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"..... per litora spargite muscum,
Naiades, et circùm vitreos considite fontes:
Pollice virgineo teneros hìc carpite flores:
Floribus et pictum, divæ, replete canistrum.
At vos, o Nymphæ Craterides, ite sub undas;
Ite, recurvato variata corallia trunco
Vellite muscosis e rupibus, et mihi conchas
Ferte, Deæ pelagi, et pingui conchylia succo."
N. Parthenii Giannettasii Ecl. 1.

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I.—*Supplementary Observations on the Anatomy of* Spirula australis, *Lamarck* *. By Prof. R. Owen, C.B., F.R.S., &c.

[Plates I.–III.]

'The Zoology of the Voyage of H.M.S. Samarang,' 4to, 1848, includes a monograph on this subject (pp. 6–17, pl. iv.), at the conclusion of which the following particulars are noted as "still remaining to be determined:—such, for example, as the structure of the male organs and that of the female organs, particularly as to whether the oviduct be single or double, whether complicated by glandular enlargements or associated with nidamental glands; the brain and cranium, the principal nerves, the tongue, beak, and lips; the structure of the eyes and the condition of the eyelids; the relations of the shell of the *Spirula*, and especially of its last or open chamber, with the muscular system of the animal"†.

The materials on which the descriptions in the above "monograph" were founded consisted of a headless specimen with the hind end of the mantle torn off (referred to the *Spirula Peronii*, De Bl. ‡), of part of the mantle with shell attached of a *Spirula reticulata*, Ow. § (taken by Dr. Bennett,

* 'Encyclopédie Méthodique,' pl. 456. fig. 5.
† *Op. cit.* p. 16. ‡ Ibid. pl. iv. figs. 1, 4, 5, 6.
§ Ibid. pl. iv. figs. 3, 9, 10.

F.L.S., off Timor), and of the then unique specimen of *Spirula australis*, Lam., in the possession of Mr. Cuming, "perfect in all its parts except the termination of one of its tentacles" *. This specimen was found by Mr. Percy Earl on the shore at Port Nicholson, New Zealand, in a fresh state.

The anatomical characters forming the main subject of the "monograph" were derived from dissections of Admiral Sir Edward Belcher's specimen: the uniqueness of the Cumingian one justified the wish of the eminent conchologist, its possessor, to retain it uncut †.

At a later period Mr. Cuming was enabled to place in my hands the specimen (Pl. I. fig. 1) from which the subjoined additional facts have been taken.

The body of *Spirula australis* is divided into head and trunk. The head with its non-retractile arms forms about one third the length of the animal. It is a short, thick cylinder, slightly swollen on each side by the eyes, of which the tegumentary pupils (ib. *a*) open 7 millims. behind the bases of the arms.

The trunk, or mantle, is elongate, subcompressed, slightly expanding at the hinder third, in the dorso-ventral direction, to lodge the shell. The margin of the anterior aperture of the mantle is thin and free, with three emarginations:—one ventral, deep and short, above which the funnel (*i*, figs. 1 & 4; Pl. III. fig. 1, *i*) projects; and two dorso-lateral, meeting at a point (Pl. I. fig. 1, *b*) which projects forwards from the middle of the dorsal border. There are two similar but shorter ventral points at the sides of the funnel. Beyond this margin the mantle gains in thickness, and again thins off to its posterior border.

The mantle terminates behind in two broad lateral lobes (ib. figs. 1, 2, 3, *c*, *c*) rounded posteriorly and clasping, as it were, the sides of the shell, concealing the umbilical turns. A portion of the last whorl projects from both the ventral (*e*) and dorsal (*f*) interspaces of these lobes, but most so from the dorsal one (fig. 2), towards which the larger end of the whorl is bent, before inclining ventrad to its termination within the body.

The dorsal part of the mantle, continued from the anterior pointed lobe backward, thins off to the margin of the aperture (ib. *f*), through which appears the part of the outer whorl of the shell: from the margin of this aperture, which is entire, the

* Lovell Reeve, 'Elements of Conchology,' 8vo, 1846, p. 18, pl. A. figs. *a–f*.

† Ibid.: "Mr. Cuming is desirous of preserving the specimen under consideration entire" (p. 18).

thin epithelium (*f*) is continued upon, and seemingly lost in, the periostracum (*g*); part of the shell is exposed at *h*, fig. 2.

The well-defined convex border of each lateral posterior or terminal lobe (*c*) of the mantle has its smooth, soft, inner layer tucked up, as it were, and bent towards the central aperture of the umbilicus.

Between the lobes is an elliptical convex substance ("bouton terminal," *De Blainville* *; "thick gland," *Gray* †) (fig. 3, *a b*) with a central depression (ib. *a d*); this disk is flanked by a pair of oblong productions (ib. *a c*, *a c*), the homologues of the better-developed muscular fin-like bodies in *Spirula reticulata* ‡.

M. de Blainville describes the lateral appendages (*a c*) as fins, "fort semblable à ce qui à lieu dans les Sépioles" §. Dr. Gray, in his account of the original Cumingian specimen affirms, "It differs from the cuttlefish in being entirely destitute of fins" ‖. It is possible that the French anatomist may have had for his subject a specimen of *Spirula reticulata*, in which they are more developed ¶. The parts (*a c*) in my example of *Spirula australis* may have been contracted; but I deem them, like those in *S. reticulata*, to be homologues of such small terminal lateral fins as one sees in *Loligopsis*. The intervening terminal gland-like mass is composed of a substance resembling dense cellular tissue, in which minute tortuous filaments were the chief structural character; its thin covering was vascular. At the middle of the central depression is a pore; but this terminates blindly, and is not the duct of a gland. If the disk (*a b*) were applied to a flat surface and the central part (*a d*) were withdrawn from the level, a vacuum would be produced, which would convert the disk into a sucker. Should the *Spirula* so attach itself, as Rumphius describes, its tentacles (fig. 1, *d*) and arms (1, 2, 3, 4) would be free to exercise their prehensile power on any passing object of food. The formal analogy to the polype, indicated by Aristotle's name for the "Poulpe," would thus be carried further in *Spirula* by its occasional repetition of the *status* of a hungry Actinia.

The mantle consists of a thin epiderm, a pigmental reticular connective tissue, and an unusually dense corium, in which the circular or transverse muscular fibres are crossed by thinner and more superficial longitudinal fasciculi (Pl. II. fig. 2, *h h*).

* "Quelques observations sur l'animal de la Spirule," Annales françaises et étrangères d'Anatomie et de Physiologie, tome i. 1837, p. 376.

† Annals and Magazine of Natural History, April 1845.

‡ 'Zoology of the Voyage of H.M.S. Samarang,' Mollusca, p. 13, pl. iv. figs. 3, 9. § *Loc. cit.* ‖ *Loc. cit.*

¶ See my Monograph, *loc. cit.* pl. iv. fig. 9, *a c*, *a c*.

These are faintly indicated in the magnified view of the mantle (Pl. I. fig. 2); but the reticular character is more strongly marked in *Spirula reticulata*, besides being associated with formal characters described and illustrated in the monograph of 1848.

The thin semitransparent epiderm is continued beyond the muscular stratum from the borders of the dorsal interspace of the terminal lobes for about 9 millims. upon the shell, the rest of which is covered by the extremely thin and minutely granular periostracum. The same modification of the mantle occurs at the ventral interspace of the lobes; but it is continued to a less extent, the thin corium of the mantle terminating by a well-defined margin from which the epiderm is continued. The production of this skin upon the shell regains the thick fleshy border of the terminal lobes of the mantle at the posterior end of the interspace, which is filled up by the soft disk (*a b*) and the fin-rudiments (*a c*).

The integument of the head is smooth; it was coloured by minute points of brownish pigment; it is so thin around the eye as to permit the black pigment of the choroid to appear through. The original coloration of the mantle had been lost by long immersion in spirit. About the middle of the dorsal aspect were two narrow oblong marks (Pl. I. fig. 1, *m*).

The inner surface of the mantle, a little behind each of the ventral angular processes, presents a linear longitudinal prominence of almost cartilaginous hardness, for the cavities at the base of the funnel.

This (Pl. I. figs. 1, 4, Pl. III. fig. 1, *i*) is a conical tube, with entire parietes; the apical outlet unusually small, due probably to strong contraction, but defended by a correspondingly small semicircular valve. At the sides of the expanded base of the funnel were the cartilaginous cavities (Pl. I. fig. 4, *o*; Pl. II. fig. 3, *o*) articulating with the pallial prominences.

The head of the *Spirula* is defined by a feeble linear constriction from the soft and broad valvular folds (Pl. I. fig. 4, *h*) continued therefrom and from the base of the funnel, one on each side, to meet and blend at the dorsal aspect of the neck. Here the valve, which, from its functional relation to the mantle-cavity, may be termed "pallial," is impressed by a triangular shallow pit with a slightly raised border (fig. 4, *k*), the base turned forwards and the apex prolonged backwards. The antero-posterior extent of the valve, which terminates backward in a thin free border, is 4 millims.; it is shorter posteriorly, where it is attached to the dorsal retractors of the head. Just behind or beyond this border the peritoneum is reflected upon the lining membrane of the mantle. The finely

punctate pigment is continued a little way on the inner surface of the mantle.

The eight ordinary arms (of which the four of the left side are shown in Pl. I. figs. 1, 4) are of nearly equal length, the first and fourth being the shortest, the third the longest; they are joined together by a short and thick web, or duplicature of the skin, at the outer side of their basal interspaces (Pl. I. fig. 5). Compared with the others, the bases of the two ventral arms (4, 4) are the thickest, and the division between them is deepest and widest. Each of the arms is conical and trihedral with the long angle outward, and one face turned inward. This surface is bounded by a well-defined border on each side (fig. 6,*l*), and is beset with numerous, minute, pedunculate acetabula, thick-set at the distal half and arranged in an irregular quincuncial order; five or six may be counted in the oblique rows that cross the surface. The acetabula (figs. 6, *a*, *b*, *c*) are oblate spheroids or pear-shaped, more flattened at the side upon which the small suctorial cavity (ib. *s*) opens, with slender peduncles (ib. *p*) equalling the acetabulum in length and inserted toward one side of the end next the arm. On some of the arms there were one, two, or three longer peduncles with larger acetabula than the rest, formed by the swelling out of one side of the sucker into a spheroidal tumour, containing a compact light-brown substance. The margin of each cup is strengthened and armed by a delicate iridescent horny hoop.

The stems of the tentacles (figs. 1, 5, *d**) equal in thickness at their base (fig. 5, *d*, *d*) those of the ordinary arms; they are cylindrical, gradually contract to their terminal expansion, the inner side of which shows a narrow longitudinal raised tract, which supports the stems of the acetabula in a double alternate series. The corresponding part of the tentacles of *Loligopsis Veranii* offers a resemblance to this structure.

The length of the oral mass (Pl. I. fig. 8, magn.) is 5 millims.: it is connected with the surrounding cephalic sheath by loose, elastic, cellular tissue, yielding readily to the protrusive and retractile movements of the mass.

Both mandibles (ib. figs. 8, 9, *p*, *q*) were of horny or chitinous tissue, of a dark brown hue, deepening to the free points, paling towards the thin inserted margins. There was no trace of calcareous superaddition.

The beak is surrounded by a double lip—the inner one (figs. 7 & 11, *n*; fig. 11^a) thin, finely plicated, with a crenate border; the outer one (fig. 7, *o*) thicker, with coarse radiating folds on its inner side, the termination of which gives the border a crenate

* "*Proboscides*," Arist.

character. The anterior or outer side of this lip is comparatively smooth (fig. 5); it is continued to the bases of the eight ordinary arms, and into the fold which connects together the contiguous sides of the bases of the third and fourth arms on each side, the interspace between which forms the sheath of the long tentacle (*d*). The outer muscular coat of the buccal mass (fig. 8, *r*) consists chiefly of a stratum of longitudinal fibres connected by cellular membrane to the inner coat (*s*), which consists of two subelliptical bundles of oblique fibres, commencing from the same mid line of the dorsal aspect of the buccal mass, and swelling as they proceed ventrad and outward to pass beneath the outer plate-layer of the under- (ventral) mandible to be inserted therein, as the temporal muscles into the coronoid processes of the vertebrate mandible, in the course most favourable for approximating the ventral (lower) to the shorter dorsal (upper) mandible.

The inner surface of the inner lip, or labial beak-sheath, is produced into many deep, sharply defined radiating folds, each of which is indented at the base, wavy at the free margin (figs. 11, *n*, 11[a]). Thin bands of longitudinal muscular fibres pass on from the two subelliptical bundles to the inner lip, for its retraction.

A labial membrane is reflected from the inner lip upon the outer one, at about 2 millims. from the transverse oral aperture; folds of the inner lip radiate from the crenate border of that aperture (fig. 7, *n*).

Dissection.—I proceed to note the appearances presented in the first steps of the dissection of my *Spirula*.

On laying open the mantle along the ventral aspect the gills were first exposed; no rectum or anal tube appeared, at least no mediastinal membrane embracing a rectum in its folds, as in an *Octopus*. The gills (Pls. II. & III. fig. 1, *a*) are suspended each by a delicate frænum or "mesobranchia" (*f*), extending from the base to half the length of the gill, the other half being free. But at the ventral interspace between the bases of the branchiæ there is a slight prominence supporting, as in the first dissected specimen, the anal orifice, the oviducal orifice (Pl. III. fig. 1, *e'*), and the renal outlet (fig. 3, *k*). Just within the border of the vent (*g*) opens the duct of the ink-bag (*h*).

The ovary (Pl. III. fig. 1, *b*) lies in the left hind compartment of the visceral chamber; the chief folds of the oviduct (ib. *e*, Pl. II. fig. 3, *e*) are on the right side, partially separated therefrom by the pellucid membrane which envelops the inner whorls of the shell, which membrane is also closely attached to the sinus surrounding the rectum.

In the angle between the branchial hearts (Pl. III. fig. 3, *b*, *c*) and the intestinal fold (*f*) is the "pericardial" or

"urocardial" chamber, containing the (supposed renal) venous follicles (ib. *d*, *d*).

Viewing the viscera from the left side (Pl. II. fig. 3), one sees the large and few convolutions of the wide oviduct (*e*) crammed with ova, of a deep yellow colour, four or five on the same transverse line: the last long recurrent fold advances over the liver, between the last chambers of the shell and the converging masses (ib. *f*) of the retractors of the head and funnel; these enter, overlap the margins, and send an aponeurosis over the exterior of the last chamber of the shell (*u*). The above parts are on the dorsal aspect; on the ventral one are the gills and the succenturial or nidamental glands.

Reflecting back the oviduct we expose the right lobe of the liver, impressed by the impacted ova in the duct which overlay that lobe.

The visceral chamber is bifid posteriorly, through the forward intrusion, at the median line, of the last whorl of the shell and the mass continued from its last chamber (Pl. II. fig. 2, *z*).

The branchiæ are attached to the membrane reflected from each side of this intrusive mass *.

The peritoneum after lining the mantle is reflected, on the dorsal side, 4 millims. below the edge of the pallial valve, upon the last chamber of the shell, and is firmly united to the periostracum on that side of that chamber; a crescentic portion is continued from the shell upon the sides of the muscular attached mass.

The inner surface of the peritoneum is smooth, of a dull silvery glistening colour, without pigment.

The tissue of the urocardial walls includes a stratum of very numerous, fine, smooth fibrils, together with capillary vessels, ramifying with some regularity.

The retractores infundibuli (Pl. I. fig. 4, *t*; Pl. II. fig. 1, *f*) pass obliquely distad and dorsad to join the retractores capitis, where these enter, or are attached to, the last shell-chamber. From this part the peritoneum, extending ventrad, sends off the "mesobranchia" and envelops the gill, from which it is continued upon the free termination of the oviduct and oviducal gland (Pl. III. fig. 6, *d*); it is then continued over the pericardium and upon its valvular outlet, and upon the end of the rectum, before being reflected to gain the inner surface of the mantle.

On the ventral side of the visceral chamber the nidamental glands (Pl. III. fig. 1, *c*, *c*) occupy nearly the same relative position as in the *Nautilus*, but, as in Decapods, are not adherent to the mantle.

* See "Monogr. on *Spirula*," *op. cit.* pl. iv. fig. 11.

The liver occupies a special peritoneal sac reflected from the dorsal aspect of the lobes upon the ventral curvature of the last chambers of the shell.

On dissecting aside from the median line the thick layer (Pl. III. fig. 2, *k*) of the longitudinal muscular bands (retractores capitis) which pass backward from the ventral side of the skull, above and behind the base of the funnel (ib. *i*), a cavity was laid open from which escaped much fine granular and oily globular matter: I had tapped, in fact, the hepatic follicles (*l'*).

The muscular parietes of the funnel (Pl. III. figs. 1, 2, *i*) are 1 millim. thick at its base, becoming gradually thinner to the apex. The aperture at this part is half a millim. in diameter, and is defended by a flat semicircular valve (*j*), attached by its base to the inner surface of the dorsal aspect of the infundibular wall.

The "retractores infundibuli" (Pl. I. fig. 4, *t*; Pl. II. fig. 2, *t*, fig. 1, *f*), arising from the aponeurotic sheath (ib. *y*) of the last shell-chamber (ib. *u*), advance, inclining, at first, ventrad to the sides of the base of the funnel, pass under the pallial valve (fig. 3, *h*) and blend peripherally with its inner surface; they next, by a free margin, blend centrally with the mass of the "retractores capitis" (Pl. II. fig. 2, *f*), closing the communication between the cavity of the mantle and the cavity of the funnel at that part.

The retractores infundibuli originate partly from the inner surface of the peripheral wall of the last shell-chamber, partly from an aponeurosis (ib. *y*) which spreads over the wall of that and preceding chambers, beneath the part of the peritoneum which is reflected therefrom to line the mantle.

One thin fascicule (Pl. II. fig. 2, *f'*) attached to the pallial ganglion (*d*) passes distad and ventrad to the mantle: a broader aponeurotic sheath is continued from the muscles over the involute whorls of the shell (Pl. II. fig. 2, *w*, *y*).

The valvular pallial fold (Pl. I. fig. 4, *h*; Pl. III. fig. 1, *h*) is muscular, and is continued partly from the base of the funnel, mainly from the muscular walls of the head.

The "retractores capitis" (Pl. II. figs. 2, 3, *f*), attached to the cranial cartilage, converge as they pass backward, become connected with the "retractores infundibuli," and finally spread upon the walls of the last chamber of the shell (ib. *u*), which serves as a fixed point for the origins of those muscles. A delicate but firm membrane (Pl. II. fig. 4, *u'*) is reflected from such muscular sheath of the shell-mouth upon and over the margin of the outer shell-chamber into its cavity, and upon the hemispheric mass (ib. *z*) occupying that chamber, and attached to the hind ends of the lobes of the liver (ib. *l*, *l'*).

The muscular fibres of the shrunken fin-like appendages

(Pl. I. fig. 3, *a c*) are disposed in regular fasciculi; they are not transversely striate.

The tongue has a single retractor (Pl. I. fig. 8, *t*: the muscles of the mandibles, *r*, *s*, are shown in this figure).

The brain is immediately covered by delicate meninges; and the part of the cartilaginous cranium protecting its periphery is thin. It presented a small anterior "cerebral" or olfactory lobe (Pl. II. fig. 2, *a*) set upon the large optic lobes (*b*), like the crystalline lens upon the vitreous humour.

The pallial nerve-trunks (*c*) perforate the "retractores infundibuli," and swell into the "ganglia pallialia" (*d*).

The visceral nerves (*e*) descend together, dorsad of the œsophagus, between the inferior salivary glands, and, with the œsophagus, enter the interspace between the hepatic lobes. They send filaments to the salivary glands as they pass between those glands; and continuing backward and ventrad between the hepatic lobes to the gastric ganglion, they send filaments to the "hemispheric mass" (*z*) in the last shell-chamber (*u*).

Dorsad of the infundibulum project the two large subspherical ear-capsules (Pl. II. fig. 6, *a*), the soft subtransparent walls of which permit the contained opaque white otocones (*b*) to be discerned. The cartilage of the auditive capsule presented a bluish hyaline colour; that of the orbits was of a grey colour and more opaque.

Immediately in advance of the acoustic capsules the cartilaginous orbital cup of the cranium extends forward, expanding. A thin sheath or layer of muscular fibres arises from the ventral side of the skull to pass upon the liver: in advance of this a fibrous layer is directly continued from the margin of the cartilaginous orbit upon the sclerotic. The pupillary aperture (Pl. I. fig. 4, *a*) is subcircular and opens into the extensive conjunctival or aqueous chamber (Pl. II. fig. 2, *l*), which extends on one side of the eyeball to near the large optic ganglion (*i*).

The conjunctive membrane is reflected from the postorbital cavity upon the side of the gullet and base of the circular eyelid; it is connected with the sclerotic (*l*) by loose laminated cellular tissue, together with granular adipose tissue and the great optic ganglion.

The precranial part of the gullet (Pl. II. fig. 2, *k*; Pl. I. figs. 8, 9, *k*) is 5 millims. in length; the tube then enters the canal or groove in the cartilaginous skull; and the brain-membrane is reflected upon the œsophagus as this tube (Pl. I. fig. 11, *a*) with the salivary ducts (*b*) passes through the cerebral ring.

Three filaments accompany the cephalic part of the œsophagus: the middle and broadest (*b*) is continued from the ventral

and fore part of the salivary gland (*g*), and includes the two ducts. The two lateral filaments (*i*) I could not satisfactorily trace; they seemed to issue from or enter the hind part of the skull, and were either nerves or vessels.

Dorsad of the ear-sacs (Pl. II. fig. 6, *a*, *b*) goes the gullet (*k*), which, beyond the skull, is crossed ventrad by the lower salivary glands (Pl. I. fig. 11, *g*), and then passes, of slender dimensions, without trace of ingluvial expansion, into the interspace of the hepatic lobes (*l*, *l*).

From each side of the gullet the pallial nerves (fig. 11, *c*) diverge to their ganglion (*d*).

The œsophagus, which lies at the lowest (ventral) part of the hepatic interspace (Pl. III. fig. 2, *a*), after a course of 5 millims., expands into the stomach (*b*), which is small. The duodenum, leaving the stomach, communicates near the pylorus with the second or pancreatic stomach (*c*), which was larger than the first. A large mass of pancreatic follicles (*d*) communicate with the second stomach.

The intestine (*e*) bends about 2 millims. obliquely backward, then turns abruptly forward and becomes "rectum" (*f*), which is 4 millims. long. The rectum is enveloped in a loose mesorectum. There are no anal appendages. In the angle of the last intestinal fold lies the ink-bag (*h*), the duct of which goes forward to pierce and terminate within the infundibular anus. This glandular bag is pyriform, scarcely 2 millims. in length; it lies close to and is connected with the urocardial capsule.

The superior salivary glands (Pl. I. fig. 10, *o*) are oblong flat bodies, applied one on each side of the basal or faucial folds of the tongue (*s*).

The posterior salivary gland (Pl. I. fig. 11, *g*; Pl. II. fig. 4, *g*, & fig. 10) appears to be single; it is deeply grooved along the middle of its dorsal aspect, and deeply notched on each side by the lateral pallial nerve-trunks. Viewed from behind, the posterior salivary glands are seen to be a pair, subtriangular in shape. The white, flat, filamentary ducts of these glands run forward on each side of, and close to, the gullet, enveloped and supported by the same cellular œsophageal envelope.

The liver is not single as in *Octopus*, but consists, as in the Decapods, of two symmetrical lobes (Pl. I. fig. 11, *l*, *l*; Pl. II. fig. 4, *l*; Pl. III. fig. 2, *l*, *l*). These are of an elongated subtriangular shape, with the base turned forward, as viewed from the ventral aspect. Each is invested by a glistening capsule. The fine muscular web connecting or passing between the "retractores" or "crura infundibuli" is spread over the two oblong lobes or divisions of the liver. When this sheet is removed the lobes are seen to be invested by a proper musculo-membranous sheath. The fibres of the seem-

ing muscular part are "smooth" and disposed in longitudinal bands.

The lower ends of the liver-lobes, or continuations of their capsules, enter the last chamber of the shell, and contribute to form the hemispheric mass (Pl. II. fig. 4, *z*), from the capsule of which the membranous siphon (ib. *v'*) is continued. The outer cellular membrane, or covering of the liver, is condensed where it connects the lobes with the "hemispheric mass," and forms a well-defined border of the part occupying the last shell-chamber.

The liver consists of well-defined pyriform sacculi; the obtuse round blind ends, being next the capsule, give the reticulate appearance (Pl. II. fig. 4, *l*).

The last chamber of the shell is filled by a solid, soft, hemispheric body, covered by delicate smooth membrane, from which the small siphuncle (ib. *v'*) is continued. The dissection made with the view of determining the nature and connexions of this membrane is represented in figure 4, Pl. II., the shell being removed.

The shell-membrane, continued from the fibrous sheath formed by the origins of the retractores capitis et infundibuli, divides into two layers, one of which (*u'*) is continued over the exterior of the shell and is lost in the periostracum; the other lines the last chamber, coating its contents (*z*), and is continued therefrom to form the membranous siphon (*v'*); from this a third thin layer extends from near the basal circumference of the hemispheric body (*z*) upon the "capsula propria" of the liver. This being removed, the structure of the hepatic gland is indicated by an irregular subhexagonal pattern of the surface. A circular indent of the shell-membrane marks the terminal margin of the calcified part of the last chamber. In the siphon fine muscular fibres could be traced the whole length.

The calcareous siphon (Pl. II. fig. 2, *v*) slightly diminishes as it passes backward, and is surrounded by a raised border where it enters the aperture in the next septum.

The anterior aorta passes to the interspace of the "retractores capitis," and goes forward alongside the œsophagus. Dorsad of this aorta the vena cava (Pl. III. fig. 3, *e*) enters the same fissure and receives the hepatic vein, which emerges between the cystic follicles and the duodenum. It then penetrates the urocardial chamber, divides, and develops the renal follicles (*d*, *d*).

Each branchial heart (Pl. III. fig. 3, *b*, *b*) is semicircular, subcompressed, with a small spherical appendage (*c*); it receives the large vein with which the renal (?) spongy appendages are connected. These follicles contained small coagulated masses, consisting of filamentary groups of cells, bent

upon themselves at acute angles, and of minute granules. A slight pressure destroys the form of most of these filamentary groups *.

The right branchial vein (*i*) crosses, dorsad of the branchial heart (reflected upward in fig. 3), in the form of a cylindrical canal, and enters the smaller end of a transversely extended systemic ventricle (*a*); the left branchial vein (*ï*) enters the opposite end. Each branchial vein is continued from the ventral side of the gill-base.

The systemic heart-substance, or "bulbus arteriosus" (*k*), bends forward at right angles to the main ventricle (*a*), and near the entry of the right branchial vein (*i*). A smaller posterior aorta (*l*) is given off from near the middle of the back part of the transverse ventricle. This aorta supplies the nidamental glands and succenturiates, the hemispheric mass of the last shell-chamber, also the capsule applied to the umbilical parts of the shell-whorls.

From the inner surface of the ventral part of the mantle, distad of the border of the pallial valve, a vein emerges; on the inner surface of the dorsal part of the mantle are glistening bands of transverse fibres intercepting orifices or transverse slits of the sinus continued from the veins from the "retractores capitis" and salivary glands.

The gills (Pl. II. fig. 1, *a*, *a'*; Pl. III. fig. 3, *g*, *g'*) are two in number, of the same structure as in other Dibranchiates; they are rather larger, relatively, than in *Loligopsis*, but have the same number of laminæ (twenty-four pairs). From the basal half or rather more of the fleshy stem is continued the frænal fold above mentioned (Pl. III. fig. 1, *f*), the layers of which are continuous with the general serous membrane of the visceral chamber. The gill (*a'* in fig. 1, Pl. II.) is reflected to show the opposite surface.

The specimen confided to me for dissection was a female. The generative organs consist, as in *Sepia*, *Sepiola*, and *Rossia*, of an ovary (Pl. III. fig. 1, *b*), an oviduct (Pl. II. fig. 3, *e*), with an oviducal gland (ib. fig. 3, *d*; Pl. III. fig. 6, *d*), and a pair of nidamental glands (Pl. III. fig. 1, *c*, *c*; Pl. II. fig. 3, *c*).

The ovarium, filled with ovisacs, the largest of which are $1\frac{1}{2}$ millim. in diameter, occupies the left side of the fundus of the visceral chamber. The oviduct is continued from its anterior part, and is soon dilated by ova, of large relative size, as in *Sepiola* and *Rossia*.

* In the sac lodging the homologous follicles of the Pearly Nautilus, Van der Hoeven found "a calcareous reddish-white and friable concrement: I believed it to contain uric acid; but the chemical inquiry of Prof. Van der Boonchesch has not confirmed my supposition" ("Contributions to the Knowledge of the Animal of *Nautilus pompilius*," Transactions of the Zoological Society, vol. iv. p. 24).

The ova are close-packed; two or three may be seen on the same transverse line along the terminal recurrent fold of the oviduct. Near its termination the glandular part is developed (Pl. III. fig. 6, *d*).

The membranous part of the oviduct terminates round the thick border of the infundibular beginning of the glandular part, the fine folds of which radiate therefrom. The oviducal gland is pyriform; its plicated substance makes a spiral turn before reaching the apex.

The outlet of the oviduct (ib. fig. 1, e') is an elliptical slit, situated posteriorly and laterad of the valvular orifice of the urocardium and of the anus.

Much loose cellular tissue connects the peritoneum with the long folds of the oviduct on the left side of the visceral mass.

Spirula is almost as devoid of external organs of natation as *Nautilus*. In both the direction in which such forces act is retrograde.

Nautilus exercises them mainly by virtue of the muscular funnel, through which it forcibly ejects into the surrounding water the respiratory currents*. *Spirula* superadds to this the ejection of that volume of water upon which the cephalic arms and their basal webs contract, after the fashion in which other Dibranchiates, especially the Octopods, propel themselves backwards. The dynamic of the recoil in both instances is exemplified by that of the cannon, when the gas of the ignited powder is driven into the surrounding atmosphere. *Spirula* is superior to *Nautilus* in the cephalic mechanism, although the thick cylindrical muscular sheath enclosing the buccal mass may exercise a similar though feebler power in the backward propulsion of the body; but inferiority in the cephalic motor, in *Nautilus*, is in some degree compensated by superiority of the infundibular one. In both instances of multilocular Cephalopods the natatory power is inferior to that of existing Dibranchiates.

Rumphius testifies of the "great post-horn" (*Nautilus*), "it keeps itself chiefly at the bottom, creeping sometimes into the nets of the fishermen; but after a storm they may be seen in troops floating on the water; 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."

I have already referred to the testimony of the same observant naturalist that "the little post-horn" (*Spirula*) "hangs to the rocks by a thin and small door," or disk—"that it sets itself fast to the rocks." The marginal indication of the

* Anat. & Phys. of Invertebrates, 8vo, 1855, p. 583.

paragraph on the *Spirula* is "En zit aan de klippen"*. Admitting this function of the terminal suctorial disk, which is peculiar to *Spirula* among Cephalopods, yet it nevertheless occasionally floats, and probably passes more of its time as a swimmer than does the *Nautilus*. Rumphius observed both multiloculars on the shores or coast of Amboyna. The subject of the present supplementary monograph, and that of J. E. Gray and Lovell Reeve, was captured, recent if not living, on the shore of New Zealand. A *Spirula*, borne away from its shores by storms or currents, would find subsistence in the open ocean as long as nutriment could be taken by its prehensile organs. In regard to its relations to *Nautilus* I would submit the following remarks.

The more or less fixed attachment of a muscle being regarded in anatomy as its "origin," the chief masses of the muscular system in both *Nautilus* and *Spirula* have a similar origin, viz. the terminal open chamber of the multilocular shell. In *Nautilus* the retractores infundibuli and retractores capitis arise on each side of the inner surface of that chamber by a single origin †, the insertional tissue or "tendon" of which, however, is continued round the circumference of the chamber at the level or line of the main parial attachments. In *Spirula* the corresponding muscular masses arise equally from the entire circumference of the terminal part of the inner surface of the last chamber, but also extend their attachments over the margin and a little way beyond it on the exterior of the shell; they are, in fact, "shell-muscles" in the same sense as those so-called in *Nautilus*. In both genera, therefore, the shell, besides other offices, serves as the *point d'appui* of the retractors of the funnel and of the head with its locomotive and prehensile organs. Moreover the last chamber of the shell in *Spirula* also receives part of the visceral mass, viz. the hind termination of the liver, which, covered by its capsule, and this again by the peritoneum or a delicate aponeurosis continued from the attached shell-muscles, constitutes the hemispheric mass that fills the chamber and forms or sends off the beginning of the membranous siphon. This siphoniferous and visceral mass ("calotte" of De Blainville ‡) is answerable in *Spirula* to the siphoniferous and visceral mass which, in *Nautilus*, occupies the

* 'D'Amboinsche Rariteitkamer,' fol. 1741, p. 61.

† 'Memoir on the Pearly Nautilus,' 4to, 1832, p. 17, pl. i. *g*.

‡ This anatomist regarded the "calotte" as wholly muscular, and its siphonal production as the tendon of such. Describing the retractores as "la gaîne musculaire que traverse l'œsophage," he proceeds, "Son extrémité antérieure qui va à la tête et aux appendices était tronquée à l'endroit de l'arrachement; mais la postérieure était bien conservée; on voyait qu'allant en se rétrécissant elle s'attachait à une lame charnue qui tapissait le fond de la première loge de la coquille, en formant une

fundus of the last chamber *, only with reversed proportions; such visceral mass occupies a smaller proportion of the last chamber in *Nautilus*, yet consists of a larger proportion of the viscera than in *Spirula*. Although by the forward extension of the last chamber beyond the muscular attachments, in *Nautilus*, a still greater proportion of the animal is contained, or may be retracted, within that chamber—nevertheless, in the degree in which the mantle may be reflected over the exterior of the shell, such proportion of the shell may be regarded as internal. Lateral prolongations of the mantle can extend over the umbilicus, and are the efficients of the deposition there of coloured calcareous matter, in *Nautilus pompilius*; and such pallial prolongations are homologous with the lateral terminal lobes of the mantle of *Spirula* (Pl. I. figs. 1, 2, 3, *c*, *c*), which similarly cover the umbilical parts of its shell.

The distinction, therefore, between *Nautilus* and *Spirula*, in regard to the shell, in its protective relation, is relative, not absolute: in the one a small proportion of the shell is occasionally "internal;" in the other a small proportion is always "external:" in both the multilocular shell corresponds with the phragmocone of the Belemnite†.

The tetrabranchiate *Orthoceras* may be called a representative analogue of the dibranchiate Belemnite, as the tetrabranchiate Ammonite is of the dibranchiate *Spirula*. The siphon is "ventral" and "marginal" in both kinds of coiled shells, but it runs along opposite sides of the coil. In *Spirula* its position is "internal" or "entomarginal;" in *Ammonites* it is "external" or "ectomarginal."

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Right-side view of *Spirula australis*, in outline, showing the four arms (1, 2, 3, 4) and the tentacle (*d*) of that side. *a*, eye-aperture; *b*, dorsal pointed lobe of fore border of mantle; *c*, umbilical fold of mantle; *e*, exposed part of outer wall of shell on the ventral side; *f*, the same on the dorsal side; *g*, longitudinal marks

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sorte de calotte se continuant par sa circonférence avec l'enveloppe de celle-ci, et donnant, au fond et vers le bord inférieur, naissance à un prolongement tubiforme pénétrant et s'attachant dans le siphon de la première cloison, puis se continuant sans autre adhérence, à ce que je suppose, jusqu'à son origine vers le sommet de la coquille, dont j'ai pu, en effet, le retirer sans briser, dans une longueur considérable; en sorte que l'on peut dire que celle-ci est dans un prolongement du muscle columellaire ou rétracteur de la tête et de ses appendices, et que le siphon membraneux n'est lui-même qu'une partie de ce muscle."—*Op. cit.* p. 379.

* *Op. cit.* pl. i. *a*.

† See the restoration of this extinct form in my 'Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals,' 8vo, 1843, p. 333, fig. 133, *b*.

on dorsal part of mantle; *i*, funnel projecting between the pair of pointed lobes on the ventral side of the fore border of the mantle. Nat. size.

Fig. 2. Dorsal view of hind part of mantle, showing the interspace between the two terminal umbilical lobes (*c*, *c*). A portion of the outer whorl of the shell is exposed, at *h*, by removal of the periostracum (*g*), with which the epithelial layer of the mantle (*f*) is continuous. Magnified 3 diameters.

Fig. 3. Terminal disk (*a b*) and appendages (*a c*), with ends of terminal lobes (*c*, *c*), of the mantle, and exposed parts of outer whorl of shell (*h*, *h*). Magn. 2 diam.

Fig. 4. Muscular mass of *Spirula*, including the head and its appendages (1, 2, 3, 4, and *d*), the funnel (*i*), the pallial valve (*h*), the retractors of the head (*f*) and funnel (*t*), which blend together to be attached to the last chamber of the shell (*u*); the digestive organs and ink-bag are also given. Nat. size.

Fig. 5. Anterior view of the head and appendages, with the mouth and bases of the peduncles. Nat. size.

Fig. 6. One of the eight arms, showing the acetabuliferous surface. Magn. 3 diam. Three detached acetabula (*b*, *d*, *e*) and their pedicles, more highly magnified.

Fig. 7. Mouth and bases of the cephalic arms and peduncles, with the outer lip laid open, exposing the inner lip and mouth. Magn. 3 diam.

Fig. 8. The buccal mass. Magn. 4 diam.

Fig. 9. The upper and lower mandibles. Magn. 6 diam.

Fig. 10. Muscles of the buccal mass, upper salivary gland, and tongue. Magn. 6 diam.

Fig. 11. Parts of *Spirula*, extending from the mouth (*n*) to the shell (*s*, *v*), magn. 3 diam.: the letters are explained in the text. 11^a, inner surface of inner lip.

Plate II.

Fig. 1. Dissection showing the funnel and its retractors, gills, a nidamental gland, ovary, and part of the shell. Magn. 3 diam.

Fig. 2. Dissection of parts of *Spirula*, from the mouth (*m*) to part of the shell (*v*); the letters are explained in the text. Magn. 3 diam.

Fig. 3. Head of *Spirula*, with pallial valve and muscles, and female organs of generation. Nat. size.

Fig. 4. Parts of *Spirula*, including the lower salivary glands, liver, and contents of last shell-chamber. Magn. 3 diam.

Fig. 5. Muscular mass of retractors of head and funnel of *Spirula*, and their attachment to the last shell-chamber. Nat. size.

Fig. 6. Acoustic organs and contiguous parts. Magn. 4 diam.

Fig. 7. Digestive organs. Magn. 4 diam.

Fig. 8. Shell of *Spirula*, with hemispheric mass filling terminal shell-chamber, raised; also part of mantle and terminal disk.

Fig. 9. Terminal chambers of shell, laid open to show origin of siphon and contents of last chamber. Magn. 2 diam.

Plate III.

Fig. 1. Female organs and funnel. Magn. 3 diam.

Fig. 2. Alimentary canal, hepatic lobes, interior of funnel, and last shell-chamber. Magnified.

Fig. 3. Circulating and respiratory organs. Magn.

Fig. 4. Digestive organs; mass of retractor muscles. Magn.

Fig. 5. Portion of oviduct, with left gill and branchial heart. Magn.

Fig. 6. Termination of oviduct with oviducal gland. Magn.