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LOOP DEVELOPMENT OF THE PENNSYLVANIAN TEREBRATULID CRYPTACANTHIA

(With 2 Plates)

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The silicified specimens forming the subject of this discussion are unusual in preserving parts or all of the internal skeleton in youthful individuals as well as adults. They were dissolved from Magdalena limestone taken from a ledge on the north side of an arroyo just east of the Grapevine Canyon road one-eighth mile south of Old Juniper and a cattle tank, about in the center of the W½SE¼SW¼ sec. 25, T. 19 S., R. 11 E., Escondido Canyon (15′) Quadrangle, Otero County, N. Mex. These fossils and others described earlier from the same place (Cooper, 1956) are from 30 to 40 feet below the top of the Magdalena formation.

The bed containing these fossils is a gray, fine-grained limestone containing a large amount of light-gray insoluble material and numerous other brachiopods, among which are: *Cleiothyridina, Punctospirifer, Stenoscisma, Dielasma,* and smaller forms still to be identified. Immature forms of several of the genera are very abundant and some small specimens appear to be adults of an undescribed genus. Gastropods and pelecypods are fairly common but their preservation is poor.

One of the most abundant brachiopods in this limestone is the hitherto poorly known and extremely rare genus *Cryptacanthia.* Although this genus has been identified in many areas of Pennsylvanian rocks, it is one of the rarest of all Pennsylvanian fossils. The original specimens on which the genus was based come from Iowa but it is known in adjacent Illinois and Missouri. It occurs in the Gaptank formation in west Texas and is known elsewhere in New Mexico and Kansas besides the occurrences mentioned above. The genus was de-

scribed by White and St. John (1867) but little has been written about it since then. Dunbar and Condra (1932) redescribed the genus and added another species from the early Permian. Study of the specimens described herein and of another preparation of the loop of *Cryptacanthia* from Madison County, Iowa, shows that this structure was improperly restored by Dunbar and Condra.

About a dozen blocks of various sizes were collected at the locality in Grapevine Canyon. These yielded about 4,000 specimens of *Cryptacanthia,* including many with almost perfect interiors and some with the loop preserved to perfection. These specimens permit a nearly complete description of the development of the loop and other details of the interior. This is the first Paleozoic long-looped brachiopod in which the stages of loop development have been described.

In comparing the New Mexico specimens with those from Iowa, which are topotypes, it was discovered that the ones from the Southwest are clearly a new species for which the name *Cryptacanthia prolifica* Cooper is here proposed.

CRYPTACANTHIA PROLIFICA Cooper, new species

Small, pentagonal in outline, length and width nearly equal but varying from an oval outline in the young to subpentagonal in the adult; inequivalve, the pedicle valve having the greater depth, posterolateral margins nearly straight forming an angle at the beak of 105° to 110°; sides narrowly rounded; anterolateral margins gently concave to straight; anterior margin truncated to gently emarginate; greatest width at about midvalve but variable with age; anterior commissure strongly sulcate; surface smooth.

Pedicle valve evenly and strongly convex, with the maximum convexity at the middle; anterior profile narrowly domed with steep, concave sides; beak small, incurved, suberect to erect; foramen elongate-elliptical, mesothyrid to submesothyrid; deltidial plates conjunct; umbo narrow, moderately convex; fold originating on anterior side of umbo, widening anteriorly to front margin, somewhat flat-topped and with a sulcus originating at about midvalve; umbonal slopes gentle, anterolateral slopes precipitate.

Brachial valve shallow, evenly and gently convex in lateral profile; anterior profile nearly flat but with a shallow median depression; umbo gently swollen; sulcus originating just anterior to the umbo, widening and deepening anteriorly to the front margin; sulcus in many specimens with a low, indistinct fold originating just anterior to

midvalve and extending to the front margin; flanks bounding sulcus gently convex.

Interior.—See Internal Morphology, below.

MEASUREMENTS IN MILLIMETERS

	Length	Brachial length	Maximum width	Thickness
Holotype	7.0	6.3	7.4	4.5
Paratype 127067a	8.9	7.8	8.9	5.1
" 127067b	8.5	7.5	8.7	4.9
" 127067c	8.0	7.1	7.9	5.0
" 127067d	7.5	6.7	8.2	4.7
" 127067e	7.5	6.9	7.4	3.7
" 127067f	7.0	6.2	6.5	3.8
" 127067g	6.5	5.8	6.4	3.8
" 127067h	6.0	5.5	5.9	3.2
" 127202a	5.6	4.8	5.3	2.6
" 127202b	5.0	4.6	4.5	2.4
" 127202c	4.5	3.9	3.8	1.9
" 127202d	4.0	3.5	3.6	1.6
" 127202e	3.5	3.0	3.0	1.2
" 127202f	3.0	2.5	2.5	1.1
" 127202g	2.5	2,4	2.4	0.8
" 127202h	2.0	1.7	1.7	0.75
" 127202i	1.5	1.25	1.3	0.56
" 127202j	1.1	0.87	0.94	0.44

Types.—Holotype, U.S.N.M. No. 127066; figured paratypes, U.S.N.M. Nos. 127202j, k, s, u, w, z; 127203h, i, l; 127204c, h, l, n, o, q, s, t; 127205h-j, l, m-q, s, t; 127206k, r; 127207p; measured paratypes, U.S.N.M. Nos. 127202a-j; 127067a-h; unfigured paratypes, U.S.N.M. Nos. 127202l-r, t, v, x; 127203a-g, j, k, m-z; 127204a, b, d-g, i-k, m, p, r, u-z; 127205a-g, k, r, u-z; 127206a-j, l-q, s-z; 127207a-o, q-z; 127208a-z; 127209.

Discussion.—The New Mexico specimens differ from *Cryptacanthia compacta* White and St. John in details of the interior as well as of the exterior. The Iowa species is much more robust and is much thicker than *C. prolifica.* In lateral profile the extremely deep pedicle valve of *C. compacta* has a pronounced bulge in it about a third the length from the anterior margin. This is a prominent feature of the species. A similar bulge occurs in *C. prolifica* but it is not so strongly marked as in the Iowa species. Furthermore *C. prolifica* is somewhat squarer in outline, especially when seen from the dorsal side, and has very distinct posterolateral shoulders. These features are not so prominent in the Iowa species which has much more rounded contours

especially in the adult form. The New Mexico species is thus a more slender one, even the largest specimens never attaining the great thickness of *C. compacta.*

The differences between the loops of the two species is very pronounced and is described below in connection with the loop of *C. prolifica.* (See text figure 1.)

EXTERNAL MORPHOLOGY OF *CRYPTACANTHIA PROLIFICA*

The abundant material on hand from the Magdalena limestone permits a detailed account of this species. Although the preservation is poor in many instances it is, nevertheless, possible to determine most of the features of the shell.

Growth.—The smallest specimen (pl. 1, D, fig. 7) that could be identified with certainty as *Cryptacanthia prolifica* is paratype U.S.N.M. No. 127202j which is 1.1 mm. long, length of brachial valve 0.87 mm., maximum width 0.94 mm., and thickness 0.44 mm. The specimen is oval in outline and has the maximum width at about the middle. The brachial valve is deeper than the pedicle valve, a condition opposite to the adult, and the anterior commissure is uniplicate. The beak is straight, blunt, and has an open delthyrium.

The pedicle valve of this specimen is nearly flat in lateral profile but with gentle curvature at the umbo. The anterior profile is broadly and gently convex. The umbonal and medial regions are gently swollen.

The brachial valve of this small specimen is gently convex in lateral profile but with the posterior half more convex than the front half which is somewhat flattened. The anterior profile is broadly and moderately convex, most convex in the middle and with long sloping sides. The umbo is somewhat narrowly swollen.

The smallest specimens are distinctly elongate-oval in outline and do not have the angularity so characteristic of the adult specimen. Sulcation of the anterior commissure starts at about the 2 mm. stage. At this stage, too, the shell begins to widen somewhat and develops some of the shouldered appearance of the adult. The young specimens remain distinctly elongate-oval until they reach about 6 mm. After 6 mm., specimens appear that have length and width equal, but no specimen smaller than 5.9 mm. was measured with length and width equal. The larger specimens generally have length and width more nearly equal than those less than 6 mm. long. All the specimens measured above 8 mm. have the length and width equal or the length slightly less than the width.

After sulcation appears at 2 mm., the sulcus becomes deeper and deeper with age. In old adults the fold becomes sulcate anteriorly. This produces emargination at the front. This is usually not strong, but a few specimens appear that are fairly deeply emarginate.

From the earliest stage seen to about 3 mm. the delthyrium acts as the foramen. After about 3 mm., small triangular deltidial plates appear in the lower angles of the delthyrium. These gradually grow to restrict that opening. After about 3.5 mm., the deltidial plates become conjunct and in late adult stages may develop an incipient reflected lip on the posterior margin. The deltidial plates never seal the line of junction to produce a symphytium.

INTERNAL MORPHOLOGY OF *CRYPTACANTHIA PROLIFICA*

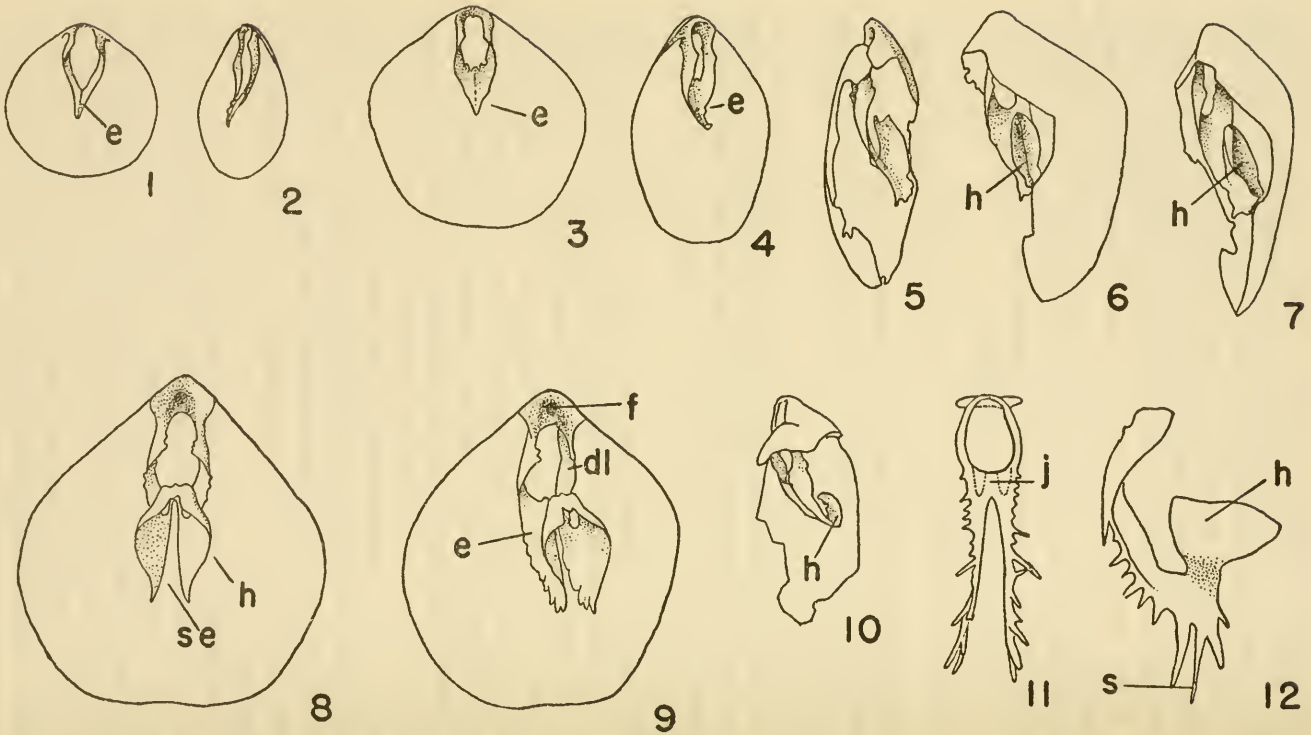
Changes of great interest and importance take place in certain structures inside *C. prolifica,* especially in the development of the loop and the hinge plate.

Interior of the pedicle valve.—The valves are firmly articulated and the processes of silicification have added to the difficulties of separating the shells. Consequently the teeth have not been seen except in the articulated state where they appear to be long, slender, and somewhat curved.

Dental plates were seen in one of the smallest stages, 1.5 to 2 mm., and it is therefore inferred that they would appear also in earlier stages. In the youngest stage seen they are receding but vertical. In the large adult they are no longer receding, are still vertical but quite stout. They are actually slightly advancing at their anterior ends and the floor of the delthyrial chamber is somewhat thickened. No details of the musculature could be determined. The valves are generally thin-shelled and the inner surfaces are not well preserved.

Interior of the brachial valve.—The most important part of the brachial valve is the cardinalia consisting of the hinge plates and the loop. Like the brachial valve no trace of the muscle scars could be determined. The median septum, or ridge, is not a conspicuous feature of this genus.

DEVELOPMENT OF THE HINGE PLATE: In the earliest stage, 1.6 to 2.0 mm. (U.S.N.M. No. 127202k), in which the cardinalia are clearly visible (pl. 2, A, fig. 1), the socket plate is a subtriangular ridge fused with the crural base on the inner wall of the valve. Buttressing the crural base is a small plate, barely visible and converging medially to join the floor. These supporting plates do not unite on the floor of the valve. Little change could be noticed in any of these plates in the next succeeding stages to the 3.1 to 3.5 mm. stage.



FIGS. 1-12
(See legend on opposite page.)

In the 3.0 to 3.5 mm. stage the buttress plates unite on the floor of the posterior chamber and in the succeeding stage (3.6 to 4.0 mm.) gradually are raised as a distinct plate above the floor at the rear of the valve. A specimen 3.4 mm. long (U.S.N.M. No. 127202l) has a complete inner hinge plate with the anterior margin free but the posterior sessile and imperforate. After the 4.0 mm. stage the hinge plate consists of a single piece, commonly with a slight, or even pronounced, convex flexure but with a round or longitudinally oval foramen at the rear (pl. 1, E, fig. 22). A few specimens have no foramen but the adult generally is so provided.

DEVELOPMENT OF THE LOOP: The collection here described does not include the complete development of the loop because no specimens smaller than 1 mm. were hollow and none of this size showed the loop. The earliest stages (0 to 1 mm.) must therefore be inferred.

FIGS. 1-12

All drawings by Lawrence B. Isham, scientific illustrator.

ABBREVIATIONS

dl—descending lamella	h—hood
e —echmidium	j—jugum
f —foramen in hinge plate	s—spines
se—split in echmidium	

Figs. 1-10, *Cryptacanthia prolifica* Cooper, new species:

1. Specimen in the 2.1-2.5 mm. stage showing slender lamellae and echmidium, × 10. (See pl. 2, B, fig. 3.) Margin restored. Paratype U.S.N.M. No. 127202s.
2. Same as above seen from the side and showing long point of echmidium, × 10.
3. Specimen in the 3.1-3.5 mm. stage showing a stouter echmidium, × 10. Paratype U.S.N.M. No. 127203g.
4. Same as preceding but turned to side to show point of echmidium, × 10.
5. Specimen in the 4.1-4.5 mm. stage showing a small but well-formed hood on the point of the echmidium, × 8. (See pl. 2, F, fig. 10,) U.S.N.M. No. 127204h.
6. Same specimen as preceding but turned to show elliptical opening of the early-formed hood, × 8.
7. Same specimen as preceding, only slightly turned to the side but showing the small cuplike hood, × 8. (See pl. 2, F, fig. 11.)
8. Specimen in the 4.6-5.0 mm. stage showing fully formed and notched hood, × 8. Paratype U.S.N.M. No. 127204t. (See pl. 1, I, fig. 27.)
9. Same as preceding but loop seen partially from side, × 8.
10. Specimen in the 3.1-3.5 mm. stage showing incipient hood on tip of echmidium, × 10. Paratype U.S.N.M. No. 127203i. (See pl. 2, D, fig. 7.)

Figs. 11, 12, *Cryptacanthia compacta:*

11. Dorsal view of the loop of *Cryptacanthia compacta* showing the long spines, deep cleft, jugum, and short descending lamellae. Dotted lines indicate where part of loop was dissolved away but jugum is intact. (Compare pl. 1, A, fig. 1.) Hypotype U.S.N.M. No. 9382a.
12. Same as preceding but showing loop from side with its long spines, prominent erect hood, and long descending lamellae. (Contrast with profile of loop of *C. prolifica,* pl. 2, H, fig. 16.)

Stages 1.1 to 1.5 mm.: The smallest specimen (U.S.N.M. No. 127202m) showing traces of the loop is a brachial valve 1.25 mm. long and had a pedicle valve estimated to be 1.50 mm. long. In this specimen only the descending lamella on one side is visible as a thin and delicate ribbon with an angular bend medially at about midvalve (0.4 mm. anterior to the brachial beak). The fact that the descending branch bends medially suggests that at this stage the anterior ends of the loop were united. It is probable that in stages below 1.0 mm. only the initial stages of the descending lamellae are present and are not bent medially at their distal ends.

Stages 1.6 to 2.0 mm.: Two specimens (U.S.N.M. Nos. 127202k, 127202n) measuring between 1.5 and 2.0 mm. in length exhibit the loop. Specimen U.S.N.M. No. 127202n is exactly 2.0 mm. long and 1.68 mm. wide. The entire loop is not visible but the pointed anterior can be seen and indicates a loop of about 0.8 mm. in length. The loop of the other specimen (U.S.N.M. No. 127202k) is broken on one side (pl. 2, A, fig. 1) but the descending branches are thin and delicate and bent medially about 0.4 mm. anterior to the beak. These two specimens thus indicate a loop of about 0.8 mm. in length, the lateral branches of which bend medially and unite distally in a sharp point.

Stages 2.1 to 2.5 mm.: Information on these stages is based on 5 specimens (U.S.N.M. Nos. 127202-o, p, q, r, s). Three of the specimens are 2.4 mm. long and 2.0 mm. wide, but two are 2.3 mm. long and 2.0 mm. wide. The loop varies in length from 1.0 to 1.2 mm. The loop is much stouter than in the preceding stage and the crural processes are visible as blunt points. The angular bend of the descending lamellae is present and the two branches unite distally to form a sharp, angular, pointed plate not greatly extended anteriorly. The line of junction between the descending branches varies from 0.3 to 0.4 mm. The descending lamellae thus unite to form a spear-shaped plate here called the *echmidium*.[1] This name is introduced because, in the development of the loop, the spear-shaped plate becomes increasingly prominent and ultimately is the site on which grow the ascending elements of the loop. At the 2.1 to 2.5 mm. stages no ascending elements or their beginnings were seen in any of the specimens.

Stages 2.6 to 3.0 mm.: Thirteen specimens with this range, having the loops preserved, appear in the collection (U.S.N.M. Nos. 127202t-z, 127203a-f). The length of the loop averages 1.33 mm. and

[1] Echmidium is derived from *aichmidion*, diminutive of *aichme*, point of a spear. The *ai* is transliterated *e*.

the length of the echmidium averages 0.55 mm. The descending lamellae are thicker and broader than in the previous stages and the bend medially is less pronounced, but the form of the loop is essentially the same. The echmidium is broader and longer and now has a long, sharp point. The crural processes are somewhat more pronounced and have sharper points than in the preceding stages. Some variation exists in the stoutness of all the elements, but generally they are stronger than the preceding. No ascending elements appear in these stages but traces of them are suspected. In two instances (U.S.N.M. Nos. 127202s, w) a ridge along the center of the echmidium is suggestive of an incipient development of the hood.

Stages 3.1 to 3.5 mm.: Seven specimens in this range preserve the loop (U.S.N.M. Nos. 127202l, 127203g-k, 127206k). In these the loop averages 1.48 mm. in length and the echmidium averages 0.65 mm. long. The shortest loop is 1.4 mm. long in a specimen 3.1 mm. long and is 1.6 mm. long in a specimen 3.5 mm. long. This interval sees the appearance of the hood. The best specimen (U.S.N.M. No. 127203i) to show this is about 3.2 mm. long with a loop 1.5 mm. long and with an echmidium 0.8 mm. long which is remarkable for the attenuation of the anterior point and the presence on this point of the first bud of the hood (pl. 2, D, fig. 7). This is 0.56 mm. long measured in the direction of shell length and is 0.24 mm. in height measured at right angles to the length. The line of contact with the echmidium is 0.24 mm. long and is located at the very end of the attenuated tip. The delicacy of this structure and its flimsy contact with the echmidium evidently account for the rarity of its preservation. The ventral face of the hood cannot be directly seen but the hood from the dorsal side appears to be elliptical and must therefore form an elliptical opening on the ventral side. From the dorsal side the echmidium shows well the suture between the two descending elements at the line of junction. At the anterior tip of the echmidium a faint trace of divergence laterally of the joined descending and ascending elements foreshadows the deep cleft in later stages.

Stages 3.6 to 4.0 mm.: Five specimens (U.S.N.M. Nos. 127203l, m, n, o, p) exhibit these stages of the loop, which has become stout, and the echmidium long, wide, and pointed but still undivided. The loop varies in length from 1.6 to 1.8 mm. and the echmidium is 0.88 to 1.0 mm. long. In two specimens (U.S.N.M. Nos. 127203n, 127203-o) the latter plate is 0.60 mm. wide but is still undivided at its anterior tip. Two specimens (U.S.N.M. Nos. 127203l, m) show the hood, the former showing the posterior half (pl. 2, E, fig. 9) and the latter the anterior half. The attachment of the hood to the ech-

midium is 0.7 mm. long and the hood varies from 0.35 to 0.5 mm. in width. The conical hood tapers rapidly in a posterodorsal direction.

Stages 4.1 to 5.0 mm.: Twelve specimens (U.S.N.M. Nos. 127203r-z, 127204c, d, h) in this size range exhibit the loop in various stages of completeness. The loop varies in length from 2.2 to 2.9 mm. but averages about 2.4 mm. The echmidium varies from 0.8 to 1.8 mm. in length and has a maximum width of 0.64 mm. Specimen U.S.N.M. No. 127204h is 4.8 mm. long and has one of the best preserved loops in this interval (pl. 2, F, figs. 10, 11). The descending lamellae are broad and flatten anteriorly on the echmidium and become nearly vertical. At the anterior end they flare laterally and unite with the lateral walls of the hood. The ventral margin of the hood slopes rapidly posterodorsally, the hood narrowing in that direction. The posterior surface of the hood is short and narrowly convex. Thus in ventral view it expands laterally but with a deep reentrant dorsally. The lateral flaring of the outer walls of the hood is the beginning of the anterior cleft of the echmidium so prominent in succeeding stages. In this specimen the cleft is 0.5 mm. long. The loop at this 4.1 to 5.0 mm. stage is thus an adult one but the anterior cleft is short. The cleft in the anterior point of the echmidium in a smaller specimen (U.S.N.M. No. 127203r) in this range is small and is noticeable only in the hood. The cleavage of the echmidium is thus initiated when the shell has attained slightly more than 4 mm. of length. Specimens of 5 mm. length show a deep cleft in the hood, about 1 mm. deep in specimen U.S.N.M. No. 127203z. The hood in this specimen is 1.5 mm. long and 1 mm. wide.

Stages 5.1 to 6.0 mm.: Four specimens (U.S.N.M. Nos. 127204k, m, t, u) in this group preserve the loop in most of its details. It is substantially the same as that of the late stages of the previous group but some modifications are evident. The cleft in the echmidium is now deeper, almost half the length of the loop which varies from 3.1 mm. to 3.6 mm. in length. The junction of the lateral branches is short and the reentrant in the hood on the posterior side is deeper in most instances but this appears to be a variable feature. The spines on the anterodorsal side of the loop are long and in two rows anterior to the junction of the lateral branches. The longest spine measures 0.4 mm. in length. The hinge plate in all members of this group is complete and usually perforate. In specimen U.S.N.M. No. 127204t, the loop is 3.6 mm. long, the hood is 1.9 mm. long, the cleft is 1.3 mm. deep, and the hood is 1.2 mm. wide (pl. 1, I, figs. 26, 27; pl. 2, G, figs. 13, 14).

Stages 6.1 to 7.0 mm.: Five specimens (U.S.N.M. Nos. 127204-o,

q, u-w) with loops represent this stage. Anteriorly the lateral branches of the loop are distinctly separated. The hood is 1.6 mm. wide and the posterior surface is long, broadly rounded, and only moderately reentrant. The anterodorsal edge is marked by a double row of fairly strong spines. The loop varies in length from 3.6 mm. to 4.4 mm. and the maximum length of the hood is 2.8 mm. (pl. 2, H, figs. 16-18).

Stages 7.1 to 8.0 mm.: One specimen only (U.S.N.M. No. 127204l) in this range shows the loop (pl. 2, I, fig. 19). The specimen is 7.5 mm. long and 7.2 mm. wide and its loop measures 4.4 mm. in length and the hood is 2.8 mm. long. The anterior spines are long. It is appropriate that at this place the adult loop be described because only one other change in it takes place.

The loop of these stages has the crural bases hidden by the complete hinge plate which is buttressed against them. The descending branches are short and stout, only 0.7 mm. of broad, flat ribbon intervening between the hinge plate and the echmidium. The crural processes are given off just anterior to the hinge plate and are short, bluntly pointed projections of 0.1 to 0.2 mm. The descending lamellae are about 0.5 mm. wide. The echmidium is broad and deeply cleft anteriorly, 1.9 mm. in a loop 4.6 mm. long. The junction or jugum between the descending lamellae is 0.62 mm. long in the above loop, or less in others, and is a narrow plate. The descending lamellae posteriorly face each other and their narrow edge is perpendicular to the inner surfaces of the valves. Anteriorly these ribbons turn about 90° to become parallel with the inner valve surfaces and at the same time become fairly deeply concave and narrow distally. The hood rests on the inner ventrally curved edge of the descending lamellae. Anteriorly the hood is a widely flaring cone, expanded above but narrowing dorsally. It also narrows posterodorsally with an opening half or less of the anterior dimensions. The base of the hood is continued posteriorly beyond its narrow termination as two converging septa which unite to form a low ridge at the proximal end of the echmidium (pl. 2, I, fig. 20). The posterior side of the hood varies from round to nearly flat and with its anterior deeply notched (pl. 1, I, fig. 26) or with only a slight trace of indentation (pl. 2, I, fig. 20). The notch is a variable feature which appears to be more prominent and more uniform in smaller stages. Seen from the side the descending lamella forms a keel along the dorsal side of the loop, the base of the hood is deeply concave and the hood itself bulges prominently in a lateral direction. The ventral surfaces of the descending lamellae are convex and spinose, one set of spines on the outer edge and the other coming off the inner convex face.

A single specimen (U.S.N.M. No. 127205h) measuring 7.9 mm. in length and 8.3 mm. wide is unique in showing unequivocally the two descending branches free of each other (pl. 2, I, fig. 21). In this specimen the jugum has been resorbed because no evidence of breakage on the descending ribbons can be seen. This is the ultimate state in the development of the loop.

Stages 8.1 to 9.0 mm.: A single specimen with loop (U.S.N.M. No. 127204e, not figured) representing these stages measures 8.6 mm. long by 8.4 mm. wide and is one of the largest specimens in the collection. The loop is 5.6 mm. long and the hood is 3.7 mm. long by 1.9 mm. wide. The hood is only moderately notched on the posterior side. The descending lamellae lie very close together but the jugum has been resorbed and the descending branches are free, the ultimate condition for the loop. If larger specimens exist it is likely that the only further change in the loop would be gradual lateral migration of the descending lamellae so that they would be more distantly spaced and subparallel.

Median septum (or ridge): No distinct septum or median ridge was seen in specimens from 1.0 mm. to 3.5 mm. After the latter length is attained a median ridge is discernible but even in large adults it is not a conspicuous feature of the shell. It is apparent that the ridge or septum never shared in the development of the loop as it does in so many modern long-looped brachiopods.

Summary of loop development of *Cryptacanthia*.—The development of the loop in stages below 1 mm. can only be inferred from the early stage in the loop development of other brachiopods. In the earliest stages it is postulated that the loop originated as two processes growing anteriorly from the hinge region, the descending branches developing an angular bend medially and finally uniting distally at about the 1 mm. stage. The descending lamellae in these stages would be thin and delicate and no echmidium would have been formed (precentronelliform stage).

After the 1 mm. stage the loop begins to thicken and at the place of junction of the distal ends of the descending lamellae the joined elements widen and flatten to form a plate having the shape of a spearhead and here called the echmidium (centronelliform stage). After the formation of the central echmidium the loop continues to strengthen, but at the anterior tip of the echmidium a bud appears in the form of a small elliptical cup. This is the incipient hood (early cryptacanthiform stage). In succeeding stages this structure expands and elongates with the growing loop. After the appearance of the hood the echmidium cleaves medially, the split lengthening and widen-

ing with growth of the loop (cryptacanthiform stage). In the final stage of development the anterior cleft is completed and the descending branches of the loop become freed of each other (early glossothyropsiform stage).

THE LOOP OF *CRYPTACANTHIA COMPACTA* WHITE AND ST. JOHN

Cryptacanthia compacta is the type species of the genus and for many years was the only known species. It is important therefore that the loop of the type species be clearly understood. As presently described and figured (Dunbar and Condra, 1932, pp. 307-309) the loop is depicted as a sort of cryptonelliform loop with long descending lamellae and long but fairly broad ascending elements. The figure of the loop given by Dunbar and Condra was reconstructed from serial sections. Study of the figured serial sections suggests that the ascending element is not properly restored and a new preparation of a loop inspired by this suspicion shows that it is entirely wrong.

The new preparation of the loop was made on a specimen from Madison County, Iowa, essentially a topotype. The preparation was not made by the usual sectioning method although it was my intention when I started the work to make serial sections. The first cut showed that the specimen was filled with clear calcite in two layers, an outer somewhat granular one and a solid inner layer of transparent light-brown calcite. On discovering this condition I scraped away the granular layer and part of the more solid mass beneath, washing frequently with acid to eliminate the needle marks. Soon a perfect loop was revealed which, however, was etched slightly too far on the dorsal side. This too liberal etching removed the bulging part of the echmidium but left the jugum joining the descending lamellae. Study of the photographs makes it clear that these descending lamellae were joined like those from New Mexico. The preparation also reveals the numerous and long spines on the dorsal side of the descending lamellae which inspired White and St. John to name the genus *Cryptacanthia.*

The specimen prepared was 5.3 mm. long and the loop measures exactly 4 mm. in length. On the dorsal side the descending lamellae are posteriorly distant but swing toward each other to be joined by a broad jugum 0.4 mm. long. Anteriorly from the jugum the descending lamellae are long and slender and diverge at a small angle. Their dorsal surface, from the posterior end of the jugum to the anterior tip, is provided with long, slender, needle-like spines, the longest one measuring 0.8 mm. in length. The descending lamellae anterior to the jugum diverge at a low angle and curve strongly in an

anteroventral direction. At their distal end they bear an unusually large hood with very short attachment to the descending lamellae. The hood is greatly enlarged posteriorly where it measures 1.7 mm. in length but narrows to its base of attachment where it is only 0.5 mm. long. The hood is not attached posteriorly to the descending elements. In ventral view the hood flares widely, 1.4 mm. wide, and the posterior edge is deeply notched.

Comparison of the loop of C. compacta *with that of* C. prolifica.— The loops of these two species are strikingly different. Posteriorly, that of *C. compacta* has more widely spaced descending lamellae and the jugum attaching these lamellae is longer and wider. The striking difference however is in the hoods. That of *C. prolifica* in the adult form has a long attachment and the posterior part is often extended as converging septa posteriorly along the inner edges of the descending lamellae. The hood of *C. compacta* on the other hand is greatly expanded posteriorly and its attachment to the distal ends of the descending lamellae is very short. Only one loop of *C. compacta* was studied, but when this is compared with the many specimens of *C. prolifica* it seems evident that the loop of the Iowa species was provided with more and longer spines than that of the New Mexico species.

COMPARISON OF THE LOOP OF *CRYPTACANTHIA* WITH LOOPS OF OTHER PALEOZOIC GENERA

The best-known long-looped Paleozoic brachiopod is *Cryptonella* whose loop typifies one major type of Paleozoic loop. It is like the end stage of both types of modern terebratellid loops. In *Cryptonella* the loop is simple in form and very slender in both ascending and descending elements. The development of this loop is not yet known but it is one of the most ancient of terebratulid loops as it occurs in the early Devonian. It is an odd fact that one of the most highly specialized loops is actually one of the earliest. The loop of *Cryptacanthia* is not cryptonelliform although it simulates that loop in its late stages.

The loop most like that of *Cryptacanthia* is that of *Glossothyropsis.* Although the loop of the type species of *Glossothyropsis* is yet unknown, other species have been taken from the Monos formation of Mexico and the Word formation of Texas which show well-preserved loops. The loop approaches the cryptonelliform loop in form, but the ascending elements are usually fairly broad and suggest the origin of the *Glossothyropsis* loop from that of *Cryptacanthia.* Elimination of the jugum joining the descending elements of *Cryptacanthia* and

narrowing of the ascending elements will produce the loop of *Glossothyropsis*.

The development of the external form of the two genera is also similar. *Glossothyropsis* is cryptacanthiform in its profiles and the disproportionate size of the two valves. The brachial valve of both genera is shallow. *Glossothyropsis* usually has a fairly strong median septum whereas that of *Cryptacanthia* is less well developed but far better developed than indicated by Girty. It is thus probable that *Glossothyropsis* is the ultimate stage of development of the cryptacanthiform loop. It is probable that the geologically youngest species of *Glossothyropsis* will be found with a loop advanced to the cryptonelliform condition by narrowing of the ascending elements.

COMPARISON OF THE LOOP STAGE OF *CRYPTACANTHIA* WITH LOOP STAGES OF OTHER TEREBRATULIDS

The only known long-looped late Paleozoic brachiopods are *Cryptacanthia, Glossothyropsis, Heterelasma,* and an unnamed genus with cryptonelliform loop. The loop development of only the first one is now known. As described here *Cryptacanthia* passes first through a centronelliform stage (stages 1.5 to 3.5 mm.). The centronelliform stage characterizes a number of the earlier Paleozoic genera, such as *Centronella, Nanothyris, Beachia, Oriskania, Rensselaeria* and a few others (Cloud, 1942). No other adult loop is now known which represents the stages between 3.0 mm. and the point at which the jugum is completely absorbed. These stages of development of the hood are here called the cryptacanthiform loop. When the descending lamellae are free and the hood is represented by a broad ascending element with a broad transverse ribbon the loop is similar to that of *Glossothyropsis* and is called the glossothyropsiform stage.

Comparison of these loop stages with the dallinid and terebratellid loops shows fundamental differences (Elliott, 1953). Both of the terebratellid families differ from *Cryptacanthia* in loop development in possessing a median septal pillar or septum in the initial stages. *Cryptacanthia* has only a modest median septum, and as revealed by *C. prolifica* this does not develop until the late stages of the ontogeny. Furthermore, the septum of *Cryptacanthia* is independent of the loop. In the terebratellids the median pillar is important because it is the site of development of the hood and median ring which produce the ascending elements of the adult loop.

The loop-development stages of the Paleozoic *Cryptacanthia* thus bear little resemblance to the stages of development of the terebratellid genera even though the glossothyropsiform loop is similar to the

loop of *Dallina* or *Magellania*. The cryptonelliform loop, which consists of long, slender descending branches, slender ascending elements, and a slender transverse band, may be the ultimate stage in the development of the cryptacanthiform loop and is thus a parallel development of the ultimate terebratellid loop.

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EXPLANATION OF PLATES

Plate 1

Unless otherwise stated all specimens are from Grapevine Canyon locality.

A. *Cryptacanthia prolifica* Cooper, new species.
Figs. 1-3. Dorsal, ventral, and side views, respectively, of a complete loop, × 6, showing the rows of spines. From a specimen in the 7 to 9 mm. stage. Paratype U.S.N.M. No. 127205l.

B. *Glossothyropsis* sp.
Figs. 4, 5. Ventral and side views of the loop of a specimen from the Word formation, Glass Mountains, Tex., showing the narrow ascending elements and the free descending branches, × 2. Figured specimen U.S.N.M. No. 127254.

C. *Cryptacanthia prolifica* Cooper, new species.
Fig. 6. Side view of a specimen 7.5 mm. long showing aberrant hood with cavity in its attachment to the descending branches, × 6. Paratype U.S.N.M. No. 127204n.

D. *Cryptacanthia prolifica* Cooper, new species.
Figs. 7-21. 7, View of the pedicle valve of the smallest specimen recognized as *C. prolifica*, × 8, paratype U.S.N.M. No. 127202j. 8-12, A series of 5 specimens showing juvenile forms with their open delthyrium, × 4, paratypes U.S.N.M. Nos. 127205m-q, respectively. 13, View of the brachial valve of a complete specimen, × 1, showing size

and form, paratype U.S.N.M. No. 127208z. 14, 15, Brachial views of two individuals more slender than normal, × 3, paratypes U.S.N.M. Nos. 127208y and 127205s. 16-20, Anterior, posterior, side, pedicle, and brachial views, respectively, × 3, of the holotype U.S.N.M. No. 127066. 21, Posterior half of a large adult showing the oval foramen and deltidial plates, × 6, paratype U.S.N.M. No. 127205t.

E. *Cryptacanthia prolifica* Cooper, new species.

Fig. 22. Posterior part of a brachial valve showing the cardinalia with the convex inner plate and its foramen, × 6, paratype U.S.N.M. No. 127205i.

F. *Cryptacanthia prolifica* Cooper, new species.

Fig. 23. Imperfect loop, × 6, with hood broken away to show the posterior extensions of the hood attachment and the jugum, paratype U.S.N.M. No. 127207p.

G. *Cryptacanthia prolifica* Cooper, new species.

Fig. 24. Partial side view of a small specimen, about 5 mm. long, showing small hood, spiny descending branches, and crural processes, × 6, paratype U.S.N.M. No. 127204s.

H. *Cryptacanthia compacta* White and St. John.

Fig. 25. Side view of a lump of calcite containing a complete loop, × 10, showing the small erect hood, hypotype U.S.N.M. No. 9382a. Specimen from Pennsylvanian, Madison County, Iowa. Photograph taken under water. Note long spines in lower left.

I. *Cryptacanthia prolifica* Cooper, new species.

Figs. 26, 27. Posterior and ventral views, respectively, of a perfect loop showing the anterior notch in the hood, anterior cleft, and the crural processes, ca. × 10, paratype U.S.N.M. No. 127204t. (For additional views see pl. 2, G, figs. 13, 14.)

Plate 2

All figures of *Cryptacanthia prolifica* Cooper, new species, and all from Grapevine Canyon locality.

A. Stage 1.6-2.0 mm. (precentronelliform stage?).

Fig. 1. Early loop stage showing very slender and delicate loop, ca. × 15, paratype U.S.N.M. No. 127202k.

B. Stages 2.1-2.5 mm. (centronelliform stage).

Fig. 2. Specimen showing stouter descending branches than the preceding which unite to form an echmidium, × 8, paratype U.S.N.M. No. 127206r.

Fig. 3. Another brachial valve with well-preserved loop showing long, pointed echmidium, × 10, paratype U.S.N.M. No. 127202s.

C. Stages 2.6-3.0 mm. (centronelliform stage or possibly early cryptacanthiform stage).

Fig. 4. Brachial valve showing loop with echmidium and incipient bud (?) of the hood, × 10, paratype U.S.N.M. No. 127202u.

Fig. 5. The loop of another specimen, × 20, showing the elbow in the descending lamellae and the echmidium with a thickening, possibly the bud of the hood, paratype U.S.N.M. No. 127202w.

D. Stages 3.1-3.5 mm. (early cryptacanthiform stage).

Fig. 6. Specimen with pedicle valve partially removed to show loop and the small hood seen from the ventral side, × 8, paratype U.S.N.M. No. 127206k.

Fig. 7. Partial view from the dorsal side showing loop with small early hood, × 8, paratype U.S.N.M. No. 127203i.

Fig. 8. Another specimen showing trace of early hood, × 8, paratype U.S.N.M. No. 127203h.

E. Stages 3.6-4.0 mm. (cryptacanthiform stage).

Fig. 9. Specimen with part of brachial valve stripped off to show upper part of hood, × 8, paratype U.S.N.M. No. 127203l.

F. Stages 4.1-4.5 mm. (cryptacanthiform stage).

Figs. 10, 11. Side and partial side views of a specimen showing the small early hood and its slender attachment to the descending branches, × 8, paratype U.S.N.M. No. 127204h.

Fig. 12. Side view of another specimen showing hood with long posterior extension, × 6, paratype U.S.N.M. No. 127204c.

G. Stages 4.6-5.0 mm. (cryptacanthiform stage).

Figs. 13, 14. Ventral and side views of an exceptionally well-preserved adult loop, × 6, paratype U.S.N.M. No. 127204t. (For additional views of this specimen see pl. 1, I, figs. 26 and 27.)

Fig. 15. Imperfect loop from dorsal side, × 6, showing jugum, paratype U.S.N.M. No. 127203x.

H. Stages 5.0-6.0 mm. (late cryptacanthiform stage).

Fig. 16. Loop seen in side view and showing long attachment to descending branches and septumlike extensions posteriorly, × 6, paratype U.S.N.M. No. 127204q.

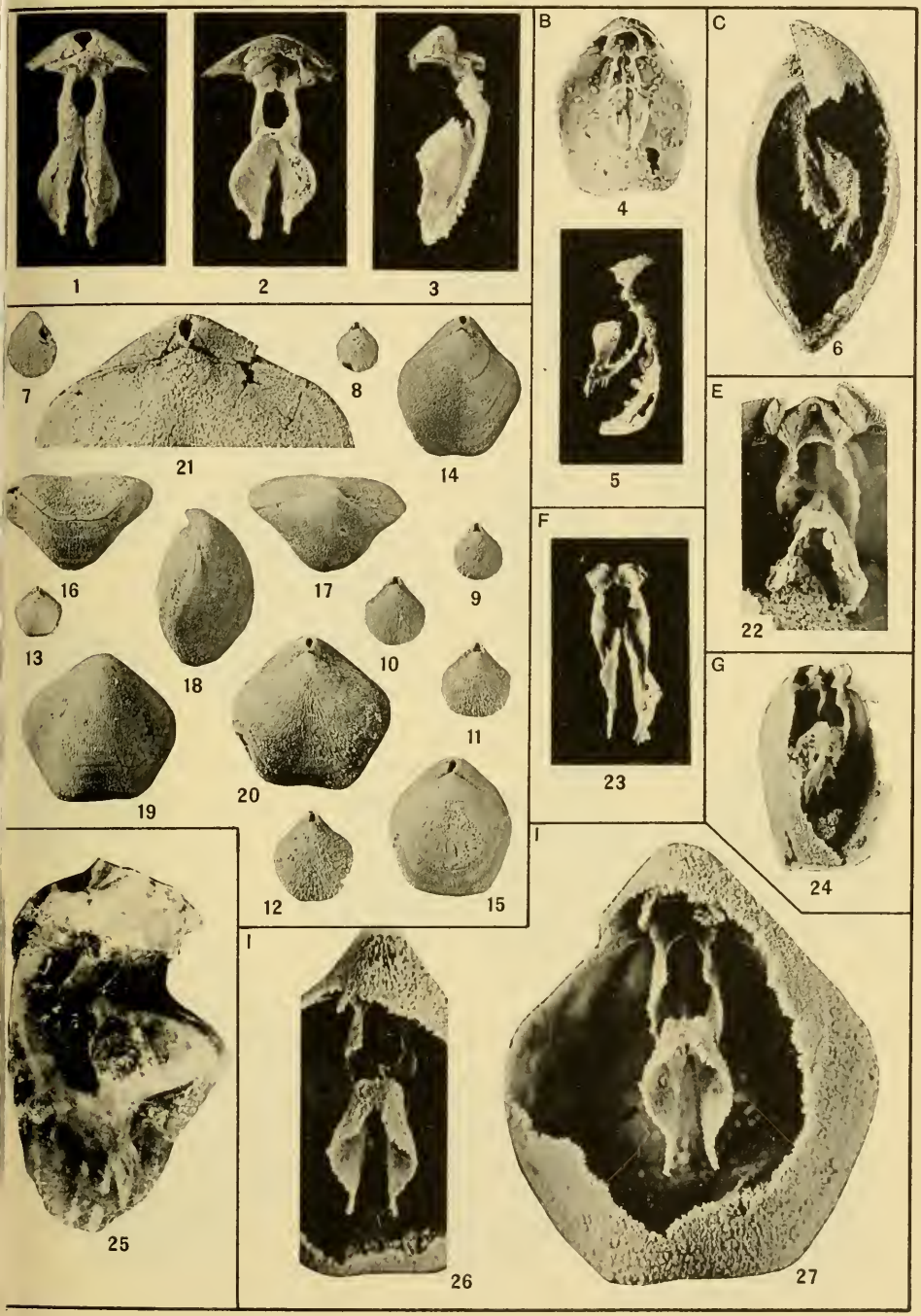
Figs. 17, 18. Two anterior views of a specimen showing the expanded hood, × 6, paratype U.S.N.M. No. 127204-o.

I. Stages 7.1-9.0 mm. (late cryptacanthiform to early glossothyropsiform stages).

Fig. 19. Adult loop seen from the laterodorsal view and showing the jugum, and the descending lamellae with their rows of spines, × 6, paratype U.S.N.M. No. 127204l.

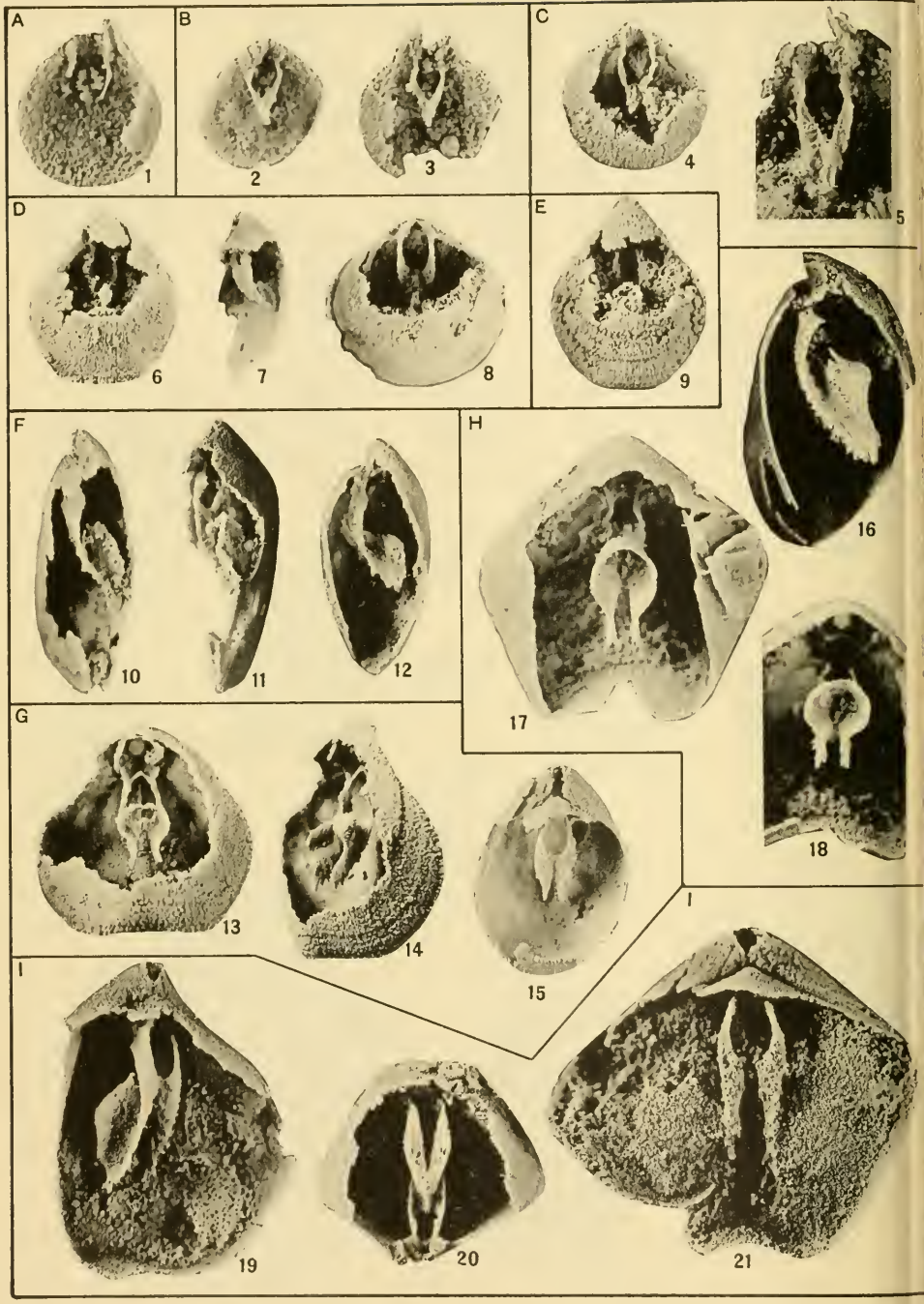
Fig. 20. Specimen seen from the posterior to show the posterior side of the hood, × 4, paratype U.S.N.M. No. 127205j.

Fig. 21. One of the largest specimens in the collection showing the descending lamellae from the dorsal side and absence of a jugum tying the branches together, × 6, paratype U.S.N.M. No. 127205h.



CRYPTACANTHIA PROLIFICA COOPER, NEW SPECIES, AND GLOSSOTHYROPSIS SP.

(SEE EXPLANATION AT END OF TEXT.)



CRYPTACANTHIA PROLIFICA COOPER, NEW SPECIES

(SEE EXPLANATION AT END OF TEXT.)