Memoir on the pearly nautilus : (Nautilus pompilius, Linn.) : with illustrations of its external form and structure / drawn up by Richard Owen.

MEMOIR

ON

THE PEARLY NAUTILUS

(*Nautilus Pompilius*, Linn.)

WITH

ILLUSTRATIONS

OF ITS EXTERNAL FORM AND INTERNAL STRUCTURE.

DRAWN UP

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Και αλλος εν οστρακῳ, οἱον κοχλιας, ὁς ουκ εξερχεται εκ του οστρακου, αλλ' εστιν ὡσπερ ο κοχλιας, και εξω ενιοτε προτεινει τας πλεκτανας.

ARISTOTELES, *Historia de Animalibus*, lib. iv. cap. 2.

MEMOIR

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THE true relations of every class of animals are now acknowledged to depend for their development chiefly on anatomical investigation: and the necessity of this mode of inquiry has been rendered more especially obvious with respect to those tribes whose outward forms, being unsupported by any firm and resisting framework, present in consequence variations extremely disproportionate to the differences exhibited in habits and powers of action. In this division of animals the most important and unexpected results have been obtained from the dissection of the Cephalopods, which, under a form approaching to that of the Polype, disguise an organization as rich in the variety of parts, as it is peculiar in their mode of arrangement. Hence they have afforded one of the strongest arguments against the theory of the simple and unbroken series, for a long time supposed to be the natural distribution of the animal kingdom: and they have subsequently been deemed not less adverse to a more modern doctrine, which, ascending to the consideration of the analogies presented in the materials of individual organisms, seeks to reduce their varied plans of composition to a principle of unity.

The characteristic peculiarity in the disposition of the organs of this remarkable class has, indeed, been considered in some measure reconcileable to the higher types; and the advocates of the doctrine of M. Geoffroy St. Hilaire have endeavoured to produce a semblance of conformity between the *Cephalopoda* and the *Vertebrata**. On the other hand, the Baron Cuvier†, whilst insisting

* Geoffroy St. Hilaire, *Principes de Philosophie Zoologique*, 8vo, 1830, p. 35.

† *Annales des Sciences Naturelles*, xix. p. 241.

on the hiatus that divides the Cuttle-fish from the vertebrate animal, seems equally disinclined to admit a conformity of organization between the *Cephalopoda* and the inferior groups of *Mollusca;* and, in concluding the anatomical history of *Octopus vulgaris*, does not hesitate to declare, "that they form not the passage to any other group, that they have not resulted from the development of other animals, and that their own development has produced nothing superior to them*." He urges, therefore, the grand importance of this class arising from its isolated character; and when it is considered that this impression was derived from an examination of the normal groups alone, it will readily be perceived how peculiarly an aberrant form demands the attention of the zoologist.

The size and singular formation of the shell of *Nautilus Pompilius*, and, above all, the obscure notices which we possess respecting its inhabitant,—just sufficient to excite without allaying curiosity,—have long rendered this animal a peculiar desideratum in zoology. And as in other sciences residual phænomena become interesting in proportion as their number is diminished by extended investigation, so of late years the capture of this animal has been looked for with increased solicitude, from the perfection which the history of the known Cephalopods has attained through the researches of the great anatomist above quoted. Not only, however, is the acquisition of this species peculiarly acceptable from its relation to the Cephalopods of the present creation, but it is at the same time the living, and perhaps sole living, archetype of a vast tribe of organized beings, whose fossilized remains testify their existence at a remote period, and in another order of things.

That this recent species of *Nautilus* should so long have escaped observation seems naturally a matter of surprise, when it is considered that the shell is far from being uncommon; and that so many enterprising individuals have recently traversed the globe, exploring every region in pursuit of zoological treasures. But the circumstances which the Baron Cuvier† so justly adduces as tending to retard the progress of Malacology in general, seem especially to have contributed to obscure the history of *Nautilus Pompilius*. Securely sheltered in the depths of the ocean at a remote part of the globe, the chances that it should fall into the hands of the scientific observer have been necessarily

* *Mémoire sur le Poulpe*, p. 43. † *Mémoire sur le Genre Tritonia*, p. 1.

few; and even when this has occurred, the descriptions and illustrations which have been given of the soft parts being uncombined with anatomy, have rendered the accident of little avail to science. Hence it has happened, that although this species of *Nautilus* is alluded to, and still bears the name given to it by Aristotle, little has subsequently been added to our knowledge respecting it.

That *Nautilus Pompilius* was really known to the Father of Natural History appears at least highly probable, from a consideration of the passage supposed to relate to it in the *History of Animals*,—a passage which, though brief, is clear, and at the same time scarcely applicable to any other animal. After describing (Book IV. Chap. i.) the different forms of the naked Cephalopods (μαλακια) with a degree of minuteness and accuracy which has seldom been surpassed, Aristotle lastly treats of those which inhabit shells; and, in characterizing them, denotes the second of the testaceous genera, by precisely that circumstance which constitutes the most marked and obvious difference between *Nautilus Pompilius* and the Paper Nautilus, or *Argonauta* of Linnæus.

"There are also," he says, "two other genera of Polypi, which are in shells; of which one is by some called 'Nautilus', and by others 'Nauticus', or 'Egg of Polypus'*. Its shell is like a hollow *pecten*†, and is not naturally adherent to the Polypus. It feeds very frequently near the land, so that it is cast by the waves upon the sand, where, the shell slipping from it, it is caught, and dies on the land. This genus also is small, and in form similar to the *bolitænæ*‡.

"But the other genus is in a shell, like a snail: it never quits its shell, but exists after the manner of a snail, and sometimes outwardly extends its arms." *Aristot. de Animal. cura J. C. Scaligeri, fol.* 1619: p. 415.

* Either from the similarity of the Argonaut shell in texture and relation to its inhabitant to that of an egg, or perhaps because *Ocythoë* at that time, as well as now, was generally found resting on a mass of eggs, occupying the greater part of the shell. Scaliger derives the term *Pompilus* from this epithet: "atque ex Aristotelis voce πολυπόδος ωον, antea à Plinio scriptum fuisse *polypu oon*: inde natum ab imperitis errorem *pompilum*." It is scarcely necessary to observe, that the term is now exclusively applied to the second genus.

† The comparison without doubt refers to this kind of bivalve, rather than to a comb. See Book IV. Chap. iv. where a species called κτεις is frequently adduced in illustration of the nature of bivalves.

‡ The fourth genus of *Polypi* of Aristotle, characterized by odour, the type of which was probably *Eledone moschata*, Leach.

In the chapter in which the above passage occurs, and in other parts of this extraordinary work, so many characteristic details are given, both of the habits, and of the structure internal as well as external, of the Cephalopods, as render it very improbable that the accurate and penetrating author would have admitted among his *Malakia* an animal that possessed not those affinities of structure which fully entitled it to rank there. But the only Cephalopod adhering to, and covered with a shell, that Aristotle could have known, is *Nautilus Pompilius*. The beauty and singularity of the shell would naturally excite his curiosity; whilst the means which were afforded to this illustrious philosopher of attaining a knowledge of the animal products of Asia, and the occurrence of the Pearly Nautilus in the Persian Gulf, render it possible that his inquiries might be gratified to such an extent as to enable him to perceive its true place in the natural system.

Pliny and the ancient writers on Natural History who succeeded Aristotle did little more than repeat his account of the singular habits of his first species of *Nautilus*—the *Argonauta* of the moderns, whilst his second species was passed over in silence.

Belon*, one of the earliest authors on Natural History subsequent to the revival of literature, was the first who described and figured the shell of *Nautilus Pompilius;* and he installed it in the vacancy which the silence of preceding naturalists during a lapse of ages had occasioned in the animal kingdom of Aristotle, and denominated it "*Nautilus alter seu secundus*"; but he was unacquainted with the soft parts. An opinion, therefore, in so great a measure conjectural, was naturally combated by succeeding authors. Rondeletius saw too little analogy between the heavy, pearly, and chambered shell of the Nautilus, and the light, fragile, monothalamous dwelling of the Argonaut, to concur in this approximation; and somewhat arbitrarily referring the peculiarities of the first of Aristotle's *genera* of *Polypi* to the second, conceives it impossible so small an animal could drag on so heavy a shell†. It was not, therefore, until

* *De Aquatilibus*, p. 381. (1553.)

† "Sed hæc secunda quam adfert, Nautilus Aristotelis esse nequit, neque enim Pectini cavo ulla ex parte comparari potest. Deinde cum Nautili corpore sint exiguo, trahere concham tantæ magnitudinis non possent. Hoc non est artificiose fingere: qui enim fingit saltem probabilia debet dicere."—Rondelet. *de Testaceis*, p. 98.

further knowledge had been acquired of the inhabitant of the Pearly Nautilus, that the supposition of Belon was adopted.

The first notice of this kind appears in the writings of Gesner*: it is, however, so obscure and brief as to render it doubtful whether the animal alluded to was really the inhabitant of the pearly and chambered shell which is described; yet the use of the word *velum* in the singular number, and the indication of the lateral disposition of the arms, in some measure favour the supposition. With evidence, however, of so slight a nature, the claims of *Nautilus Pompilius* to rank among the Cephalopods might have remained until now purely conjectural, had not more satisfactory data been afforded by the writings of Rumphius. This naturalist was enabled, during a long residence at Amboyna, to procure specimens of both the species of *Nautilus* indicated by Aristotle; and of the latter, to which the name at present exclusively applies, he has given figures both of the soft parts and of the shell, in his work entitled *D'Amboinische Rariteit-kamer*.

The animal is there represented in the supine position, with the tentacles retracted, and, as far as its general form in this state is concerned, the figure manifests considerable accuracy; but the terminations of the adherent muscles of the shell are not indicated; and what seems to have been an accidental rent in the mantle on the ventral aspect of the body, gives the idea of the fold being in a position contrary to nature. The funnel, also, is wrongly represented as a round pipe, though its real structure is accurately described in the text: and an open extremity of one of the lateral digitations might readily be mistaken for the eye, which however is indicated by the triangular corrugated body projecting just above the margin of the part on which the head reposes in the figure†.

* "Nautili picturam Io. Fauconerus, medicus egregius ex Anglia, olim ad me dedit, his verbis in epistola adscriptis: 'Mitto ad te hîc picturam cujusdam piscis ex testaceorum genere, puto, Aristotelis Nautā esse: quam mihi primum, cum in Italia essem Cæsar Odonus, Doctor medicus Bononiensis exhibuit, vir, ut humanissimus, ita in exteros admodum hospitalis, postea vero hîc in Anglia ipsum piscem vidi, quē pro loci ac temporis opportunitate pinguendum curavi. Testam habet externa parte ex fusca rufescentem: internam vero partem ita nitentem et splendentē, ut cū unionibus preciosissimis de coloris amœnitate certare posset, multa quoque habet in ipsa testæ carina tabulata eodem colore nitentia. *Velum* constat ex pellicula tenuissima. Ηλεκτραναι *ab utroque latere* demissæ carneæ sunt et molles ut polyporum cirrhi, reliqua corporis pars confusa erat et indiscreta ut reliquorum testaceorum generum.' Hæc Fauconerus Anglicum hujus piscis nomen ignorare se confessus."—Gesnerus, *Historia Animalium*, iv. p. 623.

† *Tab.* xvii. B. p. 62.

In addition to these inaccuracies, the absence of detail has rendered the figure useless and inapplicable to the purposes of science, and it has been justly pronounced by Cuvier to be "*indechiffrable.*"*

The description of the soft parts by Rumphius, though limited in a great measure to the external appearances, possesses more merit; and whilst by the account of the beak, the funnel, and the eyes, it proves the affinity of the Pearly Nautilus to the Cephalopods, it at the same time, in the account of the tentacles, digitations, and posterior membranous siphon, points out the principal external differences.

This description, translated into the French language, has been published by Denys de Montfort, in the Continuation of Buffon by Sonnini. The figures, however, with which we are also favoured by that writer, are purely fictitious. In these the errors of Rumphius's figure are strongly exaggerated, and in the attempt to represent ideas acquired from his description, they prove, as might be expected, ludicrously remote from nature.

In the progress of Natural History, therefore, after the æra of Rumphius, the nature of the animal of the Pearly Nautilus received no further elucidation; but, as the principles of classification attained greater exactness and precision, the heterogeneous shells which, from the claims of their inhabitants to the Cephalopodous character, had heretofore been grouped together, were separated into distinct genera. The first of Aristotle's *Nautili* became successively a *Cymbium* of Gualtieri† and an *Argonauta* of Linnæus‡, whilst the species least known to the ancients was permitted to retain the ancient denomination.

The figure of Rumphius, being thus unsupported by any additional evidence worthy of reliance, has become to succeeding writers a subject of comment and of doubt; and in the latest notice respecting the soft parts of the *Nautilus Pompilius* appears to have been altogether disregarded. This notice is entitled "*Description d'un Fragment de Mollusque inconnu, presumé être celui du Nautile flambé* (Nautilus Pompilius, *Linn.*)," and has been inserted by MM. Quoy and Gaimard, Naturalists to the circumnavigatory expedition of Captain Freycinet, in the 20th volume of the *Annales des Sciences Naturelles*. The portion of the animal which is the subject of their description, and of which a figure is also given, was found in the sea

* *Règne Animal*, iii. p. 366.

† *Index Testarum Conchyliorum*, tab. xi. xii.

‡ *Mus. Ludov. Ulricæ Reginæ*, p. 548, No. 148.

of the Moluccas near the Island of Celebes. There is little to be gathered from its form; but its parenchyma is said to have been the same with that of *Firola* and *Carinaria*. If, therefore, this singular animal should possess a testaceous appendage, it will probably be found from the above-mentioned analogy to *Carinaria* to resemble the shell of the first species of *Nautilus* of the ancients, rather than that of the second.

Most fortunately, however, the true inhabitant of the shell of the Pearly Nautilus has at length been secured through the zeal and activity of George Bennett, Esq. F.L.S. a Member of the Royal College of Surgeons in London, who, during a recent and protracted voyage among the Polynesian Islands, was indefatigable in collecting materials of every kind for the advancement of natural science.

The circumstances connected with its capture are thus related in his Journal:

"Island of Erromanga, New Hebrides, August 24th, 1829.—Monday: fine weather during the day. Thermometer at noon 79°. In the evening a Pearly Nautilus (*Nautilus Pompilius* of Linnæus) was seen in Marekini Bay, on the south-west side of the island, floating on the surface of the water, not far distant from the ship, and resembling, as the sailors expressed it, a dead tortoiseshell-cat in the water. It was captured, but not before the upper part of the shell had been broken by the boat-hook in the eagerness to take it, as the animal was sinking when caught. On its being brought on board, my attention was directed to possessing the inhabitant, which I succeeded in procuring. I immediately detached the animal from the fractured portions of the shell (to which it is attached by two oval muscular attachments, one on each side), and placed it in spirits, after making a pen-and-ink sketch of its external form. The animal when I examined it after it was brought on-board, kept the tentacula closely contracted, and the only evidence of vitality remaining in the animal was in a slight contractile motion of the body. On laying carefully open that portion of the shell which contains the chambers, it was found to contain water, which of course immediately escaped. The colour is stated in Shaw's Lectures, vol. ii. p. 166. (which I had on board at the time,) as being of a pale reddish-purple colour, with deeper spots and variegations: the figures given in the same work are very incorrect*. The colour of the anterior part of the body, when the

* They are copies of the figures given by Denys de Montfort, in the work above quoted.

animal was recently taken out of the water, was of a dark red colour, inclining to brown (in fact resembling the colour produced by the *Koka* on the stained cloth of Tongatabu,) intermingled with white. The mantle and remainder of the body were of a light blueish tinge."—*Journal*, Part 10th.*

On the arrival of Mr. Bennett in this country, he presented (July 1831) this specimen (together with other valuable objects of Natural History) to the Museum of the Royal College of Surgeons in London, where it is now preserved.

§ 1. *Of the External Form.*

The soft parts of *Nautilus Pompilius*, when the beak and tentacles are retracted, form an oblong mass, which is slightly compressed or flattened laterally, inclines to a point anteriorly, and terminates behind in a rounded extremity adapted to the last cavity of the chambered shell in which it is naturally lodged.

The admeasurements of the specimen were as follows:—

The length of the body	$5\frac{1}{2}$ inches.
The vertical diameter of the same	3 ——
The transverse diameter	$2\frac{1}{2}$ ——

The body is naturally divided into two parts, of which the anterior is densely muscular or ligamentous, and includes the organs of sense and locomotion; while the posterior is soft and membranous, and contains the viscera.

The latter part, though analogous to the corresponding division in the Cuttle-fish, yet resembles rather what is called the *hernia* of the viscera in the Snail; for, as in both animals it is protected by a shelly covering, the more immediate investment, or mantle, requires not that thickness and firmness of structure observable in the sac of the naked Cephalopods.

Posteriorly the mantle of *Nautilus* is as thin as fine writing-paper, and appears to be of a dry and rather brittle texture: it increases in thickness anteriorly, and is there evidently muscular; but even at the anterior margin, where the thickness was probably in a great measure owing to a state of contraction, it does not exceed one line. A fibrous texture is also evident at the thin posterior part, the fibres being chiefly disposed in the longitudinal direction.

* See also Mr. Bennett's account published in the Medical Gazette, vol. viii. p. 729, with a figure of the animal as it appeared when first taken out of the shell.

The mantle (*a*. pl. 1. 2. 3. & 5.) is attached to the posterior part of the head; but prior to being continued over the back of the animal, it is produced into a considerable fold (*b*. pl. 1. 2. & 3.). This fold is concave posteriorly, and overlaps the involuted convexity of the shell, which thus becomes coated with a layer of naker, and probably also receives from this part of the mantle the black stain which is usually observable upon it. The sides of the fold extend over the umbilicus, obliterating it on both sides by successive depositions of naker. This fold is composed of two layers of the mantle firmly adhering together, except at the commencement, where it is thinnest, and where the layers are partly detachable from each other; the rest of the fold is muscular, and of the thickness of a shilling. The anterior margin of the mantle (*c*. pl. 1. & 2.) is continued downwards and forwards on either side, free and unattached to the parts beneath. The mantle was thickest at this part, doubtless from being in a state of contraction, but, like the mantles of the *Conchifera*, it can probably extend beyond, and be reflected over the anterior margins of the shell. At the ventral aspect of the body the mantle becomes thinner, is prolonged anteriorly, and is perforated by a large aperture (*d*. pl. 1.), through which the funnel passes.

About an inch behind this aperture there are two circular convexities (*e*. *e*. pl. 1. & 2; *b*. pl. 5.) ten lines in diameter, firm to the touch, and indicating a thickening of the mantle at this part; they might be mistaken for the muscles of attachment, but are occasioned by a glandular apparatus (*c*. pl. 5; fig. 8. pl. 8.), hereafter to be described, attached to the inner surface of the mantle, and which, if not peculiar to, is in all probability more strongly developed in the female than in the male *Nautilus Pompilius*.

Behind these eminences the mantle is encircled by a thin layer of brown horny matter, readily detachable from the membrane itself. This belt (*f*. pl. 1.) is about a line in breadth at the dorsal and ventral aspects of the body; but at the sides it expands into a broad patch (*g*. pl. 1.), of an irregular oval form, convex anteriorly, and measuring about sixteen lines in the long, and nine in the short diameter. The horny matter is also thicker here than at the narrower parts of the girdle, and is divisible into several laminæ, which form the medium of attachment and, as it were, the tendons of the muscles adhering to the shell, (*l*. *l*. fig. 2. pl. 3.); to which, indeed, they are so firmly attached, that when, in

capturing the animal, the shell was unfortunately broken, one of the fragments still continued to adhere to the muscle, and this part is so represented at *h*. pl. 1.

The impression of this girdle, and particularly of the lateral expanded portions, or the muscular impressions, may be observed in the interior of the shell near the bottom of the external cavity. Occasionally a layer of the dark-coloured horny matter adheres to the naker, especially in recent shells, of which I have had an opportunity of observing a fine example (through the well-known liberality of the possessor,) in the choice cabinet of W. J. Broderip, Esq. F.R.S. &c. V.P.G.S.

From the extremity of the sac is continued a small tubular membranous process (*i*. pl. 1 ; *d*. pl. 5.), which passes through the siphonic apertures in the septa of the shell, and is continued, there is reason to believe, to the innermost chamber. This tube has been surmised to be tendinous or muscular ; but the attachment of the shell to the soft parts proves to be effected by much more adequate means. Rumphius* appears to have been acquainted with its true structure, for he calls it an artery (*een langen ader*), and in fact within the external thin membrane are included a small artery and vein. How far these vessels are continued within the chambered portion of the shell, or in what manner they are distributed, remains for some future investigation ; for in the present instance the only part of the shell that was preserved was the small portion adhering to the horny tendons, and the membranous tube had been ruptured, in removing the animal, at a few lines distance from its origin at the mantle. This tube appears to be contracted at its origin, and its diameter at the wider part is one line and a half.

The infundibulum, funnel, or vent-tube (*k*. pl. 1 ; *f*. pl. 2. & 5.), projects forward through the aperture in the under and anterior part of the mantle, to the extent of two inches. It has the form of a depressed or flattened cone with the apex directed forwards, and at each side of the base there is an obtuse and wrinkled process (*l*. pl. 1 ; *d*. *d*. fig. 2. pl. 3 ; *g*. *g*. pl. 5.) : its breadth at the base is one inch and a half.

The funnel is not, as in the Dibranchiate Cephalopods, a tube with entire parietes, and open only at the extremity, but is formed by the overlapping of the margins of a thin fleshy substance, so that when these margins are divaricated,

* *D'Amboinische Rariteit-kamer*, p. 60.

it has the form of a wide and deep canal leading forwards from the branchial cavity (fig. 2. pl. 3.). This overlapping takes place along the inferior or ventral side of the tube; and the right margin lies over the left. Within the funnel, but on the opposite side and near the external orifice, there is situated a flat, fleshy, tongue-shaped process (*e.* fig. 2. pl. 3.), rounded and thin at the extremity, which is directed towards the external orifice of the tube. The length of the unattached part of this process is ten lines, its breadth at the base seven lines. The parietes of the tube which are covered by this process, are extremely thin, and almost membranous.

The description of the funnel in Rumphius has been considered very obscure, if not incomprehensible*; but with respect to the latter part, or tongue-shaped valve (*een tonge*), a structure precisely analogous, though less developed, obtains in *Sepia* and *Loligo*. Its probable use is to act as a valve to the orifice of the vent-tube, and prevent the ingress of water or other substances when the animal moves forward, or is retained at anchor with the head against a current; and it seems to confirm this view of its use, that in *Octopus*, which possesses neither elongated pedunculated arms nor lateral fins for propelling itself forwards, the infundibulum is unprovided with such an appendage.

The sides or crura of the funnel (*f. g.* fig. 2. pl. 3; *h.* pl. 5.) diverge, and pass upwards and backwards along the outer part of the muscles of adhesion; they form the smooth surface uncovered by the mantle behind the head, which is seen at *m.* pl. 1, and are separated from the head by a constriction or neck.

The head of *Nautilus* is of a conical form, and of a much denser texture than the analogous part in the Dibranchiate Cephalopods: it is excavated in such a manner as to form a receptacle or sheath, into which the mouth and its more immediate appendages can be wholly retracted, when they are so completely concealed as to require the aid of dissection before they can be submitted to examination.

The orifice of this great sheath (which from its protecting all the parts connected with the mouth I have termed *oral*) is anterior; its superior parietes are formed by a thick triangular plate or hood (*n.* pl. 1; *h.* pl. 2; fig. 1. pl. 3.), with a wrinkled and papillose exterior; the sides give off numerous conical and

* See *Dict. des Sciences Nat.* xxxiv. p. 291.

triedral processes (*o*. pl. 1; *m*. pl. 2; *b*. fig. 2. pl. 3.); the inferior part (*n*. pl. 2.) is thin, smooth, and concave, and rests upon the funnel.

The hood or flattened part, which I have considered as surmounting the head, (the position of the animal being determined by the nervous system,) is of a white colour internally, and of a fibrous texture, resembling dense *corium*, but is doubtless muscular, and in creeping (the position of the animal being reversed,) seems calculated to act as its chief locomotive organ. In the supine position of the animal it bears considerable analogy to the foot of a Gasteropod; and in a state of rest and retraction it would serve as a rigid defence at the outlet of the shell. The dimensions of this part are in length three inches and nine lines, in breadth at the base three inches, at the apex seven lines. The apex (*c*. fig. 1. pl. 3.) of the triangular hood is anterior; it is truncate, and terminates in a thin edge, which is rounded at the angles and slightly notched in the middle. The hood increases in thickness towards the base, which is deeply excavated (*d*. fig. 1. pl. 3; *c*. pl. 4.); and the angles form two rounded flattened processes (*e*. fig. 1. pl. 3; *b*. pl. 4.), whose margins are thin, and project free to the extent of four lines.

The exterior of the hood presents three superficies, whereof the middle and superior one (*f*. fig. 1. pl. 3; *a*. *a*. pl. 4.) is plane, and bounded by nearly parallel lines, the space included being nine lines in breadth; while the lateral superficies (*n*. pl. 1; *g*. fig. 1. pl. 3.) are sinuous, and incline towards the sides of the head, but are separated from the digitations by a narrow groove (*q*. pl. 1; *h*. fig. 1. pl. 3.). The papillæ are chiefly observable on these surfaces, while on the middle surface they are only to be seen towards the anterior part. To the large concavity at the base of the hood are adapted the involuted convexity of the shell and the fold of the mantle before mentioned; but lest the shell should encroach too much upon the hood and impede the freedom of its motions, or be itself, in the act of creeping, dragged along the ground, it is supported by a semilunar ridge (*i*. fig. 1. pl. 3.), which rises from this concavity about an inch from the posterior margin of the hood. It is from this ridge that the mantle is immediately continued to form the concave fold (*a*. *b*. fig. 1. pl. 3.)*.

* It is worthy of remark, that in *Sepia* and *Loligo* there exists a corresponding ridge at the back part of the head, beneath the anterior extremity of the rudimentary shell possessed by these genera; while in *Octopus*, *Ocythoë*, and some of the species of *Eledone*, no such part exists, and the mantle is continued smoothly and uninterruptedly from the head to the back of the animal.

The lateral processes or digitations are thirty-eight in number, being disposed nineteen on either side, irregularly, one upon the other, and all directed forwards, converging towards the orifice of the oral sheath. The length of the entire mass of digitations is two inches; but the longest of these processes, when its free extremity only is measured, does not equal one inch; for they adhere, as it were, by their inner surfaces to the parietes of the head, some not extending as far as the anterior margin of the head, but terminating at different distances from it, while others project a few lines beyond it. They are mostly of a flattened triedral form, and become smaller towards the extremity, where is situated the orifice of a canal which traverses them longitudinally.

There is not the slightest appearance of acetabula on any of these processes, but the exterior superficies is more or less rugose, and in most is canaliculate near the upper margin. The largest process (*o'*. pl. 1; *m'*. pl. 2; *k*. fig. 1. pl. 3.), which lies next the hood, is papillose, and appears at first sight to form a part of the hood, but is separated from it by the narrow groove above mentioned.

Each of these hollow processes contains an annulated cirrus or tentacle (*p*. pl. 1; fig. 3. pl. 2; *c*. pl. 7.), about a line in diameter, and from two inches to two inches and a half in length; they are consequently much longer than the digitations themselves, the canals in which they are lodged being continued in the substance of the sheath towards the origins of the nerves (fig. 5. pl. 7.). These tentacles are of a rounded form, but rather flattened towards the extremity. A few of them were in the specimen protruded from their sheaths to the extent of half an inch, but the rest were completely retracted so as not to be visible, and on laying open some of the canals, the extremities of several were found as far as a quarter of an inch from the apertures; so that they appear to possess considerable projectile and retractile powers.

Of the digital processes nineteen have been enumerated on either side; but as the hood has two perforations anteriorly from which tentacles similar to those of the digitations are also protruded, we may consider this part as two digitations conjoined along the mesial line, and so reckon with Rumphius the even number of twenty digitations on either side of the head. With respect to the tentacles, to their number must be added four others, which project immediately beneath the margin of the hood, like antennæ, one before and one behind each

eye (*r. r.* pl. 1.). These, however, are of a different structure from the preceding, having at first sight the same finely annulated character, but with the circular indentations extending on one side much deeper into the substance of the tentacle, so that it is in reality composed of a number of flattened circular disks appended to a lateral stem. The eyes (*s.* pl. 1 ; *t.* pl. 2 ; *o.* pl. 7.) are about the size of hazel-nuts ; they are not contained in orbits, but are attached each by a short pedicle to the parietes of the sheath behind the digitations, and immediately beneath the margin of the hood.

Although the external configuration of the oral sheath is thus varied, its internal surface (*l.* pl. 2 ; *f.* pl. 4.) is uniform and smooth, except at the lower part near the anterior margin, where there are two clusters of soft conical papillæ, and on each side of these a group of laminæ disposed longitudinally. The smooth part is lined by a fine membrane, and is lubricated by a saponaceous substance, evidently to facilitate the motions of the mouth and its appendages.

In order to examine these parts, the cavity into which they were retracted was laid open by making a longitudinal incision along the middle surface of the hood. Upon separating the cut surfaces, the parts more immediately investing the mouth were brought into view, but the mouth itself was still concealed. (See fig. 1. pl. 2, which exhibits the appearance of the parts in this stage of the examination.) It was surrounded by tentacles of the same structure, but apparently even more numerous than those which had been noticed on the external part of the head ; and on separating these, the organs of mastication were found to be composed, as in the Cuttle-fish, of two strong hooked mandibles (*n. o.* pl. 4.) playing vertically upon each other, and surrounded by a fringed circular lip (*m.* pl. 4.).

External to this lip there are four broad flattened processes arising from the inner surface of the sheath, of which two are superior, posterior, and external (*o. o.* pl. 2; *g. g.* pl. 4.); two inferior, anterior, and more immediately embracing the mouth (*p. p.* pl. 2 ; *i. i.* pl. 4.) ; but the latter are connected on the ventral aspect by a middle part (*q.* pl. 3 ; *l.* pl. 4.), convex exteriorly, and composed of numerous laminæ disposed horizontally, and projecting internally. Each of these four processes (which may be termed *labial*) is pierced by twelve canals, the orifices of which are disposed in a single, but rather irregular series along the

anterior margin; and each canal contains a tentacle (*r.* pl. 3; *h. k.* pl. 4; *h. i.* pl. 7.) similar to, but somewhat smaller than those of the external digitations. The canals extend for about half an inch within the substance of the processes, and into some of these canals the tentacles were completely retracted, but most of them were protruded; the middle ones for the extent of an inch, the rest diminishing in length on either side: those of the inferior processes were found to be applied immediately over the orifice of the mouth, the left tentacles overlapping and concealing the right.

The inferior labial processes are about an inch in length, and ten lines in breadth; the superior and external ones are broader, but shorter: they are of equal thickness, viz. about two lines throughout, and are concave towards the mandibles. Their surfaces, both external and internal, are smooth and lubricated, and are covered by a fine membrane, which is reflected from the inner surface of the sheath, and afterwards continued from them upon the circular lip which immediately surrounds the mandibles. The structure of the labial tentacles is the same as that of the digital ones; but they are somewhat smaller, softer, and of a whiter colour.

With the external description of *Nautilus Pompilius* should be included the peculiarities of the shell; but the few observations that require to be added on that subject will be given in another part of this Memoir.

From what has already been said, it will be seen how considerable are the external differences between the Pearly Nautilus and the higher Cephalopods; nevertheless, its general plan of organization renders its claim to rank with them indisputable; and as its locomotive apparatus is confined to the head, the received denomination of the class remains undisturbed by its admission.

The inferior or ventral pair of labial processes I consider as analogous to the superadded pedunculated arms of the Cuttle-fish and Calamary, which also come off more internally than the shorter arms, and are approximated or united at their bases on the ventral aspect of the mouth. The other pair in *Nautilus* appear to result from a higher degree of organization of the part analogous to the external lip in the preceding genera. The curtailed digitations are, however, but feeble representatives of the elongated and cotyligerous arms of the Poulp or Cuttle-fish; and the retractile tentacles, pedicellate eyes, and flattened disk, which according to the testimony of Rumphius is applied to the ground

in the progressive motions of the animal, attest an obvious tendency towards the *Gasteropoda*. And while tracing these examples of affinity with the different and heretofore widely separated groups of *Mollusca*, between which this remarkable Form, I apprehend, is osculant, there may also be perceived in the whole of this singular but at the same time regular and symmetrical arrangement of palpigerous organs about the mouth, an analogical relation to the higher *Annulosa*.

§ 2. *Of the Muscular System.*

Before describing the Muscular System, it becomes necessary to notice the internal skeleton or framework (fig. 1. pl. 8.) from which its principal masses take their origin. Like that of the Dibranchiate Cephalopods, this skeleton is cartilaginous, yields readily to the knife, and in texture and semitransparency closely resembles the cartilage which constitutes the skeleton of the Skate. In *Sepia* this cartilaginous part completely encircles the œsophagus, and on the dorsal aspect of that tube is dilated into a large cavity, which contains the brain; but in *Nautilus* the circle is incomplete behind, and the brain is protected only by its membranous sheath.

The central mass of the cartilage, or body of the skeleton (*a*. fig. 1. pl. 8.), is situated on the ventral aspect of the œsophagus: it is of a triangular form, with its base towards the œsophagus, and the dorsal angles are produced on each side of that tube as far as the optic ganglions. These angles, which may be termed the cephalic processes (*b*. *b*. fig. 1. pl. 8.), have a deep semicircular groove anteriorly (*c*. fig. 1. pl. 8.) for the lodgement of the optic ganglions and part of the nervous collar surrounding the œsophagus. From the anterior part of the body of the cartilage two other processes (*d*. *d*. fig. 1. pl. 8.) arise, which diverge and pass forwards within the crura of the funnel for about half an inch, and terminate in those lateral projections at the sides of the funnel which appear just above the aperture in the mantle. Behind the origin of these processes the cartilage is continued, in the form of a ridge, for a little way between the great muscles of the shell.

In the body of the skeleton is excavated a large sinus, which receives the contents of the veins of the head and funnel, and empties itself into the commencement of the great dorsal vein.

The muscular fibres of the great oral sheath arise from the whole of the

anterior and outer part of this skeleton. They are so densely interwoven as to preclude the possibility of a description of their exact course or arrangement; the most external, however, evidently affect a longitudinal direction, and the fibres of the internal layer are transverse or circular.

The great muscles of the shell (*k. k.* fig. 2. pl. 3; *e.* pl. 5.) arise from the whole posterior part of this cartilaginous mass, which thus becomes a firm bond of union between the exterior organs of locomotion and the powers employed to drag on the heavy shell behind. These muscles are an inch and a half in length, two inches in depth, and half an inch in thickness; they are convex on the outward aspect, and slightly concave towards the viscera, where they are perforated by the ramifications of the nutrient arteries, and by numerous nerves (*l. l.* pl. 7.). They pass outwards, and as they diverge are connected along their ventral margins by a layer of transverse muscular fibres (*m.* fig. 2. pl. 3.), which separates the branchial from the abdominal cavity. Their terminations are obliquely truncate, and form the lateral oblong surfaces covered by the horny substance above described (*g.* pl. 1; *l.* fig. 2. pl. 3.); and by means of that substance they are attached to the sides of the last chamber of the shell, at the distance of half an inch from the septum or floor of the cavity.

In tracing these muscles through the higher genera of *Cephalopoda*, they were found invariably in relation to the rudimentary shell; proportioned to its various degrees of development, and where it was altogether wanting, scarcely exhibiting a trace of their existence. In *Octopus*, for example, they are partly continued from the longitudinal fibres at the base of the arms, and partly derived from the cephalic cartilage; they pass down behind the lateral crura of the funnel, are there perforated by the nerve of the *ganglion stellatum;* become attached to the sides of the mantle, and are ultimately inserted at the anterior part of the capsules of the friable styles. In Cuvier's *Mémoire sur le Poulpe* they are marked *f. f.* fig. 1. & 2. pl. 1; *k. k.* fig. 1. pl. 4. and are termed respectively, "la bride latérale qui joint la bourse à la masse viscérale". p. 13. The analogous muscles in *Loligo* are larger, and derive more of their fibres from the cephalic cartilage; they have the same course as in *Octopus*, are similarly perforated by the nerve above mentioned, and are lost in the sides of the capsule of the horny pen. In *Sepia* also they are more developed, are shorter and thicker than in *Octopus*, are also pierced by the nerve of the *ganglion stellatum*, and are inserted in the

capsule of the laminated calcareous plate. In *Nautilus* they attain their highest degree of development, and correspond in bulk and strength to the capacity and weight of the testaceous covering.

In this way a clue is obtained to the true nature of the several incysted substances above mentioned, which, from being buried in the mantle, have frequently been considered the analogues of the internal skeletons of the *Vertebrata*. But the true skeleton of the *Cephalopoda* is the internal cartilaginous part which gives origin to the muscular, and protection to the nervous system, and accordingly we find that this part, like the skeleton of the *Vertebrata*, maintains, both with respect to its composition and situation, a characteristic constancy throughout the whole class. Whilst, on the other hand, the friable styles, the horny and calcareous plates, manifest, in this very diversity of character, their relation to the dermal system, which in every class of animals is the chief seat of varieties.

Having found in the genera above described so close a correspondence in the mode of attachment of the shell to the body, in whatever degree of development it existed, it became extremely desirable to examine the other genus of *Cephalopoda*, which, like *Nautilus Pompilius*, has an external shell, viz. the Paper Nautilus, or *Nautilus primus* of the ancients, the *Argonauta* and *Ocythoë* of the moderns; an animal concerning which a difference of opinion has long subsisted among naturalists, as to whether the shell it inhabits be or be not secreted by it. For the means of examining this species I am indebted to W. J. Broderip, Esq. and Captain P. P. King, R.N.; the former gentleman having, with his usual zeal for science, permitted me to dissect the beautiful and well-preserved specimen described by him, and figured in the first volume of the Zoological Journal; and the latter gentleman having placed at my disposal several small, but equally perfect specimens, which, together with the shells in question, were taken by him out of the stomach of a dolphin.

In these specimens I found that every trace of internal shell had disappeared. Of the muscles that are attached to the capsules of the friable styles of *Octopus*, those which Cuvier has termed, in the Memoir above quoted, "les gros piliers latérals de l'entonnoir", were smaller than in *Octopus*, were round and slender, and terminated posteriorly by blending with the inner fibres of the mantle. The muscles really analogous to the shell-muscles of *Nautilus* were reduced to a few fibres, accompanying and still manifesting a relation to the *ganglion stellatum*,

near which they were inserted, and lost in the mantle. Here, therefore, a strong analogical argument is afforded to those who object to the theory of the Argonaut shell being secreted by, or forming an integrant part of the Cephalopod which inhabits and deposits its ova in it; for it is difficult to suppose, after viewing the uniform manner in which the shell is attached to the body in other Cephalopods, and the regular relation subsisting between the means of attachment and the part to be attached, that in this instance, where the shell is external, like that of *Nautilus*, and developed in a degree second only to it, Nature should, if it were really developed by the *Ocythoë*, have reduced the ordinary means of attachment to a lower degree even than in *Octopus*.

In *Nautilus Pompilius* the crura or pillars of the funnel (*m*. pl. 1 ; *h*. pl. 5.) are more distinctly separated from the muscles of the shell than in any of the preceding genera. They commence from the membrane that connects the mantle with the back of the hood, incline forwards towards the ventral aspect along the outside of the origins of the shell muscles, and are gradually augmented by additional muscular fibres arising from the cartilaginous framework, to which they thus closely adhere. Having reached the ventral aspect of the body, they divide into two thick layers, both of which advance to meet their fellows at the mesial line; the internal layers (*i*. fig. 2. pl. 3.) becoming blended together, embrace, as it were, the shell muscles ; while the external layers (*f*. *g*. fig. 2. pl. 3.) diminish to a thin edge, and overlap each other without becoming continuous ; and thus is formed the commencement of the infundibular outlet, which gives passage to the products of respiration and generation, and to the excrements. The canal is then bent forwards, passes through the aperture in the mantle, and becomes the external funnel described above.

Besides the gradual augmentation in thickness which the sides or crura of the funnel acquire from the fibres coming off from the cephalic cartilage, they are also strengthened by tolerably distinct fasciculi of longitudinal fibres (*h*. fig. 2. pl. 3.), which arise behind the terminations of the shell muscles, but in close connexion with them, pass along the inside and near the posterior margins of the crura of the funnel, and terminate at the base of the funnel. These fasciculi are analogous to the more distinct rounded columns before alluded to, which Cuvier has denominated, in *Octopus*, "les gros piliers latérals de l'entonnoir" (*e*. *e*. fig. 1. & 2. pl. 1.), and which are also very distinct in *Sepia* and *Loligo*.

On the side of the funnel next the oral sheath, there are two small but distinct muscles (*levatores infundibuli*) (*g. g.* pl. 2.), which, in addition to their use in drawing the funnel towards the head, appear to be connected with the play of the tongue-like valve with which it is provided. They are rather more than an inch in length, and are round and slender in form; arise from the cartilaginous processes at the base of the funnel; pass forwards in smooth canals in its lateral parietes, and expand to be inserted into its extremity. This extremity they will draw away from the valve, in consequence of the extreme thinness of the parietes of the funnel anterior to the attachment of the valve, and so insure the exposure of that surface of the valve previously in contact with the funnel, to any opposing current from without, whose entrance by the funnel it is designed to prevent.

Analogous muscles are present in *Octopus*, *Sepia*, and *Loligo;* but they form in these genera part of the parietes of the funnel, and are not inclosed in canals. They are most distinctly developed in *Loligo vulgaris*, and are in that animal united together prior to their insertion into the extremity of the funnel.

§ 3. *Of the Digestive System.*

As the remaining muscles in this animal are chiefly connected with the preparatory organs of digestion, they may be conveniently treated of under this head, and be preceded by a description of the jaws (*n. o.* pl. 4; fig. 2. 3. 4. 5. pl. 8.).

These are two in number, having a vertical motion, and resembling in form the bill of the Parrot reversed, the upper mandible being encased in the lower when closed: they are adapted posteriorly to a muscular basis, to which they owe their motions. Thus far they resemble the mandibles of the Dibranchiate Cephalopods; but they are not composed entirely of horny matter, nor are they uniformly of a brown or black colour, their extremities being of a dense calcareous nature, and of a blueish white colour; they are also less pointed at the end; and the oral margins of the lower mandible are notched and dentated.

They are proportionally larger than in the Cuttle-fish, each mandible measuring in length one inch and three lines, and in vertical breadth one inch. About half an inch from their anterior extremities the horny part separates into two laminæ, the exterior of which in the upper mandible (*a.* fig. 2. 3. & 5. pl. 8.) is

of little extent (from three to four lines), and is dilated and flattened above so as to form a triangular surface half an inch broad at the base. In the lower mandible the proportions of the two laminæ are reversed, the exterior one (*d.* fig. 2; *b.* fig. 4. pl. 8.) being produced to the full extent, so as to make it appear larger than the upper mandible, which is not really the case.

The calcareous extremities of both mandibles are of a hardness apparently adequate to break through the densest crustaceous coverings, or even shells of moderate thickness. That of the upper mandible is sharp-pointed, and solid to the extent of five lines from the extremity; but in the lower one the calcareous matter is deposited on both sides of a thin layer of the black horny substance (*a.* fig. 4. pl. 8.), and thus a combination of tough with dense matter is obtained, which much diminishes the liability to fracture. This mandible is also more hooked than the upper one, but is more obtuse at the end: it seems from its dentated margin evidently intended to break through hard substances, whilst the sharp edges of the beak of the Cuttle-fish better adapt it for cutting and lacerating the soft bodies of fish. Indeed in the particulars just mentioned, the mandibles of *Nautilus* differ from those of every other known species of recent *Cephalopoda*. There are, however, certain fossils called *Rhyncolites*, formerly considered to be the beaks of fossil birds, but recognised by Blumenbach as appertaining rather to the *Cephalopoda*, although evidently differing from all the recent genera then known. M. d'Orbigny having invariably met with a large kind of these *Rhyncolites* in the same stratum with the fossil shell of a large Nautilus (*Nautilus Gigas*), suspected from that circumstance that they might be the mandibles of that species. (See his Memoir in the *Annales des Sciences Nat.* v. p. 211. pl. 6.) The calcareous extremities of the mandibles of *Nautilus Pompilius*, and the peculiarities of their form, especially the flattened superior surface of the upper mandible, fully confirm that conjecture, and at the same time show that a small portion only of the beak is represented by the fossil. The transversely striated body, which is figured with the lower mandible at *b.* fig. 1. and *a. b.* fig. 2. in the plate above quoted, is the part which supports the tongue of the Nautilus, and which may be considered to represent an *os hyoides*.

In the fleshy basis (*d.* fig. 5. pl. 8.) upon which the mandibles are encased, I observed no other peculiarity than a distinct fasciculus of fibres, which, arising on each side from the posterior margin of the upper mandible, runs along the

lower surface of the fleshy mass to be inserted into the base of the under mandible so as evidently to depress it.

The circular lip (*m*. pl. 4 ; *c*. fig. 5. pl. 8.) immediately surrounding the jaws, is, in consequence of the greater extent of the outer plate of the under mandible, much deeper than in the Cuttle-fish. It is composed of two layers of thin but tough membrane, terminating anteriorly in numerous minute pointed and jagged processes forming a fringe, and well adapted to entangle and prevent the loss of the smaller fragments of the food while it is undergoing the comminuting action of the mandibles. This lip is thickened towards the margin by the interposition of muscular fibres, the exterior of which form between the two layers of membrane a thin circular sphincter, while the inner fibres are longitudinal, and extend nearly to the base of the mandibles ; so that all the requisite motions of this part are adequately provided for. The outer layer of the lip is continued upon the labial processes, and parts immediately exterior ; the inner layer turns in beneath the outer lamina of the mandibles, and is closely attached to the muscular basis.

This apparatus of the jaws is provided with four retractor muscles, and one for protrusion. Of the former, two are superior and two inferior. The upper pair (*q*. *q*. pl. 4.) arise from the extremities of the cephalic cartilages, and converge to be inserted in the groove between the outer and inner plate of the upper mandible. The lower pair (*g*. fig. 5. pl. 8.) come off from the body of the skeleton at the base of the inferior labial processes ; after a short course they expand into a kind of pouch, supporting the pharynx, and are inserted along the inferior margin of the lower mandible. The jaws are protruded by a strong semicircular muscle (*r*. pl. 4 ; *k*. pl. 7.), which is continued from the margin of one inferior labial process over the mandibles and their retractor muscles to the labial process of the opposite side. In this action the muscle is probably assisted by the inner circular fibres of the oral sheath.

The tongue of *Nautilus* (fig. 6 & 7. pl. 8.) is a beautifully constructed part. It is of large size, filling the whole cavity comprehended between the rami of the inferior mandible. It is supported by an oblong horny substance, about eight lines in length, slightly curved, and transversely striated, which may be considered as representing an *os hyoides* (fig. 6. pl. 8.). The posterior extremity of this substance is free, or connected only by a few filaments with the parts above ;

but its anterior extremity is embraced by a pair of retractor muscles, which arise from the posterior margins of the lower mandible. The fleshy substance of the tongue, thus supported, is produced anteriorly, and forms three caruncles (*c*. fig. 7. pl. 8.) very soft in texture, and beset by numerous papillæ, having all the characters of a perfect organ of taste. The anterior or terminal caruncle is the largest, and four delicate retractor or depressor muscles are inserted into it. These arise, two on either side, below the *os hyoides*, from the membrane closing the lower part of the mouth.

Behind the caruncles the dorsum of the tongue is encased with a thin layer of horny matter about five lines in length, from which arise four longitudinal rows of slender recurved prickles (*b*. fig. 7. pl. 8.), between one and two lines in length. The number of these prickles is precisely that of the labial tentacles, there being twelve in each row. An analogous structure obtains in the *Cephalopoda* and in many of the *Gasteropoda*. The necessity of such a structure becomes very apparent in the Pearly Nautilus, if, as Rumphius has asserted, it creeps with the shell uppermost; since, in that case, the tongue, having its position reversed, would be opposed, instead of being assisted by gravitation while regulating the movements of the food in the mouth. And it is worthy of remark, that in the Flamingo, which turns the upper mandible to the ground while taking its food, the tongue is similarly armed with singularly developed recurved spines, calculated, as in the Pearly Nautilus, to rake the alimentary morsels towards the fauces. Behind the horny part, the tongue again becomes soft and papillose, but the papillæ are coarser and larger than those on the anterior caruncles. At the back of the mouth two broad fleshy processes project forwards from the sides of the fauces; these also are papillose, and are perforated in the middle of their inner surfaces by a small aperture which leads into a glandular cavity, situated between the folds of the membrane. An opake whitish substance could be expressed from these cavities, which were the only traces of a salivary system detected in this animal; although, from the remarkable development of these glands in the Dibranchiate Cephalopods, they were naturally expected and carefully sought for in the Pearly Nautilus.

The pharynx has numerous longitudinal rugæ internally, and is evidently capable of considerable dilatation. The œsophagus (*s*. pl. 4.) is three fourths of an inch in length, and after having passed beneath the brain, or commissure of

the optic ganglions, dilates into a capacious pouch or crop (*t*. pl. 4.), which is of a pyriform figure, two inches and three lines long, and an inch in diameter at the broadest part. From the bottom of this crop there is continued a contracted canal (*u*. pl. 4.) of about three lines diameter, and half an inch in length, which enters the upper part of an oval gizzard (*v*. pl. 4.) situated at the bottom of the pallial sac. Close to where this tube terminates, the intestine (*w*. *w*. pl. 4.) commences, and after a course of a few lines communicates with a small round laminated pouch (*y*. pl. 4.), analogous to the spiral cæcum of the Cuttle-fish, and into which the biliary secretion is poured. From this appendage the intestine is continued, without varying materially in its dimensions, to its termination; first ascending for about an inch and a half, then making a sudden bend down towards the bottom of the sac, and returning as abruptly upon itself, passing close to the pericardium, and terminating midway between the branchiæ at the base of the funnel.

The alimentary canal is everywhere connected to the parietes of the abdomen by numerous filaments: the only trace of a mesentery exists between the last two portions of the intestine which are connected together by a membrane containing the ramifications of an artery and vein (*w'*. 15. pl. 4.).

The whole of the alimentary canal was filled with the fragments of Crustaceans*, among which portions of branchiæ, claws, and palpi were distinctly recognisable, so as to leave no doubt that the greater part of them had appertained to a Brachyurous Decapod of a hirsute character, and not a Swimmer. The crop in particular was tensely filled with these fragments, and the capability of propelling such rude and angular particles through a narrow canal into the gizzard without rupturing the thin tunics of the preparatory cavity, is not one of the least extraordinary examples of the powers of living matter.

The longitudinal rugæ into which the lining membrane of the œsophagus is thrown, disappear at its entrance into the crop. The muscular coat of the crop consists of an exterior layer of close-set circular fibres, and an inner layer of more scattered longitudinal ones. The lining membrane is thin but tough, with a smooth surface: when the cavity is empty, it is probably thrown into longitudinal folds by the action of the circular fibres.

* The fossil remains of this class of animals are not unfrequently found in the same stratum with Nautilites, Ammonites, &c.

In the canal which leads to the gizzard, the lining membrane puts on a villous appearance, and is disposed in distinct close-set longitudinal rugæ (*b*. fig. 8. pl. 8.).

The gizzard, as in the genus *Octopus*, very much resembles that of the Fowl, being girt by two broad radiate muscles, which are of the thickness of two lines. It is lined with a thick cuticular membrane, delicately furrowed and adapted to numerous fine ridges, which traverse longitudinally the whole interior of the cavity. This membrane, as commonly found in gizzards, was detached from part of the parietes, and adhered very slightly to the remainder (*d*. fig. 8. pl. 8.). The pyloric orifice is close to the cardiac, and is guarded by a valve, apparently to prevent a too ready egress of matter from the gizzard.

The contents of this part of the alimentary canal were in smaller fragments than in the crop, but of the same nature: the fragments of shell are comminuted apparently by mutual attrition, as there were no particles of sand or pebbles present adequate to produce this effect.

The globular cavity (*f*. fig. 8. pl. 8.), which communicates with the intestine at a little distance from the pylorus, is occupied with broad parallel laminæ, which are puckered transversely, so as to increase their surface and cause them to appear more numerous than they really are; their texture under the lens is seen to be follicular, and evidently fitted for secretion. The bile enters this cavity at the extremity furthest from the intestine, by a duct large enough to admit a common probe. The two laminæ on each side of the entrance of the duct increase in breadth as they approach the intestine, and are continued in a curved form along that canal, being gradually lost in its inner membrane; the lamina next the gizzard (*g*. fig. 8. pl. 8.) is peculiarly enlarged, so as evidently to present an obstacle to the regurgitation of bile towards the gizzard. A similar structure exists in the intestine of *Loligo*.

With respect to the nature of this globular laminated bag,—its reception of the biliary secretion renders it in some measure analogous to a gall-bladder; but most probably its chief use is to pour into the commencement of the intestinal canal a fluid which is necessary for the completion of digestion, so that, like the laminated and spiral cæcum of the higher Cephalopods, and the pyloric appendages of Fish, it is essentially a simple form of pancreas.

The interior of the remainder of the alimentary canal in *Nautilus* presents a few longitudinal rugæ and slight transverse puckerings. It was filled with smaller fragments of crustaceous shell similar to those in the gizzard. There

was not, however, any trace of these fragments of shell in the pyloric or pancreatic laminated bag.

The liver (*z. z.* pl. 4.) is a bulky gland, extending on each side of the crop from the œsophagus to the gizzard. There is a parallelism of form, as will be afterwards seen, between this gland and the respiratory organs; for instead of being simple and undivided as in *Ocythoë*, or bilobed as in *Sepia*, it is here divided into two lobes on each side, and these are connected by a fifth portion which passes transversely below the fundus of the crop. All these larger divisions are subdivided into numerous lobules* of an angular form, which vary in size from three to five lines. These lobules are immediately invested by a very delicate capsule, and are more loosely surrounded by a peritoneal covering common to this gland and the crop.

The liver is supplied by large branches which are given off from the aorta, as that artery winds round the bottom of the sac to gain the dorsal aspect of the crop. It is from the arterial blood alone, in this, as in other Mollusks, that the secretion of the bile takes place; there being but one system of veins in the liver, which returns the blood from that viscus, and conveys it to the vena cava at its termination. The colour of the liver is a dull red with a violet shade; its texture is pulpy and yielding. When the capsule is removed by the forceps, the surface appears under the lens to be minutely granular or acinous; and these acini are readily separable by the needle into clusters hanging from branches of the blood-vessels and duct. The branches of the duct arising from the terminal groups of the acini, form, by repeated anastomoses, two main trunks, which unite into one at a distance of about two lines from the laminated or pancreatic cavity (*h.* fig. 8. pl. 8.).

Beyond this part no other foreign secretion enters the alimentary canal, as there is not in the Pearly Nautilus any trace of structure analogous to the ink-bag of the Dibranchiate Cephalopods.

§ 4. *Circulating and Respiratory Systems.*

The peritoneum, after lining the cavity which contains the crop and liver, and enveloping those viscera, forms two distinct pouches at the bottom of the pallial sac; in one of which, the left (*l.* pl. 5.), is contained the gizzard; in the other (*m.* pl. 5.), the ovary: anterior to these, and on the ventral aspect of the liver,

* I have lately met with a similarly subdivided form of liver in *Capromys*, a Glirian quadruped from Cuba.

is another distinct cavity (*n*. pl. 5.), of a square shape, which contains the heart and principal vessels, with the glandular appendages connected therewith.

This cavity is analogous to that which Cuvier has denominated, in *Octopus vulgaris*, "*la grande cavité veineuse*"; but it is not here, as in that animal, divided by a membranous septum running along the mesial line. To prevent the confusion of ideas liable to arise from the use of the term "venous cavity", I shall hereafter, in treating of this receptacle, term it *Pericardium*. If it should be objected that a pericardium is a shut sac, and that this cavity, in addition to its extent, communicates with the exterior of the animal through the medium of the branchial cavity,—it may be urged in reply, that the same external communication exists in the pericardium of the Sturgeon, the Ray, and the Shark, through the medium of the abdominal cavity.

The pericardium of the Pearly Nautilus is separated from the branchial cavity by a strong membranous partition (*u'*. *u'*. pl. 5.), in which the following orifices are observable: in the middle, the termination of the rectum; to the right of this, the orifice of the oviduct; and on each side at the roots of the branchiæ there is a small mammillary eminence, with a transverse slit, which conducts from the branchial cavity to the pericardium. There is, moreover, a foramen at the lower part of the cavity (*o*. pl. 5.), permitting the escape of a small vessel; and by the side of this vessel a free passage is continued between the gizzard and ovary into the membranous tube or siphon that traverses the divisions of the shell; thus establishing a communication between the interior of that tube and the exterior of the animal.

The peripheral parietes of the pericardium are not distinct from the substance of the mantle, but cohere, and form with it a thin but tough parchment-like membrane; having, in place of the thick fleshy sac of the Cuttle-fish, a sufficient protection in the more extensively developed calcareous covering of the Nautilus. The venous branches from the labial and digital tentacles and adjacent parts of the head and mouth, terminate with those from the funnel in the sinus excavated in the body of the cartilaginous skeleton. From this sinus the great vena cava (1. pl. 6.) is continued, running in the interspace of the shell-muscles on the ventral aspect of the abdominal cavity, and terminating in a slightly dilated part (2. pl. 6.) just within the pericardium, where it receives, by two large trunks (3. 3. pl. 6.), the veins of the different viscera. The structure of the vena cava is very remarkable. It is of a flattened form, being included be-

tween a strong membrane on the lower or ventral aspect, and a layer of transverse muscular fibres, which decussate each other on the upper or dorsal aspect; both the membrane and the muscle pass across from the inferior margin of one of the shell-muscles to the other, they consequently increase in breadth as those muscles diverge, and complete the parietes of the abdomen on the ventral aspect: the vein, however, maintains an uniform calibre by its proper internal coat, and leaves a space on either side of it between the membrane and the muscle prior to its termination. The adhesion of the proper membrane of the vein to the muscular fibres is very strong, and these fibres form, in consequence, part of the parietes of the vein on their side throughout its whole course. But there are several small intervals left between the muscular fibres and corresponding round apertures (1′. pl. 6; *n*. pl. 7.) in the membrane of the vein and in the peritoneum; so that the latter membrane is continuous with the lining membrane of the vein. Thus the blood may pass into the general abdominal cavity, and the fluid contents of that cavity be reciprocally received or absorbed into the vein. I counted as many as fifteen of these apertures; they were largest and most numerous at the commencement of the vein; and most of them would admit the head of an eye-probe. They are too numerous and regular in their shape to allow for a moment the supposition of their being accidental, even if an analogous formation had never been met with, and this had been the solitary instance of so anomalous a structure; but the discovery of a similar one in the genus *Aplysia* prepares the mind to contemplate it with less surprise, and even leads to a suspicion that it may be more generally found on a further and more diligent investigation of the venous system in this remarkable class of animals.

The great anatomist to whom we owe the discovery, concludes his account of this structure in the *Aplysia* with the following observations:

"This communication is so little in accordance with our knowledge (of organic structure) in the vertebrate animals, that I was inclined for a long time to doubt it; and even after having communicated it to the Institute some years ago, I dared not then send my memoir to the press, so much I feared that I might be deceived: at length I have been compelled to yield to evidence, having, from the moment that I had at my disposal as many *Aplysiæ* as I wished, assured myself in every possible way,—

"1st, That there is no other vessel to convey the blood to the branchiæ, but the two great muscular and perforated canals that I have just described:

" 2nd, That all the veins of the body open mediately or immediately into these two great canals.

" But, as their communication with the abdominal cavity is evident and palpable, whether they be called *venæ cavæ*, or *cavities* analogous to the right ventricle, or lastly *branchial arteries*,—for they fulfil the functions of all these three organs,—the result in every case is, that the fluids diffused in the abdominal cavity can be mingled directly with the general mass of the blood and be carried to the branchiæ, and that the veins perform the office of the absorbent vessels.

" This extensive communication is doubtless the first stage of that still more extensive one which nature has established in the class of insects where the vessels appropriate to the nutrient fluid no longer exist; and we have already a vestige of it in the cephalopodous Mollusks, where, as I show in the article respecting them, certain spongy bodies convey also the abdominal fluid into the vena cava.

" It is from these facts that I have formed the opinion that the absorbent system ceases entirely in the Mollusks, and, *à fortiori*, in the animals below them in the scale*."

* " Cette communication est si peu d'accord avec ce que nous connaissons dans les animaux vertébrés, que j'ai voulu long-temps en douter; et même, après l'avoir fait connaître à l'Institut il y a quelques années, je n'osai pas d'abord faire imprimer mon mémoire, tant je craignais de m'être trompé; enfin je suis obligé de céder à l'évidence, et dans ce moment, où je peux disposer autant d'aplysies qu'il me plait, je viens de m'assurer par toutes les voies possibles,—

" 1°, Qu'il n'y a point d'autre vaisseau pour porter le sang aux branchies, que ces deux grands conduits musculaires et percés que je viens de décrire:

" 2°, Que toutes les veines du corps aboutissent médiatement ou immédiatement dans ces deux grands conduits.

" Or, comme leur communication avec la cavité abdominale est evidente et palpable, qu'on les appelle *veines-caves*, ou *cavités* analogues au ventricule droit, ou enfin *artères branchiales*,—car on voit qu'elles remplissent les fonctions de ces trois organes,—il résulte toujours, que les fluides épanchés dans la cavité abdominale peuvent se mêler directement dans la masse du sang, et être portés aux branchies, et que les veines font l'office des vaisseaux absorbans.

" Cette vaste communication est sans doute un premier acheminement à celle bien plus vaste encore que la nature a établie dans les insectes où il n'y a pas même des vaisseaux particuliers pour le fluide nourricier; et nous en avons deja un vestige dans les mollusques céphalopodes, où, comme je le montre à leur article, certains corps spongieux portent aussi le fluide abdominal dans la veine-cave.

" C'est d'après ces faits que j'ai pensé que le système absorbant cesse entièrement dans les mollusques, et à plus forte raison dans les animaux situés au dessous d'eux dans l'échelle."—Cuvier, *Mémoire sur le Genre Aplysia*, p. 14.

It militates, however, against this idea of the spongy bodies of the veins of the Cephalopods being a vestige of the structure just described, that in the present instance they exist together. In *Aplysia* the orifices of communication are found in the trunks of the vessels going to the branchiæ after having received all the other venous trunks of the body; but in *Nautilus* this structure occurs only in that part of the venous system which is in relation with the abdominal cavity, and anterior to the reception of the great splanchnic veins; hence it appears to have special reference to the abdominal, or at least to a great serous cavity. In both instances a peculiar muscular structure of the vein is demonstrable at the part where these orifices occur, so that their function appears to depend on, or to be in connexion with, a power of regulating their diameters.

The vena cava, having arrived in the manner just described at the septum of the pericardium, perforates that septum, and being joined by large trunks which return the blood from the liver, ovary, gizzard, and remainder of the alimentary canal, is dilated into a small membranous sinus of a transverse form (2. pl. 6.). It is here, therefore, that the greater circulation terminates, if we are to consider the lesser circulation to commence when the blood again begins to move from trunks to branches: and, according to this view, the branchiæ will be described before the account of the vascular system is proceeded with.

The respiratory organs of the Pearly Nautilus have a similar elongated pyramidal form, together with the same laminated structure and symmetrical disposition as in the Cuttle-fish; but they are four in number, being disposed two on either side, and each pair arising by a common peduncle from the inner surface of the mantle.

From this difference in the number of branchiæ, in addition to the other peculiarities in the structure of *Nautilus*, the existence of at least two orders in the class *Cephalopoda* is, I imagine, demonstrated; and the denominations of these orders might conveniently be taken from the modifications of the respiratory system. Assuming, therefore, that it is common to the class to possess branchiæ of a laminated structure, symmetrically disposed, and concealed beneath the mantle, those genera which possess two such branchiæ will form an order under the term *Dibranchiata*, and the Pearly Nautilus and other Cephalopods with shells of an analogous formation a second order, under the term *Tetrabranchiata*. It is in this sense that the expression "Dibranchiate

Cephalopods" has been made use of in this Memoir; and to this group most of the characters of the class as given by the immortal Cuvier in his *Règne Animal*, exclusively appertain.

In each lateral pair the branchiæ are of unequal sizes, the larger one being situated below, and on the outer side of the smaller. The larger branchia (*p*. pl. 5. & 6.) is about one inch and two thirds in length, and two thirds of an inch in breadth, and has forty-eight laminæ on either side; the smaller branchia (*q*. pl. 5. & 6.) is about one third less than the preceding, and has thirty-six laminæ on either side. These laminæ are disposed alternately, are themselves composed of smaller transverse laminæ, which are again similarly subdivided (fig. 2. pl. 6.), the whole being connected together, and forming the same tripinnatifid structure as in the Dibranchiate Cephalopods. The chief differences consist in the branchial laminæ of *Nautilus* being more closely set upon the central muscular stem, and being more extended in the lateral direction, so that the branchia is compressed from before backwards, and not from side to side. Moreover, in *Octopus* and *Loligo* the branchiæ are connected to the inner surface of the sac by a membrane extending their entire length; but in *Nautilus* they hang freely in the pallial cavity, being attached only at their bases; in *Sepia* the extremities of the branchiæ are unattached;—an interesting circumstance in connexion with the nearer affinity to *Spirula* and *Nautilus*, which this genus already manifests in the laminated shell developed within its mantle. The affinity of *Sepia* to *Nautilus* is also indicated by another particular in its anatomy, viz. the organ*, hitherto considered anomalous, that is appended to the branchial ventricle, but which appears to exhibit the rudimentary condition of the accessory branchia, which we find to attain its full development in *Nautilus*.

The four branchiæ of *Nautilus* receive the venous blood principally by four vessels (5. 5. pl. 5. & 6.), which are continued from the central venous sinus, arising from it on each side by a single trunk (4. 4. pl. 5. & 6.), which quickly divides, and then proceeding to their respective gills, without being joined by any other vessel, and without the interposition of any ventricle or branchial heart as in the higher Cephalopods.

In this course, however, they have attached to them clusters of glandular

* See Home's *Comp. Anat.* iv. pl. 44. 45. fig. 9.

bodies or follicles (6. 6. pl. 5. & 6.), analogous to those which are appended to the corresponding parts of the vascular system in the *Dibranchiata*. These follicles are not, however, ramified as in the Cuttle-fish, nor of a spongy aspect as in the Calamary, nor of a very elongated form as in the Poulp; but they are short and pyriform, and closely set together. To each of the branchial arteries are appended three clusters of these glands, of which one is larger than the united volume of both the others; and the larger cluster is situated on one side of the vessel, and the two smaller on the opposite side. Each of these clusters is contained in a membranous receptacle proper to itself, partitioned off, as it were, from the pericardium, but communicating with it. The septa, or walls of these receptacles (*u. u.* pl. 5.), exhibit in some parts a fibrous texture, apparently muscular, as if for the purpose of compressing the follicles, or of discharging the contents of the membranous receptacles into the general cavity of the pericardium. The two canals which form the communication between the pericardium and the branchial cavity, commence at the receptacles of the lesser clusters attached to the superior branchial arteries (*u'. u'.* pl. 5.), and terminate at the papillæ before mentioned, which are situated at the roots of the branchiæ. The pericardium and these receptacles of the glands, when first laid open, were found filled with a coagulated substance so closely compacted as to require a careful removal bit by bit before the contained follicles and vessels could be brought into view. The follicles communicate together by their contracted extremities, and terminate by rounded orifices in the dilated part of the vessel; the terminal orifices (7. 7. pl. 6.), in consequence of the previous communications, being much fewer than the follicles themselves.

With respect to the functions of these singular bodies, it has been conjectured either that they serve as "diverticula, in which the venous blood, being subdivided, can experience through the parietes of the spongy follicles the influence of the ambient fluid" (supposing the water to be admitted into the *venous cavity* by the two excretory canals); or that they serve as "excretory canals, by which the spongy body pours into the veins some substance which can only be extracted out of the ambient element:" or lastly, that they serve as "emunctories, by means of which the blood is freed of some principle that escapes by the pores or external folds of the spongy bodies*."

* "Il est donc beaucoup plus probable que ce sont ou des diverticules dans lesquels le sang veineux

In a recent state an abundance of mucus escapes on pressure from their outer pores, according to the observation of Cuvier, in the genus *Octopus;* and he found also that air or injection thrown into the vessel readily escaped from the follicles into the pericardium, and that air blown into the pericardium (*cavité veineuse*) frequently filled the veins. Professor Grant has observed, that in a living Calamary (*Loligo sagittata*, Lam.), these glandular "parts of the veins exhibited a remarkable peristaltic motion, which continued as long as any other motions of the body*." I have injected the arteries of these follicles in the Cuttle-fish, which ramify in a beautifully minute arborescent form upon them, and testify by the size and number of branches to their glandular nature.

In all the Cephalopods the follicles are appended to that part of the vascular system which terminates the greater, or commences the lesser circulation. But besides their use as connected with the respiratory system, and effecting changes in the blood itself, either by way of depuration or addition, I am induced to believe from the following considerations that they also perform a secondary function, which has not hitherto been attributed to them.

The Cephalopods of the higher order have a power of locomotion superior to all other Mollusks, and can vary their elevation in the water at will. The Pearly Nautilus also, though in general dwelling in the deep, has the power of rising and floating on the surface, as appears from the testimony of Rumphius, and the circumstances connected with the capture of the present specimen. These changes of position must obviously produce great alterations in the degree of pressure which the animals have to sustain from the surrounding medium; and the fluids contained in their sanguiferous system must, of course, suffer considerable and corresponding variations of expansion. We must suppose also that their respiration, or the transmission of the blood through the gills, will be more or less rapid, both according to the distance from the surface at which

aurait à se subdiviser, pour éprouver, au travers des parois du corps spongieux, l'influence de l'élément ambiant; ou, ce qui reviendrait au fond à-peu-près au même, des canaux excréteurs, par lesquels le corps spongieux verserait dans la veine quelque substance qu'il n'aurait guère pu lui-même extraire que de cet élément ambiant; ou, enfin, des émonctoires, par le moyen desquels le sang se débarrasserait de quelque principe qu'il verserait au dehors par les pores et les replis extérieures des corps spongieux." Cuvier, *Mém. sur le Poulpe*, p. 19.

* Edinburgh Philosophical Journal, xvi. p. 314.

they breathe, and the degree of muscular effort that may at any time have been expended.

In other classes of animals subject to the same mutations of surrounding pressure, various structures have been recognised as accommodating the sanguiferous system to these changes; as, for example, the extraordinary *rete mirabile* in the intercostal spaces of the *Cetacea**, and the varied muscular and elastic powers connected with the branchial artery of fish, which, according to Sir Everard Home†, bear a relation to their powers of descending to great depths. The auricle also in fish, and the capacious venous sinuses which terminate in it, must afford convenient receptacles to the blood when in a state of expansion, or prevented by any cause from flowing freely through the gills; and the valvular structures for obviating the regurgitation of the contents of the ventricle into the auricle, or of the auricle into the sinus, are more complete in this than in any other class of vertebrate animals. But the branchial ventricle, in those Cephalopods which possess it, is unprovided with an auricle; and the Pearly Nautilus, if we except the follicles appended to the vessels passing to the gills, has no receptacle connected with the vascular system adapted to the uses above mentioned. I am therefore induced to believe that these follicles relieve the vascular system, by affording a temporary receptacle for the blood whenever it accumulates in the vessels, either from the effects of a general expansion, or of a partial impediment in its course through the respiratory organs, and that they serve to regulate the quantity of blood sent to these organs.

After communicating with the follicles the branchial arteries continue their course outwards, and having reached the roots of the branchiæ, they become contracted in size; and at this part is situated a valve (8. pl. 6.) in each, which opposes the retrogression of the blood. Immediately beyond this valve each artery enters separately the root of the branchiæ of its respective side, and then dilates into a wider canal (9. pl. 6.), which is continued through the soft white fleshy substance (*r*. pl. 6.) forming the central stem or support of the branchia. A vein which returns the blood from the shell-muscle also penetrates on each side the muscular root of the branchiæ, and terminates at the commencement of

* J. Hunter, Observations on Whales, Philos. Trans. lxvii. p. 415.

† Philos. Trans. ciii. p. 234.

the arterial canal of the larger branchia. The interior of this canal in both branchiæ presents a double series of orifices, leading to the branches which extend along the concave margins of the laminæ; which branches subdividing as the laminæ subdivide, distribute the blood to all parts of this beautiful structure, and ultimately terminate in the branchial vein (10. 10. pl. 5. & 6.).

Of the muscularity of the part inclosing the branchial artery there can be little doubt; such a power being equally required for the propulsion of the blood into the smaller branches of the artery, and for the motions of the branchial laminæ themselves, which are indispensable in aquatic respiration.

The branchial vein returns along the opposite side of the branchia; its cavity does not present a double series of separate orifices as in the artery, but a line of alternate slits connected together like an alternately pinnate stem. After quitting the roots of the branchiæ, the veins cross over on the dorsal aspect of their corresponding arteries, but without undergoing any dilatation as in the Cuttle-fish, and enter the four corners of the systemic ventricle (*t*. pl. 5. & 6.), where each is provided at its termination with a single semilunar valve (11. 11. pl. 6.). This ventricle is transversely quadrate in form, and is eight lines in the long, and four in the short diameter: its interior presents fleshy columns decussating each other transversely. Two arteries arise from it; one superior, and small (12. pl. 5. & 6.), whose orifice is furnished with a double valve; the other inferior, and of large size (16. pl. 6.), coming off near the left corner of the ventricle, and accompanied, for the extent of five lines, by a muscular structure (16′. pl. 6.) similar to the muscular bulb of the branchial artery of fish, at the termination of which is a single valve (17. pl. 6.) In addition to these there is a singular part connected, but not communicating with the ventricle; it is an elongated pyriform sac (18. pl. 5.), attached by a contracted origin near the root of the large aorta, but soon dilating and acquiring a width of two lines, and then gradually contracting and becoming connected by its other extremity to the venous sinus above: its parietes are membranous; it contained a firm coagulated substance, but had no apparent outlet. Its position and connexions would induce a belief that it had established, at some previous period of existence, a communication between the venous sinus and systemic ventricle, independent of the branchial circulation.

The lesser aorta runs forward a little way, and gives off a branch (13. pl. 5. & 6.)

that appears to be exclusively distributed to the mucous organ of the oviduct, which is attached to the inside of the mantle just above the pericardium. The artery then sends off a small branch (14. pl. 5. & 6.), which winding round to the ventral aspect of the ventricle (to which it is connected by a process of membrane) passes through a foramen in the septum which divides the pericardium from the cavity at the bottom of the pallial sac, is then continued through that cavity, passing between the ovary and gizzard, and lastly enters, without diminution of size, the membranous tube that traverses the partitions of the shell. The third and last branch of the lesser aorta runs in the membrane or mesentery, between the last loop of the intestine (15. pl. 4. 5. & 6.).

The larger aorta passes downwards between the gizzard and ovary, and renders to both these viscera. It then winds round along the bottom of the sac, sends off large branches to the liver, and gains the dorsal aspect of the crop, along which it passes (19. pl. 4.) to the œsophagus, distributing branches on either side to the great shell-muscles. Having reached the cerebral chord, it divides into two equal branches (20. pl. 4.), which pass by the sides of the œsophagus through the nervous collar, and terminate by furnishing branches to the mouth, the surrounding parts of the head, and the funnel.

In order to facilitate the tracing of the arterial system, both vessels arising from the heart were injected with mercury, by which means the small siphuncular artery was discovered, which otherwise might have remained undetected, or at least of doubtful existence. The coats of the vessels were strong enough to bear a pressure of five inches of mercury without rupture; and more force was not employed, as this was found sufficient for all the purposes of the examination.

§ 5. *Of the Nervous System, and Organs of Sense.*

The nervous system of the Pearly Nautilus, though analogous, is in many respects inferior to that of the Dibranchiate Cephalopods. The part which corresponds to the brain of the Cuttle-fish is neither enlarged, nor lobulated, nor contained in a cartilaginous receptacle; but is a simple rounded chord or commissure (1. fig. 1. pl. 7.), placed transversely above the œsophagus, and connected at its extremities to the great ganglions. These are six in number; are disposed symmetrically about the œsophagus, and, together with the central commissure, are loosely

enveloped in a tough membrane, or dura mater. The two anterior ganglions (2. 2. fig. 1. pl. 7.), which are analogous to those termed *pes anserinus* in the Cuttle-fish, are of a flattened elongated form, are lodged in the groove on the anterior part of the cephalic cartilage, and lie on either side the œsophagus: they become gradually smaller towards the ventral aspect, and are there united so as to encircle the alimentary tube. They give off the nerves to the tentacles and parts surrounding the mouth. The middle and superior pair of ganglions (3. fig. 1. pl. 7.) are analogous to the reniform ganglions of the Cuttle-fish, and have the same peculiar fibrous structure; but they are of an oval form, and exhibit a diminution of volume corresponding with that of the central commissure or brain, being only three lines in the long, and two in the short diameter. They are continued from the central commissure more directly than the other ganglions, are connected with it by short narrow pedicles, and appertain exclusively to the eyes. The posterior ganglions (4. 4. fig. 1. pl. 7.) resemble in form the anterior, and encircle the œsophagus in a similar manner, becoming narrower as they approach to coalesce on the ventral aspect. They give off the nerves to the muscles of the shell and to the viscera.

The double collar thus formed is not, however, peculiar to *Nautilus*, but exists in other Mollusks, as, for example, in the genus *Aplysia;* where, however, the subœsophageal ganglions being more remote, the filaments that connect them to the common centre above are necessarily longer. Nor is the similarity of disposition to be overlooked in the nervous system of the higher Cephalopods, although obscured by a greater degree of concentration in the larger masses. In *Octopus*, for example, a double chord extends from the brain on either side the œsophagus, but the ganglions are united into one mass below; from which mass the nerves analogous to those supplied by the separated subœsophageal ganglions of *Nautilus* are given off. In *Sepia* also, the nerves of the arms are derived from the anterior subœsophageal ganglions, as represented at 5. 5. fig. 3. pl. 7, which figure has been added both for the purpose of comparison with the nervous system of *Nautilus*, and also on account of the errors which, as Cuvier has pointed out, exist in the figures previously given of this organ*.

In *Nautilus* the nerves which arise from the ganglions of the anterior circle

* See Scarpa, "*de Auditu et Olfacto*," tab. iv. fig. 7. 10. 11. and M. Tilesius in "Beiträge für die Zergliederungskunst," von H. F. Isenflamm, B. 1. Heft 2. tab. ii. fig. 6.

are small and numerous; they penetrate, at a short distance from their origin, the substance of the fibrous sheath, in which, from the rigidity of its texture and the similarity of colour, it became exceedingly difficult to follow them. The larger and more distinct branches (5. 5. fig. 1. pl. 7.) enter respectively the roots of the tentacles, which are lodged in the canals of the digitations, but those going to the ophthalmic tentacles are somewhat larger than the others. There did not appear to be any lateral connecting filaments between these nerves, probably because there is no simultaneous action in the parts they supply, analogous to that which is observed in the movements of the arms of the Poulp, &c. Below these branches numerous small nerves (6. 6. fig. 1. pl. 7.) are given off, which enter the external labial processes, and penetrate in a similar manner the roots of the tentacles lodged in these processes. The internal labial processes are, however, supplied in a different manner: a larger nerve (7. 7. fig. 1. pl. 7.) comes off near the ventral extremity of the ganglion, and after a course of half an inch swells out into a flattened ganglion (8. 8. fig. 1. pl. 7.), from which numerous filaments extend into the substance of the process, and are continued into the tentacles as in the preceding case: a branch (10. fig. 1. pl. 7.) also inclines and distributes filaments to the membranous laminæ situated between the inferior labial processes. A pair of nerves (11. pl. 7.) arises near the point of union of the anterior subœsophageal ganglions, and passes forwards to be distributed to the infundibulum and its muscles.

From the brain itself, or general commissure, there are given off two larger and two lesser pairs of nerves (12. pl. 7.); these supply the parts immediately surrounding the mouth, the muscles of the jaws, and the tongue.

From the ganglions composing the posterior collar numerous nerves of a flattened form (13. pl. 7.) originate, which after a course of from half an inch to an inch penetrate the muscles of the shell, without being produced to form a *ganglion stellatum* (7. fig. 3. pl. 7.), as in the Cuttle-fish. It has previously been observed that these nerves penetrate the analogous muscles in the higher *Cephalopoda* by a single trunk, which afterwards swells into a ganglion, and is distributed to the thick muscular cloak of these genera. The visceral nerves, a single pair (14. pl. 7.), which appear to combine the functions of the sympathetic and par vagum, run down on each side of the vena cava, and at the termination of that vein give off the branchial nerves (15. pl. 7.), and form on each side a

small ganglion (16. pl. 7.), which distributes nerves to the viscera. Other minute nerves (17. pl. 7.) arise mesiad of the origins of the preceding pair, and form a network upon the muscular parietes of the vena cava, accompanying that vessel as far as the pericardium, and being lost on the ventricle and glandular parts contained therein.

As there has been occasion to observe a degree of inferiority in the brain of *Nautilus*, so also we find a corresponding simplicity in the eye, which is far from presenting those complexities of structure that render it so remarkable an organ in the Dibranchiate Cephalopods. Indeed it here appears to be reduced to the simplest condition that the organ of vision can assume, without departing altogether from the type which prevails throughout the higher classes. For although the light is admitted by a single orifice into a globular cavity or *camera obscura*, and a nerve of ample size is appropriated to receive the impression, yet the parts which regulate the admission and modify the direction of the impinging rays are entirely deficient.

It has been previously remarked, that the eyes are not contained in orbits, but are attached each by a pedicle to the side of the head, immediately below the posterior lobes of the hood. The ball of the eye (*s*. pl. 1 ; *t*. pl. 2 ; *o*. pl. 7.), is about eight lines in diameter, and although contracted and wrinkled in the specimen, appears to be naturally of a globular form, rather flattened anteriorly. The diameter of the pedicle (*t*. pl. 1 ; *p*. pl. 7.) is three lines, and its length the same. On each side of the pedicle is the orifice of a sheath excavated in the substance of the hood, and containing the peculiar tentacles previously described (*r.r*. pl. 1.). Along the inferior border of the eye there is a slightly elevated ridge (*u*. pl. 1. & 2.), as it were a rudiment of an inferior eyelid, and from the middle of this ridge a smaller one (*v*. pl. 1.) is continued to the middle of the anterior surface of the eye, where the pupil (*w*. pl. 1 ; *q*. pl. 7.), which is a circular aperture less than a line in diameter, is situated. The small size of the pupil in this species is the more remarkable when contrasted with the magnitude of that aperture in the Dibranchiate Cephalopods ; but it depends most probably on the great degree of mobility which the eye of the Pearly Nautilus enjoys, in consequence of its attachment to a muscular pedicle, which enables it to be brought to bear with ease in a variety of directions ; whilst in the preceding genera corresponding motions of the head and body would have been necessary, on account of the

more fixed condition of the eye in them, if the range of vision had not been extended in the manner above mentioned, viz. by the enlarged pupil. The principal tunic of the eye is a tough exterior membrane or sclerotic (*r.* pl. 7.), thickest posteriorly or where it is continued from the pedicle, and becoming gradually thinner to the margins of the pupil.

The nervous fibres after leaving the optic ganglions enter the pedicles and form a tough pulpy mass (*s.* pl. 7.) at the floor of the eye, which extends as far forwards as the semidiameter of the globe. This nervous tissue as well as the whole interior of the cavity is covered by a black pigment, which is consequently, here, as in the Cuttle-fish, interposed between the impinging rays of light and the sentient membrane.

The contents of the globe, of whatever nature they were, had escaped by the pupil. If it had ever contained a crystalline lens, that body must have been extremely small; as otherwise, from the well known effect of ardent spirits in coagulating it, it would have been readily perceived. What adds, however, to the probability of this eye being destitute of a crystalline humour, is the total absence of ciliary plicæ or any structure analogous to them. In some parts of the cavity a membrane could be distinguished which had enveloped the fluid contents of the eye; but it had entirely disappeared at the pupil, which had in consequence freely admitted the preserving liquid into the cavity of the globe. Rumphius states that the eye of the Pearly Nautilus is filled with a dark brown sanguineous fluid. In the present specimen it unfortunately happened, that the right eye having been torn off by the boat-hook in the capture of the animal, prevented a further and more satisfactory examination of this organ.

In the simplified structure which has just been described, it is possible that the actions of some of the parts may have been so modified as to compensate more or less for the absence of others which are usually deemed essential to complete vision; otherwise we must suppose the sense of sight in the Pearly Nautilus to be reduced to the simple consciousness of the reception of light. But even this act, unless the pigment be traversed by nervous fibrils too minute to be detected, is performed in a manner incompatible with the ordinary idea of the mode in which the retina is affected by luminous rays. I am not aware that any satisfactory explanation has been given of this anomalous disposition of the black pigment by those who have made the eye of the *Cephalopoda* a peculiar

study. The hypothesis that connects it with the power they possess of blackening the water around them must fall to the ground, as the Pearly Nautilus, in which this disposition of the pigment equally exists, has no apparatus for secreting and ejecting an inky fluid.

With respect to the sense of hearing, I have not been able to detect a distinct organ for that faculty in the Pearly Nautilus. The cartilage supporting the subœsophageal nervous circle was examined, as far as considerations for the preservation of an interesting part of this rare animal would allow, but did not appear to contain any cavities or calcareous bodies resembling those in the Dibranchiate Cephalopods.

It has been conjectured, that in the Mollusks the organ of smell is as generally diffused as that of touch, and that the entire skin, which from its softness and lubricity resembles a pituitary membrane, is the seat also of this sense. But in the present species, the character of the exposed integument is opposed to the idea of its being adapted to such a function, and in this respect the Pearly Nautilus differs considerably from the rest of the class. These considerations strengthen an opinion I had been induced to form from a previous examination of the part,—that there exists in this Mollusk a distinct organ of passive smell, formed after the type of that organ in the inferior *Vertebrata*, and especially in Fish.

The part which appears to exercise the functions of that modification of the sense of smell which is enjoyed by aquatic animals, consists of a series of soft membranous laminæ (*l*. pl. 4; *g*. fig. 1. & fig. 2. pl. 7.), compactly arranged in the longitudinal direction, and situated at the entry of the mouth, between the internal labial processes. These laminæ are twenty in number, and are from one to two lines in breadth, and from four to five in length, but diminish in this respect towards the sides. They are supplied by nerves from the small ganglions which are connected to the ventral extremities of the anterior subœsophageal ganglions.

The tongue of the Pearly Nautilus would seem to give it greater pretensions to a possession of the sense, of taste than the analogous part in many of the vertebrate animals; the anterior caruncles, at least, appear peculiarly adapted to this faculty. They are supplied with two nerves, which come off from the brain or central commissure.

The papillæ upon that part of the head which is termed the hood, form a remarkable character in this species; and if they could be proved to be endowed with nerves, would be peculiar to it among Invertebrate animals: but the great difficulty experienced in tracing the nerves in the substance of the sheath renders their existence as nervous papillæ matter of conjecture only. Independently of these, however, the sense of touch is amply enjoyed by this animal in the numerous tentacles with which it is so singularly provided, and which, from their softness of texture, their annulated surface, and supply of nerves, are entitled to be considered organs of tact as much as instruments of prehension.

§ 6. *Of the Generative System.*

Aristotle was evidently acquainted with the fact, that the *Malakia*, or *Cephalopoda*, were male and female; for he speaks of them*, in contradistinction to the *Testacea*, with a special reference to this circumstance: and the propriety with which, according to this view, he classed the *Nautilus secundus* with the *Malakia*, notwithstanding it adhered to, and was covered with a shell like a snail, is fully borne out by the dissection of the present individual, which was found to possess those generative organs only which are peculiar to the female.

These consisted of an ovary, an oviduct, and, as in the Pectinibranchiate Gasteropods, of an accessory glandular apparatus. The ovary (*a*. fig. 9. pl. 8.) was situated at the bottom of the sac by the side of the gizzard, in a peritoneal cavity peculiar to itself. It was an oblong compressed body, one inch and a half in length, and an inch in breadth; convex towards the lateral aspect, and on the opposite side having two surfaces sloping away from a middle longitudinal elevation. At the anterior and dorsal angle there was an orifice (*b*. fig. 9. pl. 8.) about three lines in diameter, with a puckered margin, which conducted into the interior of the ovary. The cavity of the ovary was simple and undivided. It was filled with numerous oval bodies (*c. c*. fig. 9. pl. 8.) of different sizes, which were attached by one extremity to the ovarian capsule, but were free and perforated at the opposite end; and were smooth exteriorly, but rugose, and apparently granular on the inner surface, owing to numerous minute wavy plicæ adhering thereto. The largest of these masses (*capsulæ oviferæ*) were four or five

* *Hist. Anim.* lib. iv. cap. 11.

lines in length: they were principally attached along the line of the exterior elevated ridge, at which part the nutrient vessels penetrated the ovary.

The oviduct (*e. f.* fig. 9. pl. 8.) was not an immediate continuation of the ovary as in the *Dibranchiata*, but commenced, like that of the oviparous *Vertebrata*, by an aperture distinct from the gland. This aperture was of a semilunar form, and was situated directly above the orifice of the ovary in the peritoneal membrane which connects that gland to the pericardium. The oviduct was a flattened tube of about an inch in length, and from four to five lines in breadth; it extended forward by the side of the intestine, (without dividing as in *Ocythoë* and *Octopus*,) and terminated at the base of the funnel close to the anus. It became enlarged towards the extremity, and was deeply furrowed in the transverse direction both within and without; the parietes were also here thick and pulpy, and apparently glandular. It is probable, however, that the ova derive an additional exterior covering and connecting substance from the secretion of a large glandular apparatus (fig. 10. pl. 8.) which is situated immediately below the terminal orifice of the oviduct; and which, as no other use is obvious, I shall here describe in connexion with the genital system. This apparatus is attached to the mantle, and gives rise to the two rounded convexities observable on the ventral aspect of the body behind the funnel. It is a transversely oblong mass, composed of numerous close-set pectinated membranous laminæ, which are about a quarter of an inch in depth, and are disposed in three groups: those of the larger group extend transversely across the mesial line of the body, and are unprotected by a membrane; but the two smaller divisions are symmetrically disposed, and have the unattached edges of the laminæ covered by a thin membrane, which is reflected over them from the anterior margin of the glandular body. These divisions form the sides and anterior part of the gland; and as the secreted matter must pass backwards to escape from beneath the margin of the protecting membrane, this membrane may serve both to conduct the secretion nearer the orifice of the oviduct, and also to prevent its being drawn within the respiratory currents of water, and so washed away as soon as formed. With the exception of this distinct glandular apparatus, the generative system of the Pearly Nautilus, as exhibited in this female, differs very little from that of the higher Cephalopods.

Concluding Observations.

In consequence of this distinction of sexes, the completion of the anatomy of this interesting species awaits the arrival of a male specimen; and not only with respect to the generative system is further opportunity of dissection required, but it is desirable for the perfect elucidation of the structure of all the other organs; for the anatomy of a species can rarely be satisfactorily founded on the examination of a single individual, especially if it presents a new and uncommon form. Even with the greatest care, parts are liable to be displaced before their relations to the surrounding structures have been sufficiently ascertained; and it is only after having acquired such knowledge, that the better mode of conducting the examination is perceived. But besides the limited materials which have been afforded for this inquiry into the structure of the Pearly Nautilus, it is further to be regretted that so little information should exist relative to its habits and modes of action; its defective history in these particulars having rendered it very seldom practicable to connect the modifications of the different organs, when ascertained, with the peculiar exigencies of the species. These modifications have, however, been carefully studied with respect to the organization of allied groups of *Mollusca*, and some of the affinities of *Nautilus* have thus been attempted to be demonstrated; but many more doubtless remain to be detected by the experienced naturalist.

Before, however, entering on this subject, it is necessary to add a few observations on the relative position of the soft parts of *Nautilus Pompilius* to their testaceous covering. The shell of this species, as is well known, is a suborbicular, symmetrical, multilocular univalve, convoluted on a vertical plane, with the turns contiguous; the last being the largest, and concealing all the rest; the umbilicus being further obliterated by a deposition of nakrous matter*. It is a thick and heavy shell, when compared with *Argonauta*, has a smooth exterior, transversely marked with reddish brown bands, and is composed of

* In another recent species (*Nautilus umbilicatus*, Lam.), which much resembles the preceding in form, colour, and size, the umbilicus is not obliterated, and the gyrations consequently are distinctly visible from without. From the small fragment of shell remaining attached to the animal here described, it was not evident to which of these species it had appertained: I therefore submitted both of them to Mr. Bennett's inspection, who immediately selected *Nautilus Pompilius* as the shell to which his specimen was attached when brought on board.

an outer layer of opake testaceous substance, and an inner layer of naker. The chambers are separated by transverse partitions (*x*. *x*. pl. 1.), which are concave towards the outlet or mouth of the shell, and are severally perforated by a siphuncle (*y*. *y*. pl. 1.) through the centre of the disk. These chambers regularly increase in size* to the last (*z*. pl. 1.), which forms a capacious porch more than sufficient to contain all the soft parts of the animal. Their relations to this cavity will be best understood by a reference to pl. 1. The ventral surface of the body is applied to the concavity of the peripheral wall of the chamber, or keel of the shell; while the involuted convexity of the shell is adapted to the concavity behind the hood, and is abutted against the ridge which rises from that part. The hood, when the animal draws itself within its retreat, naturally forms the analogue to an operculum, and, from its rigid texture, seems tolerably well adapted to supply the want of that defence; and in this function we have a further instance of the analogy, before alluded to, which the hood of *Nautilus* bears to the foot of a Gasteropod, though it be in a reverse position with respect to the body.

The points of attachment of the muscles to the shell are always to be seen near the bottom of the dwelling-chamber, in the form of an expanded oval disk on each side. A narrower impression connects the lateral disks so as to form with them a sinuous circle corresponding to the horny belt which begirts the mantle; of which belt a layer is sometimes left adhering at this part to the inner surface of recent and uncleaned shells. Not only, however, is this impression to be observed in the last chamber, but it is also obvious in all the others, and renders in each that moiety of the parietes next the mouth of the shell comparatively dull, while the lower half retains the nakrous lustre: the indication of the muscular attachment is also here occasionally rendered more evident by a layer of the horny matter left adhering. From these appearances I conclude that the process of advancement preparatory to the secretion of a new partition is by no means gradual, but that the muscles, having detached their outer layer of tendon,

* This increase is regular only as regards their superficial dimensions. In all the full-grown shells that I have seen in section, the penultimate chamber is more shallow than those which immediately precede it: during the period also in which the young *Nautilus* derives sustenance from the vitellus, and when its growth may be supposed to be rapid, it probably advances proportionately further at each epoch of adding a chamber, than subsequently; and this may be the reason why after the fifth, seventh, or eighth from the beginning, the chambers again become more shallow.

slip from their attachments, and form new ones at a determinate distance from the former; the operation being analogous, remotely indeed, to a partial moulting or casting off an exuvial covering, the loss of which is repaired by the secretion of the partition closing the deserted chamber, and by the successive additions to the margins of the chamber of occupation. This process becoming repeatedly necessary from the increasing bulk of the animal, is the obvious physical cause of the camerated portion of the shell; to have filled up the whole of the chambers with calcareous matter during a more gradual process of advancement, would have produced an incumbrance incompatible with the locomotive faculties of the inhabitant.

One important point in the history of the Pearly Nautilus, viz. the exact relation of the posterior membranous tube to the siphuncular apertures of the septa and intermediate chambers, can receive but little elucidation from the present inquiry, in consequence of the loss of the shell from which the specimen was taken. In sections of recent shells its dried remains may occasionally be seen of a black colour and pergameneous texture, continuing from septum to septum as far as the central or first-formed chamber: and a further confirmation that this is the true structure of the parts, is afforded by the fossil shells of this genus. In some polished sections of these remains, not only is the continuation of the tube through all the chambers evident, but it is seen to become slightly dilated in them, and in some instances appears also to have been reflected over the outer part of the testaceous tube prior to being continued across the chamber to the next partition*. There is no indication, however, of the latter structure in the recent shells, where the membranous tube is preserved; but there is a delicate pellicle, distinct from the tube, continued over the outer part of the testaceous tube, and also over the whole inner surface of the chamber.

The above appearances in the fossil shells have been deemed confirmatory of the hypothesis of Dr. Hooke†, who supposed *Nautilus Pompilius* to have the power of generating air into, and expelling it from the deserted chambers; and that it regulated, in the same manner as Fish by means of their air-bladders, its ascent and descent in the water. Mr. Parkinson, in adopting this theory, as-

* Parkinson's Organic Remains, vol. iii. p. 102. pl. vii. These fossils are now preserved in the Museum of the Royal College of Surgeons.

† Philosophical Experiments and Observations: 8vo, Lond. 1726. pp. 307. 310.

sumes that the seat of the accumulation of the gaseous fluid is the membranous tube, and considers it to have a corresponding power of dilatation and contraction. Those who incline towards this opinion may derive from the preceding account circumstances in some measure explanatory both of the source of the supposed contained gas, and of the way by which it afterwards escapes: the one may be considered as a secretion of the artery which is continued down the membranous tube; and the communication which exists between the tube and branchial cavity through the medium of the pericardium, may be deemed explanatory of the other part of the process.

But it must be admitted, on the other hand, that the size of the artery seems barely adequate to support the vitality of the membrane, much less to effect a secretion, for which in Fish, (at least such as have an outlet to their air-bladders,) an ample gland appears to be indispensable; and with respect to the outlet, the oblique and contracted nature of the passage is ill calculated to allow of an escape of the gas sufficiently rapid to answer as a self-preserving action, or a means of defence against sudden assaults.

Much, indeed, remains to be done before the theory of the chambers and siphuncle can rest on the sound basis of experiment and observation. Mr. Bennett's observation,—that the contents of the deserted chambers in the living animal are liquid,—is an important addition to its history; though it may still be doubted whether their contents are the same under all circumstances, even during the lifetime of the animal; and the nature of the fluid, its proportional quantity*, and the precise disposition and contents of the membranous tube, still remain to be determined.

From the adhesion of the entire circumference of the mantle to the shell by means of the horny girdle, I am, on the contrary, inclined to suppose that the whole of the chambers are excluded, during the lifetime of the animal, from external influence, and are filled only by exhalations or secretions from the animal. In the present instance, supposing the animal to have risen to the surface by creating a partial vacuum in the chambers, the presence of water therein is accounted for by the fracture of the posterior part of the chamber of occupation

* It would be advisable, in the event of another fortunate capture of the *Nautilus*, to lay open the chambers under water, when the presence of gas in any of them would be ascertained, and it might be received: the contents also of the central tube, if gaseous, would at once be detected.

during its capture. With respect to the siphon, there appears to be nothing in its structure or mode of connexion with the body calculated to prevent its being filled with such fluid matter as the pericardium may contain; and as the pericardium communicates with the branchial cavity, sea-water may in this way pass into its cavity, and the relative situations of the gas and water be thus the reverse of what Mr. Parkinson supposes them to be.

The quantity of gas which according to this view must be accumulated in the camerated portion of the shell, might be supposed to be incompatible with the habits of the Pearly Nautilus as a ground-dwelling animal, and that the bottom of the sea is its principal sphere of action, is proved by the nature of its food. But the soft parts of this animal weighed, in the specimen here described, fifteen ounces *avoirdupoise*, and little more than half that weight suffices to sink the shell with all its closed chambers full of air. Although, therefore, the specific gravity of the shell is greatly diminished and is thus rendered less cumbersome to the inhabitant; yet to rise with it to the surface must require some exertion on the part of the inhabitant: while in order to float there at ease, an additional volume of air is probably taken into the dwelling-chamber, in which case the act of sinking would be accomplished by simply reversing the shell.

On a retrospect of the details of the organization of *Nautilus Pompilius*, it appears that the plan of formation of all the principal systems or collections of organs for individual functions is strictly Cephalopodic, the variations depending either on excess or defect of development.

Thus in both orders the principal masses of the muscular system take their origin from an internal cartilaginous skeleton, and extend in opposite directions before and behind their point of attachment; the anterior mass being subservient to locomotion and prehension, the posterior to respiration and attachment to a more or less developed shell. In the former division of the muscular system the Pearly Nautilus presents us with a peculiar arrangement of one of its parts, adapting the animal to a mode of progression unknown to any of the higher Cephalopods, and in which it participates with some of the inferior forms of Mollusks. The part alluded to is the flattened plate or disk which surmounts the head; but, generally considered, the anterior masses present an inferiority of development corresponding to the diminutive nature of the parts which represent the cephalic arms of the *Dibranchiata*. The posterior masses, on the con-

trary, are increased in bulk commensurate with the larger funnel, and with the more perfectly developed and capacious shell. To the presence of the latter body is doubtless to be attributed the absence of the thick stratum of muscular fibres which gives so peculiar a character to the mantle of the *Dibranchiata;* since in these we find that where the shell is advanced, as in *Sepia*, the muscular fibres are wanting at the part of the mantle in which it is lodged. And, as in addition to the difference in the structure of the mantle, the natatory organs of the higher *Cephalopoda* have no analogues in the Pearly Nautilus, we must conclude that in the active powers both of respiration and locomotion it is vastly inferior to them.

The digestive system, from the nature of its functions, and the similarity of the materials on which it has to operate, maintains a more strict affinity, and, except in a few particulars, scarcely varies in degree beyond those generic differences which have already been observed in the higher order of Cephalopods: thus we have in the Pearly Nautilus the same general form and disposition of jaws for dividing and comminuting the alimentary substances, but with a difference of texture adapted to the harder nature of the food which the submarine habits and locomotive powers of this species probably confine it to. The preparatory receptacle, or crop, is of a larger size than in the higher genera of Cephalopods, among which, however, *Octopus* and *Ocythoë* in this respect come nearest to *Nautilus*. The succeeding cavity, or laminated pancreatic bag, which is the analogue of the spiral cæcum of the *Dibranchiata*, presents a simplicity of form, which, in conjunction with the slight development of the salivary organs, constitutes the chief difference in the digestive system of *Nautilus*. In both orders of *Cephalopoda* the intestine terminates in the same manner, and apparently for the same intention,—viz. that the excrementory substances may be thrown within the influence of the respiratory currents, and so be expelled by the funnel. But in the disposition and increased length of the intestinal canal in *Nautilus*, we may observe a deviation from the character so peculiar to the intestine of the higher Cephalopods; and both in this respect, and in the minutely subdivided liver, there is an evident approximation to the Gasteropodous type of structure.

It is, however, in the respiratory and circulating systems that dissection has shown the greatest differences to subsist between *Nautilus* and the higher *Cephalopoda;* but here also the differences depend on excess and defect of develop-

ment of parts, and do not at all affect the general plan or arrangement of the organs appropriated to those functions.

To the Zoologist the single systemic heart of *Nautilus* affords an interesting example of its affinity to the inferior Mollusks; whilst at the same time it tends materially to illustrate the relations which subsist between the locomotive, circulating, and respiratory functions. In comparing the branchiæ only of the two orders of *Cephalopoda*, the increased number of these organs in the type of the *Tetrabranchiata*, appears at first sight to compensate for their diminished size; but when we reflect on the perfection, as a respiratory apparatus, which the gills of the *Dibranchiata* derive from the ventricles appropriated to accelerate the circulation through them, we are then led to consider it as one of the chief causes of their superiority over all other Mollusks in locomotive energies, manifested in the rapidity with which, by means of varied fin-like structures, they propel themselves through the water.

Whilst the organization of the Cephalopods was known only in the *Dibranchiata*, the presence of a branchial ventricle might naturally be supposed to depend on the peculiar structure of the gill: thus it has been observed, "In the Teredines the water is intimately applied to the gills from the simplicity of their structure; but in the Sepia they are more complex, and require force to apply the water to every part of them; and for this purpose there is a bulb and double valve placed at the root of each gill."—Home, *Lectures on Comp. Anat.* iv. p. 164. But the same structure of gill occurring in *Nautilus* without any ventricles being appended to the breathing organs, notwithstanding the added complexity of subdivision, renders necessary a consideration of the subject in its other relations, and irresistibly leads to the above conclusion that the Mollusks, which execute rapid and vigorous movements in water, require that degree of perfection in their respiratory system which is afforded by a superadded muscular power at the commencement of the lesser circulation.

The interesting character which *Nautilus* sustains as an osculant form between *Cephalopoda* and *Gasteropoda*, will perhaps be considered to have been sufficiently manifested by the instances of affinities already cited; but it is rendered still more evident on a consideration of the nervous system. The forms, proportions, and disposition of the principal masses of this system, appeared, indeed, at first sight to recede so far from the type of the higher Cephalopods,

as to have rendered it necessary, in the description, to refer to a Gasteropodous genus in illustration of it. The essential difference, however, as has already been shown, consists in the simpler condition of the central mass;—the source of volition being thus in harmony with the diminished energies of the muscular and the contracted sphere of the sensitive system.

The differences in the distribution of the principal nerves are not less important in a physiological point of view. In the Cephalopods, whose shells are rudimentary and internal, and whose bodies are enveloped in a naked, and as we must suppose sensible mantle, the nerves which supply that part radiate from a ganglion, which, as in the posterior roots of the spinal nerves in the *Vertebrata*, is interposed on the chord which brings them in communication with the central mass. In *Nautilus*, on the contrary, whose body is incased in an insensible calcareous covering, the analogous nerves are wholly expended on the largely developed muscles which attach the shell to the body; and these nerves, like the motor filaments of the spinal nerves, pass into the muscles directly from the brain without the interposition of any such ganglion.

The inferiority of the more intellectual senses, sight and hearing, is in correspondence with the simplicity of the brain. If, as I believe, a distinct organ for the latter sense is altogether wanting, the Pearly Nautilus exhibits in this respect an obvious approximation to the inferior Mollusks; and in receding from the higher Cephalopods in the structure of the eye, it inclines more directly towards the Gasteropods, numerous genera of which, and especially the *Pectinibranchiata* of Cuvier, present examples of this organ analogous in simplicity of structure, and in a pedicellate mode of support and attachment to the head. As the Pearly Nautilus, like the latter group of Mollusks, is also attached to a heavy shell, and participates with them in the deprivation of the locomotive instruments of the Cephalopods, we may thence deduce the more immediate principle of their reciprocal inferiority with respect to the visual organ; for what would it avail an animal to discern distant objects, which could neither overtake them if necessary for food, nor avoid them if inimical to its existence?

As the spheres of vision and of action, however, are thus limited, the power of taking cognizance of proximate objects is proportionately augmented, and the organs of the simpler sense of touch are more amply developed. In the nu-

merous and singularly disposed tentacles of *Nautilus*, we have also examples of a recurrence of structures heretofore unknown among the Cephalopods, and whose analogues are to be sought for in inferior groups. And here again, as in the case of the eye, after searching in vain among the Pteropodous genera*, we are compelled to admit the claims of the Gasteropods to a closer alliance with the highly organized class whose affinities the Pearly Nautilus has tended so materially to elucidate. Thus *Doris*, *Thethys*, and *Tritonia*, each present examples of sheathed and retractile tentacula; and in the former of these genera they have the same peculiar structure as is displayed in the ophthalmic tentacles of *Nautilus*. See Cuvier, *Mém. sur le Doris*, p. 12. pl. 2. fig. 1.

On a consideration of the generative system, it will appear that, as far as regards the female, the Pearly Nautilus does not recede materially from the Cephalopodic type; and the differences which it exhibits in this respect, having already been noticed in the description of the organs, need only to be alluded to here: but on this subject it may be remarked, that the *Pectinibranchiata* in their dicœcious mode of generation approximate closer to *Nautilus* than the other *Gasteropoda*, and present a similar laminated glandular organ in the branchial cavity, whose office is supposed to be to secrete the receptacles of the ova after they are expelled. As it is in these receptacles that the rudimentary shell is developed in the *Pectinibranchiata*, the similarity in texture and bulk of its testaceous appendage may render, in *Nautilus*, a similar nidus necessary for the protection of its ova, until that process be completed.

In whatever degree the shell is developed in the Cephalopodous Mollusks, we find it invariably characterized by the symmetry so peculiar to the disposition and general form of their soft parts: but the extent to which the Pearly Nautilus is covered by its shell, and its close attachment to it, indicated the affinity to the Gasteropods in too strong a manner to escape the penetration of Aristotle,

* The retractile tentacles of *Clio* are constructed on a plan very different from those of *Nautilus*. The considerations, indeed, on which the *Pteropoda* have been placed in the '*Règne Animal*' next in order after the *Cephalopoda*, and preceding the *Gasteropoda*, appear to be slighter than have usually influenced the immortal author of that work in the position of his groups. Their swimming like the former animals is a relation of analogy; whilst their inferiority to some, at least, of the Gasteropodous families is evidenced by the doubtful nature of their organ of vision, and by their hermaphroditical mode of generation.

who directly compares it in this respect to a snail; and the general resemblance must be sufficiently striking when, with his house above him and in the supine position, he makes his way along the sand with a moderate degree of rapidity*.

After meeting with so many unexpected modifications of structure referable to the inferior groups of Mollusks in the inhabitant of this recent chambered shell, it is natural to suppose that the series of affinities which it tends to illustrate would be rendered still more complete in the organizations of the numerous genera, whose testaceous remains are now only known in a fossil state.

Respecting the economy of these genera, we may infer from *Nautilus* that they were chiefly confined by the limitation of their locomotive faculties to creeping at the bottom of the sea, and that one of the offices assigned to them in the scheme of nature was to restrain within due limits the crustaceous and testaceous tribes around them. Granting them, indeed, the power of rising and floating on the surface, yet their navigation was in all probability of a passive kind, or influenced only by the reaction of the respiratory currents when expelled by the funnel upon the surrounding medium; and at all events it can no longer be supposed to have been aided by the fabled sails and oars of the Argonaut.

With respect to the position of the fossil-chambered shells in the natural system, it is obvious that little alteration can result from the present examination of *Nautilus*, and that, therefore, they will continue to occupy the confines of the Cephalopodous class.

Naturalists of the first rank have already selected from among these remains those forms of shell which, approaching nearest to that of *Nautilus*, may be supposed to have been secreted by a similarly organized animal. Professor de Blain-

* The testimony of Rumphius on this head is so explicit and circumstantial, that I am induced to quote the passage at length. "When he thus floats on the water, he puts out his head and all his barbs (tentacles), and spreads them upon the water, with the poop (of the shell) above water; but at the bottom he creeps in the reverse position, with his boat above him, and with his head and barbs upon the ground, making a tolerably quick progress. He keeps himself chiefly upon the ground, creeping sometimes also into the nets of the fishermen: but after a storm, as the weather becomes calm, they are seen in troops floating on the water, being driven up by the agitation of the waves. Whence one may infer, that they congregate in troops at the bottom. This sailing, however, is not of long continuance; for having taken in all their tentacles, they upset their boat, and so return to the bottom."—*D'Amboinische Rariteit-kamer*, p. 61. fol. Amsterdam, 1741.

ville has grouped together, to form his family *Nautilacea*, the genera *Orbulites*, *Nautilus*, *Polystomella*, and *Lenticulina;* and the Baron Cuvier has included with *Nautilus*, in a more extended family, the *Lituacea* of De Blainville, and the *Orthoceratites*. But if any confidence is to be placed in the description of the soft parts of *Spirula*, its organization must differ considerably from that of *Nautilus*. In the notice of this animal by Lamarck, from which all the subsequent ones appear to have been copied, it approaches much nearer the Cuttle-fish. Instead of being lodged, like the Pearly Nautilus, in the last chamber of its shell, that body is almost wholly buried in the posterior part of the animal, and is only partially visible from without. Moreover, its head is stated to be surrounded by ten arms, of which two, as in *Sepia*, are elongated, pedunculated, and provided with acetabula at the dilated extremities. The figure which corresponds to this description is published in the *Encyclopédie Méthodique* (Atlas, Coquilles, pl. 465. fig. 5. *a. b.*) ; but in the one which appears in the Illustrations to Péron's Voyage (pl. 30. fig. 4.), the pedunculated arms are omitted, and the head is represented surrounded by short conical brachia. As this is the figure which Professor De Blainville has selected for the illustrations of his '*Malacologie*', he had probably some reason for considering it as coming nearest the original, although it is asserted that the figure in the *Encyclopédie* was engraved from a pen-and-ink sketch taken by Lamarck himself from Péron's specimen. Slight, however, as are both the descriptions and figures of this interesting animal, their value is much diminished by the note* which Professor De Blainville has appended to his character of *Spirula*, (*Malacologie*, i. p. 381.) which leads us to hope that when the internal structure of that genus shall be examined, it will also present some interesting modifications of the different organs, and may perhaps be found to connect *Nautilus* with *Sepia*. The individual specimen brought to Europe by Péron was found dead, and floating on the sea between the Molluccas and the Isle of France ; it was possibly therefore in a state unfit for dissection.

The primary arrangement of the class *Cephalopoda*, so long as it continued to be founded on the anatomical structure of the naked genera only, could not

* " D'après une lettre écrite dernièrement par M. de Freminville à M. Brongniart, il paroîtroit que l'animal de la spirule seroit tout différent de cette description que nous devons à Péron. Cependant M. de Roissy, qui a vu l'individu reporté par celui-ci, nous a confirmé la caractéristique que nous venons de donner."

safely admit the establishment of more than a single order; and the preceding description of *Spirula* naturally tended to render it less probable that the inhabitants of the other multilocular shells would present such discrepancies of structure as to justify the adoption of a second. Lamarck, however, while he concludes rather hastily from *Spirula*, that all the multilocular shells appertain to veritable Cephalopods, (evidently little suspecting the variations from their plan of structure presented by *Nautilus*), at the same time adopts three primary divisions, which he characterizes according to the modifications of the shell. Succeeding naturalists, by whom the Cephalopods have been especially studied, have in general concurred with Lamarck in placing those multilocular shells in an order apart from the naked genera: thus they form the order *Polythalamacés* of De Blainville (*Malacologie*), and in the system of M. de Haan, are further separated from the microscopic species under the term *Siphonoides* (*Monographiæ Ammoniteorum et Goniatiteorum Specimen*); which appellation M. d'Orbigny, in a later and elaborate treatise on the Microscopic Cephalopods, has changed to *Sifonifères*, (*Annales des Sciences*, vii. p. 96.) The Baron Cuvier, however, has not, in his arrangement of the class, ventured beyond what the details of structure would strictly warrant; and in the latest edition of his invaluable work '*Le Règne Animal distribue d'après son Organisation*,' he says, "Les Céphalopodes ne comprennent qu'un ordre, que l'on divise en genres, d'après la nature de leur coquille."

Of the propriety, however, of considering the naked genera as constituting a distinct order, there can now be little doubt: at every step, indeed, of the preceding description, it became necessary to denote them by a collective term, since the chief points in which they differed from the *Nautilus* were participated by them in common. It cannot, of course, be assumed that the inhabitants of the chambered shells shall equally participate with *Nautilus* in its peculiar variations from the structure of the higher order; but until further details of the organization of these singular and most interesting animals are acquired, the following characters of the two orders, founded on the descriptive details contained in this Memoir, will probably be considered admissible.

Subregnum MOLLUSCA.

Classis CEPHALOPODA.

Caput magnum, discretum, oculis magnis instructum.

Os terminale, mandibulis duabus robustis aduncis armatum, brachiis cotyliferis seu tentaculiferis circumdatum.

Corpus oblongum, vaginâ exceptum, nudum, seu domo testaceâ munitum.

Branchiæ symmetricæ, elongatæ, obtectæ.

Cor systemicum.

Tubus excretorius sub capite, ad basin cujus anus.

Individua alia mascula, alia feminea.

Ordo I. DIBRANCHIATA. Cephalopodes Sépiaires, *Lam.* Cryptodibranches, *De Blainville.* Cephalopodes libres, *De Haan.*

Oculi sessiles.

Mandibulæ corneæ.

Brachia elongata, cotyledonibus interiùs adspersa.

Pallium crassum, carneum, aperturâ anticâ unicâ.

Branchiæ duæ.

Corda branchialia duo.

Tubus excretorius parietibus perfectis.

Testa rudimentaria aut nulla.

Genera hujus ordinis,—*Octopus*, *Eledona*, *Ocythoë*, *Sepiola*, *Cranchia*, *Loligo*, *Sepiotheuthis*, *Onychotheuthis*, *Sepia*, &c.

Ordo II. TETRABRANCHIATA. Cephalopodes testacés polythalamés, *Lam.* Polythalamacés, *De Blainville.* Siphonoides, *De Haan.* Sifonifères, *d'Orbigny.*

Oculi subpedunculati.

Mandibulæ ad apicem calcareæ.

Brachia abbreviata, tubulosa, tentaculis retractilibus munita.

Pallium membranaceum, aperturis anticis duabus, tubulo membranaceo postico per siphonem testæ multilocularis percurrente.

Branchiæ quatuor.

Cor branchiale nullum.

Tubus excretorius parietibus infernè solutis.
Testa interna aut externa multilocularis.

Genera hujus ordinis,—*Belemnites*, *Baculites*, *Lituola*, *Spirula* (?), *Ammonites*, *Orbulites*, *Nautilus*, *Cibicides*, *Rotalites*, &c.

Genus Nautilus.

Corpus oblongum, posticè rotundatum, tubo gracili membranaceo terminatum.
Caput supra disco ambulatorio.
Brachia utrinque novemdecim.
Appendices labiales tentaculiferæ quatuor, circum os dispositæ.
Tentacula (xcii ! !) trium generum, quorum,

Ophthalmica, lamellosa, utrinque duo.
Brachialia, annulosa, utrinque viginti.
Labialia, ———, utrinque viginti quatuor.

Totum corpus in camerâ ultimâ testæ magnæ multilocularis reconditum, et musculis duobus lateralibus affixum.

Testa (secundum Cl. Lamarckium) discoidea, spiralis, polythalamia ; parietibus simplicibus. Anfractus contigui ; ultimo alios obtegente, septa transversa, extùs concava, disco perforata : marginibus simplicissimis.

EXPLANATION OF THE PLATES*.

PLATE I.

Nautilus Pompilius, in the prone position†, with its natural relation to the shell shown by a section of that part in outline.

a. a. The mantle.

b. Its dorsal fold, applied to the involute convexity of the shell.

c. Its free anterior margin.

d. The orifice for the passage of the funnel.

e. The convexity produced by the ovarian gland.

f. f. The horny girdle for the adhesion of the mantle to the shell.

g. The horny laminæ covering the extremity of the left shell-muscle.

h. A portion of the shell, which was left adhering to this muscle.

i. i. i. The membranous tube or siphon which traverses the testaceous tubes in the camerated portion of the shell.

k. The funnel.

l. The left lateral process of the funnel.

m. The left crus or pillar of the funnel.

n. The hood, or ligamento-muscular disk that surmounts the head.

o. o. The exterior digitations of the left side.

o'. The larger one, with a papillose surface like that of the hood.

p. p. The digital tentacles, protruded from their sheaths.

q. The groove which separates the hood from the papillose digitation.

r. r. The ophthalmic tentacles.

s. The eye.

t. Its peduncle.

u. The inferior ridge, or rudimentary eye-lid.

v. The ridge running from this to

* All the parts are represented of the natural size, except where it is otherwise expressed.

† In using the terms relating to aspect and situation in the preceding description, this is considered as the natural position of the animal.

w. The pupil.
x. *x*. *x*. The partitions of the chambers.
y. *y*. *y*. The septal tubes which give passage to the membranous siphon.
z. The chamber of occupation.

PLATE II.

FIGURE 1. *Nautilus Pompilius*, in the prone position, with the orifice of the oral sheath enlarged to expose the labial processes and tentacles surrounding the mouth.

a. The mantle.
b. Its dorsal fold collapsed.
c. Its anterior margin.
d. The process of the mantle which separates the funnel from the head.
e. *e*. The convexities produced by the ovarian gland.
f. The orifice of the funnel a little widened; the funnel itself is drawn down to show the surface of the oral sheath on which it rests.
g. *g*. The *levatores infundibuli* exposed by laying open the canals in which they were concealed.
h. The hood.
i. Its superior plane surface longitudinally divided.
k. *k*. The cut-surfaces.
l. The smooth internal surface of the oral sheath.
m. *m*. The digitations, showing their orifices, the tentacles being retracted. (The entire number is given on the right side.)
m'. The large papillose digitation.
n. The inferior parietes of the oral sheath.
o. *o*. The external labial processes.
p. *p*. The internal labial processes.
q. The convex outer surface of the organ of smell.
r. *r*. The labial tentacles.
s. One of the ophthalmic tentacles.
t. The eye.
u. The inferior ridge.

FIG. 2. An ophthalmic tentacle magnified, showing its laminated structure.

FIG. 3. A digitation with its tentacle, magnified.

a. The free extremity of the digitation.

a'. The cut surface separated from the parietes of the head.

b. The digital tentacle.

b'. The cut-surface of the tentacle, exposing

c. The central nerve.

PLATE III.

FIG. 1. The supine or upper surface of the head of *Nautilus Pompilius*.

a. The origin of the mantle.

b. The dorsal fold collapsed.

c. The apex or anterior extremity of the hood.

d. The concavity at the base of the hood, which is adapted to the involute convexity of the shell.

e. e. The posterior angles of the hood, drawn outwards to show their form.

f. The middle superior surface of the hood.

g. g. The lateral surfaces.

h. The groove which separates the hood from the digitations.

i. The semilunar ridge which supports (in the reversed position) the involute convexity of the shell.

k. k. The papillose digitations, which appear to form part of the hood.

FIG. 2. The prone or under surface of the head of *Nautilus Pompilius*, with the mantle divided and the sides of the funnel divaricated to expose its cavity and the shell-muscles.

a. a. The divided portions of the mantle.

b. b. The digitations.

c. c. The funnel.

d. d. Its lateral processes.

e. Its valve.

f. The external portion of the left crus or pillar of the funnel.

g. The external portion of the right pillar turned outwards to show

h. The compressing muscle.

i. The united internal portions of the pillars of the funnel.
k. k. The shell-muscles.
l. l. Their terminations, or surfaces of attachment.
m. The transverse fibres which connect them.

PLATE IV.

Nautilus Pompilius, in the prone position, with the labial processes and tentacles, the mandibles, and the digestive organs displayed.

a. a. The hood, or upper part of the oral sheath longitudinally divided.
b. b. The posterior lobes or angles of the hood.
c. c. The posterior concavity of the hood.
d. d. The ridge in the same.
e. e. The cut-surfaces of the above parts.
f. f. The internal surface of the oral sheath.
g. g. The external labial processes.
h. h. The external labial tentacles.
i. i. The internal labial processes.
k. k. The internal labial tentacles.
l. The olfactory laminæ.
m. m. The circular fringed lip, longitudinally divided.
n. The superior mandible.
o. The inferior mandible.
p. The muscular basis on which the mandibles are fixed.
q. q. The superior pair of muscles which retract the jaws.
r. r. The semicircular muscle which protrudes the jaws, divided longitudinally.
s. The œsophagus.
t. The crop.
u. The narrow canal leading to
v. The gizzard.
w. The intestine.
w'. The terminal fold of intestine drawn out of its situation.
x. The anus.
y. The laminated pancreatic bag.

z. The liver.

15. A branch of the anterior aorta which ramifies in the membrane connecting the two portions of the terminal fold of the intestine.

19. The continuation of the posterior aorta along the dorsal aspect of the crop.

20. Its bifurcation at the œsophagus, to form a vascular circle corresponding to the nervous circle round that tube.

21. & 22. Arteries of the crop, gizzard, &c.

PLATE V.

Nautilus Pompilius, in the supine position, with part of the mantle removed to expose the branchiæ of one side, together with the heart and great vessels.

a. *a*. The mantle.

b. One of the convexities produced by the ovarian gland.

c. A section of the ovarian gland.

d. The commencement of the posterior membranous siphon.

e. The great shell-muscle of the left side.

f. The funnel.

g. *g*. The lateral processes of the funnel.

h. The left crus or pillar of the funnel.

i. The infundibular valve.

k. *k*. The digitations with the tentacles retracted.

l. The outline of the gizzard, indicating its situation.

m. The same of the ovary.

n. The partition which separates the pericardium from the peritoneal receptacles of the preceding viscera.

o. A bristle passed along the siphon through the orifice by which that tube communicates with the pericardium.

p. The larger branchia of the left side.

q. The smaller branchia of the left side; (those of the opposite side are concealed by the mantle.)

s. The common root or stem of the left branchiæ detached from the mantle.

t. The heart.

4. The trunk of the branchial arteries of the left side.
5. 5. The branchial arteries.
6. 6. The glandular follicles connected therewith.
u. One of the partitions forming the receptacle of a group of follicles.
u'. *u'*. The receptacles of the lesser groups of follicles attached to the anterior branchial arteries, which are situated in the partition dividing the pericardium from the branchial cavity.
10. 10. The branchial veins.
12. The lesser aorta.
13. The branch going to the ovarian gland.
14. The siphonic artery.
15. The artery of the intestine.
18. The elongated shut sac which is connected at its extremities with the ventricle and the venous sinus.

PLATE VI.

FIG. 1. The circulating and respiratory organs of *Nautilus Pompilius*.
1. The great vein.
1'. The orifices by which it communicates with the abdominal cavity.
2. The venous sinus.
3. 3. The splanchnic veins from the liver, ovary, gizzard, &c.
4. 4. The origins of the branchial arteries.
5. 5. The branchial arteries.
6. 6. The follicles appended to the branchial arteries.
7. 7. The orifices by which they communicate with the branchial arteries, exposed on the left side (the parts being seen from the dorsal aspect).
8. The valve at the entry of the branchial artery into the gill, exposed in the right anterior vessel.
9. The cavity of the same artery, where it is imbedded in *r*, the muscular stem of the gill laid open.
p. The larger branchia of the right side, showing the arterial surface.
p'. The same of the left side, showing the venous surface.
q. The smaller branchia of the right side, showing the arterial surface,

with *r*, the fleshy stem entire, the dotted line indicating the passage of the branchial artery into it.

q'. The smaller branchia of the left side.

s. s. The common stem of the branchiæ, by which they adhere to the inner surface of the mantle.

10. 10. The branchial veins.

11. 11. The valves placed at their terminations in

t. The ventricle, or systemic heart, laid open.

12. The origin of the lesser aorta.

13. The artery of the glandular ovarian apparatus.

14. The siphonic artery.

15. The artery of the intestine.

16. The larger aorta.

16'. Its muscular origin, or the continuation of the ventricle.

17. The valve at the extremity of this part.

Fig. 2. A lamina of the larger branchia magnified, showing its subdivisions into the smaller laminæ. The letter and figures indicate the same parts as in fig. 1.

PLATE VII.

Fig. 1. The nervous system of *Nautilus Pompilius*.

a. a. The cut-surfaces of the hood, as at *e*, plate 4.

b. b. The open ends of the digitations.

c. Four of the digital tentacles exposed by laying open the canals in which they are lodged.

d. d. The anterior ophthalmic tentacles similarly exposed at their origins.

e. The left external labial process: (the corresponding one on the right side has been removed.)

f. f. The internal labial processes.

g. The olfactory laminæ.

h. The external labial tentacles of the left side, with their origins exposed by laying open the canals at the anterior part of the process in which they are lodged.

i. The internal labial tentacles of the left side similarly exposed.

i'. The internal labial tentacles of the right side.
k. The origin, on the left side, of the muscle which protrudes the jaws.
l. The inner concave surface of the great shell-muscles.
m. The termination of the right muscle.
n. Orifices by which the vena cava communicates with the abdominal cavity.
o. The eye laid open.
p. The pedicle.
q. The pupil, seen from within.
r. The cut-edge of the sclerotic.
s. The retina.
t. The dark pigment deposited on its anterior surface, and lining the cavity of the globe.
1. The brain, or central commissure.
2. 2. The anterior subœsophageal ganglions.
3. 3. The ophthalmic ganglions.
4. 4. The posterior subœsophageal ganglions.
5. 5. The nerves of the digital tentacles.
6. 6. The nerves of the external labial tentacles.
7. 7. The nerves bringing the labial ganglions into communication with the anterior subœsophageal ganglions.
8. 8. The internal labial ganglions.
9. The nerves of the internal labial tentacles.
10. The olfactory nerves.
11. The infundibular nerves.
12. The origins of the lingual and maxillary nerves.
13. The nerves of the great shell-muscles.
14. The visceral nerves.
15. The branchial nerves.
16. The visceral ganglions.
17. The nerves ramifying on the vena cava.

Fig. 2. The olfactory laminæ magnified and separated.

Fig. 3. The brain of the Cuttle-fish. (*Sæpia officinalis*, Linn.)

1. The brain, corresponding to the central commissure of the Nautilus.
2. 2. The anterior subœsophageal mass, or *Pes anserinus*, giving off (5. 5.) the nerves to the arms.
3. 3. The great reniform or ophthalmic ganglions.
4. 4. The posterior subœsophageal mass, giving off (6. 6.) the nerves to the cloak; and (8.) the nerves to the viscera.
7. 7. The *ganglion stellatum*.
9. 9. Two small spherical bodies attached to the pedicles of the ophthalmic ganglions.

PLATE VIII.

Various parts of *Nautilus Pompilius*.

Fig. 1. Plan of the cartilaginous skeleton.

a. The body of the skeleton, containing the venous sinus, the extent of which is indicated by the dotted line.

b. *b*. The cephalic processes.

c. *c*. The groove which lodges the anterior nervous collar, and ophthalmic ganglions.

d. *d*. The infundibular processes.

Fig. 2. The mandibles.

a. The calcareous extremity of the upper mandible.

b. The extended internal horny lamina of the same.

c. The notched calcareous extremity of the lower mandible.

d. *d*. The extended external horny lamina of the same.

Fig. 3. The upper mandible, showing the form of the calcareous extremity, and the proportions of the external and internal horny laminæ.

Fig. 4. One half of the lower mandible, showing the different proportions of the two horny laminæ, and the extension of the horny substance at *a*, upon which the calcareous matter is deposited.

a'. The internal horny lamina.

b. The external horny lamina.

Fig. 5. The mandibles and their muscles.

a. The upper mandible.

b. The lower mandible.

c. c. The fringed lip which surrounds them, longitudinally divided, and removed from the right side.

d. The muscular basis on which the mandibles are fixed.

e. The membrane reflected from the circular lip upon the muscular basis of the mandibles.

f. The superior retractor muscles.

g. The inferior retractor muscles.

h. The pharynx.

i. One of the arteries of the mouth.

k. One of the nerves.

FIG. 6. The horny basis of the tongue.

FIG. 7. The tongue and fauces.

a. The horny basis of the tongue.

b. The superior horny plate supporting the recurved prickles.

c. The papillose caruncles.

d. One of the retractor muscles of the anterior caruncle.

e. The papillose dorsum of the tongue.

f. f. The papillose folds of the fauces.

g. g. The orifices of the faucial follicles.

h. A bristle passed through the pharynx.

Fig. 8.

a. The fundus of the crop.

b. The narrow plicated canal, leading to the gizzard.

c. The gizzard.

d. A portion of its cuticular lining turned back.

e. A bristle passed through the pyloric orifice.

f. The laminated pancreatic bag laid open.

g. The valvular lamina continued from it into the intestine.

h. The biliary ducts.

i. The intestine.

FIG. 9. The organs of generation.

a. The ovarian bag laid open.

b. Its anterior orifice laid open.

c. *c*. *Capsulæ oviferæ* attached by their extremities to the interior of the great membranous sac.

c′. *c*. *Capsulæ oviferæ* laid open.

d. A bristle passed through the oviduct.

e. The posterior orifice of the oviduct.

f. The anterior orifice.

g. Peritoneal membrane which attaches the oviduct to the ovary.

Fig. 10. A glandular organ attached to the inner surface of the mantle, and supposed to secrete the nidus of the ova.

a. The larger transverse group of laminæ.

b. *b*. The lesser groups of laminæ, which are covered by a membrane.

c. The membrane reflected from one of these groups.

THE END.

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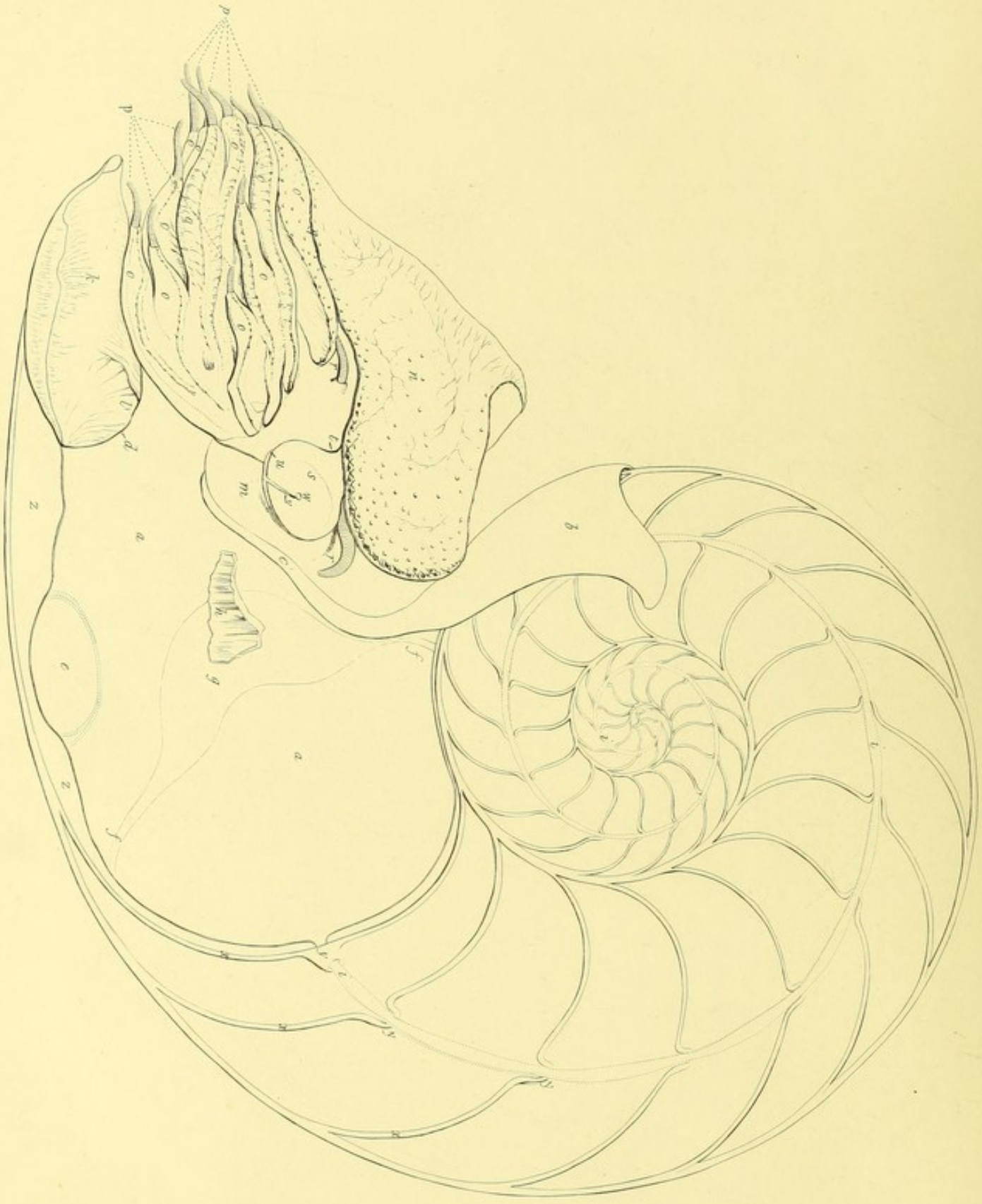

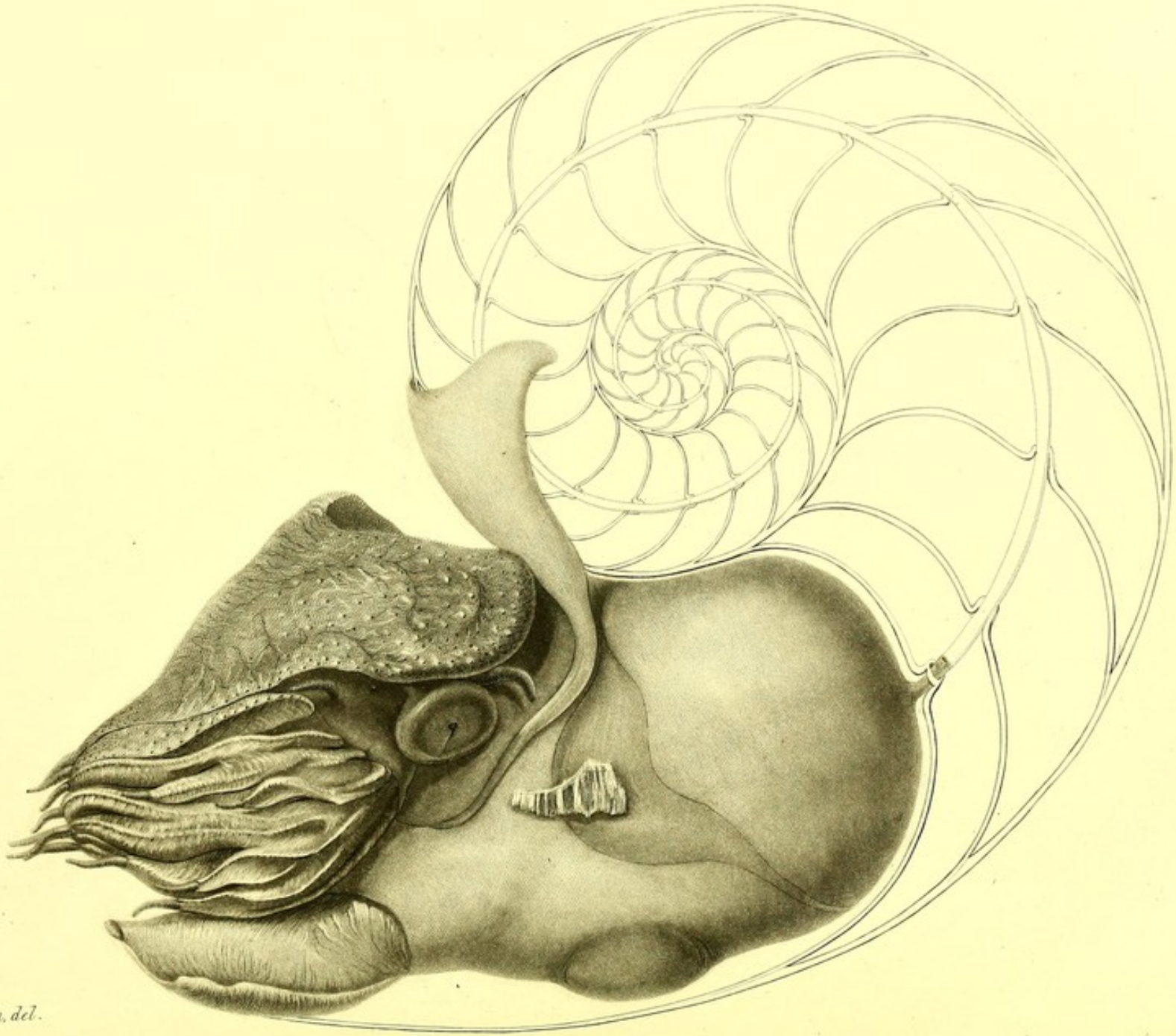

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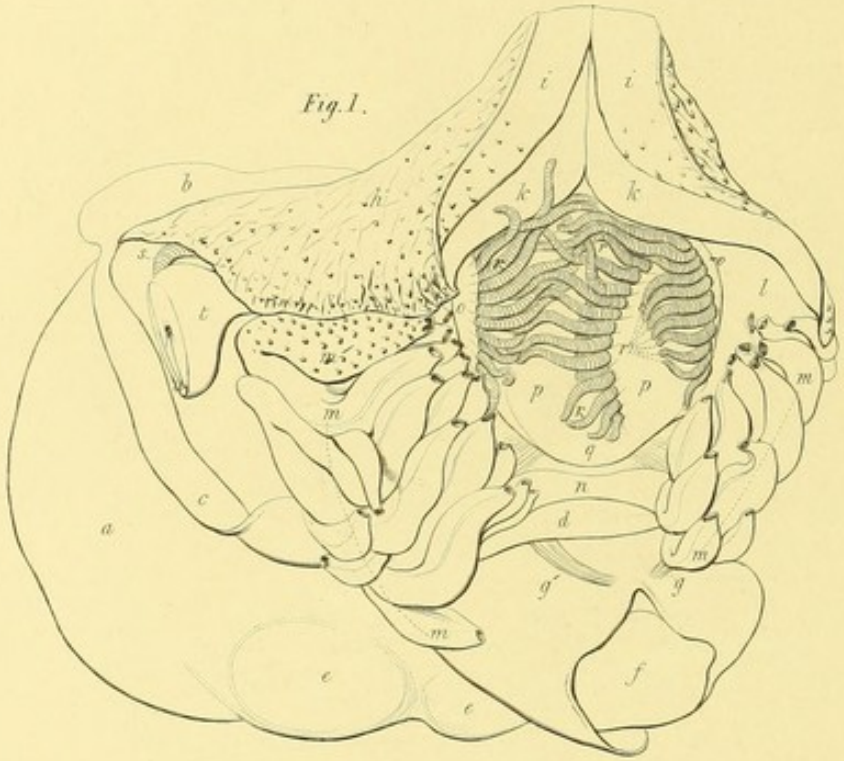

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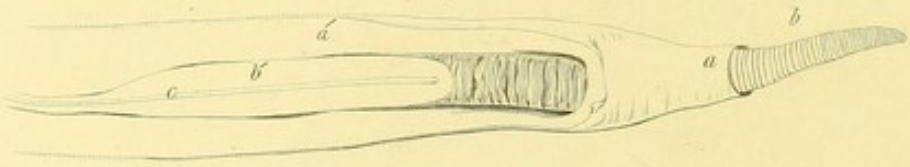

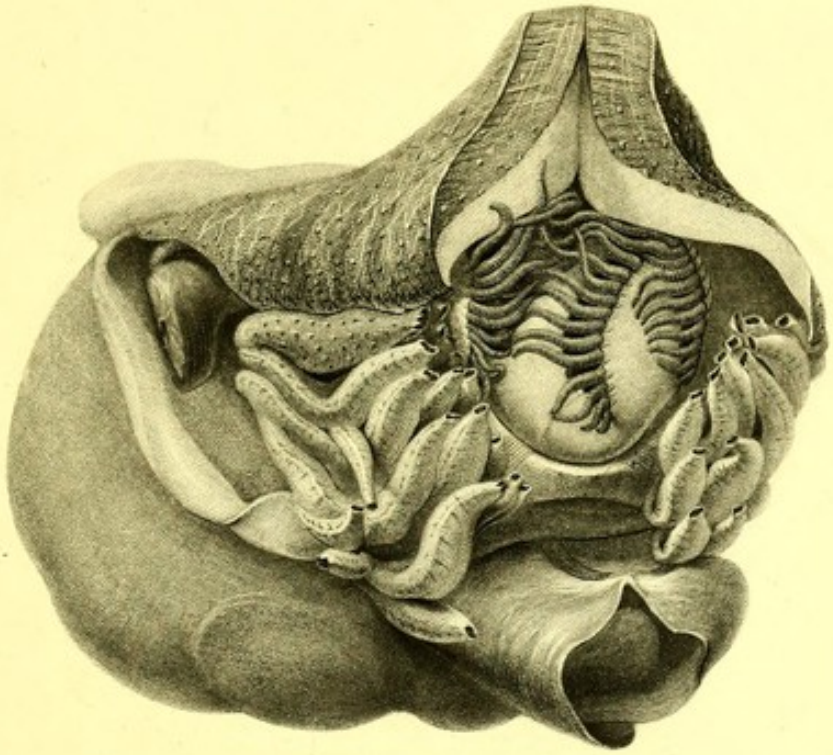

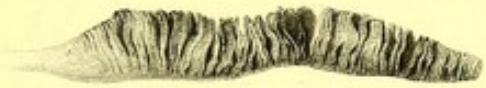

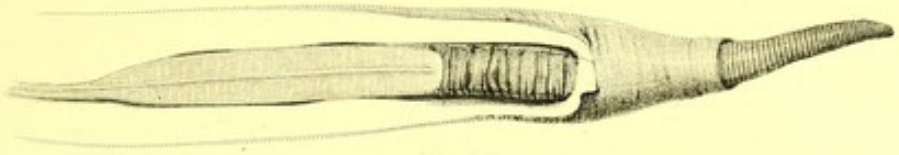

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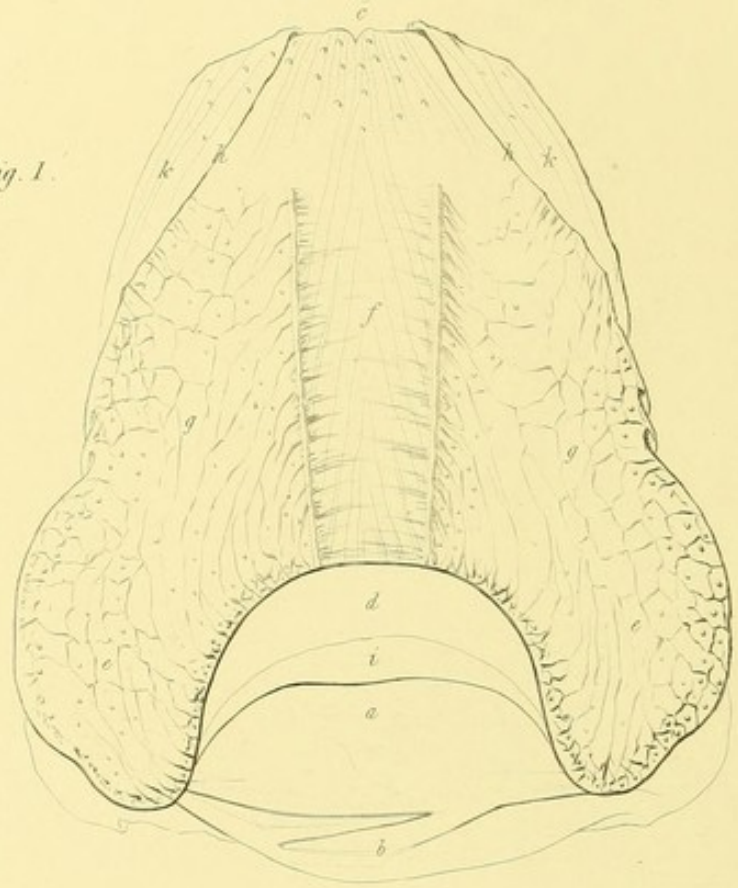
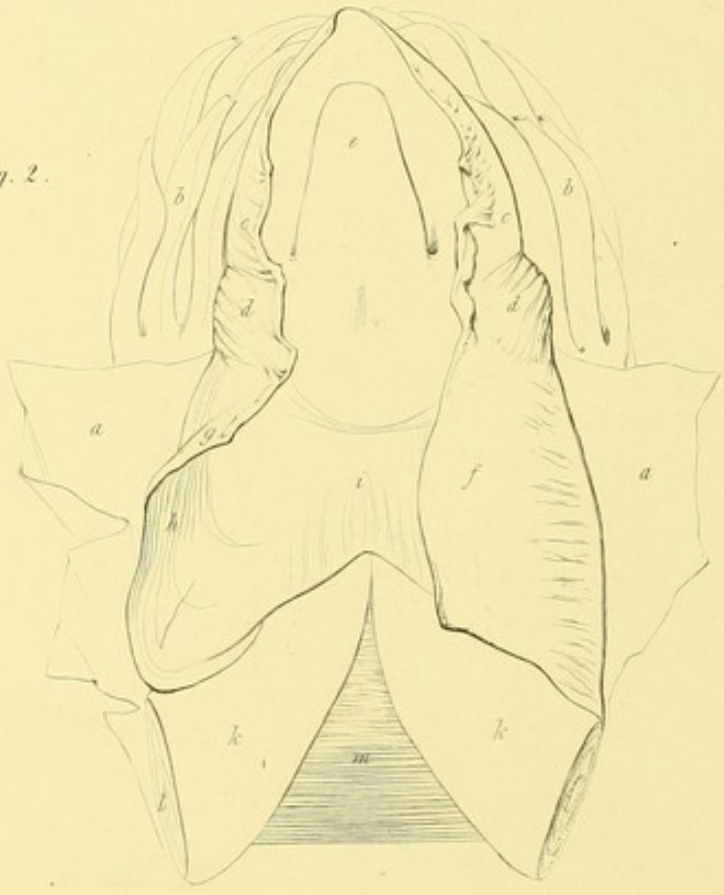
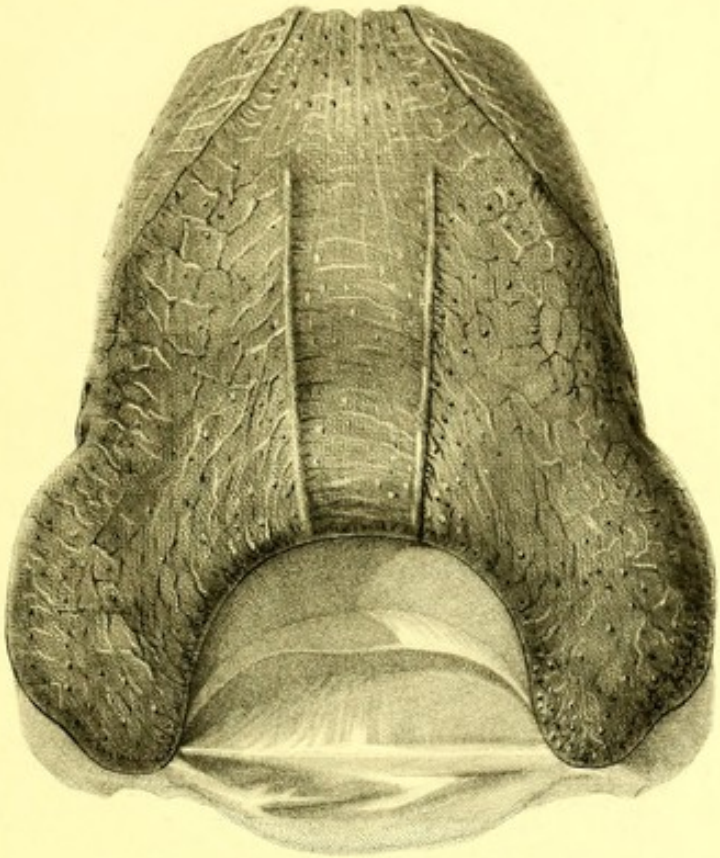
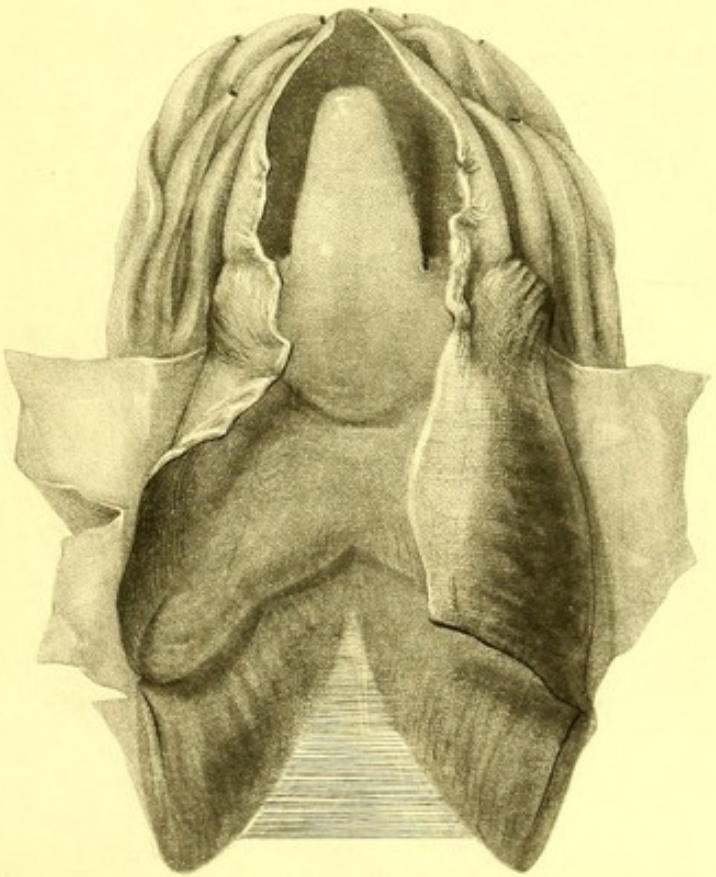


Fig. 2.







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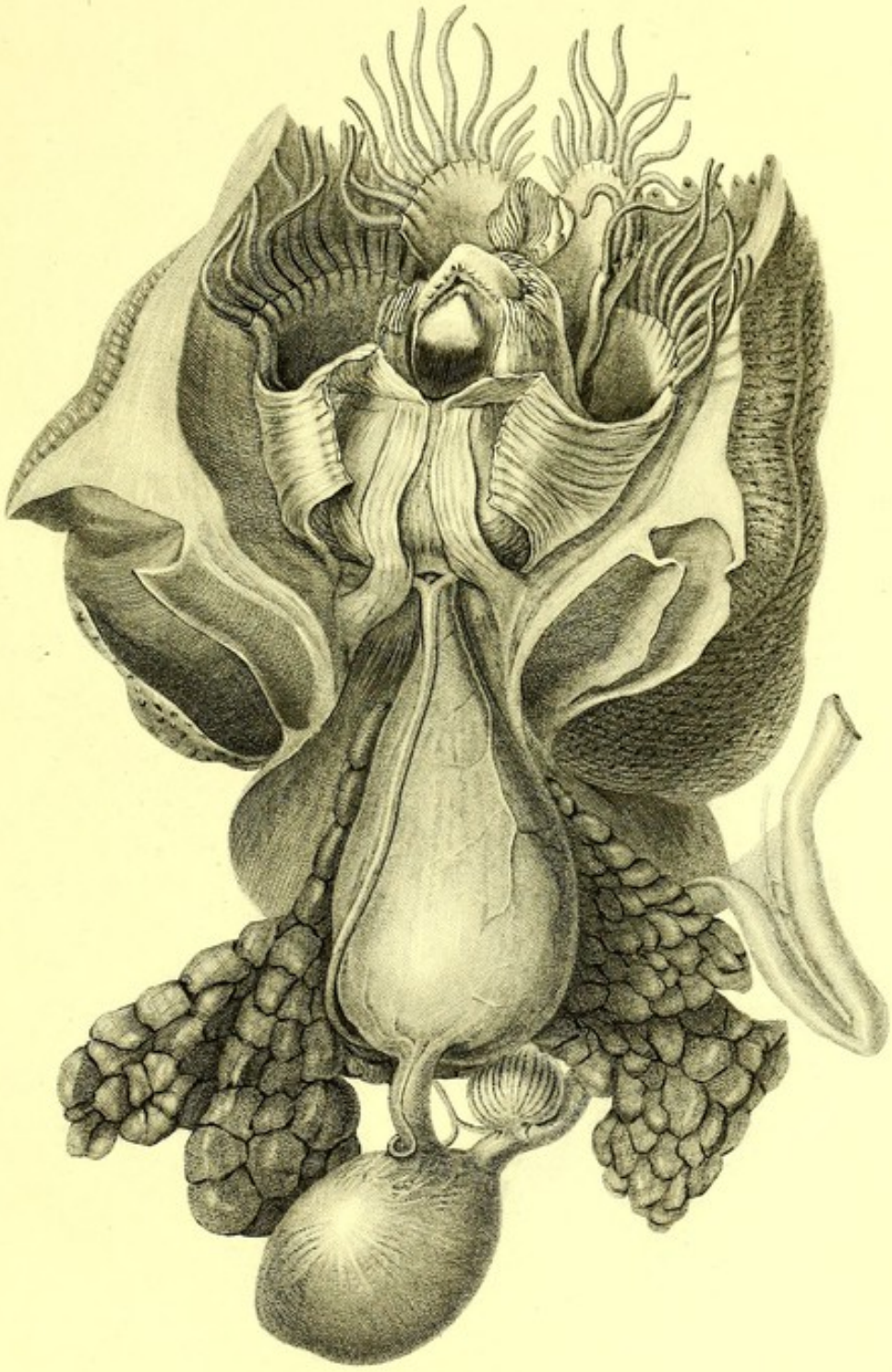

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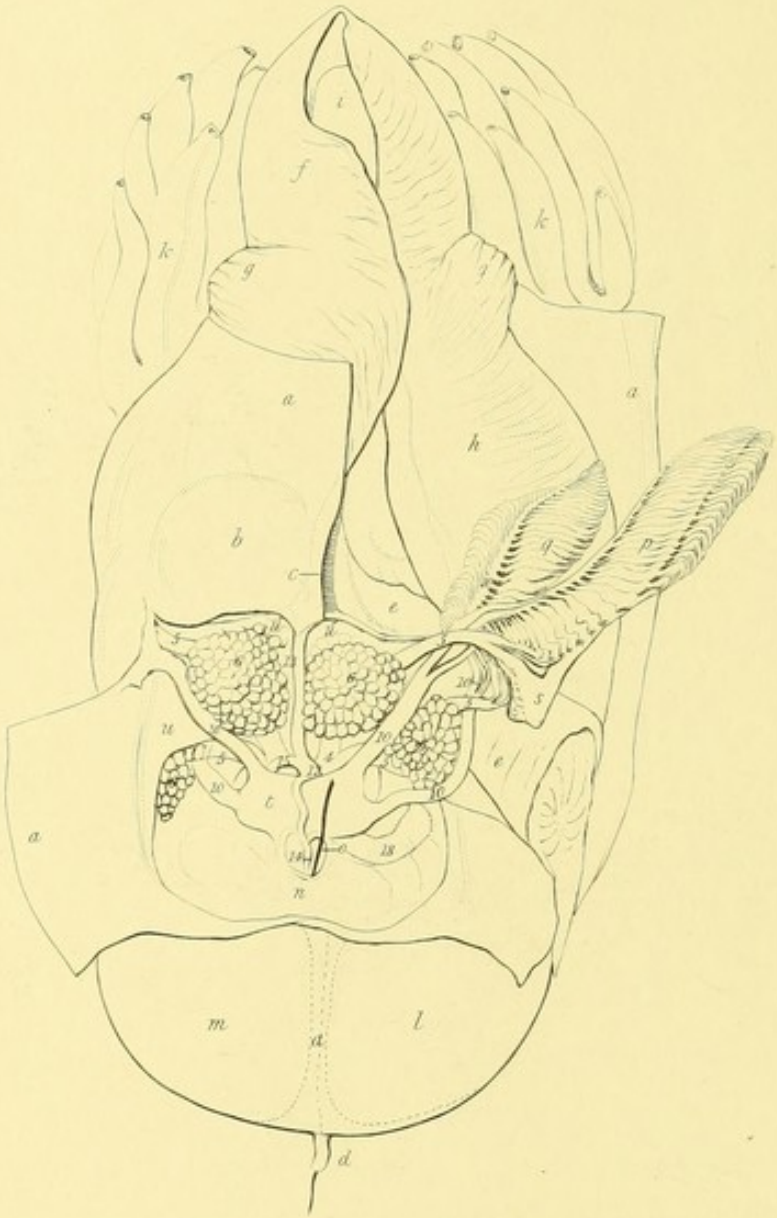
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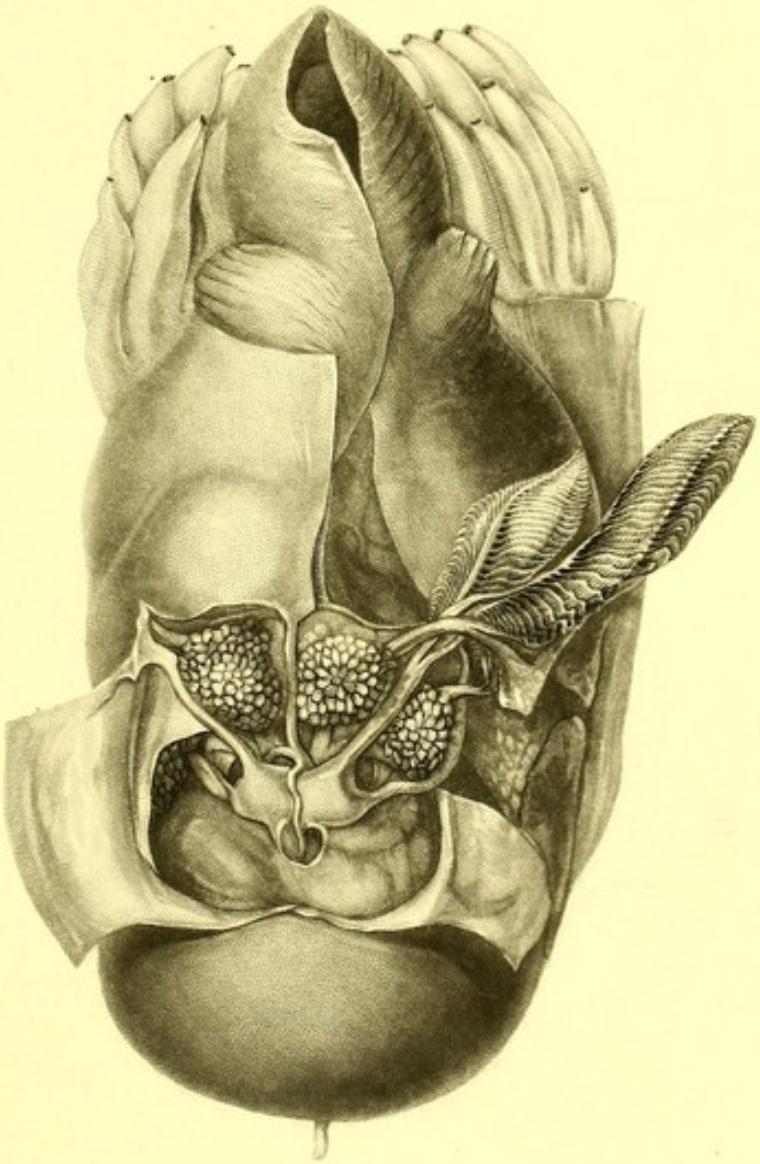

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Fig. 2.

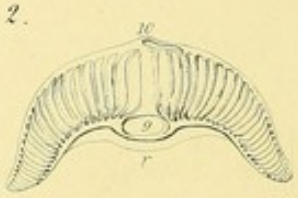
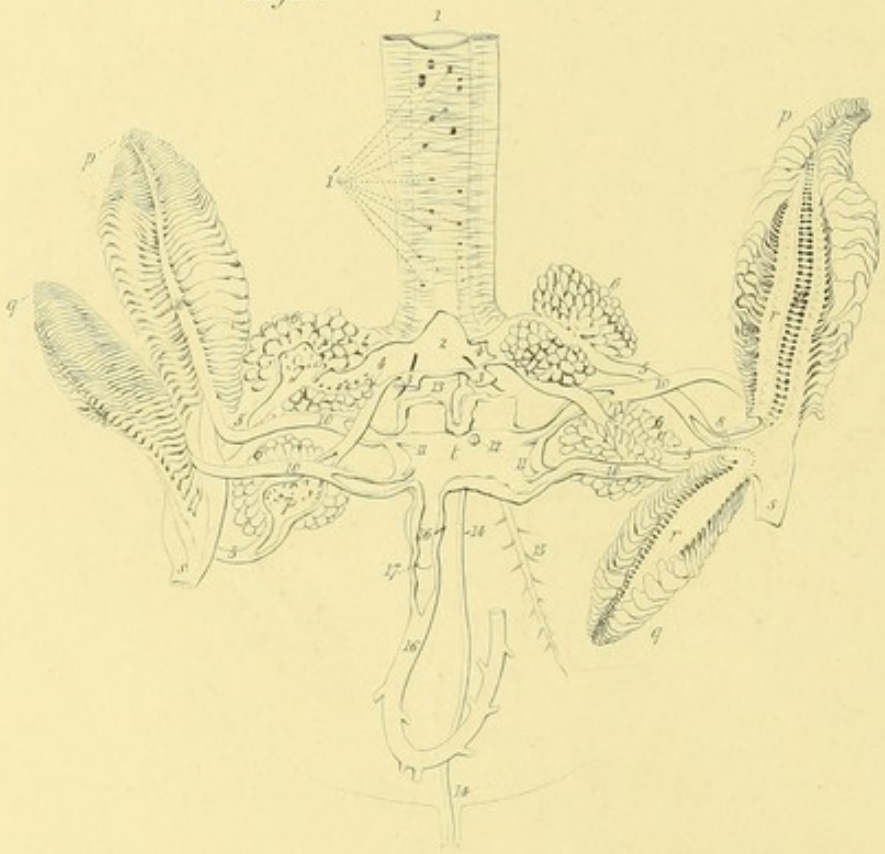


Fig. 1.



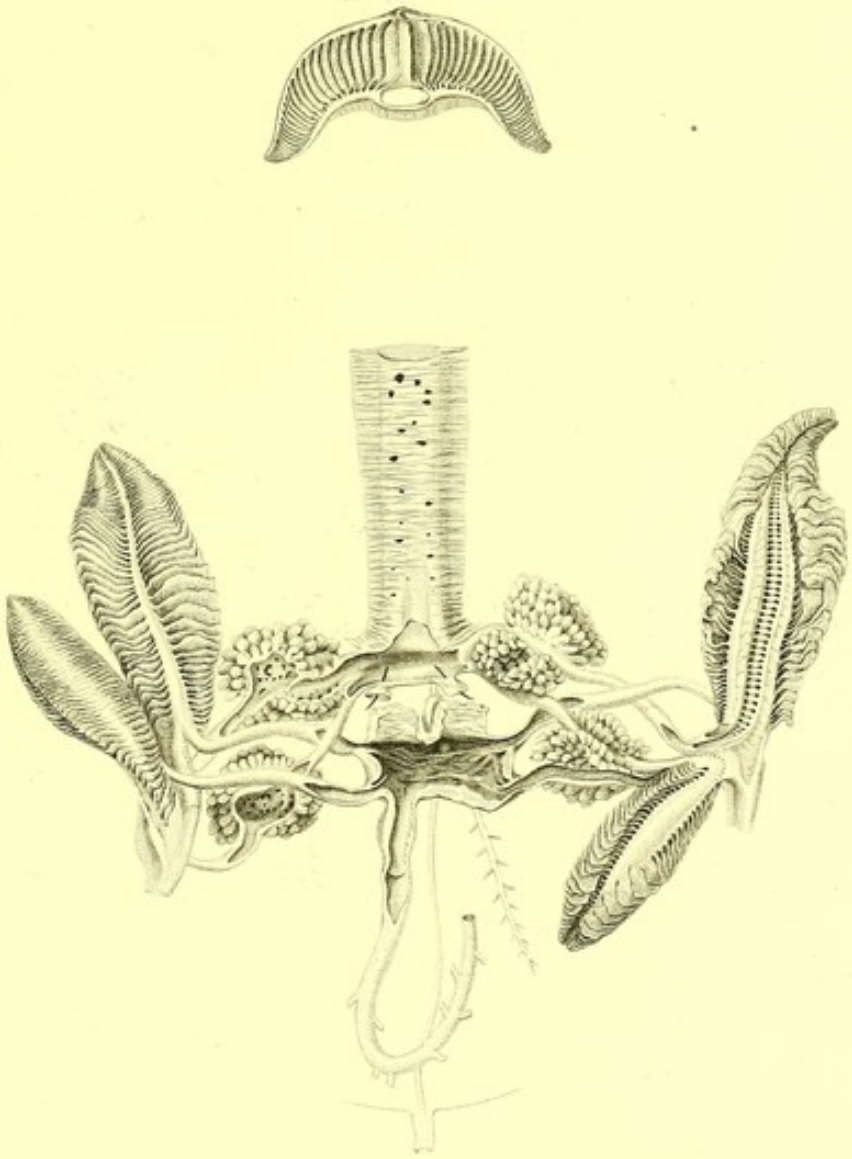


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Fig. 2.

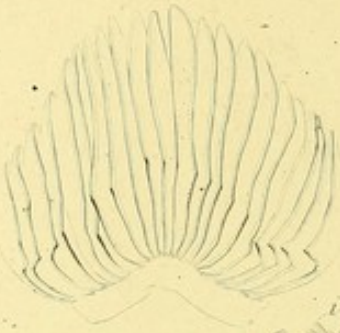
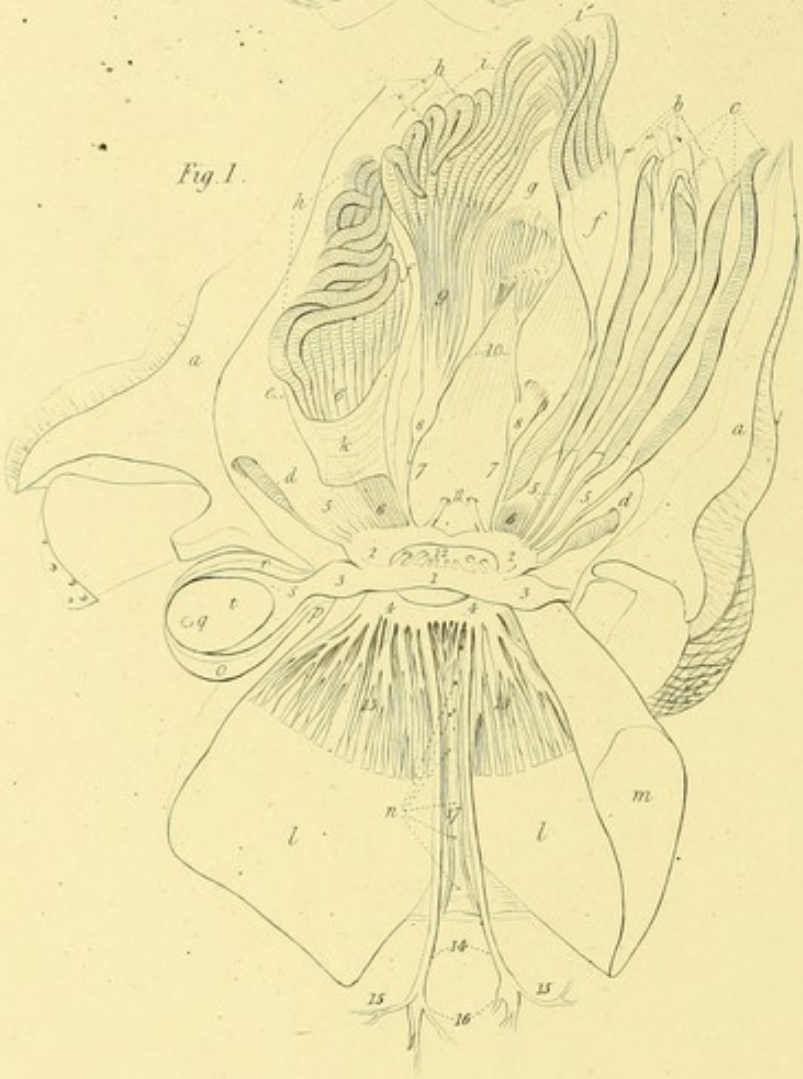


Fig. 1.



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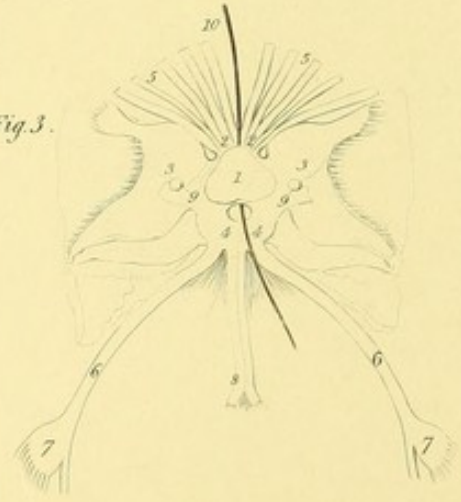

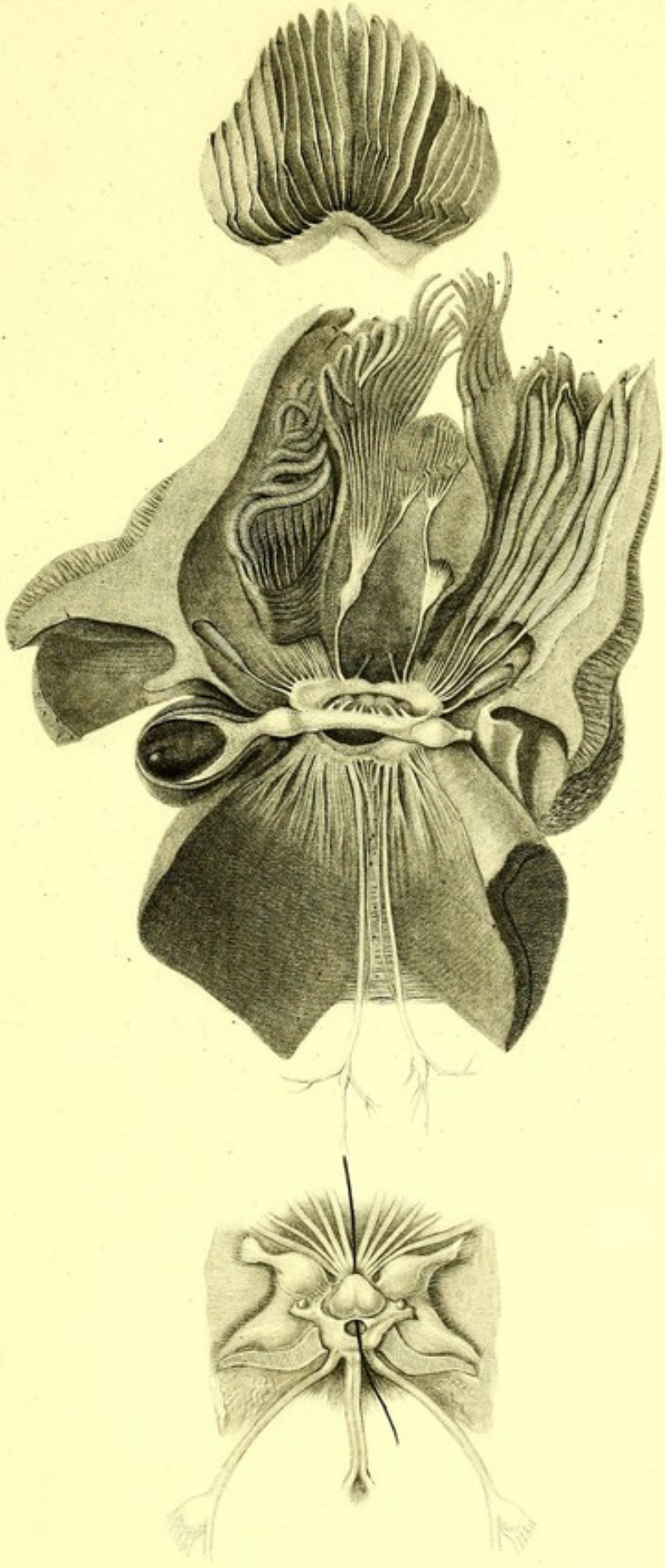

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Fig. 3.

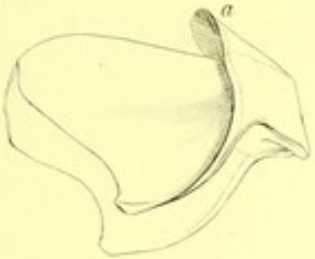


Fig. 2.

Fig. 7.

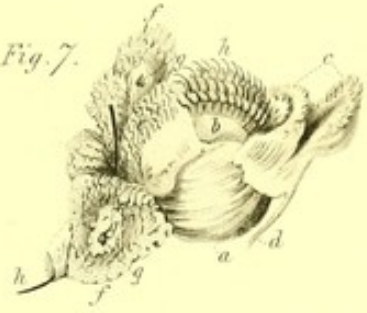
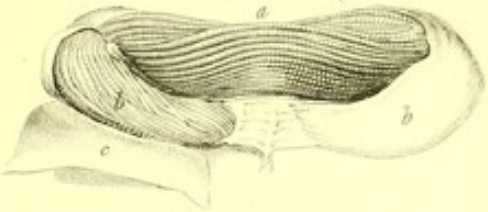


Fig. 5.

Fig. 6.

Fig. 10.



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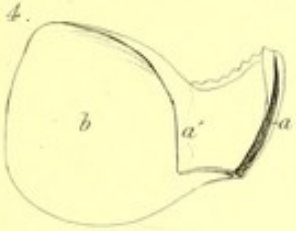

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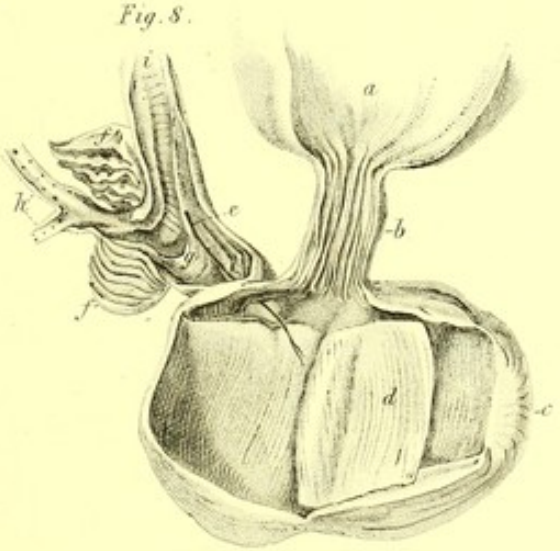

Fig. 9.

Fig. 1.