

XI. TAXONOMIC STUDIES ON THE SOFT PARTS OF THE SOLENIDAE

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(Plates II, III.)

INTRODUCTION.

The anatomy of nearly all the known genera of Solenidae has been described by Bloomer (5-17) in a series of papers published in the *Journal of Malacology*, and in the *Proceedings of the Malacological Society*. The animal of *Solen sloanii*, Gray, has been briefly described by Hedley (31) in 1899. Drew (25), in the year 1907, noted the anatomy of *Ensis directus*, Conrad, along with its habits and especially its movements. In the year 1916, Annandale and Kemp (*Mem. Ind. Mus.* V, p. 354) added a short note on what was then doubtfully considered to be a dwarfed form of *Solen fonesi*, Dunker, and I described the anatomy (28) in an appendix to the same paper. No stress has been put upon the taxonomic importance of the soft parts, however, in any of these publications with the exception of a single one of them titled "Classification of the British species of the genus *Solen*, Linné" by Bloomer (5) and scattered notes in his other papers. The present paper aims at treating the subject with a view to define the subfamilies and genera from the soft parts, including their gross internal anatomy. It is also intended to append an account of the gross anatomy of species, the soft parts of which are still unknown.

I should specially mention that I have received all the specimens from the Zoological Survey of India through the kindness of Dr. N. Annandale. Lastly, I heartily thank Prof. H. H. Bloomer for his kindness in sending his papers to me at my request.

GENERAL NOTES ON THE SOFT PARTS.

The animals are either narrow and elongated with more or less straight and parallel margins or short and broad (deep) with rounded margins.

MANTLE LOBES. The mantle lobes are fused with each other in various degrees in the different genera. The fusion, being incomplete, has left a number of gaps bounded laterally by free mantle margins and described as *apertures*. An anterior aperture for the protrusion of the foot is formed by the separation of the anterior margins of the mantle lobes. This is known as the *pedal*

aperture. It may extend posteriorly both along the dorsal and ventral margins but specially along the latter. In two species, so far studied, the free anterior margins of the mantle lobes have given rise to two muscular flaps from their inner surfaces which serve to close the pedal aperture when the foot is withdrawn into the mantle chamber. The flaps may be named the *pedal valves*. The outer surface of the thick muscular anterior margin of each mantle lobe sometimes presents a groove parallel to and slightly behind the free margin which receives a ridge from the valve. Posteriorly, the mantle lobes leave two apertures one above the other and placed at the end of two tubes formed from the mantle lobes. They are known as the anal and branchial siphon. The two siphonal tubes are either constricted completely in a single piece as in the typical genera, or completely or partially separate from each other in others. A fourth aperture has been described in the ventral margin of the fused mantle lobes. Bloomer (8, pp. 43-45) has conclusively shown that this aperture in the Solenidae is not homologous with a similar one in other Pelecypoda and is derived secondarily from the posterior end of the pedal aperture. The degree of fusion of the mantle lobes appears to have some distinct bearing on the assortment of the genera. Lastly, from the union of the mantle lobes with each other or with the walls of the siphons, spaces may be formed either demarcated or completely separated from the general mantle chamber. Thus a space has been described by Bloomer (7) in *Cultellus pellucidus* formed in the dorsal aspect anteriorly by the mantle lobes being joined together a little below their margins. This chamber does not communicate with the mantle cavity and is known as the *suprapedal chamber* [Bloomer (8), p. 41]. Another chamber may be formed by the union of the dorsal margins of the mantle lobes in front of the anterior adductor muscle and lying above the foot. In some genera a space is enclosed posteriorly by the mantle lobes (which are free at their posterior margins), and limited in front by the union of the siphonal tubes at their anterior margins with the mantle lobes, either directly along their inner side in front of their free posterior margins (*Solecurtus*, *Azor*), or through the intervention of narrow (*Novaculina*) or wide lateral processes (*Tagelus*), extending from the free posterior margins of the mantle lobes to the base of the siphonal tubes. Further, in *Tagelus* and *Azor*, the dorsal wall of the upper siphonal tube is connected with the ventral aspect of the posterior adductor muscle. This space contains the siphonal tubes (which may be completely retractile within the chamber) and may be designated as the *siphonal space*.

PALLIAL MUSCULATURE. A *cruciform muscle* is found in some genera, showing their relation to the fam. Psammobiidae.

FOOT. The foot is an elongated organ more or less cylindrical in typical forms but somewhat flattened in others. It arises from the anterior or antero-ventral aspect of the visceral mass. The shape of the foot, specially its anterior portion, is so variable in different degrees of retraction that it is difficult to form an idea

of its exact shape in preserved specimens in which the organ may be fixed in any degree of contraction. The foot of *Cuttellus javanicus* has been figured by Weber (50), who showed the different shapes it can assume in different degrees of extension.

The intrinsic pedal musculature as described by Bloomer (5), and followed by me in my specimens, requires a brief notice in order to understand the differences in the arrangement of the muscles in the different genera. The pedal musculature consists of (1) two layers of longitudinal muscles on each side (an outer, and an inner abutting on the pedal cavity) separated by (2) a dorso-ventral semi-circular band; (3) two rows of transverse muscle bands extending across the pedal cavity along its dorsal and ventral surfaces, and passing to the inner side of the semi-circular layers; (4) a thin layer of circular muscles just beneath the epithelial covering of the foot (the *pedal integument* of Bloomer); (5) lastly, a set of oblique muscles extending from the pedal integument between the outer longitudinal muscles to the outer side of the semi-circular bands.

The *protractor pedis* muscle is well developed in some genera (*Solecurtus*, etc.) but rudimentary or absent in others (*Solen*, etc.).

The *retractor pedis anterior* muscle, one on each side, consists of one or two bands which pass upwards to be attached to the valve. The pedal portion of the muscle consists of radiating fibres which spread out in the foot either on the inner side of or superficially to the longitudinal muscles of the foot. They are of some taxonomic importance in the differentiation of some genera.

The *retractor pedis posterior* muscle bifurcates into right and left portions which are attached to the corresponding valves. It does not bifurcate in *Cuttellus cultellus*, Dunker. The muscle at its insertion may either remain separate from or merge into the fibres of the posterior adductor muscle. The impression of the muscle on the valve may be of different sizes in comparison with that of the posterior adductor muscle.

LABIAL PALPS. The palps are wide and short, or narrow and elongated. The anterior lips formed by the union of the outer labial palps are either placed immediately behind the anterior adductor muscle, or are removed posteriorly from the muscle. A *labial groove* has been described by Bloomer (3) on the inside of each mantle lobe passing dorsally from the fourth aperture towards the foot. The distal portions of the labial palps are placed in the groove.

GILLS. The gills are generally narrow (in depth), elongated, and are often prolonged into the siphon. The outer lamella of the outer gill (demibranch) is generally attached to the mantle lobe along its dorsal margin. The inner lamella of the inner gill is divisible into visceral and cloacal portions in consideration of its attachment along its dorsal margin. The visceral portion is generally free (except in *Ensis*), whereas the cloacal portion is either free or joined to its fellow of the opposite side. *Branchial*

retractor muscles are developed in some genera along the axis of the gills. They serve to throw the gills into folds when the siphons are retracted and withdrawn between the valves.

The gills are of synoptorhabdic type, *i.e.* the filaments are connected by interfilamentar tissues. They are either simple and homorhabdic, or plicate (*i.e.* thrown into vertical folds) and heterorhabdic (sometimes very indistinctly).

ALIMENTARY CANAL. The *oesophagus* may vary in its course. The *stomach* has been divided by Bloomer (5) into four portions. The antero-ventral (*oesophageal*) is continuous with the oesophagus in front and separated from the antero-dorsal portion (*cardiac*) by a muscular ridge. The middle portion (*central*) is ventro-lateral in position adjoining the oesophageal portion. The posterior portion (*pyloric*) is separated from the central portion by a ridge passing ventrally, and from the cardiac portion by another passing to the dorsal aspect.

The pyloric stomach gives off the *coecum* of the crystalline style either from its ventral aspect or from its posterior end. The course of the coecum is somewhat different in the different genera.

The origin and course of the *intestine* may be thus considered in a tabular form:—

I. *Solen* type. The intestine arises directly from the ventral aspect of the pyloric chamber independently of the coecum. It consists of two limbs which pass along the dorsal and ventral aspects of the coecum respectively. The type may show the following variations:—

- (a) The two limbs of the intestine simple (not folded) (*Ceratisolen*, *Subcullellus*).
- (b) The anterior limb forming a number of large folds (*Pharella*).
- (c) The anterior limb with closely placed coils and posterior limb simple (*Siliqua*).
- (d) The anterior limb with closely placed coils and posterior limb with one or more folds (*Solen*).
- (e) The anterior limb with closely lying coils and posterior limb with a number of large loops (*Ensis*).

II. *Novaculina* type. The intestine arises directly from the pyloric stomach and forms several long loops traversing the entire length of the visceral mass.

III. *Solecurtus* type. The intestine arises in connection with the coecum as a common tube and is only separated from it outwardly by two lateral grooves. It forms a separate tube near the distal end of the coecum and then passes along the ventral aspect of the coecum (corresponding to the second limb of the first type). The course is either simple or is attended with loose or close coils. This type of intestine is also found in members of the fam. Psammobiidae to which some of the genera of the Solenidae are undoubtedly closely related. This point has already been emphasized by Dall (23) and Bloomer (16).

VASCULAR SYSTEM. The position of the heart varies somewhat in different genera. It may occupy the anterior, middle or posterior portion of the pericardial chamber.

NERVOUS SYSTEM. Some difference has been noted in the position of the *viscero-parietal ganglia* varying from beneath the bifurcation of the retractor pedis posterior muscle to the antero-ventral aspect of the posterior adductor muscle. There are also some minor differences in the origin, number and distribution of the nerves from the various ganglia.

CLASSIFICATION.

The family Solenidae may be divided into three subfamilies, two of which form natural assemblages of genera having a number of important characters in common. The genus *Novaculina*, Benson, differs so much from either of the two other subfamilies that it is best placed in a subfamily of its own.

Subfam. SOLENINAE.

1858. Subfam. Soleninae, subfam. Pharinae (pars), Adams and Adams, *Gen. Recent Mollusca*, pp. 340, 342.
 1862. Solenaria, Siliquaria (pars) Bronn, *Thier-Reichs. Malacozoa Acephala*, III (2), p. 476.

The present subfamily includes the typical genera of the family, presenting a narrow, elongated body, compressed from side to side, and a *Solen* type of intestine. It may be diagnosed as follows:—

Animal. Body elongated, narrow in depth and compressed laterally. Pedal aperture variable in extent. United ventral margins of the mantle lobes forming a very narrow elongated surface. No cruciform muscle. Siphons either fused in a single piece with two siphonal canals, or completely free from each other. No siphonal space (p. 48) posteriorly. A narrow, elongated cylindrical foot extending horizontally forward through the pedal aperture. Retractor pedis anterior muscle bifurcated or not (*Solena*, *Pharella*, *Cultellus*) and generally directed upwards and forwards. Protractor pedis muscle rudimentary or absent. Gills simple or plicate. Intestine arising directly from the pyloric stomach and consisting of two limbs. Viscero-parietal ganglia beneath the bifurcation of the retractor pedis posterior muscle or under the posterior adductor muscle (*Pharella*).

The subfamily forms a natural group by itself. Further study of the soft parts of the animals of the present subfamily will perhaps raise it to the rank of a distinct family.

Gen. *Solen*, Linné.

- 1782-93. *Solen* (pars), Linné, *Syst. Nat.*, ed. XIII (edited by Gmelin), p. 3223 (pars VI).
 1858. *Solen*, Adams and Adams, *Gen. Recent Mollusca*, II, p. 340; III, pl. xcii, fig. 1.
 1874. *Solen* (pars), Reeve, *Conch. Icon.*, XIX.

1887. *Solen*, Fischer, *Man. de Conch.*, p. 1110.

1889. *Solen* (pars), Clessin in Martini-Chemnitz, *Syst. Conch.-Cab.*, XI (*Solanacea*), p. 2.

The original genus *Solen*, Linné, has been split up by Schumacher (45) into three, viz., *Solen*, *Ensis* and *Cultellus*, the distinction of which has been confirmed by the anatomical researches of Bloomer (8, pp. 43-45). He described and compared a large number of species of *Solen* in a series of papers. I have three species of *Solen* at my disposal, viz., *S. kempi*, Preston, *S. sp.* from Japan and another species which appears to be new (*S. gravelyi*, sp. n.), the anatomy of which I have been able to study.

The following diagnosis has been drawn up from the work of Bloomer as well as from my study of the above species:—

Animal. Body elongated, and narrow, dorsal and ventral margins very nearly parallel to each other, anterior and posterior margins straight and sloping. Pedal aperture generally confined to the anterior margin, sometimes extending posteriorly. No fourth aperture. Siphon a single piece with the distal end fringed with tentacles. Anterior adductor muscle narrow and elongated. Posterior adductor muscle oval. Foot cylindrical, somewhat flattened laterally with the anterior end more or less dilated. Radiating fibres of the retractor pedis anterior muscle passing outside the longitudinal muscle of foot. Labial palps elongated and narrow ending in a point generally. Anterior lip of the mouth separated from the posterior end of the anterior adductor muscle by a distinct interval. Gills narrow and elongated, prolonged into the proximal end of the branchial siphonal canal; plicate and heterorhabdic, the plicae being free from one another. Visceral portion of the gills forming less than half their entire lengths. Inner lamella of the inner gill free in the visceral portion, but united with its fellow of the opposite side behind (except in *S. gravelyi*, sp. n.). Coecum arising from the ventral aspect of pylorus and passing forward. Intestine generally of *Solen* subtype (p. 50). Heart generally placed in the middle of the pericardial chamber. Liver not extending anteriorly over the anterior adductor muscle. A single anterior pallial nerve from each cerebro-pleural ganglion. Viscero-parietal ganglia placed beneath the bifurcation of the retractor pedis posterior muscle. A single circumpallial nerve.

Solen kempi, Preston.

1915. *Solen kempi*, Preston, *Rec. Ind. Mus.* XI, p. 305, figs. 18, 18a.

1916. *Solen kempi*, Annandale and Kemp, *Mem. Ind. Mus.* V, p. 355.

1916. *Solen annandalei*, *id.*, *ibid.*, pl. xvi, fig. 8.¹

Animal (pl. II, figs. 1-5). The body is five times longer than broad, being deepest somewhat behind the anterior end. The anterior margin is curved above and straight below. The posterior

¹ Dr. Annandale informs me that the figures on the plate have been accidentally transposed owing to incorrect labels received from the author of the species.

margin is straight. The dorsal margin is slightly concave in front and slightly convex behind. The siphon is long and segmented, but missing in the specimen as "it threw it off when captured" (Dr. N. Annandale's note). The surface of the distal end of the branchial siphon presents six small prominences. The pedal aperture is confined to the anterior margin and the antero-ventral notch. It is bounded by the pedal valves, with a small tentacle-like process from the dorsal aspect where the pedal valves meet.

The foot is long, somewhat flattened, and is shaped like the blade of a scalpel from the side; it is about half the body in length, and is more thickened in the middle than at either end.

The anterior adductor muscle is very long, five times as long as deep. The posterior adductor muscle is wide and slightly elongated.

The labial palps are narrow and greatly elongated, being somewhat wide posteriorly and tapering to a curved point behind.

The gills are elongated, about five times as long as broad, and more than one-third the body in length. The visceral portion of the gills is very small.

The oesophagus is fairly long and curved. The stomach has a well developed cardiac and pyloric portion, the latter forming a distinct cul-de-sac beyond the crystalline style. The intestine arising from the anterior end of the pyloric chamber soon forms a number of close coils and then passes round the long coecum forming loose folds in its posterior limb. It forms a round loop before ending in the rectum. The digestive gland surrounds the stomach and the beginning of the intestine.

The heart is placed in the middle of the pericardial chamber.

Considering the general structure of the body, the animal is evidently more elongated in its anterior than in its posterior portion, the effect being impressed upon all the organs in that part of the body.

Solen sp.

A single specimen was received from the Zoological Survey of India. It was brought by Dr. N. Annandale from Moji, Japan.

Animal. The body is about five times as long as broad (6.4 cm. long), with the posterior end slightly deeper than the anterior. Both the anterior and posterior margins are straight, the anterior sloping forwards. The pedal aperture is confined to the anterior margin. The siphon is very short and completely retractile inside the shell. The branchial aperture is much wider than the anal, and presents a pair of small valves at its proximal end. A longitudinal ridge extends from the ventral aspect of the proximal portion of the branchial siphon to the fused ventral margin of the mantle, with a second smaller one beneath and parallel to it.

The anterior adductor muscle is elongated, but not so narrow. The posterior adductor muscle is small and oval. The retractor pedis posterior muscle is elongated and larger than the posterior adductor muscle at its insertion.

The foot is comparatively short but wide with a free anterior oblique surface presenting a vertical ridge; it is flattened from side to side and is widest at the junction of the anterior and middle thirds of its length; lastly, it presents an oval patch of transverse folds on its ventral surface posteriorly.

The labial palps are triangular, being about one-fourth the body in length. The gap between the anterior lip and the anterior adductor muscle is comparatively short.

The gills are about half the body in length, and are about five times as long as broad; they are prolonged to the base of the labial palps; the visceral portions of the gills are about as long as the cloacal portion. The lamellae are separated by long interlamellar septa extending alternately between the principal filaments, and the plicae of both the lamellae are free from one another.

The oesophagus is short and nearly horizontal. The oesophageal stomach is narrow and elongated, and separated from the flattened cardiac chamber by a prominent muscular ridge. The pyloric chamber is wide and extends posteriorly beyond the coecum as a rounded sac. The coecum of the crystalline style is long and extends forwards along the ventral aspect of the visceral mass. The intestine begins close to the pyloric coecum and passes along the anterior aspect of the coecum forming loosely coiled folds. Without reaching the anterior end of the coecum, the intestine turns back and passes along the right side of the coecum to end in the rectum with a sharp bend.

Shell. Thick, strong, epidermis yellowish, with wide vertical flesh-coloured stripes above and long indistinct horizontal stripes of the same colour below the diagonal line from the antero-superior to the posterior inferior corner. Epidermis slightly corroded in its posterior upper quadrant. Length 4 to $4\frac{1}{2}$ times as long as broad. Greatest width near the posterior end. Anterior margin straight, sloping forwards from above, with the antero-superior angle obliquely truncate, and the antero-inferior angle slightly rounded. Posterior margin nearly straight, sloping backwards from above, and strongly rounded above and below. Umbonal teeth anterior, one in each valve, left tooth slightly stouter than the right.

Anterior adductor impression wide, elongated. Anterior retractor at a short distance behind and above the level of the anterior adductor. Posterior adductor impression small and oval. Posterior retractor triangular, smaller than posterior adductor. Retractor siphonis impression elongately oval.

Length 64 mm. Breadth 15 mm.

Solen gravelyi, sp. nov.

(Pl. II, figs. 6-9).

Three specimens of this species were collected by Dr. F. H. Gravely at Chandipore, Balasore (Orissa).¹ They seem to form a

¹ See Gravely, *Rec. Ind. Mus.*, XVI, p. 395 (1919).

new species which is named in honour of the collector. The description of the shell will follow the notes on the animal.

Animal. The body is 5 to 6 times as long as broad, nearly straight both anteriorly and posteriorly, being somewhat sloping in front. The anterior free margins of the mantle lobes bounding the pedal aperture are thick and muscular, and present a groove on their outer surface which receives a constriction of the valve just behind the anterior margin. The pedal aperture extends to the antero-ventral corner, and is slightly dorsal to the anterior end of the anterior adductor muscle. The ventral surface of the mantle is elongated and very narrow; it presents a median band along the middle line. The siphon is short and presents a longitudinal ribbing on the surface.

The anterior adductor muscle is long and narrow, and is slightly curved. The posterior adductor muscle is small and oval. The retractor pedis posterior muscle is smaller than the posterior adductor muscle at its insertion. There is a well-developed retractor siphonis muscle. The foot is a comparatively short cylindrical organ slightly flattened laterally and presents a knob-like swelling which ends in a blunt point at the free extremity.

The labial palps are narrow and elongated, less than one-fourth the body length.

The gills are very long and narrow, 9 to 10 times as long as broad. They are half as long as the body, and are prolonged over the dorsal aspect of the labial palps; the visceral portion of the gills is less than half their entire lengths. The inner lamella of the inner gill is free in the visceral portion. In the cloacal portion the inner lamella of the inner gills are free from each other—differing in this respect from the other species of *Solen* and resembling those of *Ensis*.

The oesophagus is long. The anterior limb of the intestine is simple, but the posterior limb presents loose folds posteriorly before it forms a loop for ending in the rectum.

Shell. The shell is very thin, translucent, very brittle, with a whitish epidermis somewhat corroded in its upper anterior quadrant; length about 4 to 5 times the breadth; anterior margin nearly straight and directed from above a little forward with a rounded antero-superior and antero-inferior corner; a strongly marked constriction just behind and parallel to the anterior margin; posterior margin straight or slightly convex, nearly vertical. Umbonal teeth anterior, one in each valve.

Anterior adductor impression narrow and elongated, with tapering ends. Anterior retractor impression very small, behind the anterior adductor. Posterior adductor impression small and oval, at a distance from the postero-superior angle. Posterior retractor impression rounded in front of the posterior adductor and smaller than the latter.

Length 16 mm. Breadth about 4 mm.

Type-specimen : M. 11658 Z.S.I. (*Ind. Mus.*).

Comparing the general conformation of the body of the three species under consideration we find that in *S. kempi*, Preston, the elongation has far more affected the anterior than the posterior portion of the body, and that in *S. gravelyi* the anterior and the posterior portions are perhaps equally affected in the process. In *S. sp.* from Japan the posterior portion of the body is comparatively more elongated than the anterior.

Although a large number of species of *Solen* have been described from their shells, only a few are known by their animals.

Considering the few species described by Bloomer and three species of mine, it is premature, at the present moment, to attempt to group the various species of *Solen* into sections according to the conformation of their soft parts. And the anatomical conditions may, if possible, be further co-related with the peculiarities of the shells. For the present, a division of the above species into sections may be provisionally suggested as follows:—

Section I. Body elongated equally both anteriorly and posteriorly.

Types: *S. vagina*, *S. gravelyi*.

Section II. Body elongated more anteriorly than posteriorly.

Type: *S. kempi*.

Section III. Body elongated more posteriorly than anteriorly.

Types: *S. sp.* from Japan, *S. dolerscoti*.

Subgen. *Solena*, Browne (1756).

1854. *Hypogella*, Gray, *Ann. Mag. Nat. Hist.* (2) XIV, p. 23.

1858. Subgen. *Solena*, Browne, Adams, *Gen. Recent Mollusca*, II, p. 342.

1887. Sect. *Hypogella*, Gray in Fischer, *Man. de Conch.* p. 1110.

The anatomy of *Solena rudis*, Adams, has been studied by Bloomer (11). The anatomical peculiarities in which it differs from the species of *Solen* have sufficient grounds for ranking the present animal as the type of a subgenus already erected for it. The following diagnosis has been drawn from Bloomer's anatomical work on *S. rudis*:—

Animal. Body elongated with rounded anterior and posterior margins. Pedal aperture confined to the anterior margin and guarded by pedal valves. Siphon a single piece. A pair of valves in the proximal portion of the siphon in both the apertures. Anterior adductor muscle broad and deep (more or less oval in shape). Posterior adductor muscle of the same size, being much larger than the retractor pedis posterior muscle at its insertion. Foot more or less flattened, but somewhat swollen towards the distal end. Fibres of the retractor pedis anterior muscle passing between the longitudinal muscles and the pedal integument. Labial palps relatively short and wide, the anterior lip being separated from the posterior end of the anterior adductor muscle by a short interval. Gills heterorhabdic and plicate, alternate inter-

lamellar septa extending half way up the gill. Coecum of the crystalline style arising as a posterior continuation of the pylorus, large in size, very curved and comparatively short in its course. Intestine like that of *Solen* with an additional large loop before it ends in the rectum. Heart posterior. The general conformation of the body distinctly shows that the body has been elongated in its posterior portion, perhaps beyond the posterior end of the visceral mass, the remaining anterior portion being affected to a minimum. The maximum of elongation has taken place in that portion of the body which lies behind the posterior adductor muscle.

Gen. *Neosolen*, gen. nov.

1916. *Solen?* *fonesi*, Annandale and Kemp, *Mem. Ind. Mus.* V, p. 354, fig. 5, pl. xvi, fig. 7.

1916. *Solen?* *fonesi*, Ghosh, *ibid.* p. 368, figs. 1-3.

The present genus is erected for the reception of a species which was doubtfully thought to be a dwarfed form of *Solen fonesi*, Dunker. The fairly complete literature at my disposal shows that it ought to be referred to a genus of its own. I propose for the species the name *Neosolen aquae-dulcioris*. The following diagnosis is drawn from my anatomical notes (28) and from a further examination of spirit specimens:—

Animal. Body 3 to $3\frac{1}{2}$ times as long as broad, sloping anteriorly at both the anterior and posterior margins; anterior margin slightly curved. Pedal aperture confined to the anterior margin and antero-ventral corner. Thick anterior margins of the mantle lobes extending beyond the anterior margin of the valves. Concreted ventral margins of the mantle lobes forming a narrow surface. Siphon a long segmented piece, each segment with a tentacular fringe round its distal margin. Anterior adductor muscle elongated and narrow, with a short space between it and the upper end of the pedal aperture. Posterior adductor muscle oval, of smaller size than the retractor pedis posterior muscle at its insertion. Foot elongated, cylindrical, slightly flattened laterally; it is stouter towards the apex, where it forms a distinct rounded annular swelling and still further a conical process at the tip. Fibres of the retractor pedis anterior muscle passing between the longitudinal muscles and the pedal cavity. Labial palps short and broad, subtrigonal, and about one-fourth the body length. Anterior lip immediately behind the anterior adductor muscle, with no interval between the two. Gills short and deep, $3\frac{1}{2}$ to 4 times as long as broad and more than half the body in length, just continued into the proximal portion of the branchial canal; visceral portion nearly as long as the cloacal; gills broadly plicate and sub-heterorhabdic, with inter-plical junctions. Attachment of gills similar to those in *Solen*. Coecum from the postero-ventral aspect of pylorus and passing forward in its long course. Heart pushed forward into the anterior portion of the pericardial chamber by the outgrowths of the kidneys which constrict the middle portion of the pericardium.

Viscero-parietal ganglia placed beneath the bifurcation of the retractor pedis posterior muscle.

The general conformation of the body shows that the present animal is considerably abbreviated antero-posteriorly in comparison with that of the species of *Solen*. The process of elongation has mainly affected the posterior region of the body behind the posterior adductor muscle and a small anterior region including the anterior adductor muscle. The animal is evidently more primitive than the species of *Solen*. It is quite suggestive that the type of body in *Solen* might have passed in evolution through a stage more or less resembling the present genus in descending from a still more abbreviated type of ancestor.

Type-specimen: No. M. $\frac{2981}{2}$ Z.S.I. (*Ind. Mus.*).

FURTHER NOTES ON THE ANATOMY OF *N AQUAE-DULCIORIS*,
sp. nov.

Gills. The gills are plicate and heterorhabdic. The principal filament is somewhat flattened laterally and is slightly different from the ordinary filaments. The interlamellar septa extending between the principal filaments are very short bringing the lamellar closer to each other. The plicae themselves are also connected with one another antero-posteriorly by interplicar tissues.

The oesophagus is nearly horizontal with a slight curve having its convexity directed upwards. The wide oesophageal stomach is separated from the cardiac stomach, extending beyond the former in front by a thick prominent horizontal fold. The pyloric stomach does not extend beyond the coecum of the crystalline style posteriorly. The central stomach is triangular in shape and is separated from the cardiac and pyloric chambers by a ridge continuous with that in front.

The shell was described and figured in the paper cited above.

Gen. *Ensis*, Schumacher.

- 1782-93. *Solen* (pars), Linné, *Syst. Nat.* ed XIII, edited by Gmelin.
 1817. *Ensis*, Schumacher, *Essai d'un. Nov. Syst. des Habit. des vers Testacé*, pp. 47, 143, pl. xiv, fig. 1.
 1840. *Ensatella*, Swainson, *Tr. Malac.* p. 365.
 1858. *Ensis*, Schumacher in Adams, *Gen. Recent Mollusca*, II, p. 342 ; III, pl. xcii, figs. 2, 2a, 2b.
 1887. *Ensis*, Schumacher in Fischer, *Man. Conch.*, p. 1110.
 1889. *Solen* (pars), Clessin in Martini and Chemnitz, *Conch-Cab.*, pp. 10, 14, pl.

The genus has been studied by Bloomer (5) who described the anatomy of *Ensis ensis* with full details and later on compared it with several other species (11, 12, 13). Drew (25) briefly noticed the animal of *E. directus*. He figured the siphon and the ventral aspect of the animal and gave a schematic transverse section of the body showing the attachments of the gills not fully dealt with by Bloomer. The following diagnosis is drawn from the researches of Bloomer and Drew :—

Animal. Body narrow and greatly elongated. Pedal aperture either confined to the anterior margin, or extending posteriorly

along the ventral margin for a short distance. A fourth aperture and labial grooves present. Siphon of a single piece, comparatively short, and with a tentacular fringe. Anterior adductor muscle elongated, but not very narrow. Posterior adductor muscle less elongated. Retractor pedis posterior muscle much smaller than the posterior adductor muscle at its insertion. Foot narrow and elongated, somewhat flattened laterally and swollen and keeled at the anterior extremity. Fibres of the retractor pedis anterior muscle spread on the inner side of the longitudinal muscle. Anterior lip separated from the anterior adductor muscle by a long interval. Gills elongated, heterorhabdic and plicate, the plicae being free from one another; gills extending into the siphon. Outer lamella of the outer gill attached to the mantle lobe along their dorsal margin. Inner lamella of the inner gill attached to the side of the foot along its dorsal margin, but free behind in the cloacal region. Coecum of the crystalline style short and extending postero-ventrally from the posterior end of the pyloric chamber. Intestine of *Ensis* sub-type. Digestive gland extending over the anterior adductor muscle. Heart in the middle of the pericardial chamber. Viscero-parietal ganglia beneath the bifurcation of the retractor pedis posterior muscle. Two nerves from each cerebo-pleural ganglion. Two circumpallial nerves.

The structure and general conformation of the animal distinctly show that the members of the present genus have attained the greatest degree of elongation and are greatly removed from the ancestral stock.

Gen. *Ceratisolen*, Forbes.

1847. *Pharus*, Leach, *Ann Mag. Nat. Hist.* XX, p. 272.
 1848. *Ceratisolen*, Forbes and Hanley, *A History of British Mollusca and their shells*, p. 259.
 1858. *Pharus*, Leach in Adams, *Gen. Recent Mollusca*, II, p. 343; III, pl. 92, fig. 3, 3a, 3b.
 1874. *Pharus*, Leach in Reeve, *Conch. Icon.*, XIX, fig. 1.
 1887. *Pharus*, Leach in Fischer, *Man. Conch.*, p. 1108.

The anatomy of *C. legumen* L. has been studied by Bloomer (8, pp. 31-40). The following diagnosis has been drawn up from his work:—

Animal. Body moderately elongated (comparatively shorter than that of *Solen* or *Ensis*), nearly straight along the anterior and posterior margins. Pedal aperture extending a short distance along both the ventral and dorsal aspects. A chamber above the anterior adductor muscle opening in front and continuous with the pedal aperture. A fourth aperture at the postero-ventral end of the pedal aperture continuous with it and fringed with tentacles. Siphon of two long and narrow separate tubes. Anterior adductor muscle elongated. Posterior adductor muscle placed rather posteriorly and comparatively small. Retractor pedis posterior muscle much smaller than the posterior adductor muscle at its insertion; bifurcated portions long. Foot large, conical or club-shaped, truncate. Fibres of the retractor pedis anterior muscle passing outside the longitudinal muscle. Labial palps short and wide.

Anterior lip close behind the anterior adductor muscle. Gills small and narrow, non-plicate and homorhabdic. Attachments of gills similar to those in *Solen*. No division into oesophageal and cardiac chambers. Coecum of the crystalline style from the anterior portion of the ventral aspect of the pyloric chamber. Intestine of two simple limbs. Digestive gland passing over the anterior adductor muscle. Heart placed in the middle of the pericardial chamber, blood red. A single circumpallial nerve.

The anatomical researches of Bloomer on *Ceratisolen* has disclosed some facts which help to determine the relation of *Ceratisolen* with other genera of the family. The general conformation of the body shows that the animal is less elongated than *Ensis* and *Solen* but more so than *Neosolen*, *Subcultellus* and *Cultellus*; the position of the posterior adductor muscle near the hinder end of the body is certainly compatible with the view that the posterior end has not elongated behind the attachment of the muscle. The genus, however, resembles the genus *Subcultellus* (*Cultellus pellucidus*) most closely in having a fourth aperture in continuation of the pedal aperture (a condition of great morphological importance), and in several other points, viz. in the separation of siphonal tubes, attachments of gills, relation of the pedal fibres of retractor pedis anterior muscle with the longitudinal layer of muscles, and in the direction of the coecum of the crystalline style, but differs from the latter in having simple, non-plicate gills, in the position of the heart and digestive gland. Differing from *Ensis* in the attachments of the gills, arrangement of the pedal fibres of the retractor pedis anterior muscle, direction of the coecum and its mode of origin, and in the presence of a single circumpallial nerve, the genus cannot be assigned an intermediate stage between *Ensis* and *Subcultellus*, giving origin to the former genus by the fusion of the siphonal tubes and separation of the fourth aperture. It, however, resembles the genus *Ensis* in the extension of the digestive gland over the anterior adductor muscle, a character absent in *Subcultellus* but present in *Cultellus*. Thus it obviously follows that although the genera *Ceratisolen* and *Subcultellus* are more or less related to each other and to *Ensis* on the one hand and *Cultellus* on the other, they cannot be considered to form a connecting link between the above genera in the direct line of ancestry but to represent diverging offshoots from the same stock.

Gen. *Subcultellus*, gen. nov.

- 1810. *Cultellus* (pars), Schumacher, *Essai Nouv. Syst. Habit. des Vers. Testacé*, pp. 43, 130, pl. vii, fig. 4.
- 1835. *Solen pellucidus*, Pennant, Lamarck, *Hist. Nat. Anim. Sans Vert.*, VI, p. 56.
- 1851. *Ensis pellucidus*, Pennant in Gray, *Cat. Brit. Mus.*, VII, p. 60.
- 1858. *Ensis* (pars), Adams, *Gen. Recent Moll.*, II, p. 342.
- 1874. *C. pellucidus*, Pennant in Reeve, *Conch. Icon.*, fig. 4.
- 1887. *Cultellus*, Schum. (pars), Fischer, *Man. Conch.*, p. 1, 109.
- 1889. *Cultellus*, Schum. (pars), Clessin in Martini-Chamnitz, *Conch. Cab. (Solanacea)*, XI, p. 38.

The present genus is erected for the reception of *Solen pellucidus*, Pennant (*Zool. Brit.* IV, pl. 46, fig. 23). The anatomy of *Solen (Cultellus) pellucidus* (7) and of two species of *Cultellus* [*C. javanicus* (11), *C. cultellus* (16)] has been described by Bloomer (7, 11, 16). I have been able to study the animal of *C. subellipticus*, Dunker. The animal of *C. pellucidus* differs from those of the other three species in having a fourth aperture, a suprapedal chamber, an elongated anterior adductor muscle, very small posterior adductor muscle, a wedge-shaped foot, a large coecum with a long course, and lastly in having no fringe of long tentacles round the distal margin of the siphonal tubes. These features, along with an elongated body, are sufficient to split the genus *Cultellus* into two, and I suggest to form a new genus *Subcultellus* for *Cultellus pellucidus*. The relation of *Subcultellus* with *Ceratisolen* has already been dealt with. The present diagnosis is drawn from Bloomer's work.

Animal. Body somewhat elongated (more than *Cultellus*). Pedal aperture large, extending both dorsally and ventrally to some distance posteriorly. Margins of pedal aperture crenulate. A chamber formed dorsally by the union of the mantle lobes a little below their margins. A fourth aperture at the postero-ventral end of the pedal aperture. Siphons separate, with very short anal and branchial tubes. Anterior adductor muscle elongated, wider posteriorly than anteriorly. Posterior adductor muscle very smooth, but larger than retractor pedis posterior muscle at its insertion. Foot large, wide anteriorly and terminating in a deep obliquely truncate extremity. Fibres of the retractor pedis anterior muscle passing outside the longitudinal layers of muscles. Gills similar to those in *Solen*. Anterior lip of mouth immediately behind the anterior adductor muscle. Pyloric chamber very large, coecum of the crystalline style very wide proximally and arising from the ventral aspect of the pylorus; it is of considerable length extending along the greater portion of the visceral mass. Intestine of two simple limbs. Digestive gland not extending over the anterior adductor muscle. Heart at the anterior end of the pericardial chamber.

Gen. *Cultellus*, Schumacher.

- 1782-93. *Solen* (pars), C. A. Linné, *Syst. Nat.*, ed. XIII, pp. 3223, 3224.
 1817. *Cultellus*, Schumacher, *Essai Nouv. Syst. Habit. des Vers Testacé*, pp. 43, 130, pl. vii, fig. 4.
 1835. *Solen Cultellus*, Lin. and *S. javanicus*, Lamk., Lamarck, *Hist. Nat. Anim. Sans. Vert.*, VI, pp. 56, 58.
 1858. *Cultellus*, Schum., Adams, *Gen. Recent Moll.*, II, p. 344; III, pl. xciii, figs. 2, 2a.
 1858. *Pharella*, Gray (pars), (*Solen javanicus*, Lamarck) *id.*, *ibid.*, II, p. 344, pl. xciii, figs. 1, 1a, 1b.
 1887. *Cultellus*, Schum., Fischer, *Man. Conch.*, p. 1109.
 1889. *Cultellus*, Schum., Clessin, Martini-Chernitz, *Conch. Cab.*, XI (*Solenacea*), p. 36.

Animal. Body comparatively short. Anterior and posterior ends tapering and rounded. Pedal aperture extending beyond the anterior margin both dorsally and ventrally (nearly to half the ventral margin). No fourth aperture. Siphons separate, very short, fringed with long tentacles which extend to the adjacent fused mantle margins. Anterior adductor muscle slightly elongated. Posterior adductor muscle rounded or oval, placed backward due to the elongation of the retractor pedis posterior muscle. Retractor pedis posterior muscle very small at its insertion. Foot elongated, compressed laterally and of uniform depth; free anterior end truncate obliquely. Retractor pedis anterior muscle not bifurcated. Fibres of retractor pedis anterior muscle spreading irregularly both inside and outside the longitudinal muscles. Labial palps short, wide and triangular. Anterior lip immediately behind the anterior adductor muscle. Gills heterorhabdic and broadly plicate, plicae connected by interplicar tissues; gills short and wide, visceral portions much shorter than the cloacal. Outer lamella of the outer gills free dorsally. Inner lamella of the inner gill free dorsally in the visceral portion, but united with its fellow of the opposite side below the cloacal chamber. Pyloric stomach very large. Coecum arising from the postero-ventral aspect of the pylorus, very short and passing ventrally and slightly anteriorly with a curve. Limbs of the intestine with closely formed folds at their junction. Digestive gland passing to the anterior adductor muscle. Heart occupying nearly the entire length of the short pericardial chamber.

***Cultellus subellipticus*, Dunker.**

1861. *C. subellipticus*, Dunker, *Proc. Zool. Soc.*, p. 421.

1874. *C. subellipticus*, Dunker, Reeve, *Conch. Icon.*, XIX, fig. 9.

1889. *C. subellipticus*, Dunker, Clessin, Martini-Chemnitz, *Conch. Cab.*, XI (*Solenacea*), p. 43.

Animal. The body is comparatively short, about twice as long as broad, rounded at both ends, and somewhat tapering anteriorly. The pedal aperture extends anteriorly to the antero-dorsal aspect of the anterior adductor muscle and ventrally beyond the antero-ventral corner to the level of the posterior end of the anterior adductor muscle. The siphons are very short and separate; there is a row of small tentacles round the anal and branchial apertures and a row of large tentacles round them. The anterior adductor muscle is broadly oval and comparatively small. The posterior adductor muscle is slightly elongated. The labial palps are short, triangular and tapering to a point postero-ventrally. They are about one-fourth the body in length. The foot is slightly longer than half the body and about twice as long as broad. The retractor pedis anterior muscle is short and is directed upwards and slightly forwards.

The gills are broad, about half the body in length and $2\frac{1}{2}$ to $2\frac{3}{4}$ times as long as broad. They are broadly plicate. The lamellae are closely applied to each other and are connected by extensive

interlamellar tissue only leaving spaces inside the plications. The plicae are connected with one another by interplicar tissues and the surface of the gills is covered over by a thin membrane.

The oesophagus is horizontal and short. Cardiac stomach extending slightly in front beyond the oesophageal portion. Pyloric stomach not protruding posteriorly beyond the origin of the coecum. Coecum of the crystalline style short and tapering at the distal extremity. The anterior limb of the intestine forming a few closely placed coils near the junction with the posterior limb which is simple and presents a wide loop above before it ends in the rectum.

Genus *Pharella*, Gray.

1854. *Pharella*, Gray, *Ann. Mag. Nat. Hist.* (2) XIV, p. 24.
 1858. *Pharella*, Gray, Adams, *Gen. Recent Moll.*, II, p. 343.
 1887. *Pharella*, Gray, Fischer, *Man. Conch.*, p. 1108.

The animal of a single species of *Pharella* (*P. orientalis*, Dunker)¹ is known through the researches of Bloomer (10). The following diagnosis is drawn from his paper:—

Animal. Body somewhat elongated. Pedal aperture extending over the anterior adductor muscle dorsally and along the ventral margin still further posteriorly. No fourth aperture. Siphons separate, consisting of short anal and branchial tubes, fringed with tentacles. Anterior adductor muscle large and nearly rounded. Posterior adductor muscle large and rounded. Foot large, compressed and abruptly truncate in front. Retractor pedis anterior muscle not bifurcated; its fibres passing inside the longitudinal muscles of the foot. Retractor pedis posterior muscle connected with the posterior adductor muscle. Labial palps short, wide and angular. Anterior lip separated from the anterior adductor muscle by a short interval. Gills elongated, narrow, heterorhabdic and plicate. Coecum of the crystalline style directed forward from the ventral aspect of the pylorus. Intestine of two simple limbs. A single nerve from each cerebro-pleural ganglion. Viscero-parietal ganglia under the posterior adductor muscle, each giving off a branchial and a pallial nerve. Heart towards the anterior end of the pericardial chamber.

The anatomical features of the present animal distinctly show that it is elongated in the middle region of the body between the two adductor muscles. Allowing for the necessary changes consequent upon this elongation, this genus is related to *Cultellus* which seems to be more primitive than the present one in many respects.

Genus *Siliqua*, Mühlfeldt.

1811. *Siliqua*, Mühlfeldt, *Magazin d. Ges. naturf. Fr. Berlin*, V (1), p. 38.
 1817. *Leguminaria*, Schumacher, *Essai Nouv. Syst. Habit. des Vers Testacé*, pp. 42, 126, pl. vii, fig. 1.

¹ *Solen orientalis*, Dunker, *Proc. Zool. Soc. Lond.*, p. 423 (1861). *Cultellus orientalis*, Clessin in Martini-Chemnitz, *Conch. Cab.*, XI, p. 46.

1858. *Siliqua*, Mühlf., Adams, *Gen. Recent Moll.*, II, p. 345.
 1870. *Manchaera*, Gould, *Report on the Invertebrata of Mass.* (2nd Edition), p. 46, fig. 369.
 1887. *Siliqua*, Mühlf., Fischer, *Man. Conch.*, p. 1109.
 1889. *Manchaera*, Gould, Clessin in Martini-Chemnitz, *Conch. Cab.*, XI (*Solenacea*), p. 57.

The anatomy of two species of *Siliqua* has been studied by Bloomer (13). The following diagnosis is drawn from his researches:—

Animal. Body elongated (but shorter than *Solen* and *Ensis*), 2 to 3 times as long as broad. Anterior and posterior margins more or less rounded. Entire margin of each mantle lobe fringed with a thin narrow membrane. Pedal aperture extending above to the anterior end of the adductor muscle, and below about half-way along the ventral margin. Siphon a single piece, wide and comparatively short. A muscular ridge inside each mantle lobe a short distance dorsal to the fused ventral margins. A strong siphonal retractor muscle. No fourth aperture. Anterior adductor muscle short and deep. Posterior adductor muscle slightly elongated and deep. Retractor pedis posterior muscle very small in comparison with the posterior adductor muscle at its insertion. Foot elongated and cylindrical, dilate and truncate obliquely at the extremity. Fibres of the retractor pedis anterior muscle passing partly into the pedal integument and partly inside the longitudinal muscle. Labial palps elongated and tapering. Anterior lip placed immediately behind the anterior adductor muscle. Gills broad and comparatively short, homorhabdic and non-plicate, reaching the wall dividing the siphonal chambers. Attachments of gills like *Solen*. Pyloric stomach very large. Coecum of the crystalline style arising from the ventral side of the pyloric chamber at its posterior end, large and directed towards the front. Intestine like *Solen*. Digestive gland not reaching the anterior adductor muscle. Heart in the middle of the pericardial chamber. A single nerve from each cerebro-pleural ganglion. Viscero-parietal ganglia situated between the bifurcation of the retractor pedis posterior muscle, with a branchial and a posterior pallial nerve from each ganglion.

The anatomical peculiarities of the present genus tend to show that the animals are in many respects more primitive than the other members of the subfamily.

Subfam. *NOVACULININAE*, nov.

The present subfamily is made to include the single genus *Novaculina*, Benson. It seems to be greatly removed from and more primitive than the other two subfamilies.

Animal. Body comparatively short and deep, widened out laterally, about twice as long as broad, straight anteriorly, and concave posteriorly. Pedal aperture extending ventrally as a deep wide notch at the antero-ventral corner, not extending dorsally. Fused ventral margins of the mantle lobes forming a very wide

surface and traversed by numerous transverse bands of muscle. No cruciform muscle. Siphonal tubes completely separate from each other. A wide siphonal space posteriorly. A very short stout foot with a disc-like anterior end projecting forwards and downwards. Retractor pedis anterior muscle bifurcated with the bands passing upward and backward. Gills simple, homorhabdic and non-plicate. Outer lamella of the outer gill attached dorsally to the mantle lobe. Intestine of several long loops. Heart in the middle of the pericardial chamber. Viscero-parietal ganglia beneath the bifurcation of the retractor pedis posterior muscle.

Novaculina gangetica, Benson.

(Pl. III, fig. 20-23).

1830. *Novaculina*, Benson, *Glean. Science, Calcutta*, II.
 1858. Subgen. *Novaculina*, Benson (Gen. *Siliquaria*, Schumacher), Adams, *Gen. Recent. Moll.*, II, p. 347.
 1874. *Solecirtus novaculina*, Benson sp., Reeve, *Conch. Icon.*, XIX, fig. 31 a, b.
 1887. Subgen. *Novaculina* (Gen. *Solecirtus*), Fischer, *Man. Conch.*, p. 1, 107.
 1889. *Tagelus gangeticus* (pars), Benson sp., Clessin, Martini-Chemnitz, *Conch. Cab.*, XI (*Solenacea*), p. 81.

Animal. The body is about three times as long as broad, widest in the vertical line of the antero-ventral notch. The anterior margin is nearly vertical with a deep notch at the antero-ventral corner; it does not project beyond the anterior margin of the shell. The pedal aperture is somewhat oblique and extends to the antero-ventral corner. The dorsal margin is convex in front and concave behind. The fused ventral margins form a wide surface, in breadth about one-third the body length; the surface is slightly convex in front and concave behind. The siphons consist of two separate anal and branchial tubes connected proximally with the posterior margins of the mantle lobes, through the intervention of lateral flaps. The branchial siphon is longer and stouter than the anal, being one-half to one-third the body length; the surface of both the siphons is finely ribbed, but not segmented. The apertures are constricted and without tentacular fringe. A circular space is formed round the base of the siphonal tubes and enclosed by the mantle lobes and the lateral flaps from them. This space, named the *siphonal space*, is mentioned by Weber (50, p. 280) to extend halfway between the base of the upper siphonal tube and the posterior adductor muscle. The siphons do not seem to be completely retractile inside the shell.

The anterior adductor muscle is elongated and obliquely pyriform. The anterior limb of the retractor pedis anterior muscle is placed behind the anterior adductor muscle. The posterior adductor muscle is elongated with a notch on the postero-dorsal aspect in which is lodged the retractor pedis posterior muscle. The siphonal muscle is a thick sheet, elongated and trapezoidal in shape.

The labial palps are shaped like an equilateral triangle, the outer one extending slightly more ventralwise than the inner. A

side of the palp is five times smaller than the body length. The anterior and posterior lips are comparatively wide (deep).

The gills are elongated, about half the body in length and thrice as long as broad. The inner gill extends a little further forward beneath the labial palps and slightly below the outer one along the antero-ventral margin. The gills do not extend into the branchial siphon. The visceral portion of the gills is of the same length as the portion behind. Owing to the widening out of the body from side to side, and along with it the visceral mass, the gills are directed more or less outward from their dorsal attachments. The visceral portion of the inner gill is free along its dorsal margin. The gills are simple and non-plicate, but they are capable of much folding posteriorly owing to the presence of well-developed branchial retractor muscles.

The foot is short and stout, slightly flattened from side to side and is about one-fifth the body in length. The free end is somewhat dilated to form a disc-like expansion more or less concave on the surface which presents a vertical ridge. The plane of the surface is oblique to the long axis of the foot [at right angles according to Preston (40)], which is directed forward and slightly downward from the visceral mass. The retractor pedis anterior muscle has a short and slender anterior and a stout long posterior limb, both passing upward and backward. The fibres form a thick strand in the dorso-lateral aspect of the foot posteriorly, but spread out anteriorly on the inner side of the inner longitudinal muscle-layer. The bifurcations of the retractor pedis posterior muscle are rather short. The protractor pedis muscle is wanting. The inner longitudinal layer is much thicker than the outer. The semi-circular layers are not so thick. The muscles of the pedal integument are well-developed with numerous strands of oblique muscles passing inward from the layer. Transverse muscle strands extend through the entire depth of the foot, passing to the semi-circular layers. At the distal end of the foot the longitudinal muscles are separated into distinct bundles by the branching of the semi-circular muscles and by the transverse muscles thus forming a close network.

The oesophagus is short, flattened dorso-ventrally, and is horizontal in its course. The stomach is a wide irregular cavity and differs greatly from that of the other members of the family. The oesophageal stomach is a wide cavity receiving the oesophagus on its dorsal aspect and extending in front beyond the opening of the oesophagus. It is placed towards the right side of the body. The cardiac stomach is smaller than the oesophageal chamber lying towards the left side of the visceral mass and pushing the oesophageal stomach to the right. The central cavity is a small chamber on the left side, separated by a vertical ridge from the cardiac stomach in front and by a curved ridge from the pyloric chamber behind. The pyloric stomach is a large rounded sac extending posteriorly behind the origin of the coecum. The coecum of the crystalline style arises from the antero-ventral aspect of the pyloric

chamber on the left side and passes forward and downward to reach the base of the foot, gradually shifting to the middle line in its course. The intestine begins from the right side of the pylorus close to the origin of the coecum of the crystalline style. The intestine immediately after its origin forms a number of closely placed coils and then passes forward along the dorsal aspect of the coecum to the base of the foot. It then turns backwards and passes in the same direction along the left side of the dorsal aspect of the coecum to the dorsal aspect of the visceral mass between its left wall and the stomach, where it sharply bends downward and forward to pass along the left side of the coecum to reach the base of the foot again. Lastly, it curves backward and passes along the right side to reach the posterior and dorsal aspect of the visceral mass, where it forms a broad loop to end in the rectum. The rectum has its usual course. The digestive gland surrounds the stomach but does not reach the anterior adductor muscle.

The glandular sac of the kidney is placed on the ventral aspect and then on the outer side of the non-glandular sac, extending backward to the posterior adductor muscle and lying beneath the retractor pedis posterior muscle and its bifurcation. Posteriorly from the glandular sac a big diverticulum is given off, which in its forward course gives origin to another small sac interpolated between itself and the glandular sac. The non-glandular sac in its backward course lies at first between the venacava and the pericardium in contact with its fellow of the opposite side, but separated from it in its further course by the venacava coming in contact with the pericardium. There is an interrenal aperture between the two non-glandular sacs.

The visceroparietal ganglia are placed beneath the bifurcation of the retractor pedis posterior muscle. The pedal ganglia are placed in the visceral mass just above the junction of the dorsal and ventral halves and at a distance from the base of the foot nearly equalling its long axis.

The gonads extend along the side of the stomach to the dorsal aspect of the oesophagus.

The anatomical study of the animal distinctly shows that the genus is more primitive than the members of the other two subfamilies. Further, the animal seems to be secondarily modified as shown from its flattening in the dorso-ventral direction. The short stumpy foot with a disc-like flattened surface is certainly an indication of its primitive nature.

Subfam. SOLECURTINAE.

1858. Subfam. Pharinae (pars), Adams, *Gen. Recent Moll.*, II, p. 342.
1862. Siliquaria (pars), Bronn, *Thier-Reichs, Malacozoa Acephala*, III (2), p. 476.

The present subfamily include the rest of the genera. Forming a natural group, they are more primitive than the members of the Soleninae, but are greatly specialised and less primitive than *Novaculina*. In the presence of a cruciform muscle and in the con-

nection between the coecum and intestine, they closely resemble the members of the fam. Psammobiidae to which the genera have been referred by Dall (23) and Bloomer (16). For the present they are considered to form the present subfamily, which will have to be raised to a family when the animals will be further known to us. They are undoubtedly more related to Psammobiidae than to the other two subfamilies.

The subfamily may be diagnosed as follows:—

Animal. Body comparatively short, but deep and widened out laterally. Pedal aperture extending along the entire ventral margin or a portion of it, sometimes along a small portion of the dorsal margin. United ventral margins of the mantle lobes short and comparatively wide (from side to side). A cruciform muscle in the ventral surface. Siphonal tubes either completely separate from each other or with a fused proximal portion. A large deep, linguiform foot generally protruding obliquely forward and downward from the pedal aperture. A siphonal space present or absent. Retractor pedis anterior muscle not bifurcated, and directed vertically upward. Labial palps comparatively short, generally triangular. Anterior lip close behind the anterior adductor muscle. Gills heterorhabdic, plicate, with the plicae free and flattened out antero-posteriorly. Intestine fused with the coecum and consisting of a single limb (corresponding to the second limb of Soleninae). Viscero-parietal ganglia variously placed.

Gen. *Solecurtus*, Blainville.

- 1782-93. *Solen* (pars), Linné, *Syst. Nat.*, ed. XII, p. 3225.
 1825. *Solecurtus*, Blainville, *Man. Malac. Conch.*, p. 568.
 1826. *Psammobia*, Risso, *Hist. Nat. princip, prod.* etc., IV p. 375 ;
Psammosolen, *Ibid.*, V (Index).
 1839. *Solenocurtus*, Sowerby, *Man. Conch.*, p. 99.
 1842. *Solenocurtus*, *id.*; 2nd edition, p. 262.
 1840. *Solenocurtus*, Swainson, *Tr. Malac.*, p. 366.
 1847. *Cyrtosolen*, Herrmannsen, *Indicis Gen. Malac. prim.*, p. 468.
 1858. *Macha*, Oken, Adams, *Gen. Recent Moll.*, II, p. 346; III, pl. xciii, figs. 4, 4a, 4b.
 1874. *Solecurtus*, Reeve, *Conch. Icon.*, XIX.
 1887. *Solecurtus*, Blainville, Fischer, *Man. Conch.*, p. 1, 107.
 1889. *Solecurtus*, Blainville, Clessin, Martini-Chemnitz, *Conch. Cab.*, XI (*Solenacea*), p. 84.

The anatomy of three species of *Solecurtus* has been studied by Bloomer (8, 11), viz. *S. strigillatus*, L., *S. candidus*, and *S. dombeyi*, Lam. The anatomy of the latter differs in so many points from that of the other two, that it is necessary to separate it and place in a distinct subgenus if not in a genus of its own.

The following diagnosis is drawn from Bloomer's description:—

Animal. Body short and wide with the anterior margin rounded. Pedal aperture extending above to the anterior end of the anterior adductor muscle and below nearly to the middle of the ventral margin. A wide ventral surface. Cruciform muscle typical, shaped like a cross. Siphon with a fused proximal portion, considerably wide and long and distally with separate anal and

branchial tubes with transverse ribbing. Large siphonal muscle. A siphonal space bounded in front by the fusion of the proximal portion of the siphon with the inner surface of the mantle lobes someway anterior to their posterior margins. Anterior adductor muscle narrow and elongated. Posterior adductor muscle narrow and small. Foot very large, wide and linguiform. Fibres of the retractor pedis anterior muscle passing to the pedal integument. No protractor pedis muscle. Retractor pedis posterior muscle very small at its insertion. Labial palps narrow and triangular. Anterior lip placed beneath the posterior portion of the anterior adductor muscle. Gills narrow and elongated, extending into the branchial siphon. Inner gills united dorsally in the cloacal region. Well-developed branchial retractor muscles. Pyloric stomach not produced posteriorly beyond the coecum. Coecum of the crystalline style a long and wide tube extending in front to the antero-dorsal end of the visceral mass in a curve. Intestine fused with the coecum to the distal end of the latter. Posterior limb of the intestine with a large number of irregular folds. Rectum passing closely round the posterior adductor muscle to end in the anus after bending forward along the ventral aspect. Heart placed at the anterior end of the pericardial chamber. A bulbous arteriosus in the posterior aorta. Viscero-parietal ganglia placed beneath the bifurcation of the retractor pedis posterior muscle.

Subgen. *Solecurtellus*, nov.

1818. *Solen Dombeyi*, Lamarck, *Hist. Nat. Anim. Sans. Vert.*, VI, p. 58.
 1874. *Solecurtus Dombeyi*, Reeve, *Conch. Icon.*, XI, fig. 30 a, b.
 1889. *Tagelus Dombeyi*, Lamarck, Clessin, Martini-Chemnitz, *Conch. Cab.*, XI (*Solenacea*), p. 72.

The present subgenus is erected for the reception of *Solecurtus dombeyi*, Lamarck. The following diagnosis is drawn from Bloomer's anatomical note:—

Animal. Body comparatively elongated and somewhat narrow. Pedal aperture occupying the anterior margin and nearly the entire length of the ventral aspect of the body. Cruciform muscle typically cross-shaped and placed at the posterior end of the ventral surface close to the proximal end of the siphon. Siphonal space as in *Solecurtus*. Siphon with a short proximal portion and with separate anal and branchial tubes distally. Anterior adductor muscle elongated and deep. Posterior adductor muscle oval, of the same size as the anterior adductor muscle. Foot as in *Solecurtus*. Retractor pedis anterior fibres passing inside the longitudinal muscles. Retractor pedis posterior muscle very small at its insertion. Coecum of the crystalline style large and passing forward along the ventral side of the visceral mass. Posterior limb of the intestine forming a loose fold.

Gen. *Azor*, Gray.

- 1782-93. *Solen* (pars), Linné, *Syst. Nat.*, ed. XII, pp. 3223, 3227.
 1835. *Solen* (pars), Lamarck, *Hist. Nat. Anim. Sans. Vert.*, VI, pp. 51, 59.
 1847. *Azor*, Leach, *Ann. Mag. Nat. Hist.* XX, p. 272.
 1851. *Azor*, Leach, Gray, *Cat. Brit. Mus.*, VII, p. 62.
 1858. Subgen. *Azor*, Gray (Gen. *Macha*), Adams, *Gen. Recent Moll.*, II, p. 347.
 1874. *Solecurtus coarctatus*, Reeve, *Conch. Icon.*, XIX, fig 8.
 1887. Subgen. *Azor*, Gray (Gen. *Solecurtus*), Fischer, *Man. Conch.*, p. 1107.
 1889. *Solecurtus* (pars), Clessin, Martini-Chemnitz, *Conch. Cab.*, XI, (*Solenacea*), p. 85.

The anatomy of two species of *Azor* (*A. antiquatus* and *A. coarctatus*) has been described by Bloomer (16). I have a specimen of *A. coarctatus*, Gmel. from the Persian Gulf. The present diagnosis is drawn from the animal in my possession as well as from Bloomer's descriptions.

Animal. Body comparatively short, deep, and strongly constricted laterally near the centre of the ventral surface. Pedal aperture occupying the anterior margin and nearly half the ventral margin of the mantle lobes. Posterior half of the ventral margins of the mantle lobes fused to form a wide surface. Cruciform muscle typically cross-shaped. Siphonal tubes long and separate, with a very short fused proximal portion prolonged backwards. Strongly developed retractor siphonal muscles. Two longitudinal folds on the inner surface of each mantle lobe, which terminate in the pedal aperture anteriorly, and enclose a portion of the mantle cavity behind by their united posterior end, continuous with the ventral wall of the siphon. A tentacular fringe all round the anterior, ventral and posterior margins of the mantle from the anterior to the posterior adductor muscle.

Anterior adductor muscle deep and elongated, placed obliquely, much longer (from side to side) ventrally than dorsally. Posterior adductor muscle large and nearly rounded. Foot large, short and deep. Labial palps small, somewhat elongated and triangular in shape. Gills much elongated, narrow and prolonged into the branchial siphon; cloacal portion forming half the entire length of the gill. Inner lamella of the inner gill attached to the side of the visceral mass in front and to its fellow of the opposite side behind. Well-developed branchial retractor muscles. Stomach without central portion. Pyloric stomach produced posteriorly as a blind sac beyond the origin of the coecum. Coecum of the crystalline style short and straight, passing downward and slightly forward to the ventral aspect. Intestine with closely placed folds in the upper portion of its posterior limb. Viscero-parietal ganglia placed at the antero-ventral edge of the posterior adductor muscle.

The specimen of *A. coarctatus* at my disposal differs from Bloomer's specimen in the following points. The animal is somewhat smaller in size, both the siphonal tubes are shorter and the posterior end of the body is more tapering than in Bloomer's specimen.

Gen. *Tagelus*, Gray.

1817. *Siliquaria*, Schumacher, *Essai Nouv. Syst. Habit. des Vers Testacee*, pp. 43, 129, pl vii, figs. 2, 3.
 1851. *Macha*, Gray, *Cat. Brit. Mus.*, VII, p. 61.
 1854. *Tagelus*, Gray, *Ann. Mag. Nat. Hist.* (2) XIV, p. 24.
 1858. *Siliquaria*, Schum., Adams, *Gen. Recent Moll.*, II, p. 347.
 1887. Subgen. *Tagelus*, Gray, Fischer, *Man. Conch.*, p. 1107.
 1889. *Tagelus*, Gray, Clessin, Martini-Chernnitz, *Conch., Cab.*, XI (*Solenacea*), p. 68.

The anatomy of three species of *Tagelus*, Gray (*T. rufus*, Spengler, *T. gibbus*, Spengler, and *T. divisus*, Spengler) has been described by Bloomer (10, 15) in full detail. His researches clearly point out that the two former species are closely related to each other but differ a good deal from the last one (*T. divisus*), which is somewhat related to *Solecurtellus*. A separate subgenus (*Subtagelus*) is suggested for this species in the present paper.

Animal. Body somewhat elongated and rounded anteriorly. Pedal aperture very long and wide, extending from the antero-dorsal aspect of the anterior adductor muscle, through the anterior margin, to the posterior end of the ventral margin in a vertical line with the posterior adductor muscle. Ventral margins of the mantle lobes united at a single spot with the cruciform muscle placed in it. Cruciform muscle typically cross-shaped with the posterior or both pairs of the limbs short. The mantle lobes are free at their posterior margins from the point of concrescence to the posterior end of the posterior adductor muscle. Siphon consisting of two long separate anal and branchial tubes. Siphonal space separated from the general pallial chamber by two lateral processes extending from the posterior margins of the mantle lobes to the proximal end of the siphon. Retractor siphonis muscle well-developed. Anterior adductor muscle unequally divided into two portions. Posterior adductor muscle irregularly oval or triangular, and united posteriorly with the mantle lobes and the proximal portion of the siphon. Retractor pedis posterior muscle connected with the posterior adductor muscle by its long bifurcated portions. Foot large, comparatively short and very deep. Retractor pedis anterior fibres passing inside the longitudinal muscles. Gills united dorsally at their margins beyond the foot. Anterior lip beneath the posterior division of the anterior adductor muscle. Pyloric stomach produced posteriorly beyond the origin of the coecum. Coecum of the crystalline style long, wide and produced forward and upward in a curved course to the dorsal aspect of the visceral. Limb of the intestine forming closely placed folds above. Viscero-parietal ganglia placed underneath the bifurcation of the retractor pedis posterior muscle.

The anatomical study of the genus by Bloomer (15) distinctly shows that it is somewhat related to *Solecurtellus*. It has distinctly been shown by Bloomer [(15), p. 219; (12), p. 80] that *S. rufus* is anatomically more closely related to *S. dombeyi* than to *T. gibbus*, and that the two genera resemble each other in the structure of the gills.

Subgen. *Subtagelus*, nov.

1851. *Macha divisus*, Spengler, Gray, *Cat. Brit. Mus.*, VII, p. 160.
 1854. *Tagelus* (pars), Gray, *Ann. Mag. Nat. Hist.* (2) XIV p. 24.
 1874. *Solecurtus bideus*, Reeve, *Conch. Icon.*, XIX, fig. 35.
 1887. *Tagelus divisus*, Spengler, Clessin, Martini-Chemnitz, *Conch. Cab.*, XI (*Solenacea*), p. 79.

Animal. Body similar to *Tagelus*. Mantle lobes strongly muscular. Pedal aperture resembling that of *Tagelus*. Cruciform muscle a simple broad transverse band. Anterior adductor muscle large and simple (not divided). Posterior adductor muscle large and triangular. Foot comparatively large, deep and muscular, protruding obliquely downward and forward. Protractor pedis muscle well-developed. Retractor pedis anterior and posterior muscles short. Strongly developed elevator muscles. Pyloric stomach not produced posteriorly beyond the origin of the coecum.

The above diagnostic characters, drawn from the anatomical description of Bloomer (15), clearly shows that the present animal is more primitive than the members of the genus *Tagelus*. The undivided anterior adductor muscle and the simple band-like cruciform muscle may be cited as evidence for the above conclusion. It may also be suggested that the present subgenus (which might almost be considered a genus) is closely connected to the ancestral form which has given origin to *Tagelus* on the one hand and to the type of *Psammbiidae* on the other.

CONCLUSION.

Although the little knowledge we had on the soft parts of the members of the Solenidae has been greatly enhanced by the anatomical researches of Bloomer, supplemented by my own study on the small collection of the Zoological Survey of India, we are as yet not in a position to discuss and arrive at a definite conclusion regarding the phylogenetic question of the family, unless more material comes into the hands of malacologists to be worked out by them than is the case at present. The relation between the three subfamilies is still obscure, but they seem to form fairly natural and definite groups taken by themselves. The presence of a short stout foot with a flat disc-like anterior end, and the absence of a cruciform muscle in *Novaculina* point to the comparatively primitive nature of the animal; the non-plicate gills have no taxonomic value more than as specific or subgeneric characters as shown by Ridewood (pp. 161-2). The animal is, however, otherwise specialised, and might be considered to have early separated from the ancestral stock—perhaps earlier than the appearance of the ancestral forms of the other two subfamilies.

The great width of the body from side to side seen in *Novaculina*, certainly a primitive character again, has been retained in the ancestral forms of Solecurtinae and has been handed down to its members. This ancestral type of Solecurtinae must have acquired the peculiar connection between the intestine and coecum of the

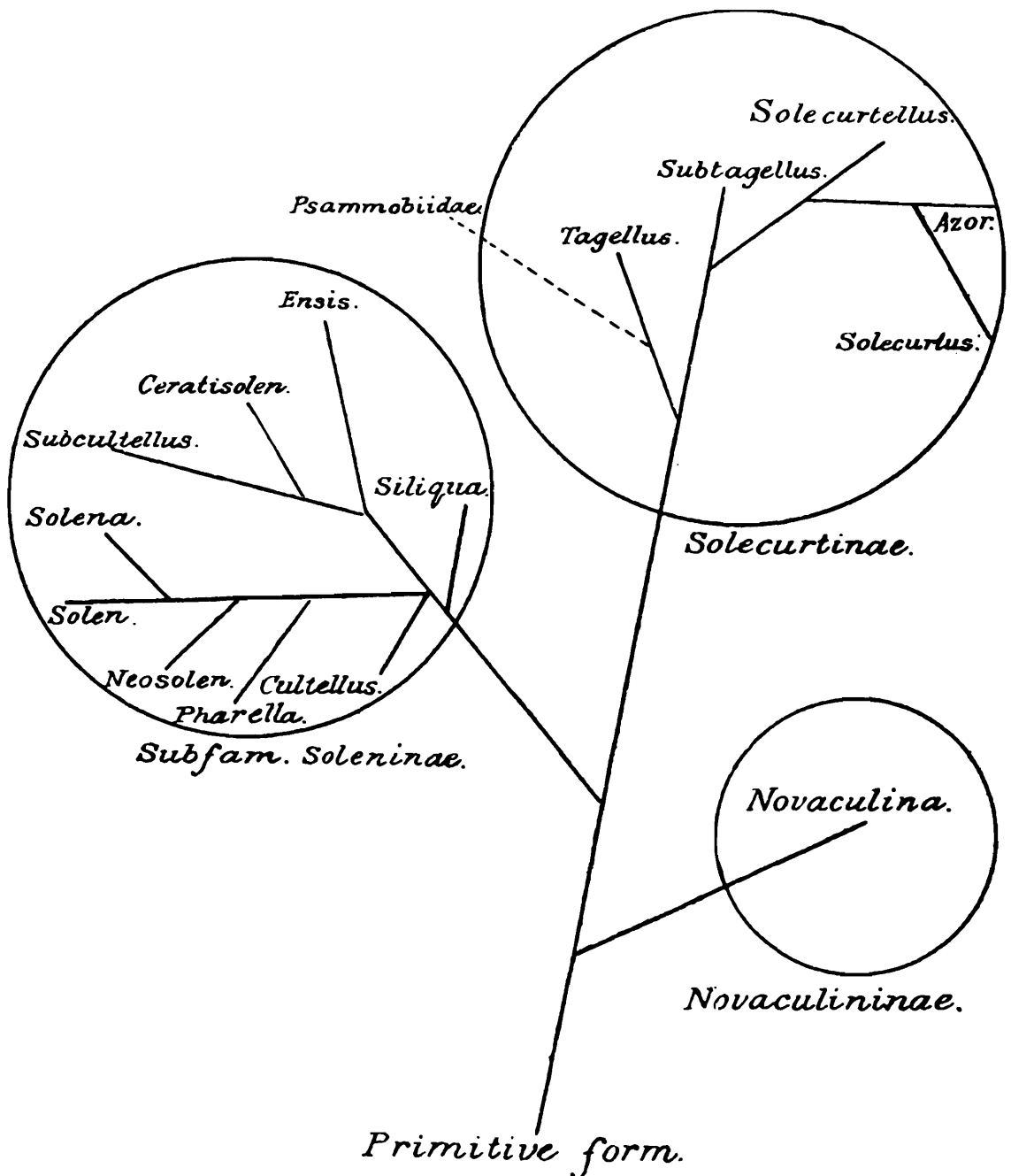
crystalline style. The question arises whether the coecum of the crystalline style has primarily originated from the side of the intestine as a side groove and has only secondarily separated from it to form a distinct and separate tube, or the coecum has primarily arisen as a ventral outgrowth of the stomach and has only secondarily acquired a connection with the intestine by the fusion of their walls. The researches of Barrois (2) have conclusively shown that the epithelial structure of the coecum of the crystalline style and intestine are quite different from each other whether they are fused together or not. Lately Bloomer has arrived at a similar conclusion, also corroborated by my own histological study on *Neosolen* and *Novaculina*.

M. Martin (*Jenaisch. für Naturwiss.* LII, 1914, pp. 363-444) has studied the relation of the crystalline style with the intestine and has found that the coecum of the crystalline style and the beginning of the intestine form together a single short wide tube in *Nucula* and in many Filibranchia. Hence, the condition found in one of the primitive types of Pelecypoda may be considered primarily at least in the present class. But it is quite probable that the condition might have arisen from one with a coecum distinct and separate from the intestine, as is still found in many Prosobranchia, and which was perhaps present in the ancestral forms before the evolution of the present class. The peculiar condition in the subfam. Solecurtinae may be easily derived from that found in *Nucula* simply by the elongation of the short conjoined portion into a long narrow tube, otherwise retaining the same primitive stage. The coeca of *Novaculina* and of the subfam. Soleninae differ from the above primitive type in being separate and distinct from the intestine. But the case of *Novaculina* seems to be different in origin from that of the members of the Soleninae. In *Novaculina*, the coecum seems to have separated at an early stage from the intestine, and in the process might have passed through a stage still found in *Modiolaria* (see Martin's paper). In the Soleninae, the condition has arisen at a later epoch secondarily from that of the Solecurtinae. The presence of connective tissue uniting the walls of the coecum and intestine, as distinctly shown by Bloomer, may be set forth as strong evidence for such a hypothesis, viz. the separation of the wall of the coecum from the intestine has taken place secondarily from a condition seen at present in the members of the Solecurtinae, the connective tissue being left as the last remnant of a former continuity of the two. Consequently it might be argued that the ancestral forms of the subfam. Soleninae have arisen from one with the intestine and coecum fused together (as in all Solecurtinae), but still without the development of a cruciform muscle, there being not a trace of it in the subfam. Soleninae; they then acquired the lateral flattening of the body and lost the connection between the coecum and intestine. It is also probable that the ancestral forms of both the subfamilies had their mantle lobes free along their ventral margins or just con-

crested at their posterior ends, as seen at present in *Tagellus*, and the fusion of the two mantle lobes gradually extended to the anterior end as the various genera originated from them. The fam. Psammobiidae, closely related to Solecurtinae, might have arisen from the same ancestral forms after the differentiation of a cruciform muscle in the fused ventral margins of the mantle lobes. The evolution of the muscle can at present be followed in the different genera of the subfam. Solecurtinae, the primitive condition as a simple transverse band being found in *Tagellus*.

Returning to the subfam. Soleninae, we find the genera *Siliqua* and *Ceratosolen* differing from the others in having simple non-plicate gills with irregular interlamellar junctions; but the plication of the gills has no taxonomic value more than as a sub-generic character as shown by Ridewood (26, pp. 161-2).

The relation between the genera of the three subfamilies may be thus provisionally represented:—



SYNOPSIS OF THE GENERA.

- a. Body flattened laterally with a narrow ventral surface ;
no cruciform muscle Subfam. Sole-
ninae.
- a¹. Gills plicate.
- a². Siphons fused to a single piece.
- a³. No fourth aperture.
- a⁴. Body and gills narrow and elongated.
- a⁵. Anterior adductor muscle nar-
row and elongated ... *Solen.*
- b⁵. Anterior adductor muscle
rounded *Solena.*
- b⁴. Body and gills short and deep ... *Neosolen.*
- b³. A fourth aperture *Ensis.*
- b². Siphons separate.
- a³. A fourth aperture continuous with pedal
aperture.
- a⁴. Body elongated ; two *long* siphonal
tubes *Ceratisolen.*
- b⁴. Body comparatively short ; two *short*
siphonal tubes *Subcultellus.*
- b³. No fourth aperture ; siphonal tubes short.
- a⁴. Gills short and deep ; anterior lip
immediately behind the anterior
adductor *Cultellus.*
- b⁴. Gills long and narrow ; anterior lip
separated from anterior adductor
muscles by an interval *Pharella.*
- b¹. Gills non-plicate *Siliqua.*
- b. Body widened laterally, with a wide ventral surface.
- a¹. Gills non-plicate ; no cruciform muscle ... Subfam Nova-
culininae
(*Novaculina*).
- b¹. Gills plicate ; a cruciform muscle Subfam Sole-
curtinae.
- a². Ventral margins of the mantle lobes fused to
form a surface ; cruciform muscle cross-
shaped.
- a³. Ventral surface long ; a long and wide
common proximal portion of the
siphon ; no tentacular fringe along the
mantle margin... .. *Solecurtus.*
- b³. Ventral surface short ; a short common
proximal portion of the siphon ; a ten-
tacular fringe along the mantle margin
Azor.
- b². Ventral margins of the mantle lobes not fused,
except at the posterior end.
- a³. A short common proximal portion of
the siphon ; anterior adductor muscle
simple ; cruciform muscle cross-shaped
Solecurtellus.
- b³. No common proximal portion of the
siphon.
- a⁴. Anterior adductor muscle simple ;
cruciform muscle band-like *Subtagelus.*
- b⁴. Anterior adductor muscle divided
into two portions ; cruciform muscle
cross-shaped *Tagelus.*

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