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UPPER DEVONIAN AND LOWER MISSISSIPPIAN
PECTINOID PELECYPODS FROM MICHIGAN,
OHIO, INDIANA, IOWA, AND MISSOURI

BY

THOMAS W. HUTCHINSON and ERWIN C. STUMM



MUSEUM OF PALEONTOLOGY
THE UNIVERSITY OF MICHIGAN
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VOLUME XX

1. Upper Devonian and Lower Mississippian Pectinoid Pelecypods from Michigan, Ohio, Indiana, Iowa, and Missouri, by Thomas W. Hutchinson and Erwin C. Stumm. Pages 1-48, with 7 plates.

UPPER DEVONIAN AND LOWER MISSISSIPPIAN PECTINOID
 PELECYPODS FROM MICHIGAN, OHIO, INDIANA,
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ABSTRACT

A restudy of the Upper Devonian and Lower Mississippian pectinoid pelecypods described by C. A. White and Alexander Winchell has resulted in redescription and illustration of four species of the genus *Aviculopecten*, one of *Pseudomonotis*, three of *Euchondria*, and four of *Pernopecten*.

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INTRODUCTION

THIS PAPER is a partial revision of pectinoid¹ pelecypods described by Alexander Winchell during the period 1861–1871 in light of subsequent work. During this period, when Winchell was “Professor of Geology, Botany, and Zoology” at the University of Michigan, he concentrated his efforts on the description of the stratigraphy and paleontology of Michigan and correlated his results with what was then known of the stratigraphy and paleontology of adjacent sedimentary basins. His paleontologic studies need revision in part because his work was never illustrated, although many drawings were prepared, and many of his descriptions are incomplete. This has resulted in misunderstanding of many of the genera and species which he erected. The material with which Winchell worked was to a large extent collected by himself but significant contributions were also made by Dr. Charles A. White (“White Collection,” University of Michigan Museum of Paleontology) and the Reverend H. Herzer, an Ohio minister whose hobby was paleontology.

The additional material herein described was either collected by Dr. G. M. Ehlers during the summer of 1915, while working for Dr. George H. Girty, or in the case of *Euchondria areolatus*, collected by A. C. Lane just prior to the turn of the present century and described by Cooper (*in* Lane, 1900). This species is revised in the present work.

Although very limited in extent, the data herein presented supports current ideas about the stratigraphic and historical relationships of the Michigan Basin with adjoining sedimentary basins. It is hoped that this material will eventually contribute to a more precise understanding of these relationships.

The measurements contained in the tables of valve measurements are expressed in millimeters. Where permitted by the preservation, the measurements were read to the nearest 0.1 mm. Because of the poor preservation of many forms, reconstructed measurements were made, and are indicated by values to the nearest 1 mm. The angles are generally to the nearest 1 degree, but in some cases, again due to poor preservation, they are estimated to the nearest 5 degrees. The measurements of convexity are perhaps the least accurate and are estimated to the nearest 0.1 mm.

The suprageneric classification follows that of Newell (1937) and Shimer and Shrock (1944, p. 366).

Symbols used to designate repositories are as follows: UMMP, University of Michigan Museum of Paleontology; USNM, United States National

¹The term refers to forms like *Pecten* in general shape without having any taxonomic implication.

Museum; AMNH, American Museum of Natural History; and UMDG, University of Missouri Department of Geology.

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Thanks are due to Dr. Richard D. Hoare, Department of Geology, Bowling Green State University, for the positive identification of material of questionable age; and to Marjorie G. Arnold, United States Geological Survey, for the loan of Dr. Ehlers' field notebook (summer, 1915).

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STRATIGRAPHIC RELATIONSHIPS

The temporal relationships of the forms described herein cannot be appreciated without a brief reference to current ideas concerning the age relationships of the various stratigraphic units involved. Figure 1 reflects these relationships graphically. The columns are representative of the uppermost Devonian and Lower Mississippian sections at the localities from which the specimens were collected. The vertical extent of a formation or group in the column is not a measure of that unit's thickness, but of the segment of time which it represents. Each column, therefore, provides a simple method of displaying temporal relationship to laterally adjacent columns.

The following is a brief discussion of each column; stratigraphic units considered in descending order:

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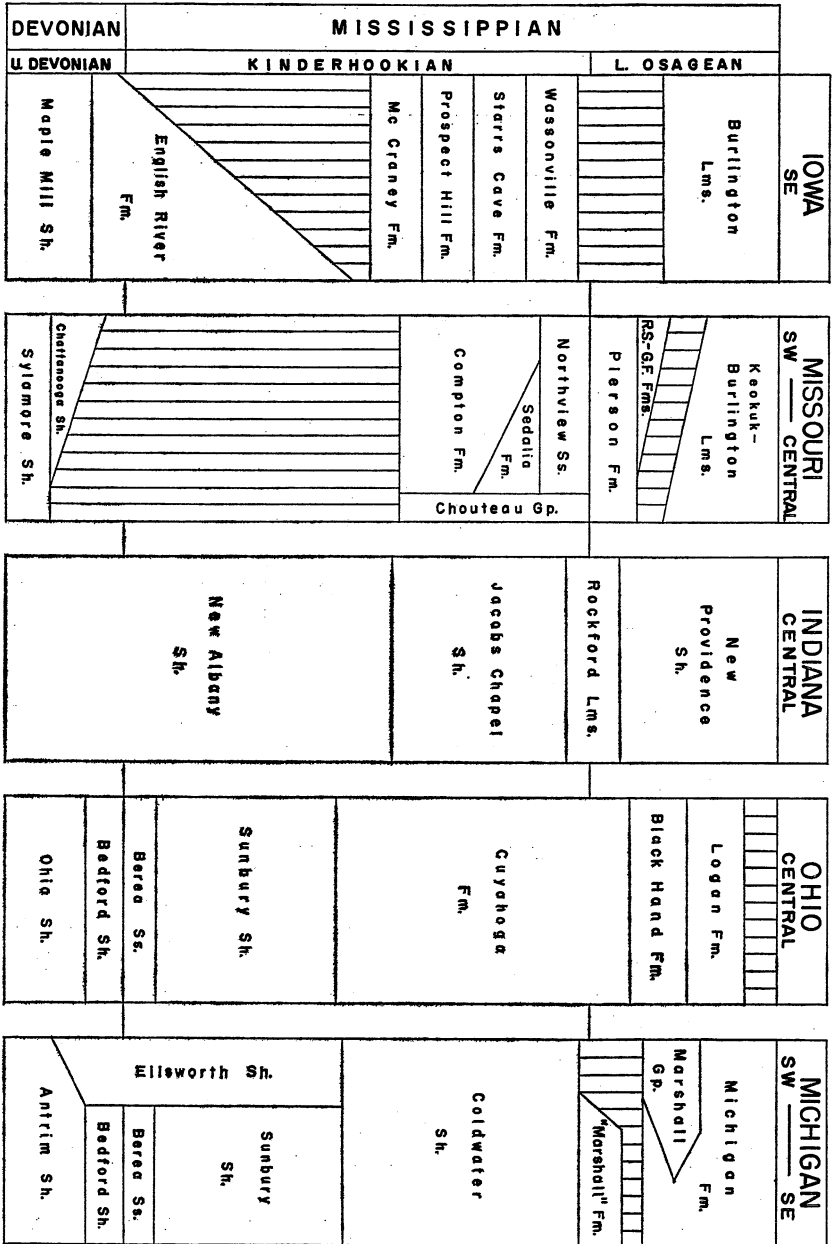


FIG. 1. Correlation chart of Upper Devonian and Lower Mississippian strata of Iowa, Missouri, Indiana, Ohio, and Michigan.

COLUMN 1—BURLINGTON, IOWA

(Weller, J. M., 1948, Collinson, 1961, Van Tuyl, 1922)

- Burlington Limestone*.—Brownish, locally dolomitic, crinoidal limestone.
- Wassonville Formation* (Bed No. 7²).—Soft, brownish, dolomitic limestone.
- Starrs Cave Formation* (Bed No. 6).—White, oolitic limestone.
- Prospect Hill Formation* (Bed No. 5).—Massive gray argillaceous siltstone, weathering buff.
- McCraney Formation* (Beds No. 3 and 4).—Brownish dolomitic limestone, upper part oolitic.
- English River Siltstone* (Bed No. 2).—Massive gray siltstone weathering buff. At Burlington this unit is Upper Devonian in age, elsewhere in southeastern Iowa the upper portions are Mississippian in age (Collinson, 1961, p. 106).
- Maple Mill Shale* (Bed No. 1²).—Bluish argillaceous shale.

COLUMN 2—SOUTHWESTERN AND CENTRAL MISSOURI

(Spreng, 1961)

- Burlington-Keokuk Formations*.—Coarsely crystalline, white to light buff crinoidal limestones; chert layers abundant.
- Reeds Springs-Grand Falls Formations*.—Finely crystalline, blue-gray limestone, locally argillaceous, abundant chert nodules.
- Pierson Formation*.—Brown dolomite, locally high in cherty limestone and silt.
- Chouteau Group*.
- Northview Formation*.—Brown, buff, and bluish siltstones and blue and blue-green shales. Characteristic worm burrows caused earlier workers to call it the "Vermicular Sandstone."
- Sedalia Formation*.—Gray to bluish-gray, finely crystalline limestone.
- Compton Formation*.—Bluish-gray, finely crystalline to sublithographic, crinoidal limestone.
- Chattanooga Shale*.—Black, fissile, carbonaceous, locally arenaceous shale.
- Sylamore Formation* (Bushburg Formation).—Yellowish-brown, fine to coarse-grained, friable sandstone.

COLUMN 3—CENTRAL INDIANA

(Weller, J. M., 1948; Collinson and others, 1962; Rexroad and Scott, 1964)

- New Providence Shale*.—Gray, gray-blue, or gray-green, locally calcareous shale.
- Rockford Limestone* ("Goniatite Limestone" of authors).—Dense, solid, gray limestone, mottled and streaked with green, weathers a rusty brown; continuous in subsurface with Chouteau Group of Upper Mississippi Valley.
- Jacobs Chapel Shale*.—Soft, green, glauconitic shale.
- New Albany Shale* (not subdivided).—Black, gray, and green fissile shales.

COLUMN 4—CENTRAL OHIO

(Weller, J. M., 1948; Hyde, 1953; Winslow, 1962; Collinson, and others, 1962)

- Logan Formation*.—Yellow and gray sandstones and shales.

² Early workers (Owen, 1852; Hall and Whitney, 1858; White, 1860; Keyes, 1895; Weller, 1899; and Van Tuyl, 1922) designated the units in this section with numbers. Those used above follow the last two authors.

Black Hand Formation.—Reddish and buff sandstones, buff and bluish shales, and quartz pebble conglomerates.

Cuyahoga Formation.—Alternating, coarse bluish sandstones and bluish shales.

Sunbury Shale.—Black, fissile, carbonaceous shale.

Berea Sandstone.—Medium to finegrained, gray quartzose sandstone.

Bedford Shale.—Red, chocolate, and gray shales with occasional ripple-marked siltstone partings.

Ohio Shale.—Black, brown, and gray, fissile, carbonaceous shale.

COLUMN 5—SOUTHERN MICHIGAN

(Weller, J. M., 1948; Monnett, 1948; Moser, 1964)

Michigan Formation.—Gray sandstones and shales, gypsum, limestone, and dolomite.

Marshall Group.

Napoleon Sandstone.—Buff and gray, medium-grained, friable sandstone.

Marshall and "*Marshall*" *Sandstones*.³—Reddish-brown and yellowish-brown sandstones, commonly argillaceous and silty.

Coldwater Shale.—Gray and red shales with sandstone and siltstone interbeds and occasional siderite nodules or layers.

Sunbury Shale.—Black, fissile, carbonaceous shales.

Bedford Shale.—Gray shales with siltstone partings.

GEOLOGIC HISTORY

To permit visualization of the spatial relationships between fossils occurring in different areas in terms of the geography and history of the time interval involved (Upper Devonian-Lower Mississippian), the following brief, and very general sequence of events is presented.

Late Upper Devonian (Fig. 2A).—This was a time of relative tectonic stability in the central interior. Topographic features included the Nashville dome, uplifted in Upper Devonian times, and the Cincinnati dome, uplifted in Middle Devonian times, and probably rather low-lying by this time (Eardley, 1962, p. 49). The Kankakee and Findlay arches had been in existence as submarine highs connecting the Cincinnati dome with the Wisconsin dome and Ontario highlands, respectively, since early Ordovician times (Eardley, 1962, pp. 50–51). The fine clastics which were deposited throughout the area represented, came from low-lying source areas, the strand lines of which were indented with many bays and gulfs (Williams, 1957, p. 293). Minor transgressions and regressions of the epicontinental sea caused fluctuations in the shore lines, but the central interior remained an interconnecting entity with few exceptions. Late Devonian times was marked by the uplift of the northern and central portions of the Appalachian geosyncline (Acadian orogeny).

³ Moser claims that the "Marshall" in the eastern part of the state is older than the true Marshall in the west.

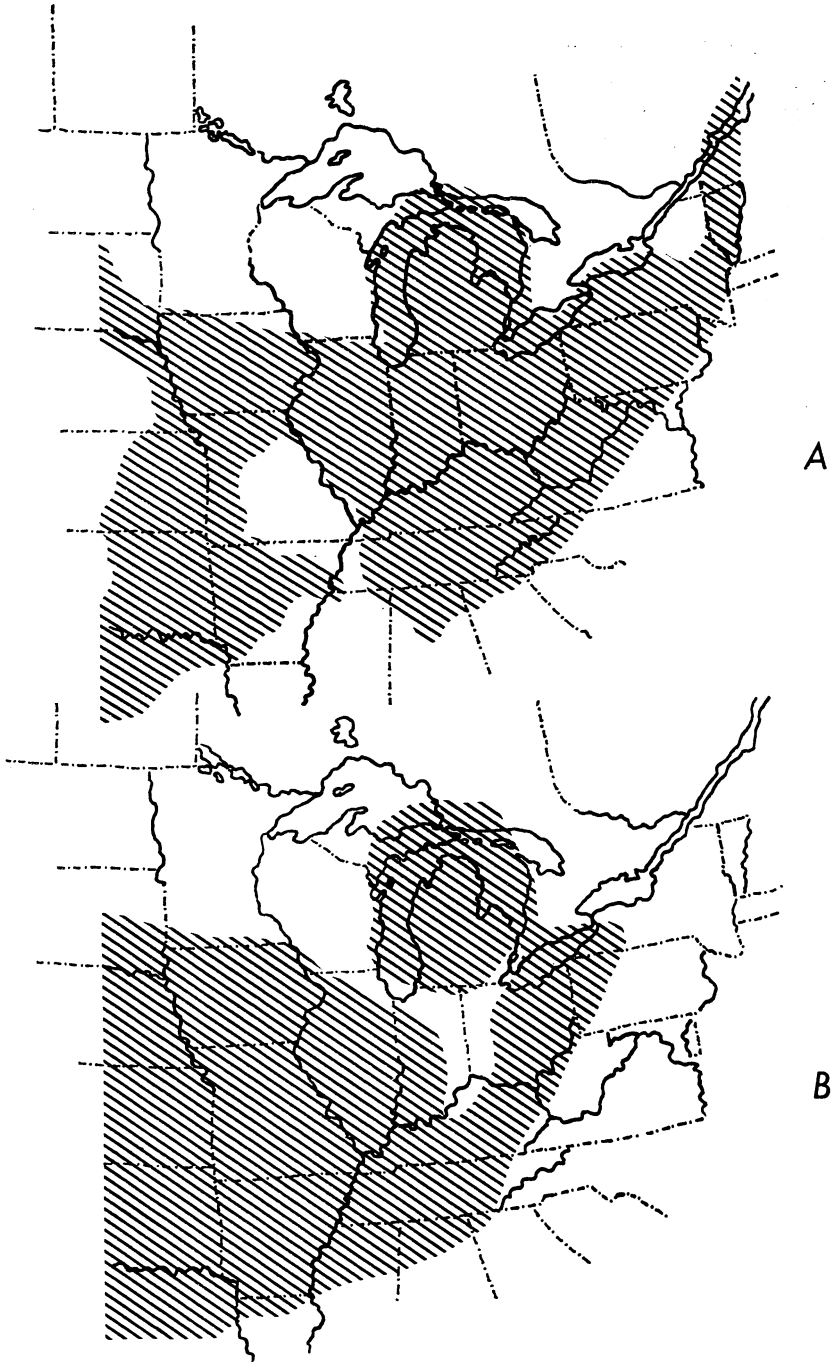


FIG. 2. Paleogeographic maps of A, Upper Devonian, and B, Lower Mississippian times.

Lower Mississippian (Fig. 2B).—No widespread unconformity separates the Devonian and Mississippian systems throughout the present area of study, although significant breaks occur at this time in the stratigraphic record in Iowa and Missouri, indicating that shore lines continued to fluctuate in this area. Depositional sites in Ohio and Indiana received some sediments from the Cincinnati dome area but the bulk of material deposited in the Ohio-Indiana area in lower Kinderhook times came from the east and southeast where the delta systems caused by the Acadian disturbance continued to dump sediments into "Ohio Bay" and to a lesser extent, adjacent areas (Pepper and others, 1954, p. 100).

Toward the close of Kinderhook times the Iowa-Illinois-Missouri seas transgressed the surrounding low-lying land areas and perhaps even the Ozark dome (Eardley, 1962, p. 52). The quiescent conditions which followed favored the deposition of carbonates and very fine clastics and continued through the end of Osage times.

Farther east, the beginning of Osage times brought a slight upwarp in the Cincinnati dome area, most likely raising the Kankakee and Findlay arches to a position of slight emergence and isolating the Michigan Basin from the rest of the depositional basins in the central interior (with perhaps the exception of a submerged area in the vicinity of Chatham, Ontario—the Chatham sag—which was the only communication with the "open" epicontinental sea). While the Ohio sediments were still coming from the south-southeast source area which had provided sediments in Kinderhook times, the Michigan Basin began an independent history, initiated with the deposition of the Michigan Formation evaporites (Monnett, 1948, p. 686; Lane, 1895, p. 19). The Michigan seas are believed to have been replenished with water from the epicontinental sea over a "sill" located somewhere in the northeastern part of the basin (Moser, 1964, p. 39), and perhaps connected to the Chatham sag.

Throughout Upper Devonian and Kinderhook times the three depositional areas (Michigan Basin, western part of Appalachian Basin-Ohio Valley, and Eastern Interior Basin and adjacent areas in Illinois, Indiana, Missouri, and Iowa) were interconnected, affording free access to each of the basins from either of the others. This is substantiated by the geographic and stratigraphic distribution of fossils discussed in this work. With the upwarping of the Cincinnati-Kankakee-Findlay arches to the extent that complete intercommunication was no longer possible, each area underwent a more or less independent depositional and environmental history throughout the remainder of the Mississippian Period.

SYSTEMATIC PALEONTOLOGY

Phylum MOLLUSCA

Class LAMELLIBRANCHIA

Order PRIONODESMACEA

Family Aviculopectenidae

Genus *Aviculopecten* McCoy, 1851

Aviculopecten McCoy, 1851, p. 171; Hall, 1884, p. xii; 1884a, p. 12; Hind, 1903, p. 66; Newell, 1937, p. 43.

Type species.—By subsequent designation, *Aviculopecten planoradiatus* McCoy, from the Carboniferous Limestone of Derbyshire, England (Hind, 1903, p. 66).

Remarks.—The original description was based on specimens of *Pecten flexosus* McCoy (*non P. flexosus* Lamarck), a form described in 1844 from the Carboniferous Limestone of Lowick, Northumberland (Girty, 1904, p. 294). This form was not mentioned at the time the genus was erected, indeed this did not occur until four years later when McCoy renamed it *Aviculopecten docens*, at which time he also indicated that it was this form upon which the genus was based (McCoy, 1855, p. 392). Notwithstanding this intent, as pointed out by Newell (1937, p. 44):

“According to Article 30, Case IIa, paragraph *a* of the International Rules of Zoological Nomenclature, those species which were not included under the generic name in the original publication are excluded from consideration in determining the types of genera. Anonymous species and *species inquirendae* are also ineligible for genotype species.”

This species cannot be the type species. Along with the generic description of *Aviculopecten*, McCoy described two forms: *Aviculopecten planoradiatus* and *A. ruthveni*, and included a line drawing of *A. docens*, the latter treated anonymously.

A restudy of some of the paratypes of *A. docens* McCoy and the primary types of *A. planoradiatus* McCoy, caused Newell to conclude that the *A. planoradiatus* material was inadequate to use by itself as a basis for the proper description of the genus, and that *A. docens* is, in fact a *Limipecten* (a genus distinguished on the basis of its peculiar ornamentation). As a result of his former conclusion he selected the Pennsylvanian forms *A. occidentalis* Shumard, and *A. exemplaris* Newell on the basis of their possession of typical characters, to use to develop his emended generic description (Newell, 1937, pp. 43, 45).

The confusion between *Aviculopecten* and *Deltopecten* over the presence or absence of resilifers is also discussed by Newell (*op. cit.*, p. 45). The belief that *Aviculopecten* did not have a resilifer was generated by an

erroneous original description. In 1892, Etheridge (p. 269) erected the genus *Deltopecten* to receive aviculopectinoid forms possessing a resilifer. The two genera were erroneously distinguished from each other on this basis until Newell's inspection of the primary type material revealed that *Aviculopecten* does possess a resilifer. The most conspicuous feature which distinguishes *Deltopecten* from *Aviculopecten* is the truly plicate valves of the former.

Aviculopecten gradocostus White

(Pl. I, Figs. 1-2, 6, Table I)

Aviculopecten gradocostus White, 1862, p. 31.

Original description (White, 1862, p. 31):

Shell large, a little inequilateral, broader than high; left valve rather flat; right valve more convex; umbones large, prominent, shell on the anterior slope bending abruptly down to the anterior wing, which is faintly radiated. Hinge line and full length of wings unknown. Surface marked by about twenty-five broad, flat, compound ribs on the body of each valve, which are well developed near the basal margin, but more indistinct on the umbones and slopes. These ribs are separated by a narrow groove, and surmounted by a distinct carina of about the same width as the groove, giving the sides of the ribs somewhat the appearance of minute steps.

Locality and position, in the sandstone of the Chemung⁴ beds at Burlington, Iowa.

Revised description.—Valves large, acline, pectiniform, slightly asymmetrical, left valve more nearly symmetrical than right. Length of valves equal to, or slightly greater than the height, length of hinge line unknown. Ventral margin regularly rounded; anterior margin rounded to a point almost one-half the distance from the ventral margin to the beak, from which point the margin of the shell body describes a straight line to the beak; posterior margin regularly rounded to a point about one-third the distance to the beak on the right valve, and about one-half the distance to the beak on the left, from which point the margin of the shell body describes a straight or slightly concave line to the beak. Umbonal angle about 105 degrees, umbos prominent, extend above hinge line.

Anterior auricular sulcus, left valve, prominent, shell body slightly overhangs auricle. Posterior auricle, left valve, merges with the shell body below in a gently curving surface (Pl. I, Fig. 6).

Ornamentation on the left valve consists of about twenty-five broad, flat fascicles⁵ separated by rather narrow grooves. The fascicles are narrowest near the center of the ventral margin, and increase in breadth toward

⁴ Several early workers correlated the Kinderhook beds at Burlington, Iowa, and the Waverly Group of Ohio with the Chemung.

⁵ The term "fascicle" as used herein denotes a group of costae distinguishable from other such groups of costae. The costae are generated by bifurcation or implantation.

both the anteroventral and posteroventral margins. Surmounting each fascicle is a single prominent costa, which is implanted rather early in ontogeny, and increases in prominence during growth. The fascicles in the center of the valve, in their earliest visible portions, consist of two or three fine, implanted costae, all of which become indistinct a short distance from the ventral margin, except for the central prominent one (Pl. I, Fig. 6). At the ventral margin several fascicles again display implanted costae. The smaller costae are most prominent and persistent on the anteriormost fascicles.

Ornamentation on the right valve also consists of fascicles, about as numerous as those on the left valve. All costae, however, are of about equal prominence, and with the exception of the central one, appear to be generated through bifurcation. There is an average of four costae per fascicle on this valve. No concentric ornamentation is present on either valve.

Remarks.—The above description is based on three external casts, one left valve and two right valves, which are part of the collection purchased from C. A. White in 1863. No shell material is presented, nor can anything be determined of the nature of the auricles or hinge structure. The referral of this species to *Aviculopecten* therefore, is on the basis of general shape and to some extent, the ornamentation.

The faint radiations on the anterior auricle of the left valve, mentioned by White in his original description, were not observed by the authors.

The fascicostate nature of the ornamentation perhaps suggests an affinity with the genus *Fasciculiconcha* Newell, but inclusion of this species in this genus is precluded by the fascicostate nature of the right valve, the lack of concentric ornamentation, and the rather flat nature of the left valve.

The ornamentation on the left valve is quite similar to that in *Deltopecten* Etheridge, but the valves do not appear to be truly plicate. The

TABLE I
MEASUREMENTS OF *Aviculopecten gradocostus* WHITE
(Measurements in mm, except for angles)

Type Specimens		
	Right Valve (2) Hypotypes	Left Valve Holotype
Length	70.4–92.1	106.1
Height	56.0	87.0
Convexity	8.8–10.5	14.6
Shell body costae	20–28	23
	fascicles	fascicles
Umbonal angle	104°–110°	106°

obsolescence of costae in the central portion of the valve is likely a product of poor preservation.

A latex mold was made of the right valve of a specimen almost identical with the one illustrated in Pl. I, Fig. 1, but which showed the ornamentation somewhat better. The impression is close to the type of ornamentation expected on typical *Aviculopectens*.

Comparison.—This species is unique in its large size and peculiar ornamentation.

Type material and repository.—The species is known from only three specimens; the holotype (a left valve) UMMP No. 2141, and two right valves herein designated hypotypes, UMMP Nos. 50113 and 50114.

Occurrence.—The labels accompanying the specimens indicate only "Kinderhook Group, Burlington, Iowa" as the locality. One of the specimens however, has on the same slab a specimen of *Aviculopecten tenuicostus* (Pl. I, Fig. 1) which would fix the stratigraphic horizon as the English River Sandstone, the only formation at this locality containing *A. tenuicostus* (Van Tuyl, 1922).

Aviculopecten caroli Winchell

(Pl. II, Figs. 1-3, 5, 7-10, Table II)

Aviculopecten caroli Winchell, 1863, p. 9; non 1865, p. 125; non 1870, p. 255; non Hall, 1884, p. 29, Pl. 9, Fig. 5; Weller, 1900, p. 82, Pl. 3, Fig. 4.

non *Crenipecten caroli*, Herrick, 1888, Pl. 5, Fig. 9; 1889, Pl. 3, Fig. 9; 1893, Pl. 24, Fig. 4.

Original description (Winchell, 1863, p. 9):

Shell medium in size, subcircular, ventricose. Hinge-line shorter than the shell; anterior ear of right valve shorter than anterior end of shell, rounded, slightly inflated, with a deep, sharply rounded notch below; posterior ear acute, slightly longer than anterior, with a broad, shallow notch below; shell otherwise nearly equilateral. Beak central, inconspicuous; greatest convexity of valve a little above the middle. External surface of the body of the valve marked by about 25 nearly equidistant, narrow, sharply-raised, radiating ribs, with two or three fine, raised striae in each of the inter-spaces; a set of very fine, sharp, close, concentric raised lines cross the smaller ribs, but are intercepted by the primary ones. The latter, however, show a tendency, toward the pallial margin of the valve, to develop nodes, which on the anterior and posterior slopes, become distinct spines. The spines sometimes occur in the spaces between the primary ribs. The wings are also marked by two sets of raised lines, but on the posterior wing the radiating set is most prominent, while on the anterior wing the concentric set is strongest. The left valve is exactly like the right, except that the notch below the anterior ear is shallower.

Length from beak to ventral margin .66(100)⁶; length of hinge-line .55(83);

⁶ Winchell's measurements are in inches. The numbers in parentheses are percentage values of the measurements taken in relation to the greatest dimension which is given the value of 100.

convexity of right valve .20(30); antero-posterior dimension .66(100). Number of concentric lines in one-tenth of an inch, 16. The adult size of the species seems to be about one inch in length and breadth.

Ranges from the base of the yellow sandstones into the base of the Burlington.

Revised description.—Valves acline, pectiniform, ventricose, medium in size. Length of valve slightly greater than height, hinge line equal in length to about four-fifths valve length. The rate of growth in the direction of the length is greater than that in the dorsoventral direction as the ratio of length to height increases with development (cf. Pl. II, Figs. 1, 7, 8). Ventral margin regularly rounded, equilateral; anterior margin regularly rounded to a point about two-thirds the distance to the beak, from which point the margin of the shell body describes a slightly concave line to the beak; posterior margin regularly rounded to a point about four-fifths the distance to the beak, from which point the margin of the shell body describes a straight line to the beak. Umbonal angle about 110 degrees, umbo distinct, projects slightly beyond hinge line. Both valves of about equal convexity.

Auricles dissimilar; anterior auricle acute, shorter than posterior, broad, rather inflated, lateral margin convex, separated from shell body below by distinct umbonal fold. Posterior auricle almost as long as posterior margin of shell body, narrow, obtuse, lateral margin concave, merges with shell body below in a gently curving surface.

Valves multicostate, additional costae generated by implantation on both valves, radial ornamentation in the form of forty to fifty thin, sharp costae in several orders, those of the first order being very prominent in relation to the others, and separated by broad interspaces in which the other, smaller costae are located. On both valves spines are developed on the shell body. On the right valve the spines are developed on the costae, on the left valve they are developed in the interspaces between costae. In both cases they are most prominent on the posterior portions of the valves (Pl. II, Figs. 2, 8). The valve margin of the left valve is elaborated into spines, which correspond to extensions of the costae and the central portions of the interspaces between costae (Pl. II, Figs. 5, 10). Concentric ornamentation is not present except for very fine, closely spaced growth-line ridges visible only in the interspaces between costae on the shell body. Auricular ornamentation consists of both costae and growth-line ridges, the latter being least well developed on the posterior auricles, whereas they are as well developed as the costae, or predominate, on the anterior auricles.

The characters of musculature and hinge structure are not known. Portions of the outer ostracum of the left valve are preserved on one specimen, in which it appears to be of homogeneous calcite.

Remarks.—The subinternal surface (the outer surface of the inner ostracum) of the left valve is preserved on three specimens, two of which are illustrated on Plate II (Figs. 7, 10). One of these (Fig. 10) displays a series of recesses, above the subinternal surface, which were occupied by the marginal spines on the outer ostracum. The specimen, retaining portions of the original shell material, is rather anomalous in certain respects, particularly in its possession of concentric thickenings in the outer ostracum and a relatively smooth interior surface where a mold of the pseudo-ornamentation of the subinternal surface would be expected.

TABLE II
MEASUREMENTS OF *Aviculopecten caroli* WINCHELL
(In millimeters except for angles)

	Type Specimens	Range of Variability (6 specimens)
	Right Valve Holotype	Left Valve
Length	19	10.2–29
Height	16.9	10.3–25.8
Length of hinge line	15.6	9.6–22
Convexity	5.1	3.5–8.4
Costae		
Anterior auricular	6
Posterior auricular	5
Shell body	24 1st order	22 1st order
Umbonal angle	112°	90°–118°
Angle between lateral auricular margin and shell body below		
Anterior	110°	100°–110°
Posterior	120°	115°–125°

The difference between the “ornamentation” exhibited by the subinternal surface and the ornamentation preserved on the external molds caused Dr. Stuart Weller (1900, p. 82) to conclude that they were most likely representatives of distinct species. Because he could not “. . . determine from his description and measurements which of these specimens Winchell considered as the type,” (p. 83), he proceeded to redescribe the species on the basis of one of the subinternal casts. This is rather peculiar because the holotype fits the measurements given by Winchell perfectly, and if Weller borrowed all the type material, this would presumably have been included. The current authors included all these specimens in the same species because the specimens with the peculiar type of ornamentation

were found to be subinternal casts which do not reflect the ornamentation present on the external surface of the shell body (Newell, 1937, p. 17); and because the general shape of the shell body and auricles is virtually identical with that of the holotype (the posterior portion of which is broken off—see Pl. II, Fig. 8), as are the umbonal angle and the convexity.

Two hypotypes of *A. caroli* mentioned by Winchell (1865, p. 125; 1870, p. 255) illustrated on Pl. VI, Fig. 1, and Pl. I, Fig. 5, respectively, are not specimens of *A. caroli*. The former appears to be a *Euchondria winchelli* (cf. Pl. III, Fig. 12), and the latter is distinctive on the basis of its ornamentation and low umbonal angle but does not possess a sufficient number of well preserved characters to provide for an adequate description.

The specimens illustrated and described by Hall (1884, p. 29, Pl. 9, Fig. 5) and illustrated by Herrick (1888, Pl. 5, Fig. 9; 1889, Pl. 3, Fig. 9; 1893, Pl. 24, Fig. 4) do not appear to be *A. caroli* either. The general shape of Hall's specimen, from the Waverly Group of Ohio, is not at all like that of the types, the umbonal angle is less and the ornamentation lacks any indication of the characteristic spinose projections on either the shell body surface or the margin. Herrick's specimen, illustrated on three occasions, is also unlike the types of *A. caroli* in general shape and lower umbonal angle.

Comparison.—This species is distinct from all other *Aviculopectens* in its marked convexity, large umbonal angle, and peculiar ornamentation.

Type material and repository.—Holotype, UMMP No. 21302; paratypes, UMMP No. 2131 (3 specimens), and hypotype, UMMP No. 50115.

Occurrence.—The species is known only from the English River Sandstone, Burlington, Iowa.

Aviculopecten tenuicostus Winchell

(Pl. I, Figs. 3, 4; Pl. II, Figs. 4, 6; Pl. III, Figs. 1-3, 5-6, 11; Pl. IV, Fig. 9; Table III)

Aviculopecten tenuicostus Winchell, 1863, p. 10; 1865, p. 125; Weller, 1900, p. 81, Pl. 3, Fig. 3.

Original description (Winchell, 1863, p. 10):

Shell small, equilateral; pallial margin circularly rounded between anterior and posterior extremities, which lie midway between the beak and the opposite side. Beak slightly prominent; body of shell bounded by a truncation from beak to each lateral margin; anterior wing of left valve moderately inflated, as long as anterior side of shell, distinctly rounded at extremity, joining hinge-line by a rounded angle, and separated from the body of shell by a broadly V-shaped sinus, rounded at the bottom. Posterior wing only very imperfectly seen. Surface (of left valve) ornamented by fine, rigid, nearly equidistant ribs, 50 or 60 in number, separated by concave intervals; similar but finer ribs or striae marking the anterior ear. Frequently from three to five equidistant

costate elevations appear, each of which bears two or three of the ribs. A few inequidistant concentric lines are seen. Right valve unknown.

Length from beak to opposite side .47; antero-posterior dimension the same.

It is a little singular that of seven specimens of this species all are left valves, showing only the anterior ear. The posterior ear is probably flat and thin.

Revised description.—Valves small, acline, pectiniform, almost equilateral. Valve length equal to or slightly less than valve height. Length of hinge line equal to about three-fourths of the valve length (estimate from portions of the posterior auricle which are preserved). Ventral margin of

TABLE III
MEASUREMENTS OF *Aviculopecten tenuicostus* WINCHELL
(In millimeters, except for angles)

	Type Specimens	Range of Variability (8 specimens)
	Left Valve (7) Syntypes	Left Valve
Length	8.6-12.9	8.6-17.2
Height	9.7-13.1	9.7-18.8
Convexity	1.9-2.6	1.9-2.9
Costae		
Anterior auricular	12-15	12-15
Shell body	52-54	52-59
Umbonal angle	80°-88°	80°-90°
Angle between lateral auricular margin and shell body below		
Anterior	105°	105°
Posterior	110°	95°-110°

shell body semicircular, anteriormost extremity one-half the distance to the beak, from which point the margin of the shell body describes a concave line to the beak. Posteriormost extremity slightly more than one-half the distance to the beak, from which point the posterior margin describes a straight line to the beak. Beak prominent, extending slightly above the hinge line; umbonal angle slightly less than 90 degrees. Left valve moderately convex, right valve unknown.

Anterior auricle triangular, large, with a rounded anterior margin, separated from shell body by prominent umbonal fold. Shell body does not overhang auricle. Size and shape of posterior auricle not known, although it is connected to the shell body below by a rather gently curving surface and is apparently somewhat smaller than the anterior one.

Ornamentation on the shell body of the left valve consists of from 45 to

65, fine, closely spaced costae which increase by implantation. On most of the specimens, from two to five rather widely spaced radial elevations are present, each of which is surmounted by two or three of the costae. Irregularly spaced concentric ridges are very weakly developed. Auricular ornamentation consists of very fine, closely spaced, radiating costae, which number about fifteen, and less well developed concentric lirae. Neither the musculature nor hinge structures are displayed, nor is any shell material preserved.

Remarks.—Both workers who described this form commented on the peculiar absence of posterior auricles on all of the seven syntypes. The areas normally occupied by this auricle on those specimens which may once have possessed it, have been crudely excavated, apparently in an attempt to reveal it. Only one specimen preserves the slightest indication of the nature of the auricle (Pl. III, Figs. 2–3). This specimen, and one other (Pl. III, Fig. 1), both from Michigan, differ from those from Iowa in respect to the costae on the anterior auricle which are larger and fewer in number, and in the virtual absence of costate elevations on the shell body. These valves are also larger than their Iowa counterparts. Additional material may reveal that these differences are persistent enough to distinguish separate subspecies. The species was referred to the genus *Aviculopecten* on the basis of its general shape and the nature of its ornamentation.

Comparison.—This species is unique in its small size, shell body shape, fine costae, and costate elevations on the shell body.

Type material and repository.—Seven syntypes, UMMP No. 2138a–g (2138e herein designated lectotype); two hypotypes, UMMP No. 27770; and one doubtfully assigned hypotype (Winchell's hypotype), UMMP No. 26765.

Occurrence.—The syntypes bear a label stating only: "Kinderhook, Burlington, Iowa." Van Tuyl (1922, pp. 56, 61) however, indicates that the only horizon at Burlington, Iowa, yielding *A. tenuicostus* is the English River Sandstone (Bed No. 2). It is therefore reasonable to suppose that these specimens also came from this formation, especially since the matrix in which the specimens occur is a buff colored siltstone which matches the lithology of the formation in question. The Michigan hypotypes are from the Marshall Sandstone, Hillsdale County, Michigan. The doubtfully assigned hypotype is from the "Lower Mississippian (Kinderhook), Rockford, Indiana." The matrix is crystalline limestone, most likely collected from the Rockford Limestone (Pl. I, Fig. 4).

Aviculopecten sp. A

(Pl. II, Fig. 11; Table IV)

Description.—Right valve flat, acline, pectiniform. Valve height equal to about three-fourths valve length, hinge line straight, total length not discernible but anterior half as long as anterior half of valve. Ventral margin regularly rounded to a point about two-thirds the distance to the hinge line from which point the margin of the shell body extends to the beak describing a slightly concave line. Beak apparently not conspicuous, does not extend beyond hinge line. Umbonal angle about 110 degrees. Anterior auricle obtuse, creates angle of about 60 degrees with shell body below. Ornamentation apparently consists of closely spaced radiating costae only. Large, centrally located resilifer prominent.

Remarks.—This species is represented by a single specimen, a right valve, preserved as a composite cast with the posterior margin broken off.

Comparison.—Although the specimen bears a superficial resemblance to *A. crenistriatus* Meek, the fact that no elements of concentric ornamentation are present (whereas radial elements are rather conspicuous, suggesting

TABLE IV
MEASUREMENTS OF *Aviculopecten* sp. A.

Figured Specimens	
Right Valve	
Length	70
Height	56.7
Convexity	5.2
Costae	
Shell body	60
Umbonal angle	115°
Angle between anterior lateral auricular margin and shell body below	60°

that the original ornamentation did not include concentric elements), the greater length in proportion to height, and the proportionally larger anterior auricle distinguish it from the type specimens of *A. crenistriatus*, examined through the courtesy of Dr. Aurèle La Rocque of The Ohio State University.

Material and repository.—One specimen, UMMP No. 50116.

Occurrence.—Marshall Formation, Battle Creek, Michigan.

Genus *Pseudomonotis* Beyrich

Pseudomonotis Beyrich, 1862, p. 10; Newell, 1937, p. 92.

Eumicrotis Meek, 1864, p. 216.

Prospodylus Zimmermann, 1886, p. 109.

Aviculomonotis Grabau, 1931, p. 322.

Type species.—Disputed between *Avicula contorta* from the Rhaetic beds, and *A. speluncaria* from the Zechstein (See Newell, 1937, p. 92).

Pseudomonotis sp.A.

(Pl. IV, Fig. 11; Table V)

Description.—Valve prosocline, sub-rhombic, concave. Length about equal to height, length of hinge equal to two-thirds length of valve. Ventral margin regularly rounded, posteroventral portion extended; anterior margin regularly rounded to beak, maximum anterior extension at slightly less than one-half the distance from the ventral to the dorsal margin; posterior margin also regularly rounded, maximum posterior extension at a position corresponding to that on the anterior margin. Umbo apparently not prominent, umbonal angle about 100 degrees.

TABLE V
MEASUREMENTS OF *Pseudomonotis* sp. A.
(In millimeters, except for angles)

Figured Specimen Right Valve	
Length	40.5
Height	42.8
Length of hinge line	37.7
Convexity	8.5
Umbonal angle	104°
Angle between lateral and auricular margin and shell body below	
Anterior	120°
Posterior	150°

Auricles medium sized; anterior acute, separated from shell body by a distinct fold; posterior auricle longer than anterior, obtuse, merges imperceptibly with shell body below.

Hinge consists of elongate grooves, more or less parallel with the hinge line, into which the ligament was inserted. A large adductor impression is preserved but no indication of pedal retractors could be found. Outer ostracum appears to be of prismatic calcite. Ornamentation not preserved.

Remarks.—According to Newell (1937, p. 94) the earliest known specimens of this genus are from rocks of Morrow (Penn.) age in Arkansas. The present species is referred to this genus because of the fact that the valve (a right one) is distinctly concave; it possesses the prosocline, rhombic outline presumed to be the "basic" form of the genus before elaboration of the valve margin as a result of fixation to the substrate, supposedly taking place in early Pennsylvanian times, and because the posterior auricle is not extended or set off from the shell body by a fold or sulcus. It was presumably, a close, free-swimming relative of the Aviculopectininae.

Material and repository.—The only specimen known; UMMP No. 50124.

Occurrence.—Intraformational conglomerate, Coldwater Shale, south-central Michigan.

Family Euchondriidae

Genus *Euchondria* Meek

Euchondria Meek, 1874, p. 445; Newell, 1937, p. 102.

Crenipecten, part of authors.

Type species.—By monotypy and original designation (Meek 1874, p. 445), *Euchondria neglecta* (Geinitz), (= *Pecten neglectus* Geinitz, 1866; = *Aviculopecten neglectus* (Geinitz) Meek, 1872).

Remarks.—The genus was erected by Meek to accommodate those forms possessing a large, centrally located resilifer, or cartilage pit, together with a series of smaller cartilage pits along the hinge on either side of the resilifer (Meek, 1874, p. 488). These cartilage pits are supposedly distinct from those in the genus *Crenipecten*, in that those of the latter are of subequal size and are equally spaced throughout the length of the hinge (Hind, 1903, p. 112).

With the erection of the Family Euchondriidae Newell (1937, p. 102), the peculiar hinge structure was elevated in importance to familial level, *Euchondria* receiving a more restrictive delineation. The suggestion that *Crenipecten* should be referred to the new family (Newell, 1937, p. 102) appears to be precluded by the familial description, i.e.; *Crenipecten* (as currently defined) does not have the requisite large oblique median resilifer. If, on the other hand, the genus *Crenipecten* is based on specimens of *Euchondria*, which because of poor preservation in the area of the beak, do not reveal the median resilifer, then this is another matter. It appears that there is a little more variety in the nature of the cartilage pits disposed

along the hinge line of *Euchondria* than allowed by Newell's generic description, which stated: "...ligament area as in *Aviculopecten* but having in addition a series of rectangular resilifers transverse to the hinge length in front and behind the larger median resilifer, the resilifers increasing in size and spacing toward the extremities of the hinge; ..." Newell himself, referred *Crenipecten winchelli* (Meek) to *Euchondria* on the basis of the shape, peculiar dissimilarity of right and left valves, and presence of a crenulated hinge, apparently without noting that the crenulations are of subequal size and equally spaced throughout the length of the hinge, except for the space occupied by the median resilifer (See Pl. III, Fig. 10).

With the description of *Pecten neglectus* Geinitz, a right valve illustrated and described as a left valve, misconceptions as to the nature of the dissimilarity of right and left valves became common. When Meek restudied the fauna from which Geinitz's type had come, he was able to find only right valves (Meek, 1872, p. 193). He concluded from this that both valves were ornamented similarly. It was not until Newell's work (1937, p. 104) that the true nature of the dissimilarity became known. By studying several faunas in which dissimilar right and left valves occurred together, in approximately equal numbers on the same bedding planes, he was able to conclude that all valves were of a single species.

Euchondria winchelli (Meek)

(Pl. III, Figs. 4, 7-10, 12; Pl. IV, Figs. 5, 7, 10, 12;

Pl. V, Fig. 7; Pl. VI, Fig. 1; Table VI)

Aviculopecten occidentalis Winchell, 1863, p. 9 (*non A. occidentalis* Shumard, 1855, p. 207); 1865, p. 126; *non* 1870, p. 255.

Aviculopecten winchelli Meek, 1875, p. 296, Pl. 15, Figs. 5a, 6; Heilprin, 1886, p. 453, Fig. 6b; p. 442, Fig. 6, p. 444, Fig. 6a; 1886a, p. 269, Fig. 6b, *non* Fig. 6, *non* Fig. 6a; Herrick, 1888, Pl. 1, Fig. 18, Pl. 6, Fig. 12, Pl. 10, Fig. 7.

Crenipecten winchelli (Meek) Hall, 1883, Pl. IX, Figs. 1, 2, 4, 25-30; 1884, p. 89, Pl. IX, Figs. 1, 2, 4, 25-30; 1884a, Pl. 1, Figs. 4-5; Weller, 1899, p. 22, Pl. 4, Fig. 15.

Aviculopecten iowensis Miller, 1883, p. 310; Weller, 1901, p. 151, Pl. 12, Fig. 9.

Euchondria winchelli (Meek) Newell, 1937, p. 104.

Revised description.—Left valve. Prosocline or acline, typically with a posteroventral extension of the shell body. Valve length equal to or slightly greater than valve height, length of hinge line equal to about three-fourths the valve length. Ventral margin regularly rounded; anterior margin rounded to a point about two-thirds the distance to the beak, from which point the margin of the shell body describes a slightly concave line to the beak; posterior margin regularly rounded to the mid-point between dorsal and ventral extremities, from which point the shell body margin describes

a straight, or slightly concave, line to the beak. Beak prominent, extends slightly beyond hinge line; umbonal angle about 100 degrees. Valve moderately convex. Anterior auricle acute, lateral margin slightly concave, intersection with shell body below creates angle of about 90 degrees; auricle flattened, separated from shell body by slight umbonal fold. Posterior auricle obtuse, usually longer than anterior, lateral margin makes angle of about 85 degrees at point of intersection with shell body margin below; auricle merges with shell body in rather gently curving surface. Shell gap apparent.

TABLE VI
MEASUREMENTS OF *Euchondria winchelli* (Meek)
(In millimeters, except for angles)

	Range of Variability (23 specimens)	
	RV ⁽⁴⁾	LV ⁽¹⁹⁾
Length	7.5-29	20.1-46.3
Height	6.9-25.7	18.2-39.5
Length of hinge line	7.5-29	15-28
Convexity	1.5-2.5	2.3-5.1
Costae		
Anterior auricular	6	7-10
Posterior auricular	6-10	5-11
Shell body	16 (faint)	56-81 (all orders)
Umbonal angle	95°-105°	95°-105°
Angle between lateral auricular margin and shell body below		
Anterior	60°	95°
Posterior	90°-95°	85°-95°

Interiors (Pl. III, Fig. 8; Pl. IV, Fig. 12; Pl. V, Fig. 7) display auricular crura, the posterior being the longer, and hinge structures consisting of a large median resilifer (the flattened area at the umbo in Pl. V, Fig. 7) and many small cartilage pits (resilifers) located on either side, along the hinge axis, of subequal size and spacing.

Shell body ornamented with about eighty closely spaced, fine costae in what appears to be three orders (the ornamentation on the early stages is not well preserved on any of the specimens in the possession of the authors), each of which is generated by implantation. Fine, irregularly spaced growth lines constitute the only concentric ornamentation. The auricles possess both costae and growth lines in about equal degrees of development.

Right valve. Generally acline, occasionally prosocline, flattened, smaller than left valve; length about equal to height or slightly less, length of hinge line about equal to length of valve. Shell body shape differs from that of left valve in that the posteriormost extremity is closer to the midpoint between dorsal and ventral margins, making the form more symmetrical. Beak not prominent, does not extend beyond the hinge line; umbonal angle about 100 degrees.

Anterior auricle obtuse, lateral margin convex, creates angle of about 60 degrees with shell body margin below, separated from shell body by slight umbonal fold. Posterior auricle more variable in shape, obtuse or acute, merges with shell body in smoothly curving surface.

The shell body either lacks ornamentation, or possesses very faint, rather widely spaced, large costae (Pl. IV, Fig. 5). The auricles are ornamented as on the left valve.

Remarks.—This species was first described from a small, fragmental right valve, by Winchell (1863, p. 9), under the name *Aviculopecten occidentalis* (Pl. IV, Fig. 10). Since Shumard (1855, p. 207) had used the name for a form described eight years earlier, Winchell's name was a junior homonym and is therefore, invalid. Twelve years later, Meek (1875, p. 296), apparently not aware of Winchell's description, described the same species from the Waverly Group at Newark, Ohio, as *Aviculopecten winchelli*. Meek's description was based on both valves, which he recognized as distinctly different, but which were collected together from the same beds containing them in about equal numbers. In 1883, Miller (p. 310), apparently without knowledge of Meek's work, noted that Winchell's *A. occidentalis*, 1863, was the junior homonym of Shumard's *A. Occidentalis*, 1855, and proceeded to rename Winchell's form *Aviculopecten iowensis*. That same year James Hall (1883, Pl. IX, Figs. 1, 2, 4, 25–30; and later, 1884, p. 89, same plates), referred Meek's species to the genus *Crenipecten* because of the crenulated hinge (Pl. III, Fig. 10). It should be noted that whereas Hall's figure (1883 and 1884, Pl. IX, Fig. 28) shows the resilifers extending almost completely across the hinge, with the exception of a small area under the beak, his specimen does not (Pl. III, Fig. 10). Notwithstanding the transfer of the species to a different genus, the species name *occidentalis* cannot be exhumed (see Art. 36, International Rules of Zoological Nomenclature). In 1899, Weller (p. 22) discussed and illustrated a form from the Northview Sandstone which differs from the specimens in the author's possession only in that the radiating costae on the auricles of the left valve are almost obsolete (comparison based on a study of Weller's description and illustration). Most recently, the species has been

referred to *Euchondria* (Newell, 1937, p. 104), on the basis of its general shape and the nature of the difference between right and left valves. The variation in hinge characters from those given in Newell's generic description (*op cit.*, p. 102), has been described above.

Comparison.—As pointed out by Newell (1937, p. 106), this species is most similar to *E. smithwickensis* Newell from the Pennsylvanian of Texas. The major features which distinguish the latter are its very angular auricles and the lack of costae on the auricles of the right valve. *E. winchelli* is otherwise distinct from other species of *Euchondria* by virtue of its non-reticulately ornamented left valve, and in possessing, on many right valves, very faint costae.

Type material and repository.—Meek's type material could not be located, but three of the specimens figured by Hall (1883 and 1884, Pl. IX, Figs. 27, 28, 29) are herein reillustrated and are hypotypes AMNH Nos. 6517/2(2), and 6517/1, respectively. In addition, the following specimens are designated hypotypes: UMMP Nos. 2144, 26739, 50117, 50118, 50122, and 50225.

Occurrence.—*Euchondria winchelli* occurs in the Marshall Sandstone of Michigan, the Waverly Group of Ohio, the McCraney Formation of Iowa, and the Northview Sandstone of Missouri.

Euchondria areolatus (Cooper)

(Pl. IV, Figs. 1-4, 6, 8; Table VII)

Aviculopecten areolatus Cooper, in Lane, 1900, p. 262, Pl. 9, Fig. 1.

Revised description.—Valves medium in size, prosocline, pectiniform; length equal to height, hinge line straight, equal in length to two-thirds valve length, moderate asymmetry produced by posteroventral extension of shell body. Ventral margin regularly rounded; anterior margin regularly rounded to a point more than two-thirds the distance to the beak, from which point the margin of the shell body describes a slightly concave line to the beak; posterior margin rounded to a point about one-half the distance to the beak, from which point the posterior margin of the shell body describes a straight line to the beak. Left valve moderately convex, greatest convexity at a point about one-third the distance from the beak to the ventral margin. Umbo prominent, projects slightly beyond hinge line, umbonal angle about 100 degrees. Prominent gap evident.

Auricles flattened, subequal, acute, both lateral margins apparently slightly concave; anterior creates angle of about 90-100 degrees with margin of shell body below, separated from shell body by distinct umbonal

fold; posterior lateral margin creates a slightly larger angle at intersection with shell body margin than anterior, posterior auricle merges with shell body below without any sharp break in slope.

Shell body ornamentation consists of about sixty-five, evenly spaced costae, apparently generated in three orders, generation taking place by implantation. Concentric elements are the fine, closely spaced growth lines, and the more conspicuous, regularly spaced fila which are well developed

TABLE VII
MEASUREMENTS OF *Euchondria areolatus* (COOPER)
(In millimeters, except for angles)

	Type Specimen	Range of Variability (6 specimens)
	Left Valve Holotype	Right Valve
Length	24.6	17.4-24.6
Height	24.5	17.9-24.9
Length of hinge line	13.8	11.5-16.2
Convexity	4.8	3.0-4.8
Costae		
Anterior auricular	5	5-6
Posterior auricular	-	5
Shell body	60	60-67
Umbonal angle	105°	95°-105°
Angle between lateral auricular margin and shell body below		
Anterior	110°	95°-110°
Posterior	120°	90°-115°

only on the younger ontogenetic stages, the more mature portions of the valve displaying only the radial elements. In combination, the fila and costae produce a reticulate pattern. Auricular ornamentation consists of about six well-defined costae per auricle, together with numerous, closely spaced growth lines.

Remarks.—The above description was based upon six specimens, all of which were collected by Lane for his Huron County report. Cooper's original description and illustration (*in* Lane, 1900, p. 262, Pl. 9, Fig. 1) reflect characters not preserved on the holotype, but just how many of the specimens were used in preparing the description is not known as he designated no secondary types.

Three of the specimens are preserved as composite casts which show portions of both the internal and external surfaces. The holotype (Pl. IV,

Fig. 1) is one of these; another is illustrated on Plate IV, Figure 8, and displays (faintly) the crenulate nature of the hinge, which together with the general shape of the valve and the ornamentation caused the author to refer the species to the genus *Euchondria*.

In the original description, Cooper mentioned a peculiar convergence of costae on the anterior part of the left valve as one of the unique characters of the species. The author could find no such convergence on any of the six specimens. What appear to be converging costae on the holotype are actually a series of scratches, the original ornamentation having been almost completely exfoliated at this point. What may have caused him to consider this a characteristic of the species is that several valves were apparently damaged on the anterior part of the shell during life. This caused a deformation suggesting a convergence of costae. The condition, however, is not restricted to *E. areolatus*, as would be expected, but has been observed on specimens of *E. perplexa* and *E. winchelli* as well (See Pl. IV, Fig. 4; Pl. V, Fig. 3; Pl. III, Fig. 7).

Comparison.—This species is to be distinguished from other species of *Euchondria* (especially *E. perplexa* and *E. winchelli*) on the basis of its proportionally shorter hinge line and its ornamentation, which includes fila, but only in the early ontogenetic stages as compared to their persistence in *E. perplexa* and their absence in *E. winchelli*. The short hinge, however, is the single most diagnostic feature.

Type material and repository.—The holotype, UMMP No. 2222, and four hypotypes, UMMP Nos. 50119–50121, and 50123, are all preserved as external molds or composite casts.

Occurrence.—The species is known only from the Coldwater Shale of Huron County, Michigan.

Euchondria perplexa n. sp.

(Pl. V, Figs. 1–6, 8–10; Table VIII)

Description.—Valves medium in size, prosocline, with a moderate gape.

Left valve. Moderately convex with a distinct posteroventral extension of the shell body. Height and length approximately equal; length of hinge line almost equal to length of valve. Ventral margin regularly rounded; anterior margin rounded to a point between one-half and two-thirds the distance to the beak, from which point the margin of the shell body describes a slightly concave line to the beak; posterior margin regularly rounded to a point about one-half the distance to the beak from which

point the margin describes a straight line to the beak. Umbo prominent, extends slightly beyond hinge line.

Auricles triangular; anterior auricle acute, flattened, lateral margin gently curved, forms angle of 90 degrees or slightly less with shell body margin below, separated from shell body elbow by distinct umbonal fold, shell body does not overhang auricle; posterior auricle obtuse, slightly smaller than anterior, lateral margin forms angle slightly greater than 90 degrees with margin of shell body below, merges with shell body without sharp break in slope.

TABLE VIII
MEASUREMENTS OF *Euchondria perplexa* n. sp.
(In millimeters, except for angles)

	Type Specimens		Range of Variability (10 specimens)	
	Right Valve (3) Paratypes	Left Valve Holotype	Right Valve (4)	Left Valve (6)
Length	16.9	22.5	16.9-35.5	17.9-32.2
Height	14.1	21.8	14.1-28.7	16.9-29.1
Length of hinge line	16.4	19.1	16.4-31	14.0-27.9
Convexity	1.9-4.9	4.3	1.9-4.9	3.2-5.4
Costae				
Anterior auricular	8	9	6-9	7-9
Posterior auricular	8-15	10	8-15	10-11
Shell body	0	95	0	60-95
		(all orders)		
Umbonal angle	105°-116°	96°	96°-116°	96°-106°
Angle between lateral auricular margin and shell body below				
Anterior	70°	105°	70°-85°	97°-107°
Posterior	105°-110°	115°	105°-118°	105°-120°

Shell body ornamentation consists of from sixty to one hundred fine, radiating costae which increase by implantation, three orders being the maximum observed. Concentric ornamentation in the form of closely spaced growth lines and less closely but more regularly spaced lirae are present. The latter in combination with the costae produce a distinct reticulate pattern, most conspicuous in the younger growth stages (Pl. V, Fig. 6). Both anterior and posterior auricles are marked by concentric lirae, growth lines and costae which produce a reticulate pattern on these structures also.

Musculature consists of large adductor located slightly posterior to center of valve; superior gill suspensaries located just ventral to beak;

short curved impression of attachment points for the pallial muscles located adjacent to the adductor impression (Pl. V, Fig. 1).

Hinge structures consist of a series of cartilage pits, elongated perpendicular to the hinge axis, on either side of a large, central oblique resilifer. The cartilage pits are subequal in size and approximately equally spaced along the hinge (Pl. V, Fig. 4).

Right valve. Valve height equal to about three-fourths the length, hinge length about equal to valve length. Shell body shape similar to that of left valve except for the lack of a posteroventral extension (Pl. V, Figs. 2, 8). Umbos prominent, extend to the hinge line; umbonal angle about 100 degrees.

Anterior auricle obtuse, lateral margin rounded, separated from shell body below by distinct umbonal fold. Posterior auricle less obtuse, lateral margin relatively straight, merges with shell body through a gently curving surface.

The shell body is ornamented with concentric elements only; growth lines and lirae best developed on the more mature portions of the shell. The auricles are ornamented with both costae and growth lines.

Comparison.—This species may be distinguished from *E. winchelli* on the basis of its reticulate ornamentation, as opposed to the radial ornamentation on the shell body of the latter, a longer proportional valve length in the right valve, a more robust appearance due to greater convexity, and a longer hinge line on the left valve (cf. Pl. V, Figs. 7, 9). It may be distinguished from *E. areolatus* on the basis of the longer hinge length on the left valve, and the concentric lirae which continue to be rather conspicuously developed on the more mature portions of the left valve.

Type material and repository.—Holotype UMMP No. 50133; six paratypes, 50126–50130, 50132.

Occurrence.—Intraformational conglomerate of clay pebbles in siderite in the Coldwater Shale of south-central Michigan.

Family Amusiidae
Genus *Pernopecten* Winchell

Pernopecten Winchell, 1865, p. 125; Hall, 1884, p. xii; 1884a, p. 12; Newell, 1937, p. 109.

Entolium (part) of authors.

Syncyclonema (part) of authors.

Pecten (*Pernopecten*) Newell, in Shimer and Shrock, 1944, p. 405.

Type species.—By original designation, *Aviculopecten limaformis* White and Whitfield.

Original description (Winchell, 1865, p. 125):

Shell bivalve, sub-equivalve, monomyary. Valves more or less inequilateral and auriculate. Hinge line straight; hinge furnished with a central, triangular cartilage pit, and a transverse plate bearing on each side of the middle a series of smaller pits diminishing in size and depth from the centre outwards. The shell seems to be thin, and probably has a structure more like *Pecten* than *Perna*.

Remarks.—Two of the characters which were mentioned in the original description have been qualified by subsequent workers. The straight hinge mentioned by Winchell is now known to characterize only the right valve, the left valve being characterized by auricles which extend above the cardinal axis and whose dorsal margins then retreat to the beak. This difference was first discussed by Meek (1875, p. 292). The other character, that of the denticulate hinge structure with central resilifer, caused a great deal of perplexity among earlier workers (Meek and Worthen, 1868, p. 453; Meek, 1875, p. 292; and Herrick, 1888, p. 57). Valves displaying all generic characteristics except that of the peculiar hinge structure noted on the type, were referred to other genera (*Entolium* and *Syncyclonema*). Newell (1937, p. 110) has stated that the presence or absence of cartilage pits on the hinge line appears to be a matter of individual variation, his conclusion following a study of Pennsylvanian forms. That this may or may not be the case for Mississippian forms as well, is a matter for future study of the earlier forms to resolve, but it should be noted that both valves of *P. limaformis* have a crenulate hinge.

Pernopecten limaformis (White and Whitfield)

(Pl. VI, Figs. 2-4, 6-10; Table IX)

Aviculo-pecten limaformis White and Whitfield, 1862, p. 295.*Pernopecten limaeformis* Winchell, 1865, p. 126.*Pernopecten limatus* Winchell, 1865, p. 126.*Pernopecten limiformis* Hall, 1884a, Pl. I, Figs. 1-2.*Pernopecten cooperensis* (part) of authors.

Revised description.—Valves medium in size, acline, sub-circular, moderately convex.

Right valve. Height slightly greater than three-fourths valve length, hinge line straight, equal in length to about one-third that of valve. Ventral margin semicircular; central portion of posterior margin inflated, producing a crest; anterior margin rounded to a point equal to about three-fourths valve height, from which point the valve margin describes a straight line to the beak. The posterodorsal margin is also straight between the dorsal edge of the crest and the beak. Lateral margins somewhat compressed, but shell

body sulci, diverging from beak toward ventral margin; not developed. Beak small, inconspicuous, even with hinge line; umbonal angle about 120 degrees.

Auricles small, subequal, obtuse, flattened, separated from shell body by rather weakly developed auricular sulci. Anterior and posterior lateral margins make angles of about 150 degrees with the margins of the shell body below (Pl. VI, Fig. 7).

TABLE IX
MEASUREMENTS OF *Pernopecten limasformis*
(White and Whitfield)
(In millimeters, except for angles)

	Type Specimens		Range of Variability (4 specimens)	
	Right Valve (1) Syntype	Left Valve (1) Syntype	Right Valve (2)	Left Valve (2)
Length	21.4	25.8	21.4-29.4	22.5-25.8
Height	20.5	24.9	20.5-26.4	22.6-24.9
Length of hinge line	7.9	8.4	7.9-9.2	8.4
Convexity	2.9	3.3	2.9-4.2	3.2-3.3
Umbonal angle	116°	...	116°-119°	118°
Angle between lateral auricular margin and shell body below				
Anterior	150°	...	148°-150°	...
Posterior	150°	...	150°-152°	...

Interior characterized by two auricular crura which diverge from the vicinity of the umbo. The posterior is the longer and becomes obsolete in the vicinity of the ventralmost portion of the crest. Hinge structure consists of a centrally located resilifer flanked by elongate cartilage pits which decrease in size with distance from the resilifer (Pl. VI, Figs. 6, 10).

Left valve. Valve length about equal to height or slightly longer; length of hinge axis⁷ slightly less than one-third valve length; ventral margin semicircular; dorsal half of posterior margin more abruptly curved to the point of junction with the posterior auricle from which point the shell body margin describes a straight line to the beak; anterior margin regularly rounded to a point a little less than three-fourths the distance from the ventral margin to the beak, from which point it describes a

⁷ Because the length of the true hinge was seldom revealed on the molds or casts of left valves of *Pernopecten* studied by the authors, the length of the "hinge axis" is herein used to replace it. This measurement was taken parallel to the dorsalmost tips of the auricles, through the points of intersection of the dorsal margins of the auricles with the slopes of the beak, between the lateral extremities of the auricles.

straight line to the beak. Umbonal angle about 120 degrees; beak prominent, rounded, projects slightly above hinge axis. Shell body sulci not sharply defined, rounded, posterior longer and more conspicuous. Shell body marginal to sulci compressed, gap prominent.

Auricles small, subequal, project above hinge axis.

Interior characterized by two short, ridgelike processes on the elongate crura; counterparts on the opposite valve are only suggested. Hinge structures identical with those of the opposite valve. Musculature and shell structure not displayed.

The ornamentation appears to have consisted, on both valves, of very faintly and irregularly spaced growth lines (Pl. VI, Figs. 2, 7).

Remarks.—The species was described by Winchell from five syntypes, presumably the same specimens used by White and Whitfield. One of these specimens is herein described as *Pernopecten* sp. A (p. 57), two others are preserved as interiors of left valves (juvenile specimens) which cannot, with any degree of certainty, be distinguished from *P. cooperensis*.

In the same paper in which Winchell erected the genus *Pernopecten*, he described *P. limatus*, a species known only from two separate valves, a right and a left. Comparison of these latter specimens with the types of *P. limaformis* revealed a striking similarity (although the left valves are considerably less well preserved), and caused the authors to conclude that they belonged to the same species (cf. Pl. VI, Figs. 2, 3, 6, 7).

Unsuccessful attempts were made to secure the material studied by Weller (1899, p. 24–28; 1901, p. 168), who placed *P. limaformis* in synonymy with *P. cooperensis*. It is most likely that Weller did not have right valves in his possession as these valves are distinct from those of *P. limaformis*, but based his conclusion on the similarities in left valves, which is quite understandable.

The type material is not sufficient for a complete generic description. The description offered by Newell (1937, p. 109) is very adequate in the light of a careful study of the type specimens.

Comparison.—Similar species are *P. cooperensis* and *P. shumardanus*. A distinction may be made between *P. limaformis* and *P. cooperensis* on the basis of right valves in that the former has a valve of greater length than height, a more prominent crest, and a semicircularly rounded ventral margin, whereas the latter has a right valve which is higher than long, has a weakly defined crest, and an elliptical, less regular ventral margin. A distinction between species on the basis of left valves is more difficult, not only because the left valve of *P. limaformis* is imperfectly known, but also because the range of variability in left valves of *P. cooperensis* is so great.

Juvenile specimens appear to be indistinguishable. In general, however, three differences appear to be persistent; *P. cooperensis* is commonly ornamented with radiating costate elevations, *P. limaformis* is not; the beak on *P. cooperensis* is more prominent and sharper than on *P. limaformis*; and *P. cooperensis* possesses more sharply flared shell body margins than *P. limaformis*.

Pernopecten shumardanus may be distinguished from the present species on the basis of its proportionally shorter hinge axis, and its lesser convexity (both in reference to the left valve, as *P. shumardanus* is only known from left valves).

Type material and repository.—Two syntypes, UMMP No. 2127 (herein designated lectotype), and 21234, and two hypotypes, UMMP No. 2200, occur as interior molds of right and left valves and exterior casts of right and left valves, respectively.

Occurrence.—From the Prospect Hill Sandstone, and the Burlington Limestone, Burlington, Iowa.

Pernopecten shumardanus Winchell

(Pl. VII, Figs. 1-3, 6; Table X)

Avicula circulus Hall, non *A. circulus* Shumard, 1858, p. 522, Pl. 7, Fig. 9.

Pernopecten shumardanus Winchell, 1865, p. 126; Hall, 1884, Pl. 1, Fig. 3; non Herrick, 1888, p. 57, Pl. 12, Figs. 13-15

Pernopecten shumardianus? Meek and Worthen, 1868, p. 453, Pl. 14, Figs. 6a, 6b.

Entolium shumardianum? Meek, 1875, p. 292, Pl. 15, Figs. 4a, 4b.

Original description (Winchell, 1865, p. 126):

... (*Avicula circulus* Hall, not Shumard). It is scarcely possible that the species identified by Hall (Iowa Rep. 522, pl. vii, fig. 9) as *A. circulus*, Shum. (Missouri Rep. 206, pl. c, fig. 14), can be the same species. Prof. Hall's figure and description do not show it, nor do specimens from the same bed, commonly regarded as *A. circulus* Hall, present satisfactory correspondence. The shell has a much shorter hinge line, with smaller ears, joining the cardinal slopes by obtuse angles. Moreover the concentric lines are very regular, and the radial ones faint, irregular dashes, entirely unlike the continuous and distinct though diminutive ribs of *A. circulus* Shumard.

Yielding to the suggestion of Dr. White, I formerly identified *A. circulus* Hall—before I had seen actual specimens—with *Aviculopecten limaformis*, White and Whitfield. I am convinced, however, on careful comparison of specimens, that we must regard *A. circulus* Hall, as a distinct species.

In general characters this species resembles *P. limatus*, and only differs in its shorter and less sharply defined cardinal slopes, and the presence of the two systems of superficial markings.

Revised description.—Left valve acline or very slightly prosocline,

subcircular valve; length about equal to height, length of hinge axis equal in length to about one-third the valve length. Ventral margin semicircular; anterior margin rounded to a point about two-thirds the distance to the beak, from which point the shell body margin describes a straight line to the beak; posterior margin rounded to a point about one-half the distance to the beak, from which point the shell body margin describes a convex arc to the beak. Umbonal angle about 120 degrees, beak projects slightly beyond hinge axis. Slight gap evident. Prominence of ventrally extending shell body sulci varies from moderately conspicuous to inconspicuous, the posterior one being the longer. Margins of shell body lateral to sulci, compressed.

Auricles medium in size, flattened, subequal, slightly obtuse; lateral margin of posterior auricle creates angle of about 155 degrees with shell body margin below, lateral margin of anterior auricle creates angle of about 145 degrees with shell body below.

TABLE X
MEASUREMENTS OF *Pernopecten shumardanus* Winchell
(In millimeters, except for angles)

	Type Specimens Left Valve (3) Syntypes
Length	23.1-37.4
Height	24.6-36.9
Length of hinge line	7.6-12
Convexity	2.8-4.2
Umbonal angle	114°-124°
Angle between lateral auricular margin and shell body below	
Anterior	150°-160°
Posterior	140°-150°

Ornamentation consists of concentric lirae, the radiating ornamentation mentioned in the original description appears to be only irregularities on the surface of the valves.

The interior of the species is known only from two illustrations, those of Meek (1875, Pl. 15, Fig. 4b) and Hall (1884, Pl. 1, Fig. 3), which indicate the presence of a cardinal groove, auricular crura, median resilifer, and no cartilage pits. The specimens from which the illustrations were made could not be located.

The right valve is not known.

Remarks.—The species was erected to accommodate those forms from the McCraney Formation at Burlington, Iowa, which had been erroneously referred to *Avicula circulus* Shumard, a distinctly unique species.⁸ It promptly became enmeshed in the controversy as to the genus and species to which this and similar forms should be referred. Meek and Worthen (1868, p. 453) expressed the opinion that *P. shumardanus* was most likely conspecific with *P. cooperensis* and *P. limatus* on the basis of similarity of general shape. Later, in 1872, Meek (p. 191) expressed the opinion that *P. shumardanus* and *P. cooperensis* are conspecific. In 1875 (p. 294) Meek states: "...it (*P. shumardanus*) certainly bears *very* close relations to *Avicula cooperensis* Shumard,..." and in comparing specimens which he believed to be right valves of *P. shumardanus* (which the present authors were not able to locate) with the type right valve of *P. limaformis* concluded that the former "...agrees almost *exactly* in all *specific* characters..." with the latter and concluded his discussion by assigning them to different genera on the basis of their hinge characters (*P. limaformis* with cartilage pits, *P. shumardanus* without). Subsequently, Newell (1937, p. 110) has suggested that the presence or absence of cartilage pits is not even specifically consistent, which if applicable to Mississippian forms, would admit the possibility that *P. limaformis* and *P. shumardanus* are indeed conspecific.

The material described and illustrated by Herrick (1888, p. 57, Pl. 12, Figs. 13–15) as *P. shumardanus* appears to be *P. cooperensis*.

Comparison.—Similar species are *P. cooperensis* and *P. limaformis*. The former differs from the present species in that it is more oblique, has a greater height than length, and has a more conspicuously pointed beak as well as more conspicuously developed shell body sulci. The distinction between *P. shumardanus* and *P. limaformis* is given above under the "comparison" of the latter species. As mentioned, a strong possibility exists that these two species may be the same.

Type material and repositories.—Three syntypes, UMMP No. 26762a–c (26762a herein designated lectotype), and the specimen illustrated by Hall (1858, Pl. 7, Fig. 9), a hypotype, AMNH No. 6523/1.

Occurrence.—The only unquestionable specimens are from the McCraney Formation, Burlington, Iowa. Numerous specimens have been reported from the Waverly of Ohio, but those examined by the authors appear to be *P. cooperensis*.

⁸ = *Pernopecten circulus* (Shumard), is distinct in that it is very small, robust, and possesses a very long aviculopectenoid hinge and an oval-shaped shell body (Pl. VI., Fig. 5).

Pernopecten cooperensis (Shumard)

(Pl. VII, Figs. 4-5, 8, 12; Table XI)

Avicula cooperensis Shumard, 1855, p. 206, Pl. C, Fig. 15.*Pernopecten cooperensis* Winchell, 1870, p. 254; Meek, 1872, p. 191; 1875, p. 293; Weller, 1899, p. 24; 1901, p. 168.*Entolium cooperensis* Keyes, 1894, p. 109.

Revised description.—Slightly prosocline or acline, rather elliptical pectinoids.

Right valve. Length slightly less than height, length of hinge line equal to about two-fifths the valve length, hinge line straight. Ventral margin elliptically rounded, curvature extends in anterior to a point about three-fourths the distance to the cardinal margin, from which point the shell body margin describes a straight line to the beak; posterior margin curved to a point about one-half the distance to the cardinal margin, at which point it protrudes slightly as a crest and then continues to the beak describing a straight line. Umbonal angle about 110 degrees; beak rather rounded as compared to that of opposite valve, does not extend beyond hinge line. Shell body sulci apparent but not conspicuous, posterior longer, producing a slight posterior obliquity. Shell body marginally lateral to sulci flattened.

Auricles small, subequal, obtuse, both lateral margins making angles of about 150 degrees with the margins of the shell body below.

Ornamentation consists of closely spaced concentric lirae on the shell body, and growth lines on both auricles, a byssal notch, which becomes obsolete with age, is preserved on the anterior auricle (Pl. VII, Fig. 4).

Left valve. Length slightly less than or equal to height, hinge axis equal in length to about one-third valve length. Ventral margin subsemicircularly rounded, continues in anterior to slightly more than one-half the distance to the beak, from which point the shell body margin describes a slightly sigmoid curve to the beak, the concave portion being located under the anterior auricle; posterior margin regularly curved to a point about one-third the distance to the beak, at which point the margin arcs toward the beak describing a slightly convex line initially and as it approaches the intersection with the posterior auricle, becomes straight and continues to the beak. Less commonly it is rather straight or slightly convexly arched, for the entire distance. Average umbonal angle between 90 to 100 degrees; umbo prominent, usually sharp due to rather deeply incised shell body sulci. Shell body sulci prominent, the posterior is longer and more conspicuous. Margins of valve adjacent to sulci flattened, occasionally posterior one flared upward. Shell gap prominent.

TABLE XI
MEASUREMENTS OF *Pernopecten cooperensis* (Shumard)
(In millimeters, except for angles)

	Range of Variability (64 specimens)	
	Right Valve (3)	Left Valve (61)
Length	15.2-25.0	10.6-33.4
Height	17.3-26.1	11.3-33.9
Length of hinge line	6.0-9.8	3.1-8.7
Convexity	1.8-2.7	1.8-2.9
Shell body costae	4-7 (faint)
Umbonal angle	108°-110°	75°-119°*
Angle between lateral auricular margin and shell body below		
Anterior	145°-150°	145°-150°
Posterior	145°-148°	147°-150°

* Majority about 90°-100°.

Auricles small, flattened, subequal, obtuse; angles created by intersection of lateral margins and margins of shell body below about 150 degrees.

Ornamentation consists of closely spaced concentric lirae, and on specimens which are well preserved, indistinct, radiating elevations, four to seven in number (Pl. VII, Fig. 8).

Remarks.—In commenting on Shumard's original description and illustration, Meek (and Worthen, 1868, p. 454; 1872, p. 191; 1875, p. 294) takes pains to minimize the importance of the radiating costae displayed on Shumard's illustration of a right valve. On the specimens inspected by the authors the right valves displayed no such ornamentation but the left valves did. On these latter valves, the radiating elevations are quite apparent, although not conspicuous, and are visible on almost all valves retaining elements of ornamentation preserved. In respect to the species, they are not as aberrant as claimed by Meek.

The history of comment on this species and comparison with similar forms is discussed in the discussion of *P. limaformis* and *P. shumardanus* above.

Type material and repositories.—The original type material, as far as can be determined, was destroyed by fire. The following specimens are here designated hypotypes; UMDG No. 12798, and USNM Nos. 146045-146047.

Occurrence.—The species is rather widespread, occurring in the Chouteau Group of Missouri, the Prospect Hill, Starrs Cave, Wassonville, and

Burlington Formations of Iowa, the Waverly Group in Ohio, and perhaps the Coldwater Formation of Michigan (fragmentary specimen).

Pernopecten sp. A.

(Pl. VII, Figs. 7, 10; Table XII)

Description.—Valve slightly prosocline, suborbicular; length slightly less than height; length of hinge line equal to about two-thirds valve length. Ventral margin describes subcircular arc which continues in posterior to a point about one-half the distance to the hinge line where the arc straightens somewhat, and continues to the beak; anterior margin regularly curved to a point about three-fourths the distance to the beak, from which point the shell body margin describes a slightly concave line to the beak. Beak prominent, extending above hinge line. Umbonal angle about 115 degrees. Valve moderately convex.

TABLE XII

MEASUREMENTS OF *Pernopecten* sp. A.
(In millimeters, except for angles)

Figured Specimens	
Left Valve	
(2)	
Length	21.1-44.0
Height	23.8-44.2
Length of hinge line	11.2-23.5
Convexity	3.7-7.7
Shell body costae	9
Umbonal angle	110°-118°
Angle between lateral auricular margin and shell body below	
Anterior	120°-124°
Posterior	180°

Auricles small, subequal, obtuse; anterior conspicuously flattened, separated from shell body by distinct umbonal fold; posterior not as flat, umbonal folds not as pronounced.

Original ornamentation consists of concentric undulations and radial costate elevations (Pl. VII, Fig. 7).

Remarks.—This species is represented by two left valves which, although displaying some characters of the genus *Pernopecten*, are also curiously aviculopectiniform, a fact which may indicate a closer affinity with the Aviculopectinidae than indicated by Newell (1937, p. 43).

Comparison.—The species is distinct in its subcircular shape, peculiar auricles, and lack of shell body sulci.

Material and repository.—Figured specimens UMMP Nos. 50135 and 26739.

Occurrence.—Prospect Hill Formation, Burlington, Iowa, and Waverly Group, Newark, Ohio.

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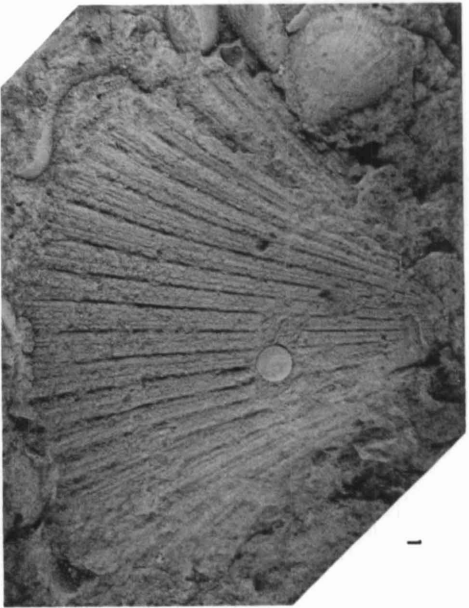
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PLATES

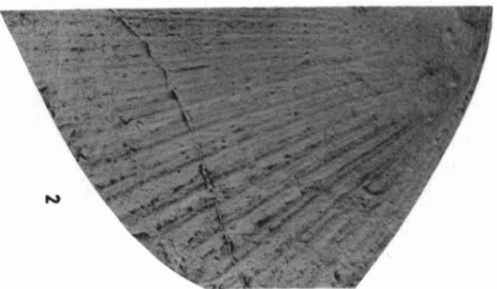
EXPLANATION OF PLATE I

	PAGE
<i>Aviculopecten gradocostus</i> White	10
FIG. 1. External cast of right valve, hypotype, UMMP No. 50113, Burlington, Iowa, probably from the English River Sandstone as indicated by the presence of <i>A. tenuicostus</i> in the matrix. $\times 1$.	
FIG. 2. Latex mold of surface of right valve showing peculiar ornamentation "in reverse," which, oddly enough, resembles typical aviculopectinoid ornamentation closer than that preserved on the natural cast, hypotype, UMMP No. 05114, Burlington, Iowa, horizon not known but lithology matches that of specimens in Figs. 1 and 6 identically (English River Sandstone?). $\times 1$.	
FIG. 6. External cast of left valve, holotype, UMMP No. 2141, English River Sandstone, Burlington, Iowa. $\times 1$.	
<i>Aviculopecten tenuicostus</i> Winchell	15
FIG. 3. External cast of left valve, syntype, UMMP No. 2138a, English River Sandstone, Burlington, Iowa. $\times 2$.	
FIG. 4. Very small left valve, doubtfully referred to this species, in crystalline limestone matrix, hypotype (one of Winchell's hypotypes), UMMP No. 26765, Kinderhook (Rockford Limestone?), Rockford, Indiana. $\times 4$.	
<i>Aviculopecten</i> sp.	18
FIG. 5. Left valve (?) of an undetermined species of <i>Aviculopecten</i> , listed as a hypotype of <i>A. caroli</i> by Winchell, it differs from this species in its low umbonal angle and unique ornamentation (see text), UMMP No. 26766, Base of Burlington Limestone, Burlington, Iowa. $\times 4$.	

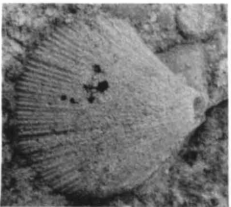
PLATE I



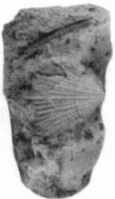
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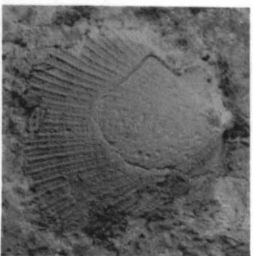
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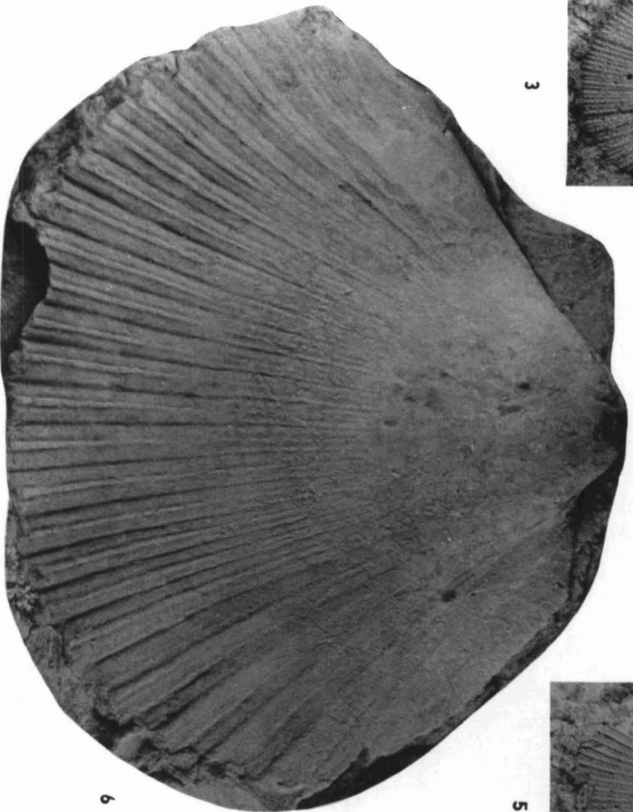
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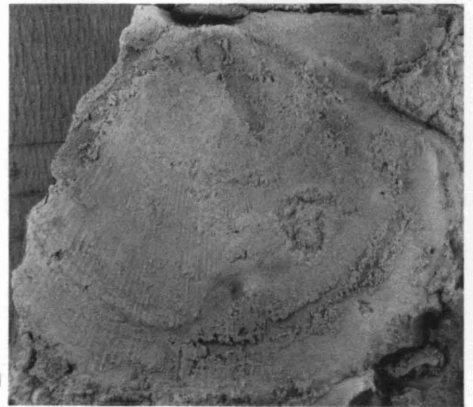
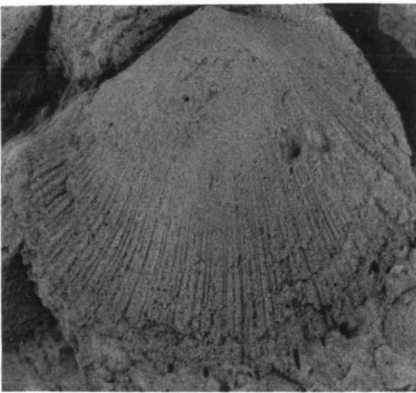
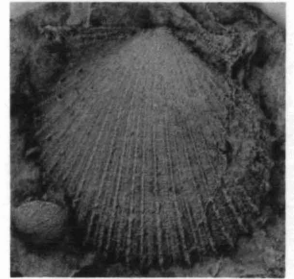
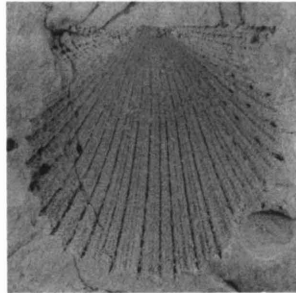
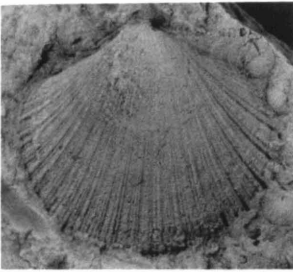
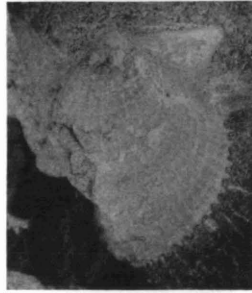
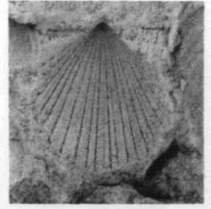
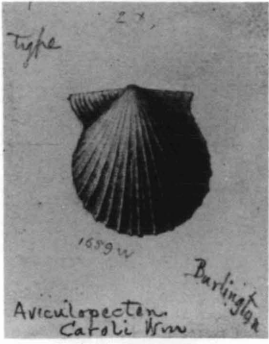


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PLATE II



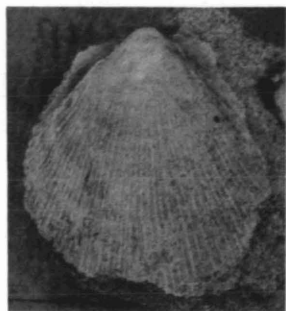
EXPLANATION OF PLATE II

	PAGE
<i>Aviculopecten caroli</i> Winchell	12
<p>FIGS. 1-3. Winchell's original drawing, wax cast, and a natural external mold of a small left valve, respectively, hypotype, UMMP No. 50115, Kinderhook (horizon not known but most likely English River Sandstone), Burlington, Iowa. Fig. 1, $\times 1$; Figs. 2-3, $\times 2$.</p> <p>FIG. 5. Portion of outer ostracum of a suspiciously anomalous left valve showing marginal spines, one of Winchell's paratypes, UMMP No. 2131, English River Sandstone, Burlington, Iowa. $\times 2$.</p> <p>FIG. 7. Natural subinternal cast of left valve showing peculiar "ornamentation," paratype, UMMP No. 2131, English River Sandstone, Burlington, Iowa. $\times 1.5$.</p> <p>FIGS. 8-9. Natural mold and latex cast respectively, of a mature right valve, note that the shell body spines on the right valve are between costae whereas on the left valve they are on the costae, holotype, UMMP No. 21302, English River Sandstone, Burlington, Iowa. $\times 2$.</p> <p>FIG. 10. Natural subinternal cast of a left valve showing molds of spines along the ventral margin of the specimen, slightly higher than the subinternal surface, paratype, UMMP No. 2131, English River Sandstone, Burlington, Iowa. $\times 2$.</p>	
<i>Aviculopecten tenuicostus</i> Winchell	15
<p>FIGS. 4, 6. External casts of left valves, syntypes, UMMP No. 2138 <i>b</i> and <i>c</i> respectively, English River Sandstone, Burlington, Iowa. $\times 2$.</p>	
<i>Aviculopecten</i> sp. A	18
<p>FIG. 11. A composite cast of a right valve, UMMP No. 50116, Marshall Formation, Battle Creek, Michigan. $\times 1$.</p>	

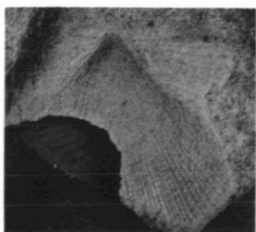
EXPLANATION OF PLATE III

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|--|------|
| <i>Aviculopecten tenuicostus</i> Winchell | 15 |
| FIG. 1. External cast of left valve, hypotype, UMMP No. 27770, Marshall Formation, Germain's Quarry, SW $\frac{1}{4}$, Sec. 22, T. 6 S., R. 3 W., Hillsdale Co., Michigan. $\times 2$. | |
| FIGS. 2-3. Counterparts of an external cast of a left valve, hypotype, UMMP No. 27770, same horizon and locality as above. $\times 2$. | |
| FIGS. 5-6, 11. External casts of left valves, Fig. 6, showing most clearly the costate elevations, syntypes, UMMP No. 2138 <i>d</i> , <i>e</i> (lectotype), and <i>f</i> respectively, English River Sandstone, Burlington, Iowa. Fig. 4, $\times 4$, Figs. 6, 11, $\times 2$. | |
| <i>Euchondria winchelli</i> (Meek) | 21 |
| FIGS. 4, 9. Winchell's original drawing and external cast of left valve from which it was apparently reconstructed, respectively, hypotype, UMMP No. 50118, probably Marshall Formation, Michigan. Both $\times 1$. | |
| FIG. 7. External cast of left valve showing extreme posteroventral extension of shell body, hypotype, UMMP No. 50117, Marshall Formation, Marshall, Michigan. $\times 2$. | |
| FIG. 8. Cast of an interior of a right valve showing posterior crus (cf. upper specimen Pl. IV, Fig. 12), hypotype, UMMP No. 26739, Waverly Group, Newark, Ohio. $\times 1$. | |
| FIG. 10. One of the specimens illustrated by Hall, presumably the one which caused him to refer the species to <i>Crenipecten</i> (see text), hypotype, AMNH No. 6517/2, Waverly Group, Licking Co., Ohio. $\times 1$. | |
| FIG. 12. Another specimen originally figured by Hall, this one possessing a nearly symmetrical shell body, hypotype, AMNH No. 6517/1, Waverly Group, Newark, Ohio. $\times 1$. | |

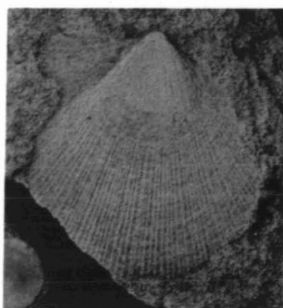
PLATE III



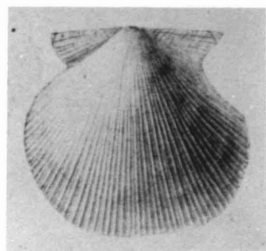
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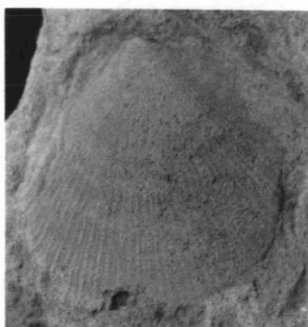
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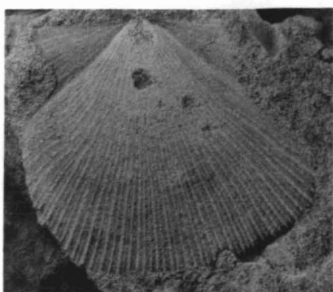
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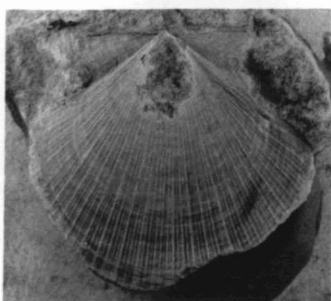
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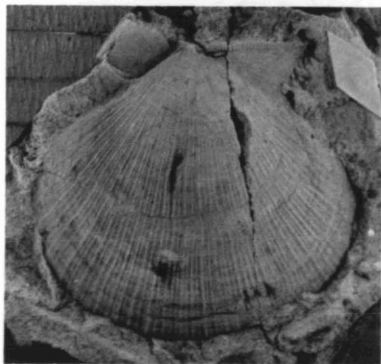
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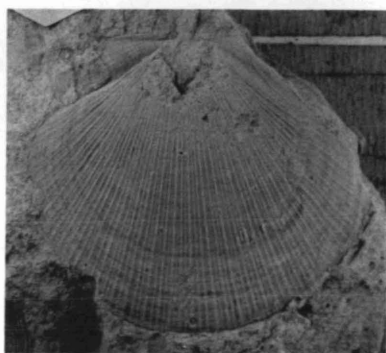
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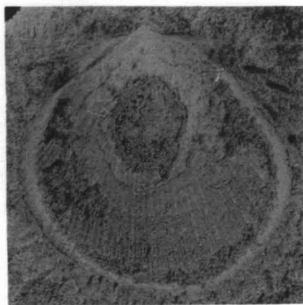
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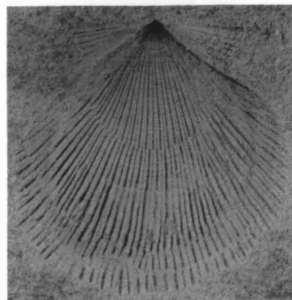
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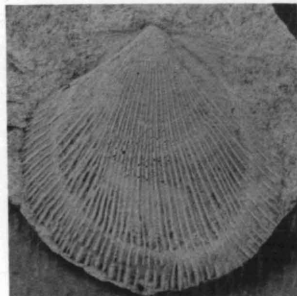
PLATE IV



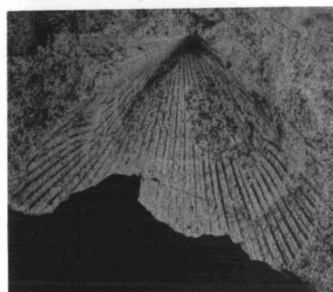
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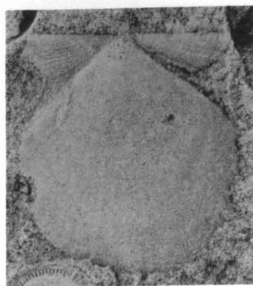
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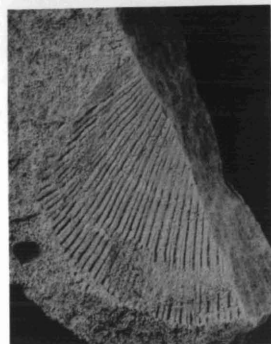
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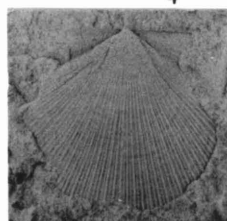
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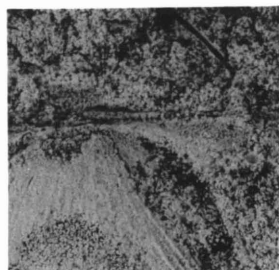
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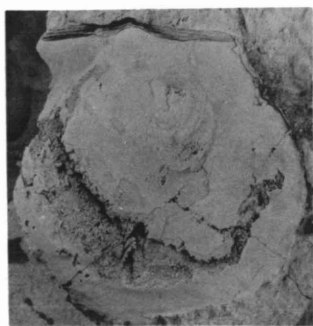
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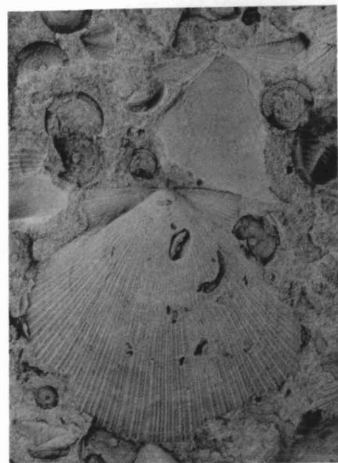
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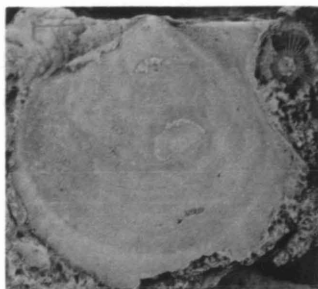
EXPLANATION OF PLATE IV

	PAGE
<i>Euchondria aerolatus</i> (Cooper)	24
FIG. 1. Composite cast of a left valve, holotype, UMMP No. 2222, Coldwater Formation, Huron Lighthouse (Pt. aux Barques Lighthouse), NE $\frac{1}{4}$, Sec. 11, T. 18 N., R. 14E., Huron Co., Michigan. \times 1.	
FIGS. 2-3. External mold and latex cast respectively, of left valve showing short hinge and posteroventral extension of shell body, hypotype, UMMP No. 50119, same horizon and locality as above. Both \times 1.	
FIGS. 4, 6. External molds of left valves showing variation in posterior auricle and posteroventral extension of shell body, hypotypes, UMMP No. 50120 and 50121, respectively, same horizon and locality as for specimens above. Both \times 2.	
FIG. 8. Composite cast of left valve showing faint traces of crenulated hinge, hypotype, UMMP No. 50123, same horizon and locality as Fig. 1. \times 4.	
<i>Euchondria winchelli</i> (Meek)	21
FIG. 5. External cast of right valve showing faint radial costae, hypotype, UMMP No. 50122, from either the Black Hand or Cuyahoga Formation, Granville, Ohio. \times 2.	
FIG. 7. External cast of small left valve, hypotype. AMNH No. 6517/1, Waverly Group, Newark, Ohio. \times 1.	
FIG. 10. Portions of right and left valves. This specimen was the holotype for <i>A. occidentalis</i> Winchell (not Shumard) and later for <i>A. iowensis</i> Miller (see text), hypotype, UMMP No. 2144, McCraney Formation, Burlington, Iowa. \times 4.	
FIG. 12. External cast of left valve (lower) and internal cast of right valve (upper), hypotype, UMMP No. 50125, from either the Black Hand or Cuyahoga Formation, Granville, Ohio. \times 1.	
<i>Aviculopecten tenuicostus</i> Winchell	15
FIG. 9. External cast of left valve, syntype, UMMP No. 2138g, English River Sandstone, Burlington, Iowa.	
<i>Pseudomonotis</i> sp. A	19
FIG. 11. Interior of right valve, UMMP No. 50124, intraformational conglomerate of clay nodules and siderite, Coldwater Shale, Waverly Quarry, NW $\frac{1}{4}$ Sec. 22, T. 5 N., R. 15 W, Ottawa Co., Michigan. \times 1.	

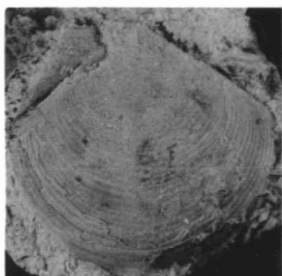
EXPLANATION OF PLATE V

	PAGE
<i>Euchondria perplexa</i> n. sp.	26
FIG. 1. Natural mold of interior of left valve showing impressions of adductor muscle and superior gill suspensaries, and extent of posteroventral extension of shell body, paratype, UMMP No. 50126, Coldwater Shale, Sec. 33, Branch Co., Michigan. $\times 1$.	
FIG. 2. Natural cast of right valve showing concentric ornamentation, paratype, UMMP No. 50127, intraformational conglomerate in Coldwater Shale, Waverly Quarry, NW $\frac{1}{4}$ Sec. 22, T. 5 N., R. 15 W., Ottawa Co., Michigan. $\times 1.5$.	
FIG. 3. Natural mold of left valve, hypotype, UMMP No. 50124, same horizon and locality as Fig. 2. $\times 1.5$.	
FIG. 4. Composite cast of interior of left valve with only a small amount of ornamentation preserved, showing the hinge characters (note the mold of the resilifer), paratype, UMMP No. 50128, same horizon and locality as Fig. 2. $\times 1.5$.	
FIG. 5. External cast of right valve showing nature of ornamentation on posterior auricle, paratype, UMMP No. 50129, intraformational conglomerate, Coldwater Shale, Peerless Cement Co., Shale Quarry, SW $\frac{1}{4}$ sec. 10, or NE $\frac{1}{4}$ sec. 16, T. 5 S., R. 7 W., Branch Co., Michigan, $\times 1.5$.	
FIG. 6. Natural mold of exterior of left valve showing auricular and shell body ornamentation, paratype, UMMP No. 50130, same horizon and locality as Fig. 5. $\times 1.5$.	
FIG. 8. External mold of right valve showing valve shape and ornamentation on shell body and anterior auricle, paratype, UMMP No. 50132, same horizon and locality as Fig. 2. $\times 1.5$.	
FIGS. 9-10. Interior and exterior counterparts, respectively, of a natural mold showing valve shape, hinge character, and ornamentation, holotype; UMMP No. 50133, same horizon and locality as Fig. 2. $\times 2$.	
<i>Euchondria winchelli</i> (Meek)	21
FIG. 7. Composite cast of left valve showing hinge characters (flattened structure at umbo is mold of median resilifer), hypotype, UMMP No. 50131, Coldwater Shale, Huron Lighthouse, NE $\frac{1}{4}$ Sec. 11, T. 18 N., R. 14 E., Huron Co., Michigan. $\times 1.5$.	

PLATE V



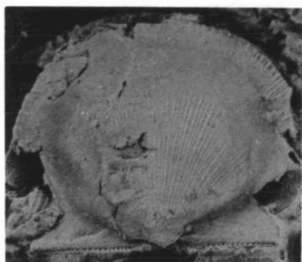
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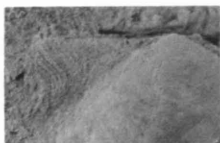
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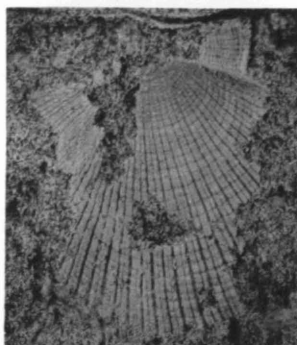
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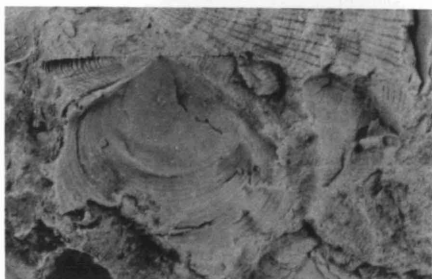
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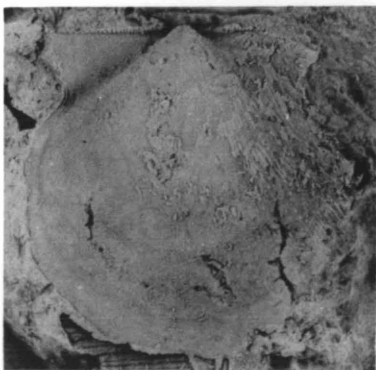
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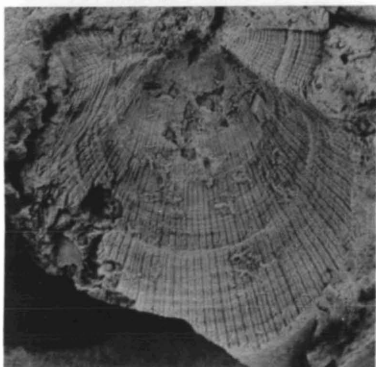
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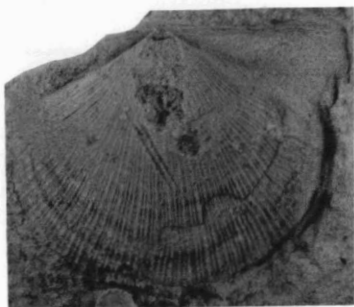


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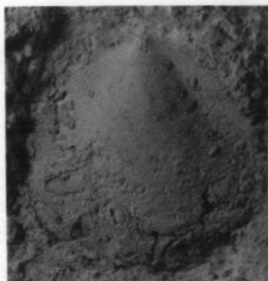


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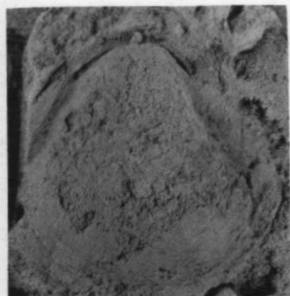
PLATE VI



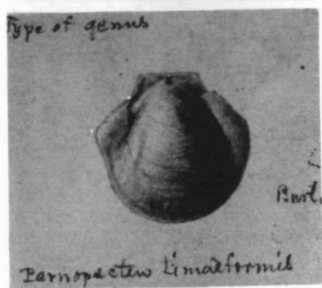
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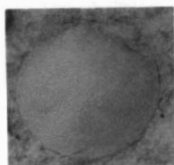
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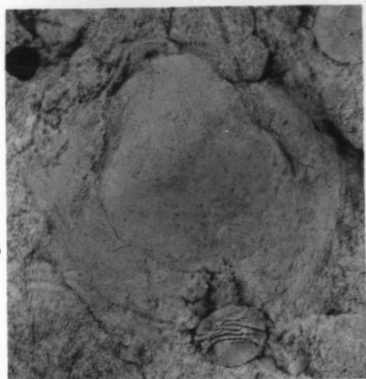
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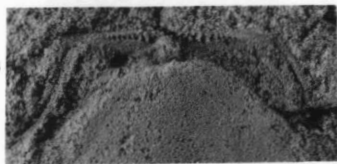
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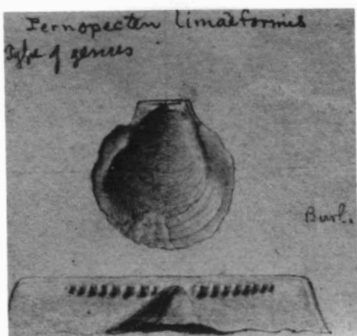
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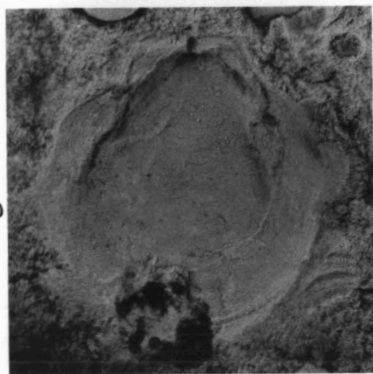
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EXPLANATION OF PLATE VI

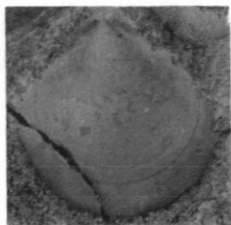
	PAGE
<i>Pernopecten limaformis</i> (White and Whitfield)	29
FIGS. 4, 6. Winchell's original-drawing (× 1) and internal mold of right valve from which it was made respectively, showing general shape, crura, and hinge characters, diplosynotype, UMMP No. 2127 (lectotype), Prospect Hill Formation, Burlington, Iowa. Fig. 6. × 2.	
FIG. 8. Enlargement of dorsal portion of specimen in Fig. 6, showing auricles and hinge structure. × 4.	
FIGS. 9-10. Winchell's original drawing (× 1) and natural cast (counterpart of specimen illustrated in Fig. 6) of interior of right valve, respectively, diplosynotype, UMMP No. 2127 (lectotype), same horizon and locality as Fig. 6, Fig. 10. × 2.	
FIG. 7. External cast of right valve showing general shape (note crest on posterior margin), hypotype*, UMMP No. 2200, base of the Burlington Limestone, Burlington, Iowa. × 1.5.	
FIG. 2. External cast of left valve showing general shape, hypotype, UMMP No. 2200, same horizon and locality as Fig. 7. × 1.5.	
FIG. 3. Internal mold of left valve showing general shape, crura, position of shell body sulci, and hinge characters, which are identical to those of the opposing valve (cf. Figs. 6, 8), diplosynotype, UMMP No. 21234, Prospect Hill Formation, Burlington, Iowa. × 1.5.	
<i>Euchondria winchelli</i> (Meek)	21
FIG. 1. External cast of left valve (cf. Pl. III, Fig. 12). This specimen was one of Winchell's hypotypes of <i>Aviculopecten caroli</i> (see p. 19), UMMP No. 26743, Waverly Group, Newark, Ohio. × 1.	
<i>Pernopecten circulus</i> (Shumard)	35
FIG. 5. External cast of right valve, note long hinge line and sub-circular outline, hypotype, UMDG No. 4357, Chouteau Group, 3.5 mi. NW of Williamsburg, Missouri. × 2.	

* This specimen, and the one illustrated in Fig. 2 were Winchell's syntypes of *P. limatus* (see p. 29).

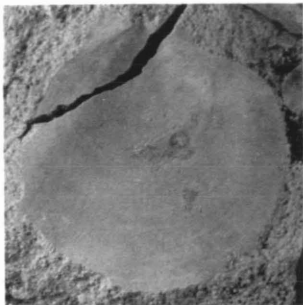
EXPLANATION OF PLATE VII

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|--|------|
| <i>Pernopecten shumardanus</i> Winchell | 22 |
| FIG. 1. Outer ostracum of left valve illustrated by Hall (1858, Pl. 7, Fig. 9), showing general shape of shell body, hypotype, AMNH No. 6523/1, horizon not indicated but judging from lithology of matrix (white oolite) probably McCraney Formation, Burlington, Iowa. $\times 1$. | |
| FIGS. 2-3, 6. Two external molds of left valves and fragments of the outer ostracum of two other left valves respectively, showing general shape, auricles, shell body sulci, and ornamentation, syntypes, UMMP No. 26762a (lectotype), b, and c respectively, McCraney Formation, Burlington, Iowa, Fig. 2, $\times 2$, Figs. 3, 6, $\times 1.5$. | |
| <i>Pernopecten cooperensis</i> (Shumard) | 35 |
| FIG. 4. External mold of right valve showing general shape, and slightly developed posterior crest, hypotype, UMDG No. 12798, Chouteau Group, Chouteau Springs, Missouri. $\times 2$. | |
| FIG. 5. External cast of right valve showing general shape and anterior margin, hypotype, USNM No. 146045, Chouteau Group, Cooper County, Missouri. $\times 2$. | |
| FIGS. 8, 12. External casts of left valves showing general shape, shell body sulci, and ornamentation (note the faint costate elevations in Fig. 8), hypotypes, USNM Nos. 146046 and 146047, from the Chouteau Group, Pinhook Bridge, 7 Mi. NE of Sedalia, Missouri, and Chouteau Group, Missouri, respectively. Both $\times 2$. | |
| <i>Pernopecten limaformis</i> (White and Whitfield) | 29 |
| FIGS. 9, 11. Internal molds of juvenile specimens, left valves, showing similarity with <i>P. cooperensis</i> , two of Winchell's original diplosyntypes (cannot be definitely assigned to either species), UMMP Nos. 2125 and 21233, respectively, Prospect Hill Sandstone, Burlington, Iowa. $\times 2$. | |
| <i>Pernopecten</i> sp. A. | 37 |
| FIG. 7. External cast of left valve included by Winchell as a diplosynotype of <i>P. limaformis</i> , note aviculopectinoid form and faint radiating ridges, UMMP No. 50135, Prospect Hill Sandstone, Burlington, Iowa. $\times 1.5$. | |
| FIG. 10. External cast of left valve, originally one of Winchell's hypotypes of <i>P. limatus</i> , UMMP No. 50134, Waverly Group, Newark, Ohio. $\times 1$. | |

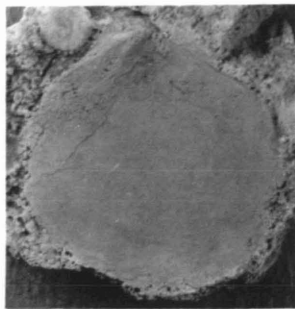
PLATE VII



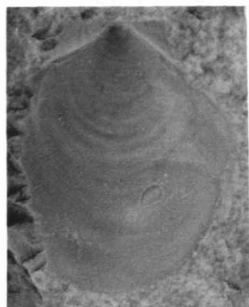
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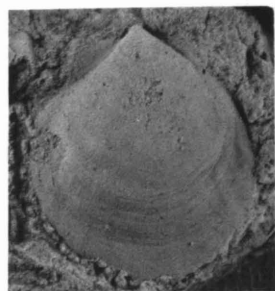
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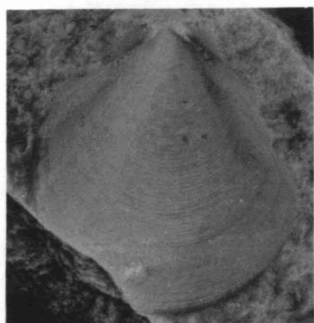
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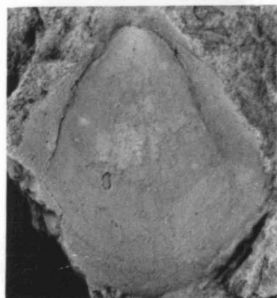
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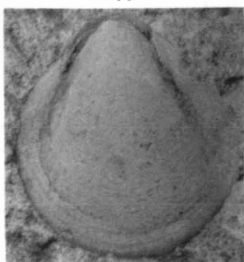
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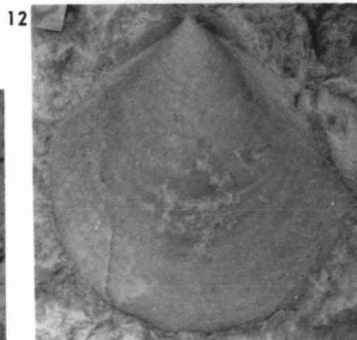
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