Synapta* to attachment of burdock heads to foreign bodies. Burdock is a herbaceous plant that produces woody burrs with bristles that attach to animals' coats for seed dispersal. He called the ossicle to which the anchor is attached a “bouclier”. I have translated this as “shield” instead of using the term “anchor plate” of Hyman (1955, p. 136).

de Quatrefages refers to “sarcodes”, a term first applied by Félix Dujardin in 1834 to the contents of infusorians. It was then extended by others to apparently homogeneous organic matter of animals. I have retained the term.

The quality of the figures in the plates in the copy of the memoir is poor.

I am grateful to J.-P. Féral for his assistance with difficult parts of the text and Janessa Fletcher for preparing the figures.

- Cuénot, L. 1948. Anatomie, éthologie et systématique des Échinodermes. *Traité de Zoologie*. Vol. XI. (P.-P. Grassé. Ed.) pp. 3–272. Paris.
- Hyman, L. 1955. *The Invertebrata: Echinodermata*. Volume IV. McGraw-Hill Book Company, Inc., New York.

MEMOIR *on the Synapta of Duvernoy* (*Synapta Duvernæa*
A. de Q.),

By A. DE QUATREFAGES.

(Read at the Academy of Sciences, 22 November 1841.)

Linnaeus, in creating the genus *Holothuria*, could easily put there the small number of animals known in his times. But, because of the investigations of the naturalists and especially of voyageurs, the species multiplied soon so that the necessity of subdividing one genus that had become too numerous was not slow to be felt. Oken and Lamarck were the first to introduce new sections. They were imitated by Cuvier, who established six tribes in the genus *Holothuria*, but without given them specific names. de Blainville accepted first five and later six divisions. Jæger separated the genus *Holothuria* into three sub-genera, subdivided into ten tribes, among which were the *Actinectes* (Lesueur) or *Minyas* (Cuvier), which are the *Actinies*. Agassiz, adopting this point of view, kept the *Minyas*, to the number of eleven genera he formed with the *holothuroids*. Finally, Brand, multiplying again the divisions proposed the establishment of seventeen genera, most of which include several sub-genera. The generic sections established by Linnaeus, correspond to those that we can call natural families without multiplying these divisions excessively, and to which we always give the name of genus. We should not be surprised to see grouped around the type recognized by the Swiss naturalist a large number of secondary forms that relate to it more or less closely, but also among which are found those that are considerably separated. This is what happened with the *holothuroids*. Among the approximately one hundred and twenty species described by various authors, there are some separated by fundamental differences from those that, known first, serve as the basis for the establishment of genera. Now, in the various changes that have been made to their classification, most naturalists appear to us to have attached too much importance to the variations of external form and have neglected more important essential characters, those on which the natural relations of beings depend. To give an example, Brant, although coming after important anatomical works, establishes all his great divisions on purely external characters, so that the only two genera that lack a respiratory organ (*Oncinolabes*, *Synapta*) are found far apart from each other and that this character, so remarkable anatomically and physiologically, is subordinated to the resemblance or the dissimilarities of the tube feet. The anatomical and

physiological characters, the only ones that establish the natural relations between the diverse beings that the naturalist is trying to classify are, it is true, often difficult to recognize. Despite the works of Colonna, Bohadsch, Cuvier, Tiedmann, Müller, Delle Chiaje, etc., the history of the holothuroids, even of those that are abundant on our shores, still leave much to be desired. An even greater reason, those of distant species is scarcely known. Among the latter, there are some that appear to separate themselves remarkably from the primitive type by their extremely elongated form, the nature of their integument and especially the absence of any special respiratory organ. This fact, already recognized by Eschscholtz, indicated to him only a considerable organic degradation and it became of interest to make anatomical investigations in favorable circumstances., on one hand, the coexisting organic modification and on the other hand, the relations that these holothuroids can have with the other radiates. In a fairly long visit that I just made on the Chausey Isles and on the coast of the Channel, I have been very happy to be able to do this work, thanks to the discovery that I made of a synaptid that is found in fairly great abundance. This species is new, and I have given it the name *Synapta* of Duvernoy (*Synapta Duvernæ* Nob.), happy to offer this small witness of my recognition of a scholar who was my professor, and who has always treated me as a friend.¹

FIRST PART

DESCRIPTION AND NATURAL HISTORY.

Synapta Duvernæ, corpore molli, vermiformi, hic et illic; moda turgido, modo constricto et transversim plicato; cuti roscola, hyaline, adhærente; vitis quinque fibrosis, opacis, albis, longitudinalibus instructa: ori plano, duodecim tentaculis pinnatifidis, circumdato; ano rotundo, nudo, terminali. — Long. 10–18 pol.

Synapta Duvernoy; soft body, vermiform, having alternatively swellings and constrictions, accompanied by transverse folds; pink skin, transparent, adhering to foreign bodies in the manner of burdock heads, with five whitish, opaque longitudinal bands of a slightly fibrous aspect; mouth flat, surrounded by two pinnatifid tentacles; anus round, naked, terminal. — Length 10–12 inches.

The *Synapta* of Duvernoy placed in fresh water and moving freely, has an elongated body, vermiform, slightly pink in color and a most remarkable transparency. One of its ends has twelve semi-transparent pinnatifid tentacles with five lateral digitations. On the lower half of

¹ We know that the synaptid genus (*Synapta*) was created by Eschscholtz for the holothuroids with a very delicate integument, lacking a respiratory tree, and having the property of adhering to foreign bodies like burdock heads. It was adopted by Jæger and by all the naturalist after him. It is the first of eleven genera proposed by Agassiz. de Blainville made it a sub-genus of his vermiform holothuroids (*Fistulaires*). In the classification of Brandt, it constituted only the second division of H. apodes, those that the author designated by the epithet of *apneumones*. All the species of the genus *Synapta* known to this day have been reported from the Red Sea or the seas of Asia and America. Thus, the presence of one of these animals in our seas constitutes alone an interesting fact of zoological geography. On the other hand, we understand why these radiates, which are deformed considerably by the action of alcohol, still have not been sufficiently studied. Despite the importance of the research. Eschscholtz and Jæger are the only naturalists, to our knowledge, who have attempted to understand their organization. The latter, in his dissertation published in 1833, has represented an open synaptid in order show the absence of a respiratory tree and the arrangements of the ovaries. But it is greatly lacking in details.

the internal surface, we see eight suckers in an elongated cup, retractile and completely hidden in the thickness of the walls of the tentacles. These border a kind of slightly concave plateau, in the center of which is found the buccal opening, folded at its periphery. The other end of the body ends in a round cone. Five white bands narrow, opaque, both fibrous and silky in appearance separate from the tentacular corona and extend the length of the body to the posterior end where they united with an indistinct ring of the same appearance, in the center of which is the anus. The space between these bands is filled by a transparent skin through which we distinguish very well the organs of reproduction in the form of yellowish cords, floating freely in the interior fluid and the digestive tube, going directly from the mouth to the other end of the animal. Some undulations, starting from one end and extending sometimes forward and sometimes in the inverse direction, ceaselessly traverse the body that thus shows alternatively dilations and constrictions with traverse folds. In the latter points, the pink color acquires a much greater intensity and the transparency disappears. When we touch the animal, we see that all the points of the skin attach to the hand like burdock heads and it is sometimes rather difficult to detach them without rupture.

The size of the synaptids varies greatly. The smallest that I have encountered are scarcely eight inches in length by five to six lines in diameter during dilation of the body, but I have found some that were more than double in both directions. The largest individuals, from sixteen to eighteen inches in length, were much deeper in color than the others. Their transparency was less. Among those of eight to ten inches, I have found some whose pink color was rather strongly marked and others in which it was hardly perceptible. The latter especially were marked by an extremely transparency. They looked like cylinders of blown glass, crossed by five ribbons of enamel, and whose interior was so transparent to allow distinguishing the least asperity of granitic sand in the digestive tube.

The Synapta of Duvernoy lives in granitic and slightly muddy sand, placed at a depth so that, at the lowest tides, they remain exposed for least an hour or two. I have never found it in banks that are only exposed at the equinoctial tides. On the other hand, it is missing entirely in sands that have all other favorable circumstances but that usually remain dry for four to five hours. It seems to prefer locations located in a way that the tide arrives there from both sides, probably because the double current brings it a greater abundance of organic detritus that appears to be its food. It is thus that at Chausey, where I discovered it, I have found it in abundance between the point called *le grand épail* and the rocks placed more to the west, in the sand banks that connect the two Romonra near the Enseigne etc. Since then, I have likewise found it at the Ile de Césambre, two leagues from Saint Malo, and especially at the foot of the ramparts of this town, opposite the emergency gate in the vicinity of Grand Bé. I have no doubt that it will be found in a large number of localities when the rather difficult techniques I have employed are used.²

The radiate lives in sand, sometimes very mobile and, despite the admirable delicacy of its tissues, it has no protective tube. The burrow it digs does not have the firmness of the gallery of some annelids, Arenicola for example, in the vicinity of which it lives. This circumstance

²I usually used, in my work, a strong iron pole, ending in the shape of a spatula, that rapidly penetrates the sand, even when mixed with gravel. This instrument was convenient to use as a lever or with its hard steel point, I separated the fragments of rocks between which hide Polinoes, Phyllodoce, and nemerteans. But its use requires a vigorous arm, and it can be replaced in many cases by an ordinary pickaxe, pointed at its end, and with a wooden handle.

has led me to think from the first that it does not live in a permanent place, but that it has rather the vagabond life like *Nephtys* and most errant annelids. I was not slow to see this opinion confirmed. When I placed the synaptids in a container of sea water with a layer of sand at the bottom, it quickly buried itself by using its tentacles. I have never seen it use, to facilitate their work, the singular means *Nephtys Arenicola* etc. use and which Audouin and Milne Edwards were the first to report. We know that the errant annelids that we just named often swallow some of the sand grasped by their proboscis, but our radiates simply push it aside. Those I experimented with crossed the narrow area given them in every direction. I often saw their improvised gallery collapse behind them. They live for a longer time under these conditions than when I kept them in pure water. This is the means I used to take them to Paris where I had the pleasure of showing them to Milne Edwards and Doyère.

The synaptids that I placed into a vessel sometimes remained immobile, the body buried in the sand and their tentacles spread on the surface, a little like *Cribina*, ready like the actinians, to retract at the least contact, at the least disturbance. This latter circumstance explains why I never found them in a similar position. It is probable that walking on the sand was sufficient movement to indicate from quite a distance of the approach of danger. I recognized nevertheless their presence at slight elevations, similar to mole-hills two to three centimeters in diameter below which they are in a vertical position with the head near the surface. In order to collect them it is necessary to give a quick blow with the pickax and thus remove them at once, because, if we miss them they bury quite rapidly by contracting and expelling water that enlarges their body and maintains them, so to say, vertical. Moreover, it is very rare to obtain them intact. Most often, we obtain only a more or less considerable portion for not having buried the ax sufficiently. For the large number of the synaptids that I have collected, I have had only four or five intact. But, although we shall see it later, this circumstance is only slightly inconvenient for the study of this curious animal.

At the moment when we find a synaptid, its digestive tube is nearly always full of sand. It is a truly marvelous spectacle to see this animal of such a frail appearance, whose body has all the transparency and delicateness of our finest gauzes, gorged with an angular granite whose least asperities we can study with a magnifying glass, and whose grains have often a diameter equal to that of the digestive tube that contains them. At the end of some hours of captivity it expels ordinarily some of these singular feces that have no adhesion to each other. They are distinguished in this respect from most of the annelids to which we could give the epitaph of arenophages. When this kind of defecation does not occur, as the animals are placed in a container with pure water, it is rare that the posterior parts do not soon die. They form a string and shortly divide into a large number of fragments, nearly always spherical. In any case, at the end of some time, spontaneous divisions occur. We then see the synaptid ordinarily swell its posterior part with water that flows into the interior of the body. At the same time, a more or less pronounced constriction forms at the place where separation will occur. The rupture of the integument takes place abruptly, or at least it becomes visible suddenly when it is complete. Nearly always, the intestine still maintains, for some time, connection between the body and the fragment. But soon the portion between the two constrictions becomes necrotic and division is achieved. It is moreover facilitated by the movements of the animal and the fragment itself, that each on their side, separates them from each other. Most often, at the moment of separation, the intestine has contracted adhesions with the integument at the constricted points, but sometimes also remain floating in their cavity. This is what I have observed several times for the fragments, and one or two times only for the anterior part strictly speaking.

When the fragments of a synaptid do not contain water at the moment of separation, they show only little or no movement, and soon putrify. But if they are full of this liquid when they detach from the animal, they continue to live, sometimes three or four days. We observe then in them, even in those whose longitudinal diameter hardly equals the transverse diameter, the same circulation of the interior liquid, the same contractions as in a completely intact synaptid. They even crawl on the bottom of the container with the appearance of spontaneity, turning when they encounter an obstacle etc. But the internal liquid is not renewed, and we can remove these fragments from the water without seeing them recover.

These spontaneous divisions occur more and more frequently according to the length of captivity and starvation is prolonged. We would say that the animal, not having sufficient nutrition for the whole body, thus uses gradually, the parts whose maintenance would cost the whole too much. Often, at the end of some days there remains only a tentacular crown placed on a small, nearly spherical balloon. Because, up to the last fragment, we see the swelling of the body by the water that the animal introduces into its interior and the circulation of which we have spoken. These facts appear all the more curious, as they show us, in an animal of large size, a repetition of the phenomena observed by Peltier in infusoria kept in a drop of water that is not renewed and subjected consequently to a true fast.

Kept in a vessel with sea water that we carefully renewed every twenty-four hours, the synaptids can live nearly eight days. Moreover, the duration of this existence appears to depend on two principal causes: first temperature, because like all marine animals placed in analogous circumstances, they perish more quickly in warm temperatures than in cold temperatures. The locality where we took them appears also to exercise here a very marked influence. Those that I took from sand with very little mud, washed at low tide by run-off from neighboring rocks resisted much better than those that I have found in the low areas inhabited by sipunculids and Arenicola.

When the container in which we place the synaptids contains no sand, we see them crawl continually on the bottom or the walls. Their locomotion is done in two ways. Their body has true crawling movements to which the undulations of which we have spoken contribute. The fragments lacking the anterior part move only by this means from one point to another. But the tentacles seem to be the principal organs of movement. We have seen that they use them to penetrate into sand. To do this, they bring them towards the interior of the mouth by contracting them, then unfold them in a way to remove the obstacles placed before them. It is also with the help of the tentacles, or better, the suckers found there, that they hasten their progression on a horizontal plane, or they even climb very easily along vertical walls of a glass vessel. The tentacles, extended and elongated as much as possible, applies its suckers to the surface and, by contracting them, moves the rest of the body.

I have never seen my synaptids in complete repose. Their tentacles are always in motion, moving outwards and folding back towards the buccal cavity into which they each penetrate in turn. This opens to receive the tentacle, and then contracts on it to seize what it has. I have often seen sand grains, adhering to the suckers, retained and swallowed by the animal. Thus, these organs serve both for movement and prehension. That are even tactile organs. We see the synaptid quite evidently explore with them foreign bodies that are found in its path. As for the general sensitivity of the surface of the body, it does not seem delicate. We can crush a synaptid quite violently without it seeming to be perceived. This kind of insensitivity has, moreover, nothing that can surprise us in an animal that lives its life in coarse and moving sand and for which sensitivity of the integument would have been a continual cause of suffering.

Light produces only a very weak impression on the synaptids. However, during the day, the activity of their movements seems to me to slow down.

When I exposed them to light from my lamp, concentrated with a lens, whatever the part of the body placed in focus was obviously disturbed but especially when I directed this light on the tentacles. I saw them then turn away and sometimes contract and partly turn back on themselves.

Existence seems to be limited, in the synaptids, to what we just described. I have not been able to recognize any trace of proper vision.

The synaptids must feed on some imperceptible organic debris adhering to sand grains that we find in their digestive tube. But we can only suspect in some way the existence of the nutritious material. As I have said above, the feces, if we can give this name to nearly pure sand, are not cohesive and I have only been able to discover some granulations analogous to those that form the residue of digestion in systolides and microscopic annelids. If there is an animal that we can believe feeds on stones, it is without contradiction this singular radiate.

As I have said above, the fragments of synaptids continue to move for a rather considerable time and the anterior trunk, that which has tentacles, appears unaffected by this reduction, either accidental or spontaneous. This kind of indifference is such that the same individual can often survive several days afterward for my studies of the internal structure, studies that can only give true results only as long as the tissue that we examine is still living, or at least has organic contractility. I separated as required for my work more or less long sections of the posterior part. This loss, far from harming the health of the animal, seemed to aid the extension of its existence. Here are, moreover, some facts that will give some idea of the persistence of life in these holothuroids. I have cut off with scissors the anterior end of a vigorous synaptid three or four millimeters from the tentacles. This contracted immediately and remained inactive for some time. But soon it unfolded and began to crawl as usual. The oblique cut necessarily exposed some of the ossicles that surround the mouth. But, on all the other points, the borders of the wound contracted. The scar, if we can thus call it, was complete in less than ten minutes. Water entered as in the normal state under what remained of the general covering of the body, swelling for its entire extent. Another cut with the scissors removed everything behind the ring of ossicles and completely isolated the mass of the mouth with its muscle and tentacles. The effect produced was absolutely the same. The tentacles, contracted a moment, were not slow to be extended. In placing this kind of disk so that the mouth was turned up, I could examine at leisure under my microscope the movement of the tentacles and the manner in which they penetrated the buccal cavity. This, which now formed only a ring, did not decrease its usual functions. I distinguished very well the movements produced by the mechanism of swallowing. The fragment gave, moreover, all the signs of spontaneity that we obtain with the intact animal. It was sufficient to touch a tentacle a little roughly to see all the corona contract and then gradually expand.

Here is another example, perhaps still more striking. We know, in general, that fresh water acts as a poison on marine animals and that a large number of radiates among others die in it nearly instantly. Now, on 2 August, I placed into fresh water an anterior trunk of a synaptid of approximately two inches in length and on the 4th it was perfectly well. Wanting to study the ovaries, I split it longitudinally, leaving intact the corona of tentacles and the digestive tube. The whole was put back into the fresh water until the 5th. At this time the integument was contracted and like balls but without fusing. The posterior end of the digestive tube was closed because of the contraction, and this kind of coecum was distended because of the water that was

accumulated there. The tentacles acted as usual. I removed all the ovaries and cut the rest in all directions, without touching, however, the tentacles, and then replaced all in fresh water. The next day, the 6th, the tentacles were half contracted, but had nevertheless their usual movements of bending alternatively inward and outward, but more slowly than in a healthy individual. Returned finally into sea water and examined on the morning of the 7th, these same tentacles were entirely contracted and still had some movement of the same nature, but scarcely marked. They ceased definitively in the afternoon. Thus, the well-being of this synaptid has resisted for five days with mutilations done as far as possible, and that outside the element in which the animal was intended to live.

SECOND PART

ANATOMY AND PHYSIOLOGY

To proceed with order in the study of the various parts of the body of the synaptid, we shall examine successively 1° the integument, 2° the body, 3° the digestive system, 4° the organs of circulation, 5° those of respiration, 6° the reproductive system.

§ I. INTEGUMENT

All external parts of the synaptid are covered with a general covering composed of two parts, namely: an external epithelium³ and a true dermis.

1. *External epithelium or epidermis* (Pl. 3, fig. 8). — When we place under the microscope a piece of a contracted synaptid, we see a very thin completely transparent layer, having in its thickness, but only in the deepest regions, some equally diaphanous granulations that we distinguish only by a slight difference in refraction (*a*). It is this external layer that we give the name external epithelium or epidermis. Despite the most minute observation with an excellent instrument, I have not been able to recognize the least indication of an organic separation between this substance and the underlying parts. Maceration and some time in alcohol have given me in this regard only uncertain results. Therefore, I am doubtful that this epithelium forms a separate membrane. I am inclined to think that it is in continuity with the dermis. On the other hand, its constant existence, its thickness that varies little in various parts of the body, should encourage us to consider it as distinct from the underlying layer, although it is intimately connected. Examples of organic continuity of two tissues, moreover, are too numerous and too well-known, even in higher animals, for it to be necessary to recall them here. Perhaps, even, the failure of the attempts I have made to isolate them is only the fault of the experiment. Because if very close animals, in some actinians, I have seen a similar epidermis separate itself in a kind of molting from tentacles whose walls are so thin. I have reproduced this effect by maceration.

³ Although this layer does not have the cellular structure of an epithelium strictly speaking, I have believed it necessary to call it thus because its general aspect recalls that of a mucous membrane, its thinness, and its transparency.

2. *Dermis* (Pl. 3, fig. 8). — Under the epithelium, or making a body with it as we just said, is found the dermis formed essentially of a granular, diaphanous substance that, in some individuals, is colored pink or at least brownish. It is in its thickness that the pigment to which the synaptid owes its color is found. This pigment, that we shall find very frequently in the course of this work, has here in the form of translucent globules of a beautiful carmine red, and whose diameter varies from $1/350$ to $1/100$ millimeters (*b*). In their interior, we generally see a variable number of very small black granules, completely opaque, whose diameter is hardly $1/2000$ millimeters. These globules of pigment can be separated from the material in which they are disseminated and float freely in the liquid. But I have never been able to recognize there a covering distinct from the interior mass. When we treat them with a solution of potassium in alcohol, we see their color first brighten and then turn brown. At the end of some time, the granules completely dissolve. The small black granules that were not attacked then float freely in the liquid and show Brownian movement.

When we look at the surface of the body of a synaptid at a magnification of 80 to 100 diameters, we recognize that the dermis is not perfectly smooth, but that it has small oval elevations with the appearance of a strawberry in a very regular quinconce arrangement in a way that their large diameter is perpendicular to the axis of the animal. These eminences are of two kinds: some have very singular hooks discovered by Eschscholtz and that are characteristic of the genus. The others serve to support weapons of another nature that we shall soon describe.

The name *harmeçon* proposed by Eschscholtz to designate the spines of synaptids give a very correct idea of these organs. They are in effect double hooks or, better perhaps, small anchors that are perfectly transparent and strongly refractory to light (Pl. 3, fig. 2, 6, 7). The branches with variable curves are round, strong and toothed on two thirds of their upper surface from the end that is very sharp. We sometimes find also two to four teeth placed in the middle of the arc formed by their union, but most often this part is smooth. These branches are supported by an equally round stalk, slightly swollen toward the middle of its length, abruptly narrowed and flat toward its end in a way to have a large crest (Pl. 3, fig. 3, *a*). The whole is terminated by an articular head in an arc (*b*), toothed anteriorly on its convex surface and swollen on the two sides.⁴

This head is applied to a shield of the same appearance as the anchor and whose form, although remaining nearly the same for the whole, varies greatly nevertheless in the details, either on the same individual or in different individuals. These shields, which have not yet been described, I believe, by any naturalist, are a kind of very irregular oval plates. One end is always very much wider than the other. They are pierced by several openings whose form and location vary singularly. In general (Pl. 3, fig. 4), the wider part has a central opening surrounded by six other similar openings. These seven openings are nearly always toothed interiorly. But these teeth vary in number and in size from one plate to another. Thus, sometimes they are very small and very numerous, sometimes very large and consequently less numerous. Most often, they occur on all the internal border, but sometimes there are only two or three strong teeth and the rest remains entirely smooth. Above these seven openings, several others are found that can be regarded as forming three rows of three openings each. The first row usually has two large lateral openings little or not toothed and one small non-toothed one in the middle. Those of the second row are small, not located in the same line and nearly always lacking teeth. Finally, the

⁴ The anchors of the synaptid figured by Jæger has a very pronounced ovoid swelling toward the upper third. Perhaps the difference in form of these organs could serve to characterize the species when they become sufficiently studied.

last row still has three non-toothed openings. Those of the middle (*a*) always, or nearly always, have an elongated form and receive the flat crest of the hook. The two other very small ones (*b*) are very small, rounded and placed in the lateral swellings of the articular head. Moreover, nothing is more variable, as we have said, than the form of the shields, the number and arrangement of their openings. However, we nearly always find the first seven such as we just described. As for the others, they have absolutely nothing fixed, and instead of uselessly multiplying the figures, we limit ourselves here to representing the two principal modification that we have encountered (fig. 8, 9).

The shield and the anchor are articulated as we just said and as we have represented (Pl. 3, fig. 5), but I have not been able to recognize either clear ligaments to hold the parts in place, or muscles to move them. Yet their adhesion is considerable enough that sometimes the anchor is broken rather than detaching from the plate. This is retained by the dermis, in the thickness of which is so great that the anchor, lying obliquely in the resting state, has hardly a third of its stem outside. In the movements of the animal, we see them erect slightly and we shall see that they can be moved at will.

The dimensions of the two pieces vary with the size of the individual in which we observe them. The anchor that I have represented (Pl. 3, fig. 2), taken from a synaptid of very large size, was approximately 1/10 millimeters in length. Its transverse diameter, at the thickest point of the stem was 1/130 millimeters. The shields had a length nearly equal to two thirds of that of the anchors. But we have said that they vary so much in all relations that we believe it useless to give precise numbers.

I have often encountered anchors having the forms shown in fig. 10 and 11, i.e., having only a stem and a more-or-less developed anvil-shaped head. On them principally, I have believed to recognize all around the solid material, a very fine, diaphanous and apparently homogeneous membrane. I have also very often seen shields such as represented in fig. 12 and 13. It is evident that these pieces were in the process of development or destruction. This last hypothesis would not be accepted because the destruction of the anchor is always done in layers, as we shall soon see. The forms that we report here are thus because these parts have not yet reached their definitive state. Consequently, it is obvious that they cannot be a simple discharge or secretion because, in that case, the branches as the terminal parts should precede the appearance of the stem. Their form, their very existence becomes inexplicable in this hypothesis. It is thus necessary that these bodies are living. It is necessary that they are themselves a living body. It is necessary that they are in themselves a vegetative force that makes them extend longitudinally and laterally, until their parts have acquired the desired form and dimensions. But by what mechanism has this taken place? Is it by solidification and concretion of a first organized matrix: Is it by intussusception with the aid of interstitial nutritive absorption? These problems that relate to the general question of cutaneous appendages seems to us impossible to resolve in the current state of science and new studies supported by direct observations.

Placed in caustic potassium, the anchors and the shields do not undergo any alteration. They are distinguished only more clearly under the microscope because all animal material has been removed. When we treat them with concentrated nitric acid, we see them dissolve rapidly with effervescence. It is thus very probable that these bodies owe the solidity to a carbonate, without doubt calcium carbonate. In using the same very weakened acid, its slower action permits us to enter into the intimate structure of these singular productions. We recognize that they are formed of layers that are very easy to observe, especially the hooks. I have been able to clearly distinguish up to four (fig. 14), When the calcareous carbonate is completely dissolved, each

anchor has only a very slight and rather formless frame, rapidly soluble in potassium, and formed by an animal framework that connects the organic molecules to each other.

The prominences that do not have anchors are covered over their entire extent by small spherical or oval bodies $1/150$ to $1/200$ millimeters in diameter (fig. 15, *a*). These small bodies are susceptible of contracting in a way to become approximately $1/60$ millimeters in length by $1/400$ in thickness. In this state, they are transversely striated in a very sensible manner. This contraction makes protrude from the interior an acicular filament of $1/30$ millimeters in length and hardly $1/1500$ mm in thickness. These kinds of protruded bristle are then placed in a manner to bristle in all directions of the eminence that has them (*b, b*). Treated with potassium, the dissolve rather rapidly, while weak acids have no effect on them. They are thus of animal nature and perhaps coriaceous.

Observations. — Eschscholtz attributed the faculty that synaptids have of adhering to foreign bodies to the only pieces of their armor that he knew as hooks. This was followed by all the zoologists who have spoken of this genus. It is, in fact, difficult not to believe that these sharp double hooks have nothing to do in this act that, as we shall see later, is completely voluntary. We note, however, that the tentacles of actinians makes the hand that grasps them experience a sensation very similar to the produced by synaptids. However, these tentacles do not have hooks and are only bristled with an innumerable quantity of the acicular bodies described for the first time by Wagner, and very similar to those are distributed in such great abundance on all the body of synaptids. It is very probable that it is to them that we must attribute in large part the adhesive property of the tentacles. We are thus led to regard them as fulfilling a similar role in the animal that concerns us. Finally, some acalephs adhere also to foreign bodies without either hooks or spicules yet discovered in them. Here the effect seems to depend uniquely on a particular secretion. Perhaps we can accept that something similar occurs in actinians, and a special production aids the action of spicules. But it would not be the same in our synaptid, because the mucous (if we can use this word) that oozes from its body dissolves as things progress in the sea water into foam like a slight dissolution of soap.

We have also attributed to anchors the sensation of intolerable burning that develops from contact with some synaptids. The species that I have found, although as formidably armed as its exotic congeners, produces nothing similar. Too many people have touched it to have the least doubt in this regard. It is thus to be presumed that it is not necessary to attribute to them the result of which we are speaking. It is probable that when we examine with care foreign species, we shall also find in the spicules that we have reported, and perhaps we will be tempted to regard them as the cause of this painful stinging. We can no longer accept this explanation because, on one hand, some actinian can be touched without danger, although their tentacles are full of spicules, just as much as in those whose least contact sometimes leads to serious consequences. On the other hand, some jellyfish that have nothing similar but produce nevertheless violent stinging that has given the name of sea nettles. In the latter, this effect is quite evidently with the secretion that oozes from the body. It is very probable that an analogous production exists in actinians and in the synaptids that cause these unfortunate effects. We are far from denying that hooks and spicules should not contribute to this result by introducing under the epidermis, like a lancet, the venomous liquid with which they are continually moistened. Perhaps even it is permissible to suspect an organ that contains the sting at the same time produces the poison.

The anchors and perhaps also the spicules of the Synapta of Duvernoy, must be of great utility for underground locomotion. These appendages, covering all the body, are able to

voluntarily stand up, in a way to give them thousands of points of attachment in all directions or to lie down against the skin to permit them to slide in the gallery that it digs, are in this regard, quite superior to the semi-retractable bristles of errant annelids. Their transverse arrangement, joined with their double hook, permits in addition to the synaptid to move as easily backward as forward, without a muscle apparatus being necessary to change direction as in tube worms. Moreover, these organs of locomotion can become, if necessary, formidable weapons. In one of my excursions, I placed in the same container synaptids and some errant annelids, *Nephtys*, *Nereides*, etc. I do not know if it was direct aggression on the part of the latter on these animals, which are so eminently carnivores. Still, it is without doubt there must have passed a terrible combat between the radiates and the articulates because, on my return, I found pell-mell, intertwined with each other and all dead or dying. The synaptids and several annelids were in sections and on the body of each of them I found many fragments of weapons, bristles or anchors, that were broken and remained in the wound that they had made. This never happened when I carried these animals separately. The synaptids in particular, although compressed in a narrow container, moved over each other with the greatest of ease and without ever attaching except when I tried to grasp them to move them elsewhere.

The dermis of the Synaptida of Duvernoy has the characters we just described only on the trunk of the animal. There alone are found the colored pigment, the anchors, the shields and spicules. Everywhere else it is colorless, transparent and uniquely form of the granular, diaphanous substance that we have reported as essential composing it. It thins, in addition, on the disk of the mouth, the base of its tentacles, and especially on the digitations of these where it is hardly possible to distinguish it from the epidermis, even with the greatest magnification.

The entire body, but principally the trunk of the synaptid, seems to be the seat of the secretion of which we talked above. It has this very remarkable character of dissolving in sea water, giving it the property of foaming. I have not been able to discover if it was the product of particular organs and what these organs are. Should we consider the pigment granules? It would be difficult to answer this question very precisely, but the apparent absence of any other organ of glandular appearance, the very considerable quantity of mucous produced by the parts of the body where this pigment is abundant could give this opinion some probability.

§ II. TRUNK.

We give the name to all the part of the body of the synaptid that is behind the crown of ossicles forming a kind of buccal ring and in the interior of which is the digestive tube. This part is covered by the integument that we have describe previously, but it contains still more distinct layers of tissue that most anatomists have considered up to here as making part of the skin. This conclusion seems incorrect to us. Among these tissues are found, among others, muscles that are essentially organs of locomotion and that belong so little to the integument strictly speaking, that they are separated from it by a special tissue. Moreover, the essential character of the skin, the integument, in general is the covering of the entire surface of the animal that they function to protect against foreign bodies. Now, the layers that we are going to describe belong exclusively to the trunk. We consider them consequently as constituting essentially the body of the synaptid, as representing in it this union of muscles and more or less solid parts that we find in the higher animals in the same area and that, in the latter as in our radiate, are covered on the exterior by the integument and the interior circumscribed to form the visceral cavity.

There are four layers. We recognize, proceeding from the exterior to the interior, 1° an elastic fibrous tissue; 2° a muscle layer with transverse fibers; 3° longitudinal muscles; 4° an internal epithelium lining the wall of the abdominal cavity.

1° *Elastic fibrous tissue* (Pl. 3, fig. 16). — When, by a sufficient maceration, we have separated and raised the dermis, we find below a rather thick layer of a granulose tissue, transparent (*a*), traversed throughout its thickness by very fine fibers 1/1200 to 1/150 millimeters in diameter (*b*) that cross in all directions, leaving large meshes between them. These fibers remain fairly resistant to putrefaction. It is only with sufficient maceration that has disorganized the granular matrix that surrounds them are we able to clearly distinguish them. Their appearance, their arrangement recalls a little the fibrous tissue of the pelican pouch. As I have not recognized in them any sign of organic contractility, although they are eminently elastic, I have thought that they have analogous functions. They form all around the body a sheath that gives it firmness and facilitates the movement of the liquid that distends the interior. The tissue into which they enter is the firmest part of the body of the synaptid. It is rather resistant to cutting instruments and has more firmness than its extreme transparency would suggest at first.

2° and 3° *Muscle layers with transverse fibers and longitudinal muscles* (Pl. 2, fig. 2). — We combine here these two organ systems, especially because their functions have the greatest relation, then because it is sometimes difficult to clearly distinguish the limits as we shall see later.

These layers have been considered up to now as simple dependencies of the skin. We have opposed this point of view above in which the lack of a basis emerges especially from the examination of the muscle parts that no more deserve the name of skins than the abdominal muscles of Man and other vertebrates. It is they that by their alternating contractions and relaxations determine all general movements of the synaptid. Their action alone is sufficient for movement. Without doubt, the tentacles are auxiliary power, but their aid is by no means necessary, as is proven by the ability of simple fragments to move, even on a glass plate, by means of crawling.

The muscle layer of transverse fibers forms a complete sheath from one end to the other of the synaptid. This fact, that analogy makes it necessary to accept, is extremely difficult to recognize in the fresh animal. The opacity of the longitudinal muscles prevents following the transverse muscles under the microscope outside of the gap they leave between them and we can believe sometimes the latter are inserted only on their internal surface. But in examining synaptids preserved for some time in alcohol and that, by contracting strongly, have brought together the fibers of the external layer in a way to give it more firmness, we can rather easily separate the two layers from each other and recognize that, in all that concerns us, the fibers form a complete ring so that their ensemble makes an enveloping layer continuous from one end of the animal to the other.

The transverse muscle fibers of the body of the synaptic are hardly 1/200 millimeters in diameter. They are little distinct, as embedded in a completely transparent and homogeneous matrix that seems to replace in these animals the cellular tissue of higher animals (Pl. 2, fig. 2–6). Their transparency and their homogeneity is as great as that of the material that surrounds them. I have never seen there those granulations that the muscles of systolids and annelids often have. During contraction, they decrease in length and increase proportionally in thickness without having the least trace of transverse stripes, in which they resemble those animals that we just named.

We find in the Synapta of Duvernoy, as in all holothuroids, five muscle bands that run the length of the body, from the tentacular crown to the anus (Pl. 4, fig. 1, *pp*). These longitudinal muscles are, with the mass of the mouth, the only parts that are not transparent. Seen by reflection in the living animal, they form five small bands similar to be small bands of the finest tissue, white in color that is distinguished from the preceding layers, even when the animal is contracted. Much thicker than the rest of the body, they make a considerable round protrusion into the interior. Measured in an individual of 18 inches, they are three and a half millimeters in width and one and half millimeters in thickness. They increase considerable toward their anterior end, before attaching to the ossicles of the mouth, crisscrossing their fibers and forming a complete covering, opaque in some large individuals, up to an inch behind the tentacles. Posteriorly, they are lost in the sphincter of the anus.

These large muscles are formed of fibers continuing without interruption from one end to the other. At least it was impossible for me to distinguish anything analogous, either in form or functions to the white transverse lines of the straight abdominal muscles of man. These fibers, very different in this from those we just described, are as distinct as those from the muscles of vertebrates. They are isolated easily and are approximately $1/90$ millimeter in length. Their form (Pl. 2, fig. 2, *a*; Pl. 3, fig. 17) is that of a perfectly smooth cylindrical cord (*a, a*). Their fine structure, their mode of adherence, is moreover the same as in the transverse fibers. But they have moreover, the remarkable phenomenon that during contraction, it forms transverse stripes (*b, b*) that completely disappears when the muscle relaxes.

At the internal surface of the longitudinal muscles are found small corpuscles that have sometimes the form of a shuttle or a curved cylinder, swollen at one end but more often irregular round and pierced in the middle by a circular opening (Pl. 4, fig. 3). Their dimensions vary with that of the individual that we examine. But in a synaptid of approximately a foot in length, the first are nearly $1/25$ millimeters in length and $1/150$ in thickness. Those that are rounded are approximately $1/60$ millimeters. We feel there is nothing absolute in these measurements. These corpuscles have the same appearance as the plates and anchors of the dermis, and are, like them, composed of calcium carbonate with an animal frame as I recognized with the aid of reagents.

We must also report in passing, except to return to it later, that each longitudinal muscle contains in its center a vessel that runs from one end to the other and in which circulates nutritive fluid (Pl. 4, fig. 1, *oo*).

4° *Internal epithelium*. — All the internal surface of the muscle layer is covered with an epithelium of very fine granular structure. The granules, always embedded in the diaphanous material of which we have already spoken, are hardly $1/200$ millimeters in diameter and are themselves perfectly transparent. This epithelium is a production or better a continuation of the integument. The dermis and the epidermis merge in penetrating the aquifer openings and come to supply this membrane that itself produces the mesenteric strands and the external epithelium of the intestine, as we shall see later.

Observations. — The ensemble of the six layers that we just examined varies singularly in its diverse dimensions according to the needs of the animal that can shorten or lengthen it, contracting or dilating it in all directions by filling its abdominal cavity with water. We comprehend that it is quite difficult, because of these continual changes, to know the thickness exactly. However, by measuring the diameter of the body in its two states of dilation and contraction, separating then a fragment and then measuring the thickness of the walls, we can, by a simple proportion, know how much it decreases when the animal expands, assuming however that this thickness is in inverse ratio to its area, which is quite probable. It is necessary

to take care in this small calculation, to subtract on both sides the width of the longitudinal muscles, which does not appear to vary. We find, by this process, that in a synaptid whose body contracted to 8 millimeters in diameter and 25 when dilated, of which the ensemble of layers that concern us has, in the first case, 1 millimeter in thickness. This thickness is about $26/199$ to $1/4$ of a millimeter during expansion.

Chemical analysis of the tissues of lower animals would offer, we have no doubt, very interesting results to anyone who could do it with any consequence. I was far from being in favorable conditions in this regard, as I have only been able to examine only very roughly the effect of a small number of reagents. A slice of the trunk of the synaptid with the integument attached dissolves quite rapidly in a solution of potassium in alcohol. At the end of twelve hours, there remains no more than a homogeneous mass of reddish-brown color, composed of extremely fine granulations and in the midst of which we find all the calcareous pieces of which we have spoken. The action of sulfuric acid and concentrated nitric acid appears to us worthy of being noted. The first disorganizes these tissues but without charring them. At the end of twelve hours, they form a white homogenous mass with very fine granules and in which we no longer find any trace of calcareous pieces. We would say that the acid, like the alkali, dissolves certain distinct molecules, leaving the rest untouched. We understand how interesting it would be to investigate what are the organic elements that can resist these two powerful agents of destruction. What are those that were exposed to their action. Nitric acid seems to no effect on either. It makes the tissue slightly yellow, greatly contracts them, but does not seem to alter them in any way, at least in the cold and when they are exposed to it for a fairly limited time. They thus behave in this acid nearly like the nervous substance of high animals. We know that these isolated facts do not have great importance, but perhaps they will inspire some naturalist better placed than we, to pursue investigations that would certainly not be without interest to science.

The ensemble of the tissues we just examined have a fairly great firmness that we cannot easily tear them and especially cut them with a sharp instrument. If we try to break a synaptid by pulling on its two ends, we also find a very noticeable resistance. But if we grasp it either with the fingers or with forceps, especially toward the posterior part and hold it suspended in air, it divides at the compressed point with such a rapidity that we sometimes have no time in which to transfer it from one container to another. The mechanism for these ruptures, that appear to me to be voluntary, is the same as the of spontaneous divisions. We shall see, when we consider the digestive tube, how in this case the synaptid replaces the normal sphincter with a veritable artificial sphincter.

The contraction of these tissues in all directions is most remarkable and we have reported the fact that cicatrization seems to follow immediately the removal of the parts and to be due only to the contraction of the surface of the wound. We understand how, because of this property, dissection of these animals should be difficult. With the goal of making it easier, I have tried to sedate the them with opium. But this means, that had been quite successful in some other circumstances, did not give me here give results nearly as satisfactory. Its action was slow. The synaptids placed in a container where I had placed a very strong dose of laudanum of Rousseau shrank to the point of bursting their integument and the contractility of the tissues remained nearly the same.

§ III. DIGESTIVE SYSTEM.

The digestive system of the Synapta of Duvernoy consists of: 1° the mouth and the buccal cavity or pharynx; 2° intestine; 3° mesenteries.

1. *Mouth and buccal cavity* (Pl. 4, fig. 1). — We have said above that the mouth of our synaptid was terminal, in the middle of the disk surrounded by tentacles. This disk is formed in large part by muscles that, coming from the tentacles, are lost in the sphincter of the mouth (Pl. 5, fig. 4, *aa*). This part is covered by very thin layers in which we find a very small number of pigment globules. Toward the middle of the space between the tentacles and the mouth, they form a slightly fringed fold (Pl. 4, fig. 1, *c*). After this point, the disk becomes very slightly concave in inclining toward the buccal opening. All these parts are white, ordinarily tending to yellowish or reddish. This is the color of the muscles that is seen throughout the integument.

The completely opened mouth has a circular opening (Pl. 4, fig. 1, *d*), slightly folded, surrounded by a kind of raised portion formed in large part by a transparent and granulose substance (Pl. 5, fig. 4, *c*) covered by the layers that, after this point, appear entirely mixed and undergo a slight change in structure (Pl. 5, fig. 4, *d*). The granulations of the dermis become smaller and more numerous. Thus modified, the membrane lines all the interior of the digestive tube, and can be compared, at least as regards its anatomical position, to the mucosa of higher animals.

Immediately after the mouth, the digestive tube swells into a cavity in the interior of which the epithelium (the mucosa) forms very tight and fringed longitudinal folds (Pl. 4, fig. 1, *e*). We understand that the dimensions of this cavity should vary with the size of the individual observed, and because of its movements. In general, in the state of semi-contraction, where we can study it, it appears to me to have approximately two times the diameter of the mouth width and two and a half or three times its length. It narrows again and takes an ellipsoidal shape. This second narrowing, much narrower than the mouth, connects directly with the intestine.

Before describing the very complicated muscle system of the mouth and the oral cavity, we must speak of the ossicles that are the principal point of support and that we find in synaptids as in the other holothuroids. These parts are twelve in number, articulated together to form a regular dodecagon around the mouth, but at some distance from this opening. Each of them is formed of a thick plate with round edges, swollen at the two ends, curved in a way that its external surface is a little more concave than the internal. The anterior border (fig. 5) is raised into an arc on its middle third. Under the elevation, in some of them, is a regular oval opening (*b*). It is through this opening, as we shall say later, that water enters and leaves the interior of the synaptid. The number of plates that have these openings is five. They are always placed in a way that the water opening corresponds to one of the spaces between two of the longitudinal bands of the body.

The pieces of which we speak differ greatly in respect to the calcareous concretions that we have reported and from those that we shall describe later. They do not have the same transparency and are barely translucent. They are flexible and do not break like the anchors and the shields. Moreover, their composition is far from being simple. We can easily distinguish three parts. When we study them in a carefully made section (Pl. 5, fig. 7, *c, c*), they appear solidly united to each other by a firm substance, homogeneous, transparent, very elastic, that permits some movement to them. Their ends are round and have no serrations. These ends are as transparent as the rest. By macerating them sufficiently, we remove the muscle tissue and others that adhere there. But at the same time, the round transparent portion, that forms most of the two kinds of articulated heads (Pl. 4, fig. 5, *cc*) disappears and the abruptly truncated ends have fine serrations. If, in this state, we place the piece in a solution of potassium in alcohol,

the first effect of the reagent is to make visible a very fine membrane that covers it on all sides that goes down to the smallest dentations on the ends. This membrane is quickly dissolved and at the end of 12–14 hours of immersion, this plate becomes transparent and shows then it is composed of granulations of 1/200 to 1/300 millimeters, irregularly grouped and that pressure disaggregates quite easily (fig. 6). In treating them with an acid, we see these granulations dissolve with the release of gas. The piece itself, treated first with an acid, dissolves with gas. When the acid weakens, we find a slight scaffold, still keeping some traces of the original form of the ossicle itself.

It is evident, according to these details, that the bodies of which we speak, are composed of granules of calcium carbonate on an animal frame and that, except for the difference in salts, they resemble the bones of mammals. But this does not end the relationship between the skeletal parts of animals so far apart from all other points of view. This rounded transparent part, that simple maceration removes, has the greatest analogy to interarticular cartilage. Only its volume is here proportionally considerably more. And the state in which it leaves the body after its disappearance recalls what happens when we remove the epiphysis of a tibia, for example, before it fuses to the body of the bone. The membrane, which the action of alcohol revealed, is arranged around the solid piece of the synaptid, absolutely like the periosteum around the bone of mammals. There is not even the mode used to give stability to the pieces, giving them some freedom of movement that does not recall what we observe in the higher vertebrates. The substance that covers the articulations seems to have all the properties of our articulating ligaments. Finally, the position of the skeleton is still that we find in vertebrates⁵. While in the mollusks, articulates and most rayonates, the solid parts, when they exist, are either dependencies or emanations of the dermis, here the pieces of which we speak are placed in the interior of the tissues, without any relation to the integument and attach to the muscles at all sides. We have already said that the large muscles of the body insert there on a wide area. We shall see that those of the tentacle do the same. These come from the external parts, relative to the circle of ossicles. But among the muscles of the mouth, we are going to see several that, located interiorly relative to this same circle, also come to seek a point of attachment.

We have said that the terminal disk of the synaptid was formed in large part by the muscle planes coming from the tentacles. These muscles go up the circular rim of the mouth and merge with a rather strong sphincter (Pl. 5, fig. 4, *bb*) whose fibers seem to cross theirs. With this sphincter is attached posteriorly a strong muscle mass with longitudinal fibers (Pl. 4, fig. I, *f*) that runs all along the buccal cavity and surrounds it completely. Another very thick muscle layer, but with circular transverse fibers, covers it in its turn (fig. 1, *g*). These two masses seem to be mixed near the posterior opening of the buccal cavity where a second very strong sphincter is found (*i*). From this point leave two pyramidal muscles (*h*), whose base seems to merge with the mass of those that we just described, and whose top goes to attach on the articulations of the ossicles in a way to attach to two of these ossicles (Pl. 5, fig. 7, *d*). The interval between these various muscles is filled, except that occupied by the circulatory organ, by the homogenous and transparent material that seems to take the place of cellular tissue.

The action of these various muscles is easy to conceive. The sphincters serve to close the anterior and posterior openings of the buccal cavity. The first has for antagonists the muscles coming from the tentacles. It is to be noted that these cannot contract to bend the tentacle from

⁵ Duvernoy is, I believe, the first who understood this relation between vertebrates and echinoderms and who reported it in urchins in a note read to the Société d'Histoire naturelles de Strasbourg, reproduced in the journal of the *Institute*.

outside to inside without acting at the same time on the mouth so as to open it. The large muscle mass with longitudinal and circular fibers that surround the buccal cavity are the agents of swallowing and are more than sufficient to overcome the obstacle offered by the second. Finally, the pyramidal muscles are elevators all this mass, and they have for antagonists the longitudinal muscles of the intestine that we shall describe later.

The fibers of all these muscles resemble those of the transverse muscle layer and not those of the large longitudinal muscles. They are inconspicuous, cannot be isolated, and seem almost to form a body with the matrix that bathes them on all sides. During contraction, they do not show transverse striations.

II. *Intestine*. — Immediately after the posterior opening of the buccal cavity, the digestive tube of the synaptic dilates abruptly and the intestine begins there (Pl. 4, fig. 1, *k, l*). This consists of a cylindrical tube of a caliber everywhere equal and extends in a straight line from the buccal cavity to the anus. We see easily, when the body of the animal is distended by water, that the length of this organ does not exceed that of the body, but in the state of contraction, the intestine is folded and seems to have circumvolutions. Its wall is composed of several superposed layers, namely, proceeding from outside to inside, 1° an external epithelium, 2° a continuous muscle layer with annular transverse fibers, 3° longitudinal muscles, 4° an internal epithelium.

1. *External epithelium*. — This epithelium recalls nearly entirely that which we have seen line the internal surface of the muscles of the trunk, to which it is moreover attached by mesenterial straps. Its structure is the same, but it differs in that it has here and there pigment granules (Pl. 2, fig. 3, *d*) whose size varies from 1/75 to 3/300 millimeters. These granules (Pl. 4, fig. 2) are red carmine, all the darker as they are smaller, and their structure is more complex than in those of the epidermis or at least more distinct. They are composed of an exterior covering (*a*) diaphanous in color containing a homogeneous colored substance. In the largest we find, in addition, a second vesicle (*b*) whose content is completely transparent, not colored and in the middle of which are five to six very small black, opaque granulations of which we have already spoken. This second vesicle lacks pigment grains that are less than 1/100 millimeters, but the small opaque bodies are observed even in the smallest. I have succeeded two or three times in separating, by simple maceration, the external epithelium from the underlying parts.

2. *Muscle layer with transverse fibers*. — From the muscle mass that surrounds the posterior constriction of the buccal cavity are detached two planes of muscles (Pl. 4, fig. 1, *j*), first rather strong that makes the walls of the intestine opaque, but whose thickness decreases rapidly. The exterior plane is composed of annular fibers forming a continuous sheath from one end of the intestine to the other. They are not very marked and seem more than those of the trunk to merge in some way in the homogeneous matrix that envelops them completely. It is easy, moreover, to observe their contraction, that occurs without the slightest transverse fold.

3. *Longitudinal muscles*. — The internal plane that leaves from the buccal mass is composed of longitudinal fibers and envelops all the intestine. But at some distance from its origin, it is separated into four bundles that run without interruption to the anus where they end in a sphincter like the five external longitudinal fibers. The intestinal muscles have neither the thickness nor the opaqueness of the latter. Their elementary fibers are far from having the same appearance. On the contrary, they are completely similar to those of the transverse muscle layer but are only a little more pronounced (Pl. 2, fig. 3, *b*).

4. *Internal epithelium*. — The interior of the intestine is covered at first by an extremely fine epithelium, a continuation of that which we have seen lining the interior of the buccal

cavity. Its structure does not change, but the folds that it forms are here elongated, communicating together and are not fringed as in the first part of the digestive tube (Pl. 4, fig. 1, *k*). When the animal contracts, it forms, in addition, transverse folds with fairly regular spaces that are a little perpendicular to the axis of the intestine.

III. *Mesenteries*. — The digestive tube is not entirely free in the body of the synaptid. It is held in place by mesenterial straps of such extreme thinness and transparency that we can hardly perceive them. The straps (Pl. 4, fig. 4) appear as membranes formed by a homogeneous transparent substance with granules similar to those of the epithelium, but also containing other larger ones up to 1/150 millimeters that refract light a little more strongly than the rest of the substance that surrounds them. These granules are, moreover, very distinct. They are isolated when the membrane is torn and float in the liquid. They seemed to me to be composed of an enveloping membrane and a more tenacious transparent material than the general matrix of the mesentery. Despite the most careful attention, it has been impossible, even in using weak acids, to discover the least trace of fibers in the mesenteric membranes, and yet they move, fold, contract in every direction under the eyes of the observer. We shall return to this important fact later.

The mesentery seems, we have said, to be the continuation of the internal epithelium of the body and the external epithelium of the intestine. It is thus a dependance, an extension of the exterior layers of the integument. It has been impossible for me to ascertain if it is formed of two back-to-back lamellae doubling to line the walls of the abdominal cavity and the digestive tube or if there was an extension of material. Its structure, everywhere I examined it, appeared to me perfectly identical. It does not form a continuous attachment the length of the digestive tube, but is carried by wide straps, sometimes toward one, sometimes toward the other of the longitudinal muscles of the trunk. These points of attachment are approximately an inch or a half-inch in length and appeared to me distributed in a nearly regular way around the axis of the animal in a way to form a spiral that, from front to back, would go from right to left.

Observations. — The ensemble of parts that we just described is very far from having the thickness that we have found in the integument and diverse layers that compose the trunk. Except for the buccal mass and the parts of the intestine that immediately follow, all the rest is so tenuous that any direct measurement is impossible. It is hardly an approximation that we can estimate it to 1/5 or 1/6 millimeter. This decrease in thickness that we report should be attributed to the absence of fibrous tissue and to the thinning of all the other layers, especially the muscle portions. The colored pigment is much rarer there and even sometimes even nearly absent. This results in a much greater transparency. The intestine has really the appearance, even in the largest individuals, of being formed of animated, moving glass. It is nevertheless this envelope, both very thin and frail, that receives and circulates in its cavity very heavy sand with coarse grains and bristling with asperities!

The determination of the different parts of the digestive tube of the synaptid is not very difficult. We have given to the first cavity the epithet of buccal or pharyngeal, because its opening serves for prehension. It has the role of swallowing. The grains of sand that the synaptid introduces there never stay there. This first cavity empties immediately into the intestine. It is the same throughout its length. There is nothing that we can consider either a stomach or a cloaca. It appears to have the same role everywhere, so identical is the structure of its various parts. I have sometimes found the synaptids gorged to the pharynx with grains of granite whose weight and roughness contrasts in an astonished manner with the apparent delicateness of the tissues that contain them.

The arrangement of the different layers that form the intestine have a rather marked general resemblance with that we have already found in the trunk. In both, we find an external layer and an internal layer having the greatest similarity and essentially integumentary or coming from the integument. Between the two, we encounter in both cases longitudinal muscles in the form of small bands, located in the interior of a muscle sheath with transverse fibers. These general facts would seem at first to support those who want to see only a skin there where we have distinguished a body with its layers. But the differences are not less sensible and more fundamental. Thus, the two layers of the integument are reduced to one in covering the intestine. The fibrous tissue is completely lacking in the latter. The structure of the longitudinal muscles and the elementary fiber are completely different. All change in these muscles up to their number is less in the intestine. This fact seems decisive to us.

In fact, in accepting that there is in the synaptid only a simple skin with skin muscles circumscribing an interior cavity in the middle of which floats the intestine, it follows that this skin, in reflecting itself to form the intestine, has not only modifications of structure analogous to those that we observe in the vertebrates, but solutions of continuity and extreme changes in important parts. It follows that the skin muscles change successively in direction, force, of elementary structure. It follows finally that in the various parts of the body of these layers are very different, and that some of the layers that compose them can disappear. These consequences seem to us in very flagrant contradiction with what we see everywhere else for the opinion from which they arise to be correct. By considering, on the contrary, the anatomical composition as we do, by restricting the name of integument to the two most exterior layers, and by considering the underlying parts as not being their dependences, everything returns to the normal state. The integument covers all parts of the animal, having no other alterations than those that depend on their more or less thickness. They are modified at the entrance of the openings of the cavities to penetrate to the interior, but this modification does not exceed the limits of those experienced by the skin when it becomes a mucous membrane, even if it is also considerable. We completely relate, in this regard, the radiates that concern us to other animals placed at higher levels in the scale of beings.

The epithelium that lines the internal surface of the visceral cavity, that which covers the exterior of the intestine, finally the mesenterial straps are, we have said, in continuity and come from the integument whose two lamellae seem fused into one. In regard to its anatomical position, this membrane entirely recalls the serous membranes of higher animals. This resemblance is strengthened by the presence, in the mesenteries, of the small transparent granules that are easy to isolate, and consequently independent of the tissue that surrounds them and that seem placed there like the mesenterial glands of higher animals. I am very far, despite these comparisons, from concluding they are identical and, as I have said above, I have not even been able to show positively that the mesenteries result from the fusion of the two lamellae, as one could presume with sufficient probability. Whatever it is, the position of this integumentary production and one of its functions at least (suspension and maintenance of the intestinal canal) are found in the peritoneum of higher animals and, as in some of the latter, the peritoneal cavity that it envelops is in direct communication with the respiratory fluid. In the case where we accept this determination as probable, it is necessary to remark that the synaptid has this peculiarity that, in it, the serosa and the integument seem to be in immediate communication, unless we suppose that the very short duct that serves for the introduction of water into the interior of the body has an intermediate modification analogous to the mucosa that we find in vertebrates in analogous circumstances.

We have said that a rather considerable sphincter surrounds the anus, and that it was at this point that ended on the one hand the four longitudinal muscles of the intestine and on the other the five small external muscle bands. This sphincter always has the same conditions and is regenerated in some way with each rupture of the synaptid by a mechanism that deserves description. Whether the fragmentation takes place slowly or abruptly, there is established strong contractions in the part of the longitudinal muscles near this point. The transverse fibers are found very close to each other and form a very distinct ring at the end of the intestine and another at the end of the body. This contracts with enough force to include the intestinal ring and in a very short time, often in some seconds, it establishes an adhesion so that the two rings merge and form a single muscle mass. The rapidity of this fusion is quite remarkable between parts covered, as we have said above, with a membrane that, in the case of which we speak, is found necessarily interposed between the tissues that tend to unite. We shall return later to this fact. It happens sometimes that this kind of fusion does not take place. In this case, each of the rings is obliterated separately by increasing contraction of the circular fibers. I have never seen sand grains escape from an intestine that remained floating in the body cavity. After a short time, it was distended by swallowed water that accumulated there.

When we compress the parts that we just described between lamellae, we see exude everywhere, but mainly from the mesentery, a perfectly homogenous, transparent material that forms round globules or droplets refracting light a little more strongly than sea water. This substance seems to be only this kind of organized matrix which we have seen develop in all tissues and that we might call the cellular tissue of our synaptid. We see how it has relations with the substance of Infusoria, Systolides, Intestines, Planariae ... produced by the same means. Dujardin was the first to call attention to this important fact and gave it the name sarcode. One understands that I want to speak here of the formation of the vacuoles, a phenomenon that I have not seen a single time in the study of the radiates, although I have seen it manifested very often when I examined the animals I have just cited.

I have not been able to recognize in any part of the digestive tube the least trace of vessels. If they exist, I believe I can say that they must be excessively thin, and that the fluid that they contain has no trace of globules. It differs in this from that which we are going to describe as filling the organs of circulation of the trunk. Moreover, it seems to me rather difficult that any vessels should have escaped my investigations. All these parts, being very thin and perfectly transparent, have been explored many times with the aid of the microscope at all magnifications. One can understand the care I took in these investigations.

§ IV. ORGANS OF CIRCULATION.

The circulatory system of the synaptids is extremely simple. The circular ring (Pl. 4, fig. 1, *n*), is located under the terminal disk around the buccal mass and communicates widely with the interior of the tentacles or, to speak more exactly, is continuous anteriorly with their cavities. Posteriorly, this ring gives off five branches of rather small caliber (*o*) that run the length of the longitudinal muscles of the body and everywhere having the same diameter. I have not been able discover branches and the circulation appears to me to be as in the tentacles.

It is impossible to recognize in fresh material whether there is a clear covering to these circulatory canals, unless we wish to consider them to be the transparent layer located under the ossicles of the tentacles (Pl. 4, fig. 13, *a*) and that entirely covers the interior of this system. But it is not the same when we examine synaptids that have had some time in alcohol. We recognize

then that this kind of internal epithelium is really a distinct membrane forming vessels. One can succeed, as I have done, to separate it from the muscle layers by simple traction without tearing it. This indicates a rather great firmness. We can then isolate easily the buccal ring and the vessels that leave it to go to the muscles. I have not, moreover, observed in any part of the vascular wall, the least trace of contraction that would give any direction to the blood. But it nevertheless receives a continual impulse, sometimes forward, sometimes backwards because of incessant movements of the tentacles and the buccal mass. The position of the central vascular ring, relative to the ossicles that form the skeleton of the synaptid, seems to vary with the movements of the animal. When it extends its tentacles and completely expands its terminal disk, the buccal mass rises and occupies all the space circumscribed by the ossicles. Then the ring is pushed out of this circle. But when the synaptid contracts and brings back its mouth inwards, the vascular ring comes to be placed inside the circle. It is in this position that I have drawn it.

The blood, or the nourishing fluid that circulates in this system, is colorless, a little denser and more refringent than sea water. It has an infinite number of brownish spherical globules resembling rather oil droplets, more refractory to light than the surround liquid (Pl. 5, fig. 6). Their diameter varies from $1/50$ to $1/100$ millimeters. They appear completely homogenous. I have not been able to recognize a distinct covering. However, I have never seen any fusion when they come into contact, even at a rather considerable pressure enough to flatten them.

Observations. — Although we find in the synaptid only a single system of vessels coming from the central ring, there is no less a true circulation. This fact is very easy to recognize in the tentacles. We see globules, coming from the body of the animal, penetrate into the tentacular cavities, carried by an external current that runs along the walls and follows exactly all the cavities (Pl. 5, fig. 5, *a*). The first current is divided into as many arms as there are lateral appendages. The globules behave in them as the bodies in the tentacles. Then each digitation provides a central counter-current whose union forms in the center of the tentacle a great current (*b*) that brings back toward the body the blood that it has respired. It follows that the periphery of the tentacle is always bathed by the venous blood (so to speak), and that this part of the cavity has a pulmonary artery for its function. While the center where the arterial blood circulates represents the vein of the same name. The opacity of the parts has prevented me from distinguishing clearly the progress of the globules, and consequently of the blood itself in the five muscle vessels. I have believed however that it took place in the opposite direction, i.e. that arterial blood formed the superficial current and venous blood the central current. These movements, completely independent of any contraction, are determined by the action of extremely fine and very difficult to perceive vibratile cilia that seem to line all the circulatory vessels. When we put a drop of alcoholic potassium hydroxide solution between the compressing lamella, and it comes into contact with the blood, the first effect, certainly due to the action of alcohol, seems to be to coagulate it. But soon we see it quickly dissolve and the globules, although resisting a little longer, undergo the same. The action of the acids determines the formation of a true clot. It is the same with death and we can even follow all the stages visually. If we remove a tentacle near its base, it contracts very quickly, as we have already said, and the quantity of liquid that flows out appears to be insignificant. Placing the tentacle under the microscope, we see at the end of some moments, the liquid part of the blood coagulates in the area of the wound and holds the globules that remain immobile, despite the constriction and pressures we can apply to the organ observed. A little beyond, circulation is in full activity, but soon it slows at the end of the branches and we can recognize the formation of

the clot. If the experience is prolonged sufficiently, we see all movement cease, first in the lateral branches, then in the terminal extension and death marches on, so to say, gradually from the circumference to the center where we still observe circulation of the globules long after it has ceased everywhere else. It is rather difficult to explain here the continuation of movement when the layer of vibratile cilia is deeply encrusted by the clot. I have tried in vain to distinguish them on the globules themselves and I believe I can affirm there are none.

The ordinary means of dissection generally fail before the excessive contractility of all parts of the synapata. Pins are powerless when it comes to fixing and keeping parts apart that break or tear in a few seconds. It is especially in the study of organs that surround the mouth that I have had to struggle with when I worked on fresh individuals. To get around this in a way, I usually worked on sections. It was by happy chance that I have been able to observe the vascular ring in its entirety. Two times I cut close enough to study it with the microscope. I believe it is difficult to discover it by any other means. It is necessary to make many scissor cuts before having success. These parts are, on the contrary, easy to isolate on specimens that have been in alcohol for several months. All the preceding details have been verified in this way.

§ V. ORGANS OF RESPIRATION.

We consider as organs of respiration: 1° the tentacles, 2° the large cavity between the trunk strictly speaking and the intestine.

I. *Tentacles*. — The tentacles are hollow organs whose cavity is an extension of the large central vascular ring. Their walls are made up of several layers: 1° integument; 2° muscle layer with transverse fibers; 3° muscle layer with longitudinal fibers; 4° layer with calcareous concretions. 5° internal membrane or wall strictly speaking; 6° finally we place here the description of the suckers that we cannot separate anatomically from the tentacles, although they appear to play in relation to them only a role of support and whose functions are, to all appearances, entirely different.

1° *Integument*. — We have little to add to the details that we have already entered. We shall recall here only that on the tentacles, the integument is much thinner and that the two component layers seem to be entirely merged on the digitations. They have, moreover, neither anchors nor shields, nor needles, no pigment. This gives these parts great transparency. But they are not less distinct from the underlying layers. On an individual preserved in alcohol, I have been able to detach them and remove them nearly in one piece, separating them from the muscles below.

2° and 3° *Muscle layers*. — The arrangement of the muscles in the tentacles is the same as in the rest of the body. We find first a continuous external layer in which we hardly recognize transverse fibers. Then below the muscle planes, with longitudinal and much more clearly defined fibers. Each tentacle has two upper muscles and two lower ones that run from one end to the other, and two which are attached to the small peculiar muscle bundles of each digitation (Pl. 5, fig. 7, *aa*). We have already noted that, in contact, they open this orifice at the same time as they bend tentacle toward it. The lower muscles attach to the ossicles of the mouth, so that the interval that separates them respond to the articulation of two of the ossicles. It follows that each of them receives two muscles coming from two different tentacles or, in other words, that each tentacle is attached to two of these solid pieces.

4° *Layers with calcareous concretions*. — Under the two muscle planes is found a layer of perfectly transparent and homogenous substance, completely filled with calcareous concretions having the most bizarre and varied forms. We can, however, describe them as very irregular

cylinders, covered with protuberances sometimes folded on themselves into a ring, sometimes only more or less curved in different directions, and nearly always having, in this case, swellings with irregular growths at their two ends (Pl. 4, fig. 7–12). Their sizes are as varied as their forms. In a synaptid of 15 inches, I found some that were up to a seventh of a millimeter in length while others were scarcely $1/20$ of $1/30$ of a millimeter. These latter had in general an annular form. In addition, these concretions even increase, not only in volume but even in number with the size of the individual that we examine. They are rather rare in small synaptids, while in the one I just cited they were tangled up with each other and formed a tight layer, especially on the sides of the tentacle and its first digitations (Pl. 4, fig. 13, *b*). Their external appearance and their composition is completely similar to that of the calcareous pieces of the skin and has no relation with that we have found in the ossicles that surround the mouth.

5° *Internal membrane*. — This membrane is nothing other than the covering for the respiratory canals. We do not have to return to it. We shall only recall that we can be sure of its existence as an anatomically distinct member of superposed tissues only in individuals that have been submitted to the action of alcohol.

6° *Suckers*. — Suckers, we have said, are few in number and arranged in pairs toward the middle third of the tentacle (Pl. 4, fig. 1, *b*). The developed organs have the form of an elongated pyriform cup, supported by a stalk. Their end is hollowed out into an almost hemispherical cavity, surrounded by a large cushion. At the bottom of this is a wide group of vibratile cilia. Their structure is quite complicated. The layers of the integument, especially the dermis (*a*) before surrounding the pedicel, increase greatly in thickness. Two layers become very distinct from each other over all the external surface of the sucker. The cushion of which we have spoken is uniquely formed by them. The membrane that lines the cavity is, on the contrary, rather thin, without any granules and seems formed by a simple extension of the epidermis or, better without doubt, by a lamella resulting from the fusion of two integumentary layers. Under the skin runs a muscle layer with longitudinal fibers (*b*) that completely envelops the sucker and seems to take its point of attachment in the cushion. Beyond the stalk, it appears to divide into two planes. The exterior fibers (*f*) diverge in all directions and are lost in the nearby integument. Internal fibers (*e*) join in a cylindrical bundle that extends from front to back under the skin toward the median line of the tentacle where they encounter a similar muscle coming from the symmetrical sucker. These two bundles unite with each other and with those of all the other suckers and are extended following the midline. I have followed the resulting muscle up to the very base of the tentacle. This anatomical arrangement explains how the suckers can be entirely withdrawn under the integument, to the point where it is quite rare to be able to study them next to the integument when we have separated the tentacle to examine it at high magnification under the microscope.

Under the muscle layer that we just described, and in the body of the sucker, we see a homogeneous, transparent mass (*c*) in which it is extremely difficult to distinguish the transverse fibers. What we could consider as such could be as well be taken for simple folds due to contraction of the longitudinal muscle fibers. Nevertheless, this mass is of muscle nature, at least it is contractile. The decrease in transverse diameters of the suckers has appeared to me due to its action. Finally, at the very center of this mass, we see an organ (*d*) of granular appearance, whose aspect recalls that of some glandular body of the systolids and small annelids. But it has been impossible for me to even suggest the function.

It seems to us rather singular to find in the suckers an inverse arrangement of that we have seen up to now in the superposition of the muscle layers. Does there exist between the layers

and longitudinal muscles a plane of this nature with transverse fibers? If so, its thickness must be very minimal and the fibers very difficult to see. Because, despite all our efforts, we have not been successful in discovering it. Is the elasticity of the dermis that here acquires an abnormal development sufficient to counterbalance the action of the longitudinal muscle and assure the free exercise of the functions of the organ? This is possible and we would freely accept this hypothesis.

II. *Visceral or abdominal respiratory cavity.* The space between the digestive tube and the internal surface of the layers of trunk is continuously filled with water in synaptids. When we dry them and they contract, we see this liquid expelled little by little, draining from under the tentacular crown. The ducts that involved are very difficult to see. However, we see the internal pore in an animal that had been in alcohol by opening the anterior part of the body longitudinally and carefully detaching the mass of the mouth. In a fresh individual, it is necessary to use scissors to remove the largest part of the buccal mass very close to the calcareous ring. Then, place the piece under the microscope and compress it. We can thus see, between some tentacles, a very small mamelon pierced in its center by an orifice surrounded by vibratile cilia (Pl. 5, fig. 7, f). This mamelon corresponds to the opening in the center of one of the calcareous pieces. We distinguish sometimes very well a duct that, crossing the integument, widens beyond the pore, directed toward this opening that it crosses. Internally, it ends at one of the intervals left by the pyramidal muscles that, we have indicated, are the elevators of the muscle mass.

These ducts, as we have already said, are sometimes four, sometimes five in number. They are always found in one of the spaces left between the longitudinal muscles of the body. It is through them that the modified integument, fused into a single lamella, enters the abdominal cavity to coat the walls and line the intestine, held in place by the straps of which we have already spoken. Thus, the formation of this kind of peritoneal membrane is like that of the mucous membrane in higher animals although it has at least partly the functions of a true serous membrane.

Observations. — The important role of the tentacles of the holothuroids in respiration is a fact too generally accepted for it to be necessary stop here. We shall note only that it is even less possible to deduce it in synaptids than in other groups of the same family because of the width of the cavity and the small distance that separates the blood from the respiratory liquid. It seems to us nearly as useless to insist on the functions that we attribute to the abdominal cavity. Continuously filled with a water that appears to be renewed rather frequently, circumscribed by a wall lined with a very fine membrane, it is impossible that it is found thus in contact with the ambient liquid without any action being exerted. Now, the analogy indicates to us that action must be considered at least in part respiratory, because this vast cavity can hardly be considered as represent in the respiratory tree of the holothuroids strictly speaking, generally considered as an accessory organ of respiration. It would be possible, however, that there was also in both, but especially in synaptids, a true nutritive function because of the immediate contact of water with the digestive organs, and this was the means used by nature, to make up for the absence of blood vessels, that we believe to have observed in the latter radiates elsewhere than in the longitudinal muscles of the body.

The respiratory tree of the holothurians and the corresponding cavity of synaptids differ essentially from each other by a remarkable anatomical arrangement. The first has a single opening posteriorly, at least in the species studied thus far. In the Synapta of Duvernoy, we find multiple anterior openings. It is evident that the fragility of our radiates required this change, without which it would have been exposed to wounding and consequently scarring that would

have without doubt compromised its existence in making impossible the introduction and renewal of water in its interior.

§ VI. REPRODUCTIVE ORGANS.

The Synapta of Duvernoy offers us perhaps the most complete example of hermaphroditism yet reported. The male and female organs are perfectly distinct but united in a common sheath and arranged in such a way that the first envelops the second.

When we examine the living synaptid swollen with sea water, we distinguish very well, across the integument, the reproductive organs in the form of yellowing cords floating in the abdominal cavity, bypassing it in several directions and appearing suspended from the buccal mass. By carefully opening the animal in a way to leave the first mesenteric strand intact, we see on both sides of it two of these cords that seem to be attached to the pyramidal muscles (Pl. 4, fig. 1, *q*), cords that at some distance from their origin produce branches as large as the trunk itself, and whose number varies from three to five. In the fresh animal, it is more than difficult to follow these cords beyond the apparent point of attachment. But examining animals preserved in alcohol, we can isolate these parts. We recognize then that the two trunks penetrate into the pharyngeal muscle mass, bypass the buccal cavity and reunite into a common canal that goes to open outside by an opening located behind the calcareous ring. The two large trunks of which we have spoken are strongly restrained at their origin. It is the same for the branches that leave them. Both are perfectly cylindrical for the remainder of their extent. Their dimensions in length and thickness vary according to the period when they are observed.⁶

In studying the structure of these organs under the microscope, we recognize that they are so many hollow cylinders composed of several layer and enclosing in their internal cavity the testis and the ovary. We shall examine successively these diverse parts.

I. *Wall of the cylinder.* — The structure of the walls of the reproductive organs resemble those of all the cavities that we have described until now. We distinguish: 1° an external epithelium; 2° a muscle layer with transverse fibers, 3° a muscle layer with longitudinal fibers.

1° *External epithelium.* This epithelium is an extension of that which lines all the abdominal cavity and which we can easily assure ourselves in the individuals preserved in alcohol. When we examine them in the living, we see that all the surface is bristly with very fine vibratile cilia (Pl. 5, fig. 1. *a*). The movements of the reproductive organs depend without doubt as much on this circumstance as on the presence of muscle layers that we are going to describe. Some pigment grains similar those we have seen on the digestive tube are scattered here and there on this epithelium.

2° and 3° *Muscle layers.* — These layers have nothing particular and resemble completely those that we have found in the tentacles. The longitudinal fibers are more marked and run from one end to the other, in forming a complete sheath. The transverse fibers located exteriorly are little apparent. We shall observe that this description concerns only the developed organ as a result of gestation. Before reaching this state, the two muscle layers have remarkable changes to which we shall return later.

⁶ The arrangement of the reproductive organs is completely similar to that in the Synapta of Besel, except the first trunk is much larger and that it appears to open into one of the tentacles beyond the first lateral digitations. This circumstance leads us to doubt the correctness of the figure that we cite. These organs are also much more divided in the Synapta of Besel than in those of Duvernoy and the ensemble of their latter ramifications form a kind of large ball, due without doubt nearly only to the effect of alcohol.

II. *Testis*. — In the first synaptids that I had the occasion to study during the month of August, I found under the layers that I just described, instead of a simple epithelium, a tissue that, by its singular appearance, did not lend itself to any plausible determination. It consisted of stalactiform protuberances (*c, c*) lining nearly all the interior of the cavity, leaving only here and there free intervals where we could distinguish some eggs that developed in the gaps left by these organs. Each of these protuberances was covered by a proper membrane that seems to fold up to pass from one to the other. Their interior was divided into rather large cells by walls of an extreme delicacy. These kinds of chambers contained a granular, transparent material. At first, I believed that this was the interior wall of the ovary, a very thick and irregularly swollen. But, towards the first days of July, having opened a synaptid whose ovaries had developed so that they reached nearly to the posterior end, it was easy for me to recognize that this enigmatic organ was nothing other than the testis. The granulations that the cells contained had organized themselves into spermatozoids, which pressure caused to be released in myriads and that were active for a rather long period in sea water. These spermatozoids of the synaptid are extremely small. The perfectly spherical body is scarcely $1/300$ millimeters. The tail is approximately three times greater than the body and so thin that its end escapes the greatest magnification (Pl. 5, fig. 2, *a*). Several were united by the middle of the body (*b*). Each of them seems to make efforts for their individual freedom. Their movements in the liquid were remarkably sustained and recalled those of some Infusoria, much more than those that I have observed in other spermatozoids. One of them covers the entire surface of my slide, which is fifteen millimeters, making several circuits and scarcely stopping two seconds on two or three different occasions. If we take $1/75$ for the total length of this small being, we see that it covers in the space of a few minutes, a distance equal to nearly 4000 times its total length.

In some synaptids observed still later and where they eggs were more developed, I have seen them fill all the interior of the reproductive cords. The testicular protuberances that first occupied most of this cavity had entirely disappeared and proper walls of the organ no longer remained and there remained only the proper walls of the organ whose muscles were then well developed. We shall return later to this fact, that we are only stating here.

III. *Ovaries*. — Between the spaces left by the testicular protuberances, we find a pulpy, transparent material that seems to form the very substance of the ovary, and in the middle of which develop the eggs. These, examined in a synaptid whose spermatozoans are no longer apparent, have an exterior covering, membranous, very flexible and easy to tear by compression. A very thin layer, perfectly transparent, separates it from a yellowish yolk, semi-opaque, whose very distinct granulations are approximately $1/400$ millimeters, and at the center of which we see the vesicle of Purkinje. This has a proper covering formed by a membrane of extreme thinness, containing a substance more transparent than that of the yolk and whose granules are scarcely $1/1000$ in diameter. Finally, we also see very clearly the germinal spot of Wagner, similar to a drop of oily substance, very transparent, and in which I could not distinguish a proper covering.

In the individual whose testis contains spermatozoids, I have found these various parts, perhaps more clearly defined, except for Wagner's spot that, here as in higher animals, has disappeared without doubt because fertilization has already taken place. The transparent layer that surrounds the yolk, has also increased in thickness. This last is still less translucent at the same time that its volume has increased.

Observations. — The dimensions of the cords that contain the reproductive organs vary according to time they are examined. When the eggs first are seen, these cords are scarcely a

millimeter in diameter and two or three inches in length in a synaptid of ten inches. Later, depending on how their contents are developed, they reach up to the posterior end of the abdominal cavity and are nearly three millimeters in thickness. These exterior changes have accompanied modifications in the very structure that appears to us to merit all the attention of naturalists. The muscle layers exist, such as we have described, only at a certain time when the eggs are already rather large and that they have been fertilized indicated by the disappearance of Wagner's spot. In the early days of their appearance, we find in the walls of the organs that concern us, only some longitudinal fibers that we can distinguish clearly only toward the anterior and middle part of the cord. More posteriorly, these fibers are found in some kind in this transparent matrix of which we have already spoken so often, and which seems to be constituted here with the rest of the wall because the latter has only a membrane that is perfectly homogeneous in appearance. This portion of the organ is nonetheless contractile. I was especially struck, in examining the end of these ovaries where the most attentive eye could not distinguish the least appearance of fiber, to see it curve on itself in various directions, elongating, contracting, and even changing into a concave cup the round convex end.

A few days later, at the same time that the eggs increase in size, we see the longitudinal fibers appear little by little and to show up to the end of the cords. Finally, the transverse fibers appear in their turn. At first, they are little distinct and are only at the anterior part of the organ. Later, better marked, they form a continuous layer in all its extent. It is impossible, in the presence of the facts, not to be struck by the analogy that they present with the we see occur in the reproductive organs of female mammals at the time of gestation. Moreover, we shall return to this subject later and compare these results with those from the examination of the muscle system in other parts of the synaptid. We shall try to indicate some physiological consequences that appear to us to be possible to be deduced from all these observations.

The anatomical arrangement of the organs responsible for secreting, one the egg, the other the fertilizing liquid, is well worth noting. It presents us a cast of hermaphroditism as complete as possible. The two organs, being here perfectly distinct, one of them really constituting the surrounding walls of the other. The mechanism of fertilization, the atrophy of the testes that seems to be the result, are easy to explain since then. The development of the eggs and the secretion of the sperm appear to be combined in a way that the latter if completely worked out at the moment when the former begin to be constricted in the intertesticular lacunae. The eggs, continuing to grow, must necessarily compress the testes more and more and express on them in some way the fertilizing liquid. But soon, by their progressive development, they repress the latter more and more and end by completely atrophying them. Thus, this single cause, so simple, the natural growth of the ovules, leads to successively fertilization by the testis and then the disappearance of this organ that has become useless since it has fulfilled the function that was its responsibility. It is also harmful in that it occupies space the eggs need to reach their full development.

That which we have seen of the composition of the eggs of synaptiids proves to us that the more or less simplicity of their organization is far from depending on the degree that the animal occupies on the animal scale. We find here all the parts reported in the highest species. There is not even the albumen that does not appear represented by this transparent membrane that separates the external membrane from the yolk. It cannot be a membrane specific to the latter. Its very thickness, from the first moment when I observed it, opposes our adopting this opinion. The result is that the yolk is missing entirely, which we would have to regard as quite extraordinary, but I presume that the opaqueness of the body has prevented me from

distinguishing it. If it exists, which seems probable, it follows that the egg of this radiate, whose anatomical organization is certainly simpler, has seven distinct parts, namely: the outer covering, the transparent layer that separates it from the yolk, the covering of the latter, the yolk, the covering specific to the Purkinji vesicle, the vesicle itself, finally, the germinal spot of Wagner. The disappearance of the latter, after the ovule has been fertilized by the sperm, shows us the repetition of a fact already reported in a large number of animals. It would be interesting to see it repeated everywhere under the same circumstances.

It would be greatly to be desired that naturalists located in a favorable situation would be actively occupied with the embryogenesis of lower animals. The number of beings that, after coming out of the egg, undergo metamorphosis, seems to increase as we devote ourselves more to the interesting investigations. It seems to us without doubt that it will multiply more day by day. It appears probable to us that the holothuroids, in general, are in this category. All the radiates that we have been able to observe on the coasts of the Mediterranean, as in the ocean, have appeared to present to us the characters of animals that have reached their last phase of organic development, although they can still grow until the moment of their death. The synaptids, in particular, have shown us reproductive organs well characterized by the presence of more or less advanced ovules and had thus all reached the adult stage. But, on the other hand, I have never encountered any that were less than six inches long, and it will certainly not occur to anyone that that they were this size in leaving the egg. Why, then, in localities where they are abundant, are not smaller ones encountered, as occurs for actinians for example? Is it not permissible to suppose that before reaching the definitive form at which they can reproduce, they have to undergo some transformations? Is it not believable that, like insects, some mollusks and crustaceans, like asteroids, campanularians and even sponges and sponges, they have their larval state during which, without doubt, they differ completely from that what they will be one day.

THIRD PART

ZOOLOGICAL AFFINITIES. — GENERAL CONSIDERATIONS.

§ AFFINITIES.

The naturalists who have accepted the genus *Synapta* have attached it closely to the holothuroids, and this opinion is basically really true. But if there are between this genus and the true holothuroids some evident relations that do permit separating them, it is necessary to recognize also that the differences between the two groups are so great that it is necessary to carefully distinguish them from each other. There is more distance perhaps from *Holothuria tubulosa* that has been better studied and *Synapta de Duvernoy* than the first of the quadrumanes to the last of the cetaceans because, in the latter, all the functions remain the same and are fulfilled by the same organs modified only in their form, while in our radiates we see nearly all the organs are reduced and a large number even disappear completely, which results in a very remarkable simplification of the organism. We pass rapidly in review, in comparing them, the most essential characters of these two types so different, although belonging to the same family.

We leave aside the exterior differences in general form. These characters appear to us to have little importance and can serve only to establish more or less artificial subdivisions in a genus too numerous. The transparency or opaqueness of the integument has more value to our eyes, because they can be only the result of a basic difference in the structure of the tissues. However, all the exterior layers of the synaptid are as diaphanous as those of the holothuroids are not.

The number of layers in the composition of the body is nearly the same in holothuroids and synaptids. Delle Chiaje, who has pushed this kind of research the farthest, has recognized the existence of the epidermis, the dermis and a tissue that he named fibro-elastic. He has also distinguished the muscle layer with transverse fibers, longitudinal muscles describe as by all the authors, and finally the internal epithelium from which originates the mesentery and afterwards the exterior covering of the respiratory tree and of the other viscera contained in the abdominal cavity.

But between an integument strictly speaking and the layers that constitute in some way the flesh of holothuroids, he found one that is lacking in synaptids. On the other hand, he has indicated in these diverse layers nothing that resembles calcareous concretions that we have found either in the dermis or under the internal epithelium. However, this is not a reason to accept entirely their non-existence. Dujardin has kindly communicated to us some notes where the integument of some holothuroids of the division of Cucumaria has irregular concretions whose nature appears evidently similar to that of the concretions of which we speak. We know moreover that there exists in the holothuroids whose body is covered with a kind of stony carapace (*Cuvieria squamata* Péron), and if, for lack of sufficient notes on their anatomy, we do not yet know where to place them in the general framework of the family, we can no longer regard the dermal productions as belonging exclusively to the synaptids.

But a character that seems to belong only to these concretions of synaptids consists in the form of anchors with double hooks. It is especially the role that the singular weapons play in location. The genus *Oricinolabes* (Brandt) appears to have the same peculiarity. But it is probably very close to the synaptids. Perhaps we shall find later something similar in other species belonging to the division of *Fistulaires* of de Blainville. From then on, we would have there a good external character to distinguish this division from the family of holothuroids.

The analogy is still supported when we examine the structure of the body. We find in the synaptids the five large longitudinal muscles reported in all holothuroids and the muscle sheath that covers them.

It is the same with the tentacles, essential organs of respiration, that have nothing particular in synaptids with the accomplishment of this function and in which, as in the holothuroids, the liquid for respiration is moved in a single large cavity representing both veins and arteries. The calcareous concretions that we have described as being a dependance, have not been recognized by any of the naturalists who have dealt with holothuroids. But Dujardin found them, although in different forms, in *H. cucumis*.

But we do not believe that the suckers of the *Synapta* of Duvernoy have yet been reported in holothuroids strictly speaking. These organs, which seem to play a role in locomotion just as essential as the large trunk muscles themselves, probably do not exist in *H. tubulosa* and the other related species that we see climbing the vertical walls of a container with the help of their feet or suckers, without ceasing to move their tentacles. In their turn, the synaptids do not have the least trace of these feet, which obviously supplement the suckers of which we speak. The nature of these two kinds of organs of locomotion is, moreover, very different. The feet of

holothuroids are in direct communication with the circulatory system, and become erect in order to function, while nothing similar occurs in the synaptid. There is indeed an analogy of function but not the slightest anatomical resemblance.

The reproductive system has great analogies in their anatomical arrangement, or at least the hermaphroditic organ of *Synapta* is located absolutely as that we named the ovaries in the holothuroids. Could we not presume that these ovaries also offer in the latter the union of male and female organs?

We know that until this day, naturalists could not determine the first in a positive way and that Delle Chiaje in particular sought it in vain in *H. tubulosa*. However, we know that the testis of the synaptid has only a temporary existence and that it disappears after finishing its functions. If is the same in the holothuroids strictly speaking, it is easy to understand why it has escaped to this day investigations made with the goal of discovering it. If our conjecture is verified, it would be on the principal traits common to the two genera of animals that concern us.

The circulatory system presents us again in the two type fundamental similarities. We find in the synaptid, the circumbuccal ring giving to each large muscle of the trunk a single vessel both arterial and venous.

But all the abdominal circulatory system of holothuroids seems to be lacking in the synaptid, and the very remarkable part of a very complex system in the first of these radiates, the only one that has distinct vessels for arterial blood and venous blood, the only one where we find an organ recalling the heart of animals higher on the scale, this part, we say, disappears in the second.

The digestive tube in both opens at the two ends of the body. But in the holothuroid it forms true circumvolutions. It has distinct parts whose structure and dimensions vary. It is straight and especially uniform in the synaptid.

The holothuroid has a complete mesentery, attaching both the diverse parts of the intestine including all the abdominal organs and fixing them to the cavity that contains them. It is a true peritoneum with very complex folds as in the vertebrates. Its functions are, it is true, the same in the synaptids, but this organ is infinitely simpler and has only interrupted straps in all the abdominal cavity.

Finally, we find in synaptids no accessory organ that we can regard as an annex of the digestive tube. We do not see the least trace of these numerous systems with still undetermined functions that are enclosed in the abdomen of holothuroids. The respiratory tree has disappeared to be replaced physiologically by the cavity itself, and its opening, having become multiples of one that it was, is found in front and outside instead of opening behind and in an interior intermediary organ.

We see that the differences that separate the synaptids from the holothuroids strictly speaking, although very great, consist only in the reduction of parts making up the organic systems, reductions that, in many cases, goes to complete elimination. A synaptid, if we can express it thus, is a holothuroid reduced to its simplest expression.

But if this simplification, in weakening the zoological relations of synaptids with the type from which they derive, gives rise to new affinities that seem to us very interesting to indicate. If we put aside, for the moment, the distinction of numerous layers of tissue of which we have shown to exist in our radiates, and that we only to be complete in the trunk and digestive tube, we see a remarkable link established between it and the actinians, as they have generally been described. In both, we have a tissue of very similar nature, more or less transparent, remarkably contract, form the exterior of the animal and folded in the interior to form the digestive tube. In

the synaptid, no more than in the actinians, we do not find any accessory organ appearing to depend on the latter. In both, the limit between the exterior and anterior of the body is occupied by tentacles whose number and more or less simple form are of little importance to us. Between the walls of the trunk and intestine we find, in both, a vast cavity in which penetrates the ambient liquid, and where float freely the reproductive organs. The walls of the actinians are evidently brought to mind by the mesenterial straps of the synaptid. If the digestive organ does not stop in the interior of the latter's body, if it reaches the posterior end and opens outside, if we at the same time find still in it a remnant of circulation and a circumbuccal skeleton, it is because this animal is still a holothuroid, but also as near as possible to actinians. In another memoir, we shall return to these comparisons by describing a genus of the actinian family that, on its side, has some anatomical details that results in an evident tendency towards the holothuroids. We shall show, in addition, that these similarities are nearly supported in the detailed examination of these various parts of the body and that, in particular, the complications of the tissues of the tissues of synaptulids is no way a character separating them from the actinians whose organic composition is much more complex than most zoologists have believed.

Blainville has already noted correctly, basing himself on the observations of Lesueur, that *Actinectes* (Lesueur) or *Minys* (Cuv.), both being true free actinians, have great relations with the holothuroids. Perhaps the details that we have just indicated, joined to those that we shall publish next, will show more and more the affinity that prevails between these two great families. It seems probable to us that it will be necessary, from this report, to return one day to the classification of Lamarck and place them immediately following each other.

Whatever are the relations of the synaptids with the other families of the radiates, it is evident, according to the anatomical details that we have considered, that this genus is considerably farther from the primitive type, taking for them the best studied species, *Holothuria tubulosa* in particular, and that we can, until more informed, consider the two species as the two extremes of the grand family of holothuroids. It is to be presumed that between these two terms we shall find numerous intermediaries destined to connect them to each other, and that around each of them will group forms that derive from them although distinguished in some points. Thus, on one hand, the anatomy of *Cucumaria*, although recalling in general that of *Holothuria tubulosa*, appears to differ from it in some relations (note communicated by Dujardin). On the other hand, the chiridotes of Eschscholta, so close moreover to the synaptids as far as we can tell, already show us a rudiment of the respiratory tree. Perhaps we shall also find in them, by thorough study, the first traces of organs that are missing in the latter. The genus *Oncinolabes*, which joins the absence of the abdominal respiratory tree, the transparent skin and the anchors of synaptids, will probably have to be connected more than done by Brandt. It is true that it is very distinct in that it has very developed feet on the length of the body in five distinct rows, but we are far from being fixed on the value of this character. If, for example, the simplicity of composition, remaining moreover the same, these feet are only simple appendices of the interior vessels or kinds of caeca communicating with the abdominal cavity, and that water would distend voluntarily by the animal, we can attribute their absence or their presence a characteristic value as great as the whole organization, so complex in some, so simple in others.

The preceding reflections, while tending to show what is missing in the various methods proposed until now for the distribution of holothuroids, prove to us even better the insufficiency of the methods that we have to improve them. We shall be careful, we understand, in making such an attempt. Perhaps we shall only be able to conclude from this work that the synaptids have not yet had their real value in classification, and in the grand family of which they make

part, they have a well-marked place, and that they could rightly be placed in some type of sub-family or some other large division that we want to establish, and in which would be placed according to all characters, the oncinlabes and the chirodotes. Other sub-groups are perhaps still to be discovered in the holothuroids. It is useless, anyway, to note how the radiate condition is more marked in the Synapta of Duvernoy than in *Holothuria tubulosa*. However, it would not be surprising that we find one day in *Cuvieria* (Péron) and in other species with obviously distinct dorsal and ventral surfaces, anatomical modifications still tending more in the latter toward bilateral symmetry. If this presumption comes to be confirmed by facts, it would be very interesting to see if this group of holothuroids concerns, on one hand, animals with paired symmetry, very probably species of mollusks with a thick and opaque integument, a solid and stony carapace and, on the other hand, true radiates, in particular the actinians by the synaptids whose tissues have so much resemblance to those of the latter by their general appearance and all of their most essential properties.

§ II. GENERAL CONSIDERATIONS.

There has been no question, in the preceding, of the organic system that seems, in general to preside over animal life, the nervous system. Despite numerous investigations made on fresh animals and on individuals preserved in alcohol, and in varying all kinds of means of investigation, it has been up to now impossible for us to discover it. We shall not draw any consequence of the uselessness of our efforts. We simply expose the fact. The existence of a nervous system in the true radiates, such as holothuroids, urchins, actinians, is in our opinion, one of the problems that still awaits a solution. Naturalists of great merit have said they have found it in some of them. Others have believed it necessary to attribute it to organs described as such a completely different meaning. It appears difficult to us to adopt one or the other of these opinions. We prefer to remain, in this regard, in a philosophical doubt.

The organization of animals that we call lower, is it really as simple as we have accepted for so long a time? Or does the organization approach that of higher animals by some degree of complication? These are the important questions raised for some years. But for the solution of which it seems to us that we have generally sought facts unsuitable to decidedly resolve this problem. It is not, in fact, in studying beings whose place in our classifications is still doubtful because of their smallness that we can reach the truth: the dimensions of an animal, we know well today, often has little influence on its zoological affinities. Laborious research can lead, in this case, to recognize its nature, to show we have completely mistaken the rank that it has reached in the scale of beings. These results are very important, without doubt, because the remove errors that lead to false general conclusions. But by making the question relating to lower animals clearer, they leave it completely. We see that we refer here to the beautiful publications of Dujardin and Ehrenberg on infusoria and rotifers, to the remarkable work of Doyère on tardigrades. It is very evident that the latter animal belongs to a type of articulate. It seems without doubt that it also to this great division that belongs the rotifers. The place that a very large number of infusoria should occupy seems very problematic. It seems probable to us that we must relate them later to several different types. Also, the question of the more or less complicated organisms in beings firmly placed at the bottom of the scale, appears to us a little outside the results obtained by learned and laborious naturalists we have must quoted. The detailed study of the large species generally recognized as belonging to a type of radiate, and in presenting manifestly the characters, seems to more suited to throw some light on this fine

question of general zoology, and in this respect, the anatomy of synaptids could perhaps be useful. The old naturalists would certainly regard this animal as very simple in organization, and Réamur would not have hesitated to apply to the greater part of his work the term jelly animal, by which he characterized the acalephs. However, this membrane, as thin as the finest gauze, as transparent as the cleanest glass, has shown us six layers of tissues distinct from each other, most of which could be isolated by various means. We recall, especially, on this subject, some of the observations that we have made on the integument and the internal epithelium of the abdominal cavity. In a synaptid preserved in alcohol, we have been able to remove the first up to above the digitations of the tentacles, leaving intact the underlying muscle layers. In the same individual, we have detached, without tearing the internal epithelium, over a rather great extent of the abdominal muscles. We have seen it fold up to line the intestine and the ovaries, behaving, in a word, like a true member of a higher animal. It is permissible for us to conclude from these facts that the apparent simplicity of the structure disappears in some lower animals after attentive observation aided by the various investigative procedures known today.

But is this to say from this that we should consider these animals as complex in organization as those we place at the top of the scale? Is this to say, especially, that we can always establish identity between these beings so far from each other. Certainly not. We are far from thinking that. We believe there exists animals very much simpler than our synaptid. We believe that from it to the sponge, there should be found many intermediaries. We believe especially that we should act with much caution when it is a matter of assimilation, of which we shall speak later. Examination of the muscle fiber in the various states it has in the synaptid, will furnish us evident proof of it. But what are the intermediaries? What series of successive degradations did they pass through to reach these beings where all the organs merge into a single homogeneous and living mass, where all the functions have disappeared, if this is not those that are immediately linked to nutrition? We still know nothing about it and we are reduced to gathering the necessary facts to resolve these interesting problems with confidence.

We have reported, as worthy of note, the ability to contract that seems to occur in all parts of the body of the Synapta of Duvernoy. This vital phenomenon is manifested, as we know, more or less energetically in all lower animals, and is even one of the largest obstacles that the anatomists encounter in their study. It is natural, in the presence of such a general fact, to ask if this property belongs to a particular tissue or whether it is distributed more or less equally with some modifications to all parts of the organism. This latter opinion seems to us very probable. Without doubt, the contractions to a certain extent are particularly due to the muscle fibers. The various movements of the animal accord too well with their direction for it to be otherwise. But these fibers do not seem to be the exclusive site of the faculty of which we speak. May we recall here what we have said of the movements of the ovary. Where the most sustained attention did not distinguish the least trace of fibers, and especially the really very active folds of the mesenteries in which we can, I believe, confirm that nothing similar exists⁷. This membrane is so thin that we can scarcely believe it 1/29 millimeters thick, results from all appearances from two lamellae of the epithelium. In any case, we can hardly believe that it is of a very different

⁷ The microscopical observations reported in this work, as well as all those that I made during my visit to the coasts of the Channel, have been made with a microscope of George Oberhauser. We know how far this skillful artist perfected his instruments. I shall add that my objective, n° 8 (300 diameters) has been tested with great care by Dujardin, who has not found it in any way inferior to the sets of lenses with which he made his beautiful observations on the locomotory filaments of infusoria, in particular *Euglena*.

nature from the latter, and consequently we can hardly refuse to the epithelium itself the faculty of active contraction so evident in the mesentery. But, consequently, the analogy leads us to think that the various other tissues must not be inferior in this regard to that which it seems to play in Synapta the role of serous membranes of higher animals and represents, consequently, a tissue that nothing, in the latter, can lead us to believe to be contractile. Moreover, the fact is easy to verify for the integument. It is sufficient to remove a piece with curved scissors to see it contract immediately afterwards very strongly. Whether the piece is taken from the body and contains consequently elastic fibrous issue, or whether it is taken from around the mouth, or at the base of the tentacles, parts that lack this tissue, the result is the same. We must observe, however, that the faculty of which we speak does not appear to us in any way identical in the different cases of which we just cited, and that in the latter especially, it seems to approach rather a kind of elasticity, a certain general tendency of tissues to take a spherical form when excited by physical agents, than the spontaneous contractility of the muscle fiber.

We are naturally led in speaking of contractility, to occupy ourselves with organs in which this property appears particularly developed, in those where it is manifested in a constant way and in some way more regular, and on the action of which depend on the various movements of the animal. We have reported several kinds. In some we encountered long, cylindrical fibers that we can easily isolate and that seem united with each other by an infinitely small amount of the homogeneous and diaphanous substance that is like the matrix of all the organs of the synaptids, and which consequently plays here the same role as the cellular tissue in higher animals. These eminently locomotory organs have these characters only in the five small longitudinal bands of the body. They alone merit the name of muscles, if we want to give this qualification only to the parts having an evident relation and a nearly identical structure to the fleshy parts of the higher animals. But beside these small bands, we find an equally contractile layer whose action is very evident in the living animal. Now this layer no longer shows us very distinct fibers that we can isolate. They are adherent to each other and form a whole whose parts can be seen only by the play of light. We would say that they are embedded in their matrix like the bundles of some skin muscles in the cellular tissue or in the thickness itself of the dermis. However, in the latter case, we have kept, with reason, the name of muscle for the locomotor organ nearly mixed with the integument. We are thus authorized, it seems to us, to give the qualification of muscle layers, of muscles, to the parts of synaptids and other analogous animals that have both a fibrous structure and evident contractility. We must only report the different characters that they may have and this is what we have tried to do with all possible care.

Examination of these various muscle fibers appears to us appropriate to suggest some reflections that are not without interest. In the five small, longitudinal bands of the body, they appear, as we have said, during the state of relaxation as perfectly homogeneous cylinders with a smooth surface. With contraction, we see circular stripes cover this surface and then return to its original state. This kind of fiber thus is in between the muscle fibers of higher animals, vertebrates for example, and those of lower animals, as Dujardin and Doyère have described in systolids, tardigrades etc, so that we find in Nais, microscopic errant annelids, some larvae of insects etc. Here, the same homogeneity in the elementary fiber but not the same regularity in form during relaxation. Here again, the absence of wrinkling during contractions is brought about by a simple movement of bringing the two ends together with an increase in transverse diameter. Our synaptid also has this form and mode of contraction in all its other muscle parts. In this respect again, it connects the two ends of the animal scale.

But these latter fibers themselves are far from having the same distinctness everywhere we study them. Very distinct in the four longitudinal bands of the intestine, in the longitudinal muscles of the tentacles and suckers, they are already much less distinct in the muscle layers with transverse fibers, either of the body or of the intestine. They are inconspicuous in the corresponding layer of the tentacles and disappear nearly entirely in that of the suckers. Finally, nothing resembling these fibers is seen in the midst of the granular tissue of the mesentery. Despite the absence of this organic modification, that the largest number anatomists regard as absolutely necessary to produce contraction, we see extended movements: the sucker tightens, the mesentery undulates under the eyes of observer.

Finally, as if nature had wanted us to witness the gradual appearance of these various ways of life, we have seen the ovary show first toward its end a homogeneous substance and nevertheless very contractile, uniting higher with some scarcely distinct homogeneous fibers. We have seen these fibers are characteristic more when the reproductive organ begins to function, acquiring a surplus of vital energy. Finally, as this local over-excitation increases, and at the moment when the expulsion of the eggs requires energetic circular contractions, the transverse fibers appear in their turn, where nothing of their presence had been detected several days before. Thus, the same animal shows us, on one hand, gradual annihilation of the muscle fiber and its fusion more and more complete in the matrix of the various tissues and, on the other, the successive appearance and more and more evident characterization of the same fiber in one and the same organ.

These are not theories here. They are simple facts noted several times either by the same individual, or by different individuals, by the same observer using the same instruments, the same means of investigation. Facts that, consequently, serve reciprocally as counter-tests. It seems to us, since then, difficult to refuse the consequences that come from them and the most immediate of which is that the fiber is not an organic necessity for the mechanism of contraction. This proposition, which would have appeared a heresy in the eyes of anthropotomists, will not at all be due to chance for naturalists familiar with microscopic research. All have been able to make observations analogous to ours. And moreover, what is the elemental muscle fiber as it occurs in all animals transparent enough that we can examine it in the living? It is a homogeneous cord, having the property of contracting on itself, without there being new fibrils to cause this movement. Now, can we not conceive this homogeneous and contractile matter united in a more considerable mass and having a form other than a cord, or a fiber? There is certainly nothing repugnant to the most severe mind, and we see that the facts and the reasoning are fully in accord. But even this point once agreed, there still remains an important question to resolve. Wherever we find the more or less characteristic muscle fiber, we see it contracting only its length. Physiologists have for a long time rejected the elongation force of Bartès, a force that resulted necessarily from the contractility in all directions of the elementary muscle fibers. Observation has shown that wherever the famous professor of Montpellier has believed to find proofs to support this theory, nature had placed distinct muscle planes whose alternating or simultaneous action produced the effects he invoked as proof of his opinion. In a word, contractility in one direction of the muscle fiber is a general fact that we encounter everywhere it is possible to observe it. Will it be the same of a mass, of a lamella, in which the elementary contractile material, if it is permitted to use this word, is distributed in a perfectly identical manner? Or will this mass, this lamella, contract indifferently in all directions at the will of the animal? If this last fact were once well proven, it would establish, it seems to us, a very clear line of demarcation for the animals in which it is observed. The facts reported by Dujardin in

his Memoir of the Infusoria appears to establish that the sarcode has this important property. But this singular substance that we find in the highest animals and very probably to Man himself. It seems to need more study before it can enter into the discussion of physiological problems. In any case, it seems to have only few points in common with a muscle mass such as we understand it here. The movements that we have observed at the end of the ovary and the mesentery of the synaptid, movements that occur in all directions, could appear more appropriate to resolve the question. It would be the same with those presented by some infusoria. But it could very well be that they were due to the action of distinct lamellae, each contractile in one direction and superposed in a way to represent the muscle planes in opposite directions. This explanation could especially apply to the ovary of synaptids, where we see pronounced later two planes of fibers, one longitudinal, the other, transverse. It is quite possible in fact, that the direction of both, and consequently their action, must be in harmony that existed before them. Perhaps even it is only the consequence of this former state. Now, it is difficult to conceive that a mass that had been submitted to movements of contraction in all directions, giving rise in some way to fibers regularly perpendicular to each other and arranged in the order that we find around all the cavities of the same animal. If the mesentery of the synaptid, if the integuments of infusoria do not show us anything similar to what we suppose here, can we not blame the imperfection of our instruments? However that may be, in the presence of the fact so remarkable and so general of the unity of direction in the contraction of the muscle fiber, the wisest thing to do appears to not make a quick judgement and that direct observation would perhaps one day invalidate.

In speaking of the liquid content of the circulatory system of synaptids, we have used the two terms, nourishing fluid and blood. The first whose signification has something more general, more vague, appears perhaps more correct than the second, whose sense is much more precise. We believe, however, that we are able to apply here the latter with missing the exactness and rigor in our expressions. Without doubt is not a matter here of entirely equating this liquid to the blood of mammals, such as it exists, mixing the blood strictly speaking with the products of digestion and of the lymphatic circulation. But we employ this word when it is a matter of the liquid contained in the vessels of crustaceans and annelids, and that with reason because it physiologically has the same functions as the blood of vertebrates. However, in the synaptids, we find a colorless liquid, susceptible of coagulation, entraining colored globules and of constant form and texture. This liquid moves in closed vessels. It serves evidently for the maintenance of the body and is exposed in special organs to the action of air dissolved in the water. It gives us thus all the essential characters of true blood, plus perhaps that of the two classes of articulates that we just cited. Therefore, we are right, it seems to us, to give it this name in all its meaning, except to report the differences that separates the blood of these animals whose nourishing fluid was first designated by this expression.

We recall that we have said of the marvelous quickness with which a wounded synaptid at any point of the body contracts the borders of this wound, and seems, by this alone, to heal it instantly. It is evident that in such case, there can be no production of new tissue, and that the first function is cicatrization, if it is allowed to use here this completely surgical expression. It seems to us to find a complete analogy between that which occurs then in our radiate and the phenomena that occurs in such a case by higher animals and Man himself. We know that, in the latter, the union that occurs with the aid of plastic lymph, very probably the liquid and colorless part of the blood that pours into the solution of continuity, is often organized very quickly and forms a true seal. We have thought we recognized that the things happened in the same way in

the synaptid, that the plastic lymph was replaced by organic matrix of which we have so frequently spoken, and the pressure is sufficient to call all the tissues of the animal to come out. But the quickness with which this fusion takes place is very remarkable, especially when it takes place between organs separated by distinct peripheral tissues: when, for example, the digestive tube the walls of the trunk of a synaptid ruptured in the middle are united in a way to make an anal opening perfectly free and nearly a true artificial sphincter. However, this fact is not more marvelous than that we see every day in the plant kingdom. We know that by twisting together the young shoots of the same tree, the interposed layers of the bark disappear as the stems grow and that they so mixed under the same cortical covering. It is probable that, in the case of which we speak, it produces a very similar phenomenon and that the fusion of the parts is in addition greatly facilitated by the very nature of the interposed membranes almost completely formed of this substance we so often attribute to the cellular tissue of higher animals, but whose vital energy would seem here much more marked relatively speaking than in the latter.

EXPLANATION OF THE PLATES.

PLATE 2.

Fig. 1. SYNAPTA OF DUVERNOY, *of natural size*. We see, across the integument, the digestive tube and the reproductive organs.

Fig. 2. *Muscles of the body, magnified 300 times*. — *a*. Portion of one of the five longitudinal muscles. — *b*. Muscles with transverse fibers.

Fig. 3. *Muscles of the intestine, magnified 300 times*. — *a*. Longitudinal muscles. — *b*. Muscles with transverse fibers. — *c*. Pigment.

PLATE 3.

Fig. 1. *Integument seen at a magnification of 300 diameters*. — *a*. Epidermis. — *b*, *b*. Dermis dotted with pigment globules.

Fig. 2. *Anchors*.

Fig. 3. *Articulating end of an anchor*. — *a*. Palette. *b*. Articular head.

Fig. 4. *Shield*. *a*. Longitudinal opening that will receive the palette of the anchor. — *b*, *b*. Circular openings where the two swollen ends of the articular head of the anchor are located.

Fig. 5. *Anchor and anchor and articulated shield*.

Fig. 6 and 7. *Heads of anchors, with curves a little different than those that we have represented above*.

Fig. 8 and 9. *Ends of two shields, whose openings differ from those we have represented in fig. 4*.

Fig. 10 and 11. *Anchors in the process of formation and whose branches are still not developed*.

Fig. 12 and 13. *Shields in the process of formation*.

Fig. 14. *End of an anchor showing the superposition of the layers that compose it*.

Fig. 15. *Acicules*. — *a*, *a*. Hollow and contractile organs that enclose the acicules. — *b*, *b*. The same, contracted and emitting the acicules.

Fig. 16. *Elastic fibrous tissue, seen at a magnification of 300 diameters*. — *a*. Granulose substance, transparent, crossed in all directions by fibers *b*.

Fig. 17. *Muscle fibers of the longitudinal muscles of the trunk*. (300 diameters). — *a*. Relaxed fibers. — *b*. Fibers during contraction.

PLATE 3.

Fig. 1. *Organs of circulation. Anterior part of the digestive system*. — *a*, *a*, *a*. Tentacles. — *b*, *b*. — Suckers. — *c*, *c*. Circular fold formed by the integument. *d*. Mouth. *e*. Buccal or pharyngeal cavity. *f*. Longitudinal muscle of the pharynx. — *g*. Pharyngeal muscle with annular transverse fibers. *h*, *h*. Elevator muscles of the buccal mass.

i, Posterior sphincter of the buccal cavity. — *j*, Wall of the digestive tube, thickened at the origin and tapering very rapidly. — *k*, Portion of the open digestive tube. — *l*, Digestive tube, forming folds after contraction of the animal. — *m, m*, Circumbuccal calcareous ring. — *n, n*, Vascular ring. — *o, o, o*, Vascular trunks of the longitudinal muscles of the trunk. — *p, p*, These longitudinal muscles. — *q, q*, Reproductive organs, whose two branches unite behind the buccal mass to open outside by a single opening.

Fig. 2. *Pigment of the digestive tube*. — *a*, First vesicle, enclosing the colored substance. — *b*, Second vesicle whose content is colorless.

Fig. 3. *Calcareous concretions of the internal surface of the longitudinal muscles of the trunk*.

Fig. 4. *Mesentery seen at 300 diameters*.

PLATE 5.

Fig. 1. *Reproductive organs*. — *a, a*, External epithelium formed by a fold of the peritoneal membrane and with vibratile cilia. — *b, b*, Muscle layer. — *c, c*, Mammelons of the testis forming the internal wall of the reproductive organ. The spermatozooids not completely developed have only very small granulations distributed in the cells of the mal organ. — *d, e, f, g*, Non-fertilized egg in which we distinguish very clearly the covering. *D*: yolk, *e*: Purkinje vesicle, *f*: Wagner's spot, *g, h*, Substance of the ovary in the middle of which are developed the eggs.

Fig. 3. *Spermatozooids*. — *a*, Isolated spermatozooids seen at a magnification of 300 diameters. — *b*, The same, supposedly bigger. — *c*, The same, united by the body that we often obtain by compressing the testis.

Fig. 3. *Suckers*. — *a*, Very thick dermis covered by its epidermis. — *b*, Muscle layer with longitudinal fibers that spread out at the base of the tentacle. — *c*, Muscle mass with fibers or with transverse folds. — *d*, Glandular organ. — *e*, Retractor muscle of the sucker.

Fig. 4. *Portion of the mouth, very enlarged*. — *a, a, a*, Muscles coming from the tentacles. — *b, b*, Sphincter of the mouth. — *c, c*, Granulose substance forming a ridge all around the mouth. — *d, d*, Integument bent toward the interior of the mouth.

Fig. 5. *Semi-contracted tentacle and circulation*. — *a, a*, Direction of the afferent current at the periphery of the tentacular cavity. — *b, b*, Direction of the central or efferent current.

Fig. 6. *Globules of the blood seen at a magnification of 300 diameters*.

Fig. 7. *Tentacles and aquafer opening, seen below with the aid of a section that exposed the circumbuccal calcareous ring*. — *a, a*, Lower longitudinal muscles of the tentacles. We distinguish, at each lateral digitation, the corresponding muscles that are inserted there. — *b, b*, Portion of the trunk. — *c, c*, Ossicles. — *d, d*, Elevator muscles of the buccal mass. — *e, e*, Longitudinal muscles of the trunk. — *f*, Aquafer opening passing through the central opening of one of the ossicles.

De J. del.

Delaplane sc.

Organisation des Synapses.

De. p. del.

Schmels. sc.

Organisation des Synapses.

De Q. del.

Schmeltz sc.

Organisation des Synapses.

Organisation des Synaptes.