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LXXVIII. *Observations on Dr. Buckland's Theory of the Action of the Siphuncle in the Pearly Nautilus.* By THOMAS WRIGHT, M.R.C.S.*

ALTHOUGH the valuable memoir by Professor Owen on the *Nautilus pompilius* has thrown a new and important light upon the history and organization of siphoniferous cephalopods, still, however, much remains to be learned of the singular structure of this interesting group of the *Mollusca*. From the announcement made by Professor Owen in his article "Cephalopoda," in the *Cyclopædia of Anatomy and Physiology*, I was led to expect that Dr. Buckland's *Bridgewater Treatise* would contain a satisfactory explanation of the action of the siphuncular apparatus of these mollusks. Whilst I admire the tone, talent, and highly popular style of the *Bridgewater* essay, still I am of opinion that the learned author's theory of the action of the siphuncle is at variance with the facts revealed by the dissection of the animal. On this subject Dr. Buckland observes: "The last contrivance, which I shall here notice, is that which regulates the ascent and descent of the animal by the mechanism of the *Siphuncle*. The use of this organ has never yet been satisfactorily made out; even Mr. Owen's most important Memoir leaves its manner of operation uncertain; but the appearances which it occasionally presents in a fossil state supply evidence, which taken in conjunction with Mr. Owen's representation of its termination in a large sac surrounding the heart of the animal, appears sufficient to decide this long-disputed question. If we suppose this sac to contain a *pericardial fluid*, the place of which is alternately changed from the pericardium to the siphuncle, we shall find in this shifting fluid an hydraulic balance or adjusting power, causing the shell to sink when the pericardial fluid is forced into the siphuncle, and to become buoyant, whenever this fluid returns to the pericardium. On this hypothesis also the chambers would be continually filled with air alone, the elasticity of which would readily admit of the alternate expansion and contraction of the siphuncle, in the act of admitting or rejecting the pericardial fluid†." In order to estimate the value of this hypothesis, it is necessary to inquire whether the nautilus spends the greater portion of its existence at the bed of the sea, or navigates the surface of its waters. The few authenticated instances where this mollusk has been seen at the surface, when compared with the thousands of its shells which

* Communicated by the Author.

† *Bridgewater Treatises*, VI. *Geology and Mineralogy*, vol. i. p. 325.

are annually imported into Europe, affords *prima facie* evidence that the nautilus is an inhabitant of the silent depths of the sea; but when we inquire whether the organization of the animal sanctions this inference, we discover in its anatomy peculiarities of structure to adapt it to such a mode of life, the function of which it is impossible to mistake. The number and rudimentary condition of the cephalic appendages, the presence of a ligamento-muscular disc analogous to the foot of gasteropods, and adapted as a locomotive instrument for creeping along the bottom, the simple structure and pedunculated character of the eyes, the dense calcareous nature of the jaws, the structure of the digestive organs, but above all the contents of the stomach, which consisted, according to Owen, of the remains of a species of crab*, constitute an assemblage of characters which enable us to pronounce the manor of this mollusk to be the bed of the sea, where it preys upon crustacea and other invertebrata. But the nautilus has been seen occasionally at the surface of the water, and the question naturally arises, what are the conditions necessary to accomplish its ascent and descent?

- 1st. That the animal should be capable of rendering itself specifically lighter and heavier than the ambient element.
- 2nd. That the mechanism by which this act is accomplished should be under the control of its will.

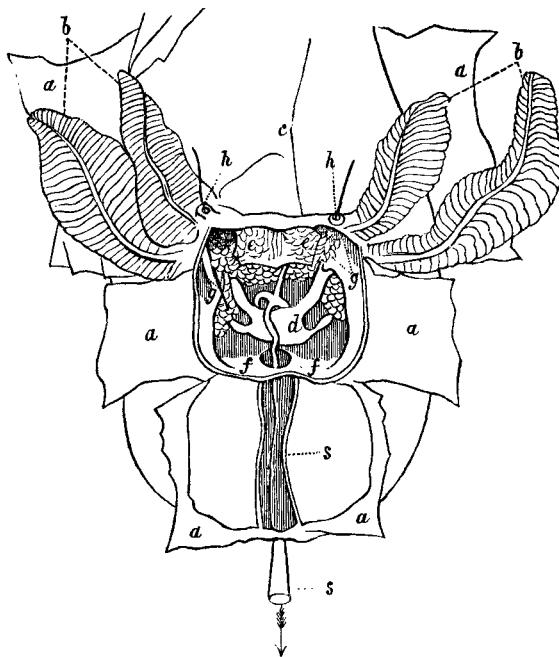
Now, Professor Buckland's theory allows only of *a change of place* in the adjusting fluid, from the pericardial cavity into the siphuncle, and *vice versâ*; consequently the specific gravity of the *entire animal* remains the same. The accompanying outline †, from Owen's dissections, shows the relative position of the internal organs: *a a* is the enveloping fleshy mantle dissected off to expose *b b*, the branchiæ floating in *c*, the branchial chamber for the reception of the water; *d* is the heart with its large vascular canals surrounded by clusters of glandular follicles, *e e*. The capacious pericardium *ff* is laid open to show its boundary and relation to the central organs of the circulation; it is partially divided internally by thin muscular septa, *g g*.

From the posterior wall of this musculo-membranous bag there proceeds a canal, or siphuncle, *s s*, destined to traverse all the chambers of the shell: the arrow shows the direction of this aquiferous tube. Anteriorly the pericardium communicates

* Art. *Cephalopoda*, Cyclopædia of Anatomy, p. 531.

† For splendid figures of the animal and shell of the *Nautilus pompilius*, consult Dr. Buckland's 31st and 34th plates; also Prof. Owen's invaluable memoir.

with the branchial chamber *c*, by two apertures *h h*, through each of which a bristle is passed to indicate the channels of



communication. From this arrangement it is evident that the pericardial bag has three openings, *one* behind which conducts the fluid into the siphon, and *two* before which open into the branchial chamber, into which the sea water is constantly flowing to bathe the respiratory organs. With this mechanism before me, I humbly submit whether it is not a reasonable inference to suppose *that the sea water alone is the ballast by which the nautilus is retained at the bottom, and its ejection the means by which the animal is enabled to rise to the surface at pleasure.*

Thus by relaxing the anterior orifices, *h h*, that communicate with the common branchial chamber, the water would flow into the pericardial sac, and from thence into the siphon *s*: during this distended condition of the apparatus the animal and shell would be specifically heavier, and the nautilus, in obedience to a prescribed law, would remain at the bottom without any muscular effort on the part of the

animal to retain itself in that situation. Let us suppose that it is the will of the animal to rise to the surface; by calling into action the muscular layers of the pericardium, its watery contents would be ejected through the two orifices *h h*, a partial vacuum would be thus produced, the remaining portion of the fluid which filled the siphuncle would flow into that cavity, and from thence be ejected from the body: it is clear, therefore, that the nautilus would be thus rendered specifically lighter, and would consequently ascend to the surface. When it wishes to descend, it has only to admit the water through the orifices *h h*, the siphuncular apparatus would be again distended, its gravity increased, and its descent to the bottom accomplished*.

This explanation of the action of the siphuncle is applicable to the various modifications of structure observed in the mechanism of that tube, and avoids the many serious objections which may be reasonably urged against Dr. Buckland's hypothesis:

- 1st, We have not sufficient evidence to support the supposition that the air contained in the chambers of the shell undergoes compression; on the contrary, we find that the *Nautilus Sypho* from the tertiary strata of Dax possessed a calcareous siphon, which passed through the entire chamber and entered the aperture in the adjoining plate; and it can be demonstrated that the spirula has a calcareous siphon of an analogous structure extended along the concave side of the shell, so that in these mollusks the siphuncle is a *continuous calcareous tube* incapable of dilatation, and consequently their ascent and descent in the water was accomplished *without those conditions on which Dr. Buckland's hypothesis rests*, i. e. the dilatability of the siphon, and compression of the confined air.
- 2nd, I have already shown that the nautilus is peculiarly adapted for seeking its prey among the myriads of invertebrata that crowd the bed of the sea. Now according to Dr. Buckland, "When the arms and body are expanded, the fluid remains in the pericardium, and the siphuncle is empty, and collapsed, and surrounded by the portions of air that are permanently confined within each air chamber; in this state, the specific gravity of the body and shell together is such as to cause the

* This explanation was proposed in a course of lectures on Fossil Zoology, which I delivered at the Philosophical Institution of this town, (Cheltenham) a report of which the Editor of the Naturalist has kindly inserted in the last number of his valuable periodical.

animal to rise, and be sustained floating at the surface*." If this explanation be correct, the nautilus cannot remain at the bottom unless the siphon is distended by the retreat of the animal into the last chamber of its shell. What a prodigious muscular effort must, therefore, be constantly required to keep the nautilus at the bed of the sea! Again, it may be asked, how is the nautilus to seize its prey at the bottom, seeing the instant its head is protruded to search, and its arms expanded to seize it, "the fluid would be forced back again into the cavity of the pericardium, and thus the shell, diminished as to its specific gravity, would have a tendency to rise†"? This theory, therefore, is at variance with the inference obtained from an examination of the organization of the nautilus, that it seeks its prey at the bottom, and is but an occasional visitor at the surface: it is opposed likewise to a well-known law of the animal œconomy, that mechanical contrivances are always substituted, where long-continued action is required, to œconomise the expenditure of muscular power; a familiar example is afforded in the *Conchifera*, where an elastic ligament is employed to keep open the valves of the shell, adductor muscles being furnished for the occasional closing of the same. If we test the theory by this principle, we find that to keep the tube distended and the air compressed, in order that the nautilus may remain at the bottom, a constant muscular effort would require to be sustained, in order to overcome the elasticity of the confined air, the expansion of which is, according to Dr. Buckland, the power by which the siphuncle is emptied of its aqueous contents. The explanation which I have ventured to propose is in perfect harmony with the œconomical law alluded to; for whilst the nautilus is at the bed of the sea, the muscular powers of the pericardium would be in a passive state, just as the adductor muscle of the conchifer is in a state of repose when the valves are kept open by the elastic hinge; *no effort would be required to keep the animal in its natural situation*; as in the *Conchifera*, so it may be in the nautilus; an effort of the will shuts the valves of the former, and the contraction of the pericardium, by ejecting the watery ballast from the siphuncle of the latter, would allow it to change its feeding ground, ascend to a higher stratum of the water, or to its surface if required.

* Bridgewater Treatise, vol. i. p. 329 note.

† *Ibid.*, p. 330.

3rd, In reviewing the nature of the peculiar glandular appendages that surround the large vascular canals of the nautilus, I deem it an unfair inference to suppose that they are the organs that secrete the fluid which circulates in the siphuncular apparatus, seeing that the same modifications of glandular structure exist in the dibranchiate cephalopods which are destitute of a siphoniferous shell: the true function of these follicular bodies is a physiological problem that yet remains to be solved.

Nuneham House, Cheltenham, May 8th, 1838.

LXXIX. *Proceedings of Learned Societies.*

GEOLOGICAL SOCIETY.

Anniversary Address of the Rev. W. Whewell, M.A., F.R.S., President.

[Continued from p. 440.]

IN attempting a rapid survey of the contributions to geological knowledge which have come under our notice during the past year, I may perhaps be allowed to advert to a distinction of the subject into Descriptive Geology and Geological Dynamics; the former science having for its object the description of the strata and other features of the earth's surface as they now exist; and the latter science being employed in examining and reducing to law the causes which may have produced such phenomena. We appear to be directed to such a separation of our subject by the present condition of our geological studies, in which we and our predecessors have accumulated a vast store of facts of observation, and have laboured with intense curiosity, but hitherto with very imperfect success, to extract from these facts a clear and connected knowledge of the history of the earth's changes. Nearly the same was the condition of astronomy at the time of Kepler, when the accumulated observations of twenty centuries resisted all the attempts of that ingenious man and his contemporaries to construct a science of physical astronomy. But though checked by such failures, they were not far from success; and when for the next succeeding century philosophers had employed themselves in creating a distinct science of Dynamics, the science of physical astronomy, full and complete, made its appearance, as if it were a matter of course; and thus showed the wisdom of separately cultivating the study of causes, and the classification of facts.

DESCRIPTIVE GEOLOGY.

If we begin with geological facts, our attention is first drawn to that district on the earth's surface within which the facts have been subjected to a satisfactory comparison and classification, which may be considered, in a general way, as including England, France, Italy, Germany, and Scandinavia. The language which the rocks of these various countries speak has been, in a great measure, reduced to the same geological alphabet. The questions of the determination of