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LATE PALEOZOIC PELECYPODS: PECTINACEA

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PREFACE

By Raymond C. Moore

Kansas is fortunate in having an abundance of well-preserved fossils. These remains of once-existing animals and plants, buried in rock, are by no means mere objects of curiosity, popular or scientific. Interest in them is not confined to the evidence that they yield of great geographic changes which the region, now called Kansas, has witnessed during its geologic history—ancient swamps choked with subtropical types of plant growth where now is grassy plain, widespread salt-water seas where now is high, dry ground, and many other contrasting environments. Many of the vanished animals and plants of Kansas, represented by the fossils, are sufficiently like living forms to cause wonder that so little change should have occurred between ancestors and descendants in 100 million years, or, referring to fossils of eastern Kansas rock formations, in more than 200 million years. Many of the known former inhabitants of this region, on the other hand, are so unlike any animals or plants of the modern world that they would seem not to belong to this planet if interconnecting types of life were not also known from the fossil record. But in the minds of matter-of-fact citizens of "practical" bent, these observations have only academic interest; they have no application to affairs of commerce. Such a conclusion is largely erroneous.

Study of fossils—paleontology—has direct practical value as applied to identification of the rock strata from which the fossils were obtained. It is particularly true of geologic investigations in Kansas that careful observations of the distribution and nature of certain kinds of fossils have much use in strictly economic work—investigations having as their object the development of mineral deposits useful to man. This use of fossils is more or less restricted to application in the hands of the trained geologist, but it is none the less important on this account. In many instances the "layman" or amateur geologist is able to make practical use of observations and study of fossils, without considering so-called cultural interests. The uses that are of economic significance, here considered, are dependent primarily on the fact that the kinds, or species, of fossils and the associations of groups of fossils of certain kinds are restricted in occurrence to particular rock layers. The fossils are somewhat like labels, and there are different "labels" or combinations of "labels" for different rock strata. Because many fossils superficially resemble one another closely, or are actually so closely alike that discrimination is difficult, good illustrations and careful descriptions prepared by an able specialist in this branch of geologic study are needful. Publication of the results of paleontologic research makes generally available knowledge that otherwise could be utilized only by the geologist who made the painstaking study for himself.

Critical investigations of Kansas fossils have constituted only a rather small part of the activities of the State Geological Survey, although large use has been made of paleontologic observations in conducting certain field work pertaining to general or economic geology. It is evident that research in this field should be supported, however, because, as already indicated, the results are practically useful in work on geological problems of Kansas; also, it is apparent that as regards the Upper Carboniferous (Pennsylvanian) and Permian rocks of eastern Kansas, and to some extent the Cretaceous and Tertiary deposits of western Kansas, the geologic section of Kansas is fitted to serve as a standard for comparison in studies of other parts of North America and of other continents. Thus, paleontologic studies in Kansas have extremely wide application.

Experience indicates that among different methods of paleontologic study, that illustrated by the present work is most valuable. Here we have a certain group of fossils that is closely related biologically; representatives of this group from all rock strata where they are known, but especially Kansas and adjoining territory, are brought together; critical comparative study of form and structure of these fossils, with special reference to their geologic occurrence, is best fitted to bring out significant features in identification and use of the fossils. This type of investigation, best suited to define biologic distinctions, lacks consideration of the natural association of fossils to form assemblages called faunas, in the case of animals, and floras, in the case of plants. This latter study is also significant, but it cannot be made very satisfactorily until the biologic discriminations within each class of organisms have been established. Much of the older paleontologic work in Kansas had the defect that insufficient comparative study of similar groups of fossil organisms from precisely known geologic horizons was provided; hence, various kinds (species) of animals or plants that are actually distinct were grouped together, and in some cases forms that seemed different now appear to have been separated on merely superficial dissimilarities.

The following report by Doctor Newell covers one group of shells belonging to the class called Pelecypoda. These are two-shelled invertebrates that are represented by the very abundant, highly varied clams of marine waters and by the mussels of fresh-water streams and lakes. Pelecypods are very numerous as fossils in many rock formations of Kansas, but they have never been exhaustively studied. It is reasonably certain that fuller knowledge of these shells will make them much more useful in practical geologic work, and this is greatly to be desired since the pelecypods are so common. This volume deals with the "scallops" or *Pecten*-like forms, and is the first of a number of projected reports dealing with the late Paleozoic pelecypods, based mainly on the large collections of fossils from Kansas and adjacent states of the northern Mid-Continent region of the United States.

To date no comprehensive study of the American Late Paleozoic pelecypods has appeared. The many species known from rocks of Pennsylvanian and Permian age have been described in various publications, but the descriptions commonly were incidental to general faunal studies. Many of the original descriptions are inadequate, and are accompanied by poor illustrations or none at all. There has been much confusion regarding the precise nature of a great many pelecypod species; consequently these species have been variously interpreted by paleontologists. In many instances it is impossible to discover the true characters of a species without recourse to the type specimens, because the descriptions of a large proportion of the Pennsylvanian and Permian species are so generalized as to embrace many similar, but nevertheless distinct, forms. Unfortunately, some of the types described by the early paleontologists have been destroyed or lost, and in instances in which the exact locality and horizon from which the original specimens came is unknown, it is often impossible to determine to which of several species a particular name should be applied.

Modern technique for investigating internal characters of fossil shells has not been in general use. Consequently, few paleontologists have been able to give satisfactory descriptions of Late Paleozoic pelecypods. It is not surprising, then, that the shell interior of many pelecypod species and genera is still unknown. The microscope, now considered as essential equipment of the paleontologist, has been used only too infrequently in past studies of pelecypod shells, with the result that one whole line of evidence for classification has been neglected—that of shell microstructure.

The work of two men, F. B. Meek and G. H. Girty, in Pennsylvanian and Permian pelecypods indisputably stands above the work of all other American authors. Girty's descriptions are particularly satisfactory because of the high quality of the illustrations accompanying them.

The pelecypods of the Upper Paleozoic rocks of the Mid-Continent region, including Texas, Oklahoma, Kansas, Missouri, Nebraska, and Iowa, in many cases are well preserved and locally are very abundant. Although this class of Mollusca has been of little use in the past for stratigraphic correlation in the Upper Paleozoic rocks, there is reason to believe that certain groups of the pelecypods eventually will be comparable to the fusulinids, brachiopods, and gastropods as useful index fossils.

LATE PALEOZOIC PELECYPODS: PECTINACEA

Norman D. Newell

INTRODUCTION

The aviculopectens and related pectinoids constitute a characteristic element of the Medial and Late Paleozoic faunas. (The term, pectinoid, is used in a nontaxonomic sense in reference to the *Pecten*-like shape of these shells; the very similar term, pectinid, denotes an actual member of the *Pecten* group, rather than a shell that merely resembles representatives of this group.) These shells form a distinctive group of genera which are superficially alike in the *Pecten*-like shape, but are remarkably diversified in ornamentation and hinge characters. Although their ancestry is uncertain, the Paleozoic pectinoids undoubtedly originated in some of the Late Ordovician or Early Silurian pterioids (*Pteria*-like shells) undergoing a marked florescence in the Devonian period. By analogy with comparable modern forms, it is probable that these ancient pectinoids were the most active and highly specialized of the Paleozoic pelecypods. Some of them probably were able to swim about on one side by clapping the valves together after the habit of modern pectens; others (*Pseudomonotis*) were sessile, like the modern *Hinnites* and various Spondylidae. Probably all of the ancient forms, like the modern ones, employed a byssal attachment at some period in life, as suggested by the invariable possession of a byssal notch below the anterior auricle of the right valve.

Ever since McCoy, in 1851, enumerated in *Aviculopecten,* the characters by which he sought to distinguish Paleozoic pectinoids from the later ones, the classification of the early forms has been the subject of much discussion and controversy. The chaotic state of the classification is most apparent if reference is made to the widely varying ideas of the principal students of the group, Meek (1874), Waagen (1881), Hall (1884), De Koninck (1885), Jackson (1890), Frech (1891), Etheridge (1892), Hind (1903), Girty (1903, 1904a, 1904b, 1904c, 1909), Etheridge and Dun (1906), Licharew (1927), and others. A surprisingly small part of the literature written on generic classification has been based on observations of specimens. It has been customary for each student to discuss the published accounts of various genera and thereby to deduce something of the generic characters. Commonly the author's diagnosis and opinions regarding his genus have been quoted time and again, and accepted as authentic. Very few of the Paleozoic genera, as determined by the type species, were accurately portrayed in the original descriptions, and few of the original accounts are sufficiently complete in essential particulars to be wholly satisfactory.

An inherent difficulty in the study of the Paleozoic pectinoids has retarded progress in the understanding of these shells. The extreme rarity of the specimens exhibiting critical characters of hinge and musculature has prevented a clear understanding of the fundamental nature of the majority of described forms. Only after special and tedious preparation of specimens by technique not used by all paleontologists can most of the characters of the older pectinoid shells be observed. It is remarkable, in consideration of the handicap under which investigators have worked, that there have been any large contributions to the classification of this group.

The name *Aviculopecten,* based upon supposed hinge characters, has been employed hundreds of times since McCoy's diagnosis, but the published accounts and illustrations of the hinge of the Paleozoic pectinoids are indeed few in number. It is small wonder that there is such lack of agreement concerning the identity and significance of characters described in various forms of pectinoids.

In my studies of Paleozoic pectinoids I have found that the characters of the ligament area in various unlike stocks are conservative and persistent, and therefore available for the classification of larger groups. The ligament area is the shell surface to which the ligament is attached. Four kinds of ligament areas are distinguishable, and are comparable respectively to those of modern Pectinidae, Pteriidae, Pernidae, and Arcidae. An examination of the ligaments in modern representatives of these groups shows that the ligament is a complicated structure. The conservatism of a particular type of ligament in various modern and fossil pelecypod tribes suggests that ligament structures afford an extremely important, but sorely neglected, line of supplementary evidence in determining relationships between various groups of these mollusks.

It has seemed advisable, after an analysis of the data at hand, to regard the general features of hinge, ligament, and musculature as family characters in the Late Paleozoic pectinoids. Type of ornamentation, general form, and the shape of the resilifers have proved to be useful generic characters. More trivial, yet more or less persistent details of form and ornamentation are useful specific characters.

I am not able to demonstrate the close affinities implied by the term variety between two closely similar forms, and consequently do not feel the need for three names for a form when two indicate the probable relationships just as well. The terms genus and species, as employed for extinct groups, can never mean just what they do in living forms. A paleontological species, as employed here, is the lowest practicable division in a hierarchy of biologic divisions. Of necessity, a fossil species must be described more or less objectively. If a suite of specimens has certain distinctive characters, a paleontologist is justified in describing these characters. He lacks, however, many of the criteria for evaluating them according to the concepts of zoology. Observed variations in fossil shells may equally well suggest ecads, mutants, or species in the biologic sense. The advisability of applying a name to a particular form should be determined by utility not only in stratigraphy, but also in tracing lines of descent. It is ordinarily unwise to describe a pelecypod species from a single specimen, but where there are several specimens in a collection from a single locality, it is possible to learn something of the variability of the species.

SUMMARY OF RESULTS

The original plan for this volume included a restudy of the known Paleozoic pectinoid genera, based on genotype species. Unfortunately, it has not been possible to secure specimens in every case. Although I have had access to some of the finest collections in the country, the rarity of well-preserved specimens of pectinoids, particularly those from the Middle Paleozoic rocks, has been a handicap. Several genera have been based upon rare and poorly known foreign species and it is difficult to obtain good specimens for study. A serious attempt has been made to establish the generic status of the Pennsylvanian and Permian species. Naturally, this program necessitated work on a few type species from rocks of various geologic systems.

Available type specimens were restudied in an effort to establish the recognizable, valid species described from the North American Pennsylvanian and Permian rocks, and to discover synonyms. The difficulties in this program were many, some insurmountable. A large number of original type specimens were lost or destroyed. In such instances I have made every attempt to recognize the species, either through topotype specimens or from the original descriptions and figures. Many species cannot be authoritatively established. There is no merit whatsoever in paleontology in using a specific name that is not established by authoritative specimens.

At the beginning of this investigation, 11 generic names were in general use by American writers for Paleozoic genera of pectinoids. New and old Paleozoic genera, considered in the following pages, are 28 in number; of these, 19 are treated in greater or less detail. There are 21 securely established genera, and 5 are still poorly known. Two were found to be synonyms of previously established genera. Eight genera are defined here for the first time. It was discovered that 75 specific names had been introduced for American Pennsylvanian and Permian forms. Of these, I was able to secure the type specimens or topotype specimens for 53 species. Forty can now be securely established on the basis of the types, but 8 must be suppressed as synonyms or homonyms. Twenty are species *inquirenda,* and most of these can never be recognized with certainty. Four names are retained for distinctive species in the absence of type or topotype specimens. Thirty species are described as new, making a total of 74 species recognized as valid.

Two new families and one new subfamily are erected for the reception of distinctive divisions of the Paleozoic *Pecten*-like shells, and new information has required that one previously defined family and one subfamily be emended.

During this investigation it was found that four characters can be employed consistently in the classification of Paleozoic pectinoids: (1) Musculature. Two types of musculature are distinguished —one like that of modern Pectinidae (and Amussiidae), the other embodying features of both Pectinidae and Pteriidae. (2) Hinge. Four types of hinge, found also in other, unrelated, pelecypod stocks, occur in the Paleozoic Pectinacea. One group is characterized by a ligament like that of modern *Arca,* another like modern *Pteria,* a third like *Perna,* and a fourth like *Pecten.* In each of the four groups of Paleozoic shells there are forms unlike in shape, ornamentation, and shell structure. (3) Ornamentation. The two valves in most pectinoid shells are ornamented differently. The types and combinations of shell ornamentation, where both valves are considered, are useful in delimiting compact groups. (4) Shell microstructure. Each valve is characterized by having three unlike layers, a filmlike outer calcite layer, a massive inner aragonite layer, within which is a small area of fibrous aragonite at the muscle impressions. The outer layer is generally prismatic in the right valve and structureless in the left, and there are three characteristic shapes of prisms. The outer layer in some shells is alike in both valves, having radially crossed-lamellar structure. The massive inner layer is commonly concentrically crossed-lamellar, and in some instances nacreous.

A restudy of type species has shown that there is much misunderstanding regarding some of the significant characters of the older pectinoids. Emphasis is placed on the importance of hinge characters by some authors, on general form by others. The existing classifications are highly artificial and inconsistent. An examination of large collections shows that general configuration is the chief character by which the Paleozoic *Pecten*-like forms can be classed together under Pectinacea rather than Pteriacea.

Prevalent ideas regarding Paleozoic pectinoids are based partly on misconceptions regarding hinge characters, and there has been general lack of agreement regarding features which should be considered most important. The kind of hinge originally described for *Aviculopecten* is fictitious, according to my study of original specimens. The four different kinds of hinge structures among pectinoids serve for recognition of four families: Pterinopectinidae, Aviculopectinidae, Euchondriidae, and Amussiidae.

The shell microstructure is not yet known for many of the genera of the Pterinopectinidae, but in most of the Paleozoic representatives of the last three families, the outer shell layer of the right valve is composed of calcite prisms of a shape characteristic for each family. Within the families there are many types and combinations of ornamentation which serve for a natural classification into genera.

The Aviculopectinidae are divided into subfamilies, which are based on form and shell structure.

COLLECTIONS

Probably never before has there been assembled for study such fine collections of various kinds of Upper Paleozoic pelecypods as those now available to me. The great collections of the Kansas and Nebraska Geological Surveys, with exact stratigraphic data, represent almost every fossiliferous Pennsylvanian and Permian horizon in the northern Mid-Continent region. These collections supply unusually complete data in various pelecypod stocks that may be used to aid in distinguishing slight but useful variations, and also for determining the more significant products of progressive change through a thick succession of rocks. The extensive collections at Peabody Museum, Yale University, including the Braun-Schuchert collection, contain many hundreds of choice Pennsylvanian specimens. The Yale material supplements admirably the collections from Oklahoma and north-central Texas in the Kansas and Nebraska Geological Survey collections. A small collection of good specimens was lent from the geological museum at the University of Oklahoma. Three other small collections of Oklahoma and Texas specimens were received from Richard Hollingsworth, Ralph King, and from the University of Iowa. An exceedingly fine assemblage that was presented to me by Dr. J. Brookes Knight includes all of the pelecypods in his unique collection from the St. Louis outlier region. A special feature of this collection is the large number of juvenile specimens, particularly in the Nuculacea, including many nearly complete ontogenetic series. Some unusually fine specimens described in this volume were lent by the U. S. National Museum at Washington. A number of Permian forms from the Glass Mountains of West Texas, property of the Texas Bureau of Economic Geology, were accessible to me at Peabody Museum. Many of the Pennsylvanian specimens were collected personally by me.

Although the present volume is devoted only to the *Pecten*-like shells, further studies are contemplated, based on these collections.

PREPARATION OF SPECIMENS

Specimens of Paleozoic pelecypods wholly free from rock matrix are seldom discovered. Unlike brachiopods, pelecypod shells do not withstand very well viscissitudes of exposure to weathering, nor are they commonly silicified, so that free specimens, exhibiting all of the shell features, are uncommon, except perhaps, in the case of nuculoids in soft shale.

I was introduced to an important technique for the preparation of fossil specimens by Drs. J. Brookes Knight and G. Arthur Cooper. Very surprising results can be secured by working with very sharp, fine tools in conjunction with a binocular microscope. The most important requisite in the work is the need for infinite care and patience. The equipment employed in this preparation consists of a small pin vise, such as can be procured from hardware supply companies, and a number of small sewing needles, fine phonograph needles, and two or three jeweler's broaches. Three kinds of points generally are sufficient for all purposes. The original point of the needles is suitable for a few uses, but is used least of all. The sewing and phonograph needles can be cut off obliquely at the tip for a kind of gouging tool to be used in excavating rounded spaces between external costae. The most useful tool of all is an oblique chisel edge. Such an edge can be obtained by grinding down the point by hand on a fine carborundum block; or, better, it can be shaped on a motor-driven carborundum wheel. It is highly important that the chisel edge of the needle be sharpened frequently.

In dealing with ordinary limestone, it was found that much of the matrix can be cut away with a corborundum dental drill. Then the matrix is shaved down with the small chisel edge, this work being always done with a binocular microscope at low or intermediate magnification. Generally it is necessary to keep the specimens wet with water, glycerin, or xylol, in order to distinguish between shell and matrix. When the matrix has been cut down to a paper-thin film, it can be flaked off some specimens without scratching the shell.

Potassium hydroxide can be used in a few cases for the removal of shaly matrix. It should be used only as a last resort, however, because it is commonly destructive to the surface of the shells.

Shell microstructure generally can be observed without use of thin sections if the specimen is examined under some liquid, such as xylol or Canada balsam. Thin sections are usually necessary, however, in photographing shell structure, because of the high magnifications required.

Modeling-clay or dental-wax impressions facilitate measuring the umbonal angle and shell convexity, and also aid in preparing diagrams of surface profiles.

DISTRIBUTION

Lithologic associations.—Some types of the ancient pectinoids thrived apparently in only a restricted range of environment. Some hint of these ecologic restrictions are given by the kind of rock in which the pectinoid shells are found, and an attempt was made in this investigation to note and record the general rock types associated with different kinds of shells. For example, specimens of *Dunbarella* and *Euchondria*, according to my experience, are found in black carbonaceous shales or the calcareous equivalent, or argillaceous shales. I have never seen a representative of one of these genera in argillaceous limestone, oölite, or pure limestone. The new genera, *Pterinopectinella*, *Annuliconcha* and *Girtypecten* were found invariably in relatively pure limestones, presumably deposited in an environment of clear water. *Fasciculiconcha*, *Clavicosta*, *Pseudomonotis*, *Streblochondria*, and *Aviculopecten* appear more commonly in argillaceous limestones, but all of them are also found locally in limestone oölites, and sandy or shaly beds.

The genus *Limipecten* is not uncommon in shaly beds of the Pennsylvanian rocks in Texas and Oklahoma, but appears to be exceedingly rare in equivalent rocks in the northern Mid-Continent region.

Stratigraphic distribution.—Pectinoids from various separate provinces in North America have been included in this study so that a single chart showing the stratigraphic range of various species is not feasible. In order to indicate the general sequence of stratigraphic divisions in the main provinces, the following correlation tables were compiled from various sources representing the most up-to-date and best-established correlations obtainable at the present time.

TABLE I.—PRINCIPAL DIVISIONS OF THE AMERICAN MARINE PERMIAN ROCKS

ARBITRARY DESIGNATIONS.	Trans-Pecos Texas.		North Texas.	Kansas, Nebraska, Oklahoma.		Cordilleran Region.	Russia.
Upper Permian	Rustler Castile Capitan		Double Mt.	Quartermaster Day Creek Whitehorse	Cimarron series	*Absent*	Post-Artinskian
Middle Permian	Delaware Mt. Bone Springs	Word Leonard	Clearfork	Dog Creek Blaine Enid Upper Sumner		Phosphoria Kaibab Coconino Supai	Artinskian
Lower Permian	Hueco	Wolfcamp	Wichita Putnam Moran Pueblo Upper Harpersville	Lower Sumner Chase Council Grove Admire	Big Blue series	Bird Springs	Upper Uralian

CARBONIFEROUS ROCKS

TABLE II.—PRINCIPAL DIVISIONS OF THE AMERICAN UPPER CARBONIFEROUS (PENNSYLVANIAN) ROCKS

ARBITRARY DESIGNATIONS.	West Texas.	North-central Texas.		Oklahoma, Arkansas.	Kansas, Nebraska, Missouri.		Illinois.	Pennsylvania, Ohio, W. Virginia.		Russia.
Upper Pennsylvanian	Gaptank	Cisco	Lower Harpersville Thrifty Graham	Wabaunsee Shawnee	Virgil	Wabaunsee Shawnee	*Absent*	Monongahela		Lower Uralian
		Canyon	Upper Caddo Creek	Nelagoney		Douglas	Merom Embarass	Ames	Conemaugh	
Middle Pennsylvanian			Lower Caddo Creek Brad Graford	Ochelata Dewey Nellie Bly	Missouri	Pedee Lansing Kansas City	La Salle Macoupin Centralia	Cambridge		
		Palo Pinto		Hogshooter		Bronson	Shoal Creek			
		Strawn	Upper Mineral Wells	Coffeyville		Bourbon	Trivoli	Brush Creek		
Lower Pennsylvanian			Lower Mineral Wells	Holdenville Wewoka Wetumka	Des Moines	Marmaton	Gimlet Sparland Brereton St. David Summum	Allegheny		Moscovian
			Garner	Senora Thurman Stuart Boggy Savanna McAlester Hartshorne		Cherokee	Liverpool Greenbush Wiley Seahorne Delong Seville Pope Creek			
	Upper Haymond		Millsap Lake	Atoka		*Absent*	Tarter	Kanawha	Pottsville	
	Lower Haymond Dimple Tesnus	Bend	Smithwick Marble Falls	Bloyd Hale	Morrow		Babylon Wayside			
	Absent							New River Pocahontas		

MISSISSIPPIAN ROCKS

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A large number of individuals have spared no effort to help me secure type specimens and other material for study. Especially important were the services of Dr. J. Brookes Knight, of Princeton University, who was instrumental in kindling my interest in Paleozoic pelecypods, expressing confidence in my work by entrusting to me all of his unique collection of pelecypods from the St. Louis Pennsylvanian outlier, and most important, supplying a constant inspiration, both through personal contact and by example of achievement. Dr. J. Marvin Weller, of the Illinois Geological Survey, helped me borrow the type specimens of species described by Meek and Worthen.

Doctors Carl O. Dunbar, G. E. Condra, and R. C. Moore made the project possible by placing the splendid collections of Peabody Museum, Yale University, the Nebraska Geological Survey, and the Kansas Geological Survey at my disposal. In addition to furnishing constructive counsel as teacher and friend, Doctor Dunbar was instrumental in obtaining for me a Sterling Research Fellowship at Yale University, without which I could not have undertaken this study.

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SHELL MORPHOLOGY

GLOSSARY OF SHELL TERMS

In some particulars, pectinoid shells are so unlike the shells of other pelecypods that a special terminology has been used for them by some authors; hence, it is desirable to define briefly some of the terms used in the text. A list of these, arranged in alphabetical order, follows.

Adductor impression.—The single large muscle "scar" just back of the middle of each valve will be called the adductor impression. The insertion of the retractor muscle of the foot is continuous with the anterodorsal part of the adductor impression, and it is generally indistinguishable from that of the adductor proper.

Auricle.—The anterior and posterior extensions of the pectinoid shell along the dorsal margin are the auricles. These are sometimes called "ears" or "wings."

Auricular crura.—In shells like *Amussium, Pernopecten,* and *Entolium* there is a pair of internal ridges diverging from the beak of each valve along the juncture of the auricles with the shell body. These internal ridges or crura (singular, crus) do not function primitively as teeth, since they are not in contact and are not alternate, but are in direct apposition. In Spondylidae, however, they assume the rôle of interlocking teeth.

Auricular sulcus.—This is a more or less distinct external furrow at the juncture of an auricle with the body of the shell.

Byssus.—The group of conchiolin strands by which many pelecypods make a temporary attachment is known as the byssus. It is secreted by special glands of the foot, and while still fluid is attached by the foot to extraneous objects.

Byssal notch.—When at rest the pectinoid shell lies on the right valve. A deep notch under the anterior auricle of this valve permits the small foot to be extruded without opening the valves widely. In some forms, like *Pernopecten* and *Amussium,* the notch is lost in the adult, but its existence in the juvenile can be seen in early growth lines.

Byssal sinus.—The front edge of the anterior auricle in the left valve generally has a broad, slight indentation or sinus. Most commonly the margin of the auricle is recurved inward toward the beaks at the hinge line forming a sigmoidal outline, somewhat unlike the simple sinus below the posterior auricle. The relatively deep anterior notch in the right valve and the shallow anterior byssal sinus in the left afford a ready means for orienting *Pecten*-like shells.

Cardinal area.—In many shells, like members of the Arcidae and Pteriidae, two flat areas diverge upward from the hinge axis of the two valves. The flattened area of each valve is generally called cardinal area. In many of the Paleozoic pectinoids, as in modern Arcidae and Pteriidae, the cardinal area corresponds to the ligament area, or surface of ligament attachment. A few of the Paleozoic forms, such as *Pernopecten,* like most modern Pectinidae, have no cardinal area.

Cardinal axis.—This is the axis of rotation for the valves. The axis in the Aviculopectinidae and Pterinopectinidae, as in *Arca* or *Pteria,* lies well below the dorsal margin of the shell.

Cardinal costa.—In some genera, a pronounced ridge occurs on both sides of the beak, lying at the angle between the cardinal area and the outer shell surface. These ridges, the cardinal costae, are not comparable to ordinary ornamentation, because they may occur in otherwise unornamented forms.

Cardinal margin.—The cardinal margin is the dorsal margin of the shell. In those forms possessing cardinal areas the cardinal margin is not quite straight, but forms the sides of a low triangle, the base of which is the cardinal axis. The triangular shape of the cardinal area is more distinct in some forms than in others.

Chevron grooves.—The V-shaped ligament grooves typically developed on the cardinal areas of Arcidae and Pterinopectinidae may be termed chevron grooves. In some pelecypods, like *Myalina,* the anterior part of the chevron is suppressed or obsolete.

Convexity.—This term is used for the maximum convexity of a single valve, measured from the plane of commissure to the outer surface of the shell.

Costae.—Costae (singular, costa) are external radial ridges. When costae increase in number by bifurcation or intercalation, a shell is said to be *multicostate;* when they are fascicled, the shell is *fascicostate.* When the costae do not increase in number the shell is *simplicicostate.* Those costae which appear first at the umbones are said to belong to the first order; the next ones to appear belong to the second order, etc.

Fila.—Fila (singular, filum) are regular, concentric lirae. They may be distinguished arbitrarily from ordinary growth lines which are irregular and relatively fine; and from imbricating lamellae. If there are two ranks of fila, the coarse ones are said to be of the first order, and the finer ones are of the second order. Fila, like the edges of imbricating lamellae, are only a special kind of growth lines.

Gape.—In some pelecypods the valves, when closed, are only in contact along the dorsal and ventral margins. Such shells gape anteriorly and posteriorly.

Growth lines.—These are irregular and generally obscure lines marking the successive advances of the shell margin.

Height.—It is convenient to measure the height in pectinoids, as in dimyarian pelecypods, from the beaks to the ventral margin, at right angles to the hinge.

Hypostracum.—The term hypostracum is applied to a filmlike calcareous secretion of the muscles, deposited between the muscle and shell proper, coextensive with the muscle impressions.

Interspaces.—Interspaces are striae, or external furrows separating adjoining fila or costae.

Lamellar layer.—The calcareous shell, or ostracum, is commonly divisible into two or more layers of unlike structure. Ordinarily one or more of the layers is constructed of microscopic lamellae of calcite or aragonite separated by equally thin layers of conchiolin. The two most common types of lamellar structure are the nacreous or pearly structure and the crossed lamellar structure. Shell structure is more fully discussed on page 24.

Length.—In pectinoids the length is the greatest dimension of the body of the shell measured parallel to, and below the hinge. The hinge is in some instances longer than the shell body. Its length is designated separately as the "hinge length."

Levator impressions.—Small pits on the inner surface under the beaks mark the insertions of the superior retractor muscles, or levator muscles of the foot. Such muscles characterize the Pteriidae and older Pectinacea but are absent in the Pectinidae *sensu stricto.*

Ligament (*see resilium*).—The ligament commonly consists of two unlike kinds of elastic conchiolin. One kind is impregnated with calcareous spicules, the fibrous ligament, and is elastic chiefly to compressional stresses. This part of the ligament is located mainly below (ventral to) the hinge axis. The other type of ligament, the lamellar ligament, contains no calcareous material. It is elastic to both compressional and tensional stresses.

Midumbonal line.—An imaginary, usually curved, line bisecting the umbonal angle may be termed the midumbonal line.

Musculature.—The muscles of the modern Pectinidae or Pteriidae that produce an impression on the shell are: the levators of the foot, generally two to each valve (absent in Pectinidae), attached at the interior of the umbones; retractors of the foot, one to each valve (right retractor missing in Pectinidae), inserted at the anterodorsal part of the large adductor impression; adductor system, inserted slightly behind the center of both valves; orbicular or pallial system, inserted at a pallial line; and the gill suspensories (in the Pectinidae), just below the adductors.

Obliquity.—The obliquity of a shell may be stated conveniently in terms of the inclination of the midumbonal line. Shells with a forward obliquity, like most Pteriidae, are *prosocline;* upright shells, like most Pectinidae, are *acline;* and shells with a backward obliquity, like *Streblochondria,* n. gen., are *opisthocline.* As determined by ontogeny, acline shells are derived in every case from prosocline shells, and in turn acline shells give rise to opisthocline shells. In the latter group, the midumbonal line tends to describe a semicircle or C, open toward the anterior end of the shell.

Ostracum.—In many kinds of pelecypods, such as Aviculopectinidae, *Unio, Pteria,* there are two separate layers constituting the ostracum or shell proper. The outer layer is commonly prismatic or homogeneous and will be termed the *outer ostracum.* The inner layer is commonly nacreous or crossed-lamellar and will be termed the *inner ostracum.*

Pallial line.—The insertion of the shell of the orbicular or pallial muscle system is called the pallial line. The line may be continuous or consist of a series of pits. The mantle is not attached to the shell outside of the pallial line.

Periostracum.—An outer film of conchiolin, called the periostracum, is present in many groups of pelecypods. It is generally present in the modern Pteriacea and absent in modern Pectinacea.

Plane of valves.—The plane of commissure or plane approximately coinciding with the valve margins may be called the plane of the valves. In valves with front and rear gape the plane of the valves includes only the hinge line and ventral margin.

Plicae.—Plicae (singular, plica) are ribs or folds involving the entire thickness of the shell and interlocking at the margin. Many of the post-Paleozoic pectinoids are plicate, whereas almost all of the Paleozoic forms are either smooth or costate. The costae in the early forms are generally confined to a thin outer layer of the shell, but in some of these individuals the shell margin is obscurely plicate.

Prismatic layer.—The outer layer of the ostracum is in some cases prismatic. It occurs in nearly all modern Pteriacea and many Paleozoic pectinoids. The layer consists of closely spaced polygonal prisms of calcite in a matrix of conchiolin. Such a layer appears to be invariably absent in the adults of modern Pectinidae, but it is present in the juvenile right valves of some species. The prismatic layer in general occurs in only the right valves of the Paleozoic forms.

Resilifer.—The triangular or rectangular fossette for the reception of the resilium, below the dorsal margin of both valves, is called the resilifer.

Resilium.—As generally employed, the term applies to a triangular ligament structure residing in a central pit along the inner margin of each valve. The resilium, as properly defined, is invariably an organ of compression, the functional part being ventral to the hinge axis. The fibrous ligament of *Arca* is morphologically and mechanically a resilium, but the term is never applied to the arcas because the fibrous ligament is not contained in triangular pits. Structurally the "resilia" of *Pteria, Yoldia,* and *Pecten* are different and I doubt the propriety of employing the term to diverse structures. I have avoided employing the term resilium wherever possible.

Retractor.—In Pteriidae a muscle extends from the anterodorsal margin of the adductor impression in both valves to the foot. These muscles are the pedal retractors. In modern Pectinidae there is no retractor in the right valve, the single retractor present occurring in the left valve.

Shell body.—The shell body is the pectinoid or pterioid shell minus the auricles.

Shell structure.—In its complete development the pelecypod shell consists of three parts, *ostracum, hypostracum* and *periostracum.* The ostracum makes up most of the calcareous shell and may have a complicated microstructure. The hypostracum is a thin filmlike calcareous layer secreted by cells of the muscles at their insertions in the shell. The hypostracum may or may not have a fibrous structure. The periostracum is a thin layer of conchiolin covering the outer surface of the ostracum.

Shell thickness.—The shell material of a pelecypod is thickest near the hinge and thinnest near the ends and ventral margin, with more or less gradation in thickness in the intermediate areas. The thickness is, however, for practical purposes nearly uniform over the central area of both valves, and measurements of shell thickness in this report are given for the central parts of shells having a stated height and length.

Sinus.—This is an indentation of the shell margin which may be shown in growth lines.

Subinternal mold.—Very commonly the outer calcite layer of the ostracum is preserved in the Paleozoic pectinoids after there is no trace of the inner, aragonite layer, or the hinge structures. In all such examples the inner as well as the outer surface of the preserved layer exhibits distinct growth lines and general features of ornamentation. A natural mold of this surface presents a striking, but generally misleading, resemblance to the external surface of the shell. Such molds are not replicas of either the inner or outer surface of the original shell and the term subinternal mold is applied to them.

Transition zone.—This term is used for an area along the outer slopes of the umbonal folds of some pectinoid shells where there is a transition between the ornamentation of the shell body and a slightly different ornamentation of the auricles.

Umbonal angle.—The umbonal angle is the angle of divergence of the umbonal folds. When either of the umbonal folds is particularly obscure, a precise, or even approximate, value of the umbonal angle cannot be obtained. Commonly the angle flares outward so abruptly that a different measurement can be obtained at different growth stages. Ordinarily it is convenient to record only the maximum umbonal angle at a given shell size.

Umbonal folds.—The umbonal folds are the low folds or shoulders that bound the umbo and set it off from the auricles.

MODERN PELECYPODS COMPARED WITH ANCIENT PECTINOIDS

It has often been said that the aviculopectens are structurally intermediate between the Pteriidae and Pectinidae. A proper approach to an understanding of the ancient shells lies in an examination of similar modern ones. In the following pages a review is made of some shell characters of modern Pectinidae and Pteriidae and the ligament structures in *Arca,* with emphasis on those features that are also displayed by the Paleozoic shells. The modern examples that are most frequently referred to are *Pinctada vulgaris* (Schum.) and *Pecten tenuicostatus* Mighels, because the literature on these species is particularly satisfactory. Personal observations were made on the shells and anatomy of some other modern species.

ORIENTATION

The animal of *Pecten* or *Pteria* has undergone a remarkable torsion as compared to more primitive pelecypods. In most pelecypods the hinge is dorsal and the opposite margin of the valves ventral, but in the Pectinidae, Pteriidae and similar monomyarian forms there has been a torsion of the body within the shell concurrent with the progressive reduction and loss of the anterior adductor muscle. The relation of the soft parts to the shell of *Pteria* and *Pecten* are such that the hinge line properly can be said to be anterior, the auricles, therefore, are ventral and dorsal. The correct orientation of these shells is further complicated by the circumstance that the animal in every case rests on what is anatomically the right valve. There has been a slight further torsion of part of the body to permit the foot to be extruded through a slit in the lower valve. As regards the actual living position of the valves, they might be considered dorsal and ventral. The torsion in these forms is comparable to that of the flounder among fishes. It is much less confusing for purposes of description to consider the hinge margin dorsal and the valves right and left, than to employ a more accurate terminology.

Difficulty has been experienced by several authors in orienting Paleozoic pectinoid shells properly. There are three criteria, any one of which is infallible for distinguishing right and left valves of pectinoids and pterioids. (1) The most obvious distinction is the deep byssal notch or slit below the anterior auricle of the right valve. A corresponding sinus occurs below the anterior auricle of the left valve, but it is quite shallow as compared with the deep notch of the complementary valve. Concerning the orientation of modern *Pecten,* Davenport (1900, p. 864) says:

> I was interested to see whether the *Pecten* ever lies on its left side—a condition which would be comparable in a way with left-handedness in dextral gastropods. If the abnormal condition ever occurs, it will show itself by the circumstance that the notch will appear on the left side of the (left) valve, viewed exteriorly. Now although over a thousand notched shells of *Aequipecten irradians* (Lamarck) were examined by me, I found no exception to the condition of being notched on the right (anterior) ear.

Jackson (1890, p. 334) found no exception to this rule:

> Professor Hyatt informs me in a letter that he has examined over three hundred specimens of *Pecten irradians,* all of which lie habitually on the right valve . . . This habit of lying on the right valve is characteristic of many related genera, as *Perna, Spondylus, Plicatula, Hinnites,* and *Anomia.* Patten, in his studies of *Pecten Jacobeus,* says that this species, which has a deeply convex right valve and a flat left valve, lies habitually on the right side, and if turned on the left side in an aquarium soon rights itself. The studies of young *Pecten irradians* were interesting on this point. I turned them several times on the left valve intentionally and in every case they almost immediately extended the foot with which they laid hold of the glass, and with a sudden jerk righted themselves, showing that they were uneasy in the reversed position.

(2) Pterioids and pectinoids pass through the same form stages during their early development. At an early stage the shells are subrhombic in form with a forward, or prosocline, obliquity, and there is a distinct anterior lobe. The proper orientation of any pectinoid or pterioid shell can be determined by an examination of the growth lines at the beaks.

(3) Finally the adductor impression without exception occurs just behind the middle of each valve.

In adults of almost all of the Paleozoic pectinoids, and the early growth stages of later forms, the left or upper valve is more convex than the right one. But the adult shells of many post-Paleozoic Pectinidae have a right valve much more convex than the left.

There is no known Paleozoic pectinoid in which the right valve is markedly more convex than the left, although a very few forms have valves of subequal convexity.

RELATION OF FORM TO HABIT

The particular characters of form embraced by the term "pectinoid" have a very ancient origin. Many shells from the Middle and Upper Paleozoic rocks are superficially so like modern Pectinidae that they were described by early workers under the name *Pecten*. The details of shape which have been so persistent through the vast ages of geologic time suggest that the pectinoid form is truly a fundamental character which endured while other characters underwent progressive change.

It has been suggested often that the high degree of symmetry in some of the modern pectinoids has been acquired by their swimming habit. There seems to be a definite correlation between form and habits in the modern Pectinidae. Drew (1906, p. 4) says:

> Pecten is one of the ablest swimmers among lamellibranchs. The whole structure of the animal is modified for this purpose. The valves have become rounded in outline, flattened, and comparatively light. The posterior adductor muscle, which is very powerful, is well developed so the shell may be opened quickly when the muscle relaxes, and the hinge line is straight so there may be no unnecessary strains in opening and in closing the shell. Each gill is attached by one lamella only, so water in the temporary cloacal chamber may be thrown out without injuring the gills, and the gills and margins of the mantle are provided with muscles to withdraw them from the margins of the shell when the shell is closed.

According to Verrill (1897, p. 48):

> Those species (of modern Pectinidae) that are best specialized for swimming have a broadly rounded, symmetrical, and compressed shell, frequently with thin, nearly smooth valves, but generally strengthened by corrugations, undulations, external radial ribs, or internal lirae or flutings. Species that swim but little when adult often have a high and narrow form, with auricles oblique and usually unequal, and the byssal notch is often highly developed, while the shell itself may become oblique and unsymmetrical, or heavy and thick, with strong ribs and grooves.

Perhaps the development of the pectinoid symmetry out of some pterioid radical was determined by unusually active habits which ultimately led to a locomotion by swimming. Some of the modern Pteriidae exhibit a degree of activity such as the ancestral Pectinacea might have had. Regarding *Pinctada vulgaris* (Schum.), one of the typical Pteriidae, Herdman (1904, p. 50) says:

> Although the pearl oyster has not the power of moving rapidly through the water or over the sea bottom after the fashion of *Lima* and of some species of *Pecten*, by the violent expulsion of water caused by a sudden closure of the valves, still it can eject a jet of water with some force to a distance of 9 to 12 inches.

It is a curious fact that the right or lower valve in the primitive Pectinacea is the less convex of the two valves. In a few genera of Paleozoic forms, and many of the later ones, the valves are subequal. There are several post-Paleozoic forms in which the lower valve is very convex, whereas the upper one is flattened or concave. However, in the latter group as well as the equivalve forms the early ontogenetic stages preserved in the umbones show that the juveniles possessed a flattened lower valve, and a more convex upper one.

The convexity of the valves has a mechanical effect on the swimming habit in modern Pectinidae. According to Verrill (1897, p. 44) the group having the upper valve relatively flat is not well suited for a swimming habit because—

> If currents of water should be expelled in the usual way, from the subauricular margins, the currents would naturally be forced upward and out of the convex lower valve, and thus the reaction would be strongly downward, so that the shell would not be raised from the bottom. In those species that are able to rise to the surface and swim actively about, the left or upper valve is always the more convex, and therefore the expelled currents of water must be directed more or less down as well as backward.

This statement must be qualified by recalling that the equivalve *Amussium*, and *Aequipecten irradians*, in which the lower valve is the more convex, are good swimmers. Nevertheless the mechanical principles indicated by Verrill possibly have had some effect on the development of the Pectinacea.

A characteristic feature of all Pectinacea and the more typical Pteriacea is the deep slit or byssal notch at the ventral margin of the anterior auricle of the right or lower valve. (The Limidae, commonly placed in the Pectinacea by paleontologists, are classified by Pelseneer, on gill structures, in the Ostracea; shells do not have a byssal notch, and are essentially bilaterally symmetrical). This notch generally is ascribed to the habit of fixation by means of a byssus. Jackson (1890, p. 344) points out, however, that the notch owes its existence to the location of the foot so close to the line of union of the valves. If the notch were not present, the valves would have to open very wide to allow the extension of the foot. He shows, further, that the very young *Pecten* has no byssal fixation, and the notch at this period may be considered as a foot aperture. The presence of a byssal notch, apparently, is not conclusive evidence of a byssal habit. Jackson says (p. 344):

> This has important bearing on fossil forms which are considered as byssated or attached if a notch exists in this region; whereas they may with equal reason be considered, as far as the notch is concerned, as free forms which crawled while lying on one side with the foot extended through a special notch produced by the existence of such a habit.

In a masterly discussion of the problem Yonge (1936, p. 95) has presented appealing evidence that the "power of swimming possessed by certain Lamellibranchia is secondary, all the modifications which have made it possible having been evoluted in the first place in response to the needs of monomyarians originally attached by the byssus." He believes (p. 95), with Drew (1906), that the water current produced by *Pecten* in clapping the valves together is "primarily of service in cleansing the mantle chamber (of sediment), and is used habitually for locomotion by only a few forms, it seems quite possible that those forms that do use it for locomotion may have simply perfected an already existing mechanism primarily designed for another purpose."

According to this hypothesis pectinoids had acquired something of their characteristic expression and morphology before the adoption of the swimming habit.

Whatever may have been the habits of locomotion of the ancient pectinoids, it scarcely can be doubted that they were active, because pectinoid shells perforated by borings, or covered by encrusting organisms are relatively uncommon, even where they are associated with pelecypod shells that are so modified.

ORNAMENTATION

The shell ornamentation in all modern and ancient Pectinacea can be resolved into concentric and radial elements, or the shells may be smooth. The radial ornamentation may consist of plications in which the entire shell is radially folded so that the shell margins interlock, or the shell may simply be costate. Of these two types, the latter is the more common. In plicate shells the plications are commonly simple, that is, they do not multiply in number during growth. Costate shells present a greater variety in ornamentation. The costae may appear in successive orders during shell growth by implantation either singly or in pairs between older costae; or the increase may take place by longitudinal division of costae. Furthermore, costae may be grouped into fasicles. Imbricate lamellae of growth commonly give rise to more or less regularly spaced spines which may originate either from the furrows between costae, or from the costae themselves. A concentric ornamentation may be produced by fila, that is, regularly spaced concentric ridges. Fila are, in reality, only a special kind of growth varices, recording regular habits of growth, and usually they are consistent in a given species or genus.

The basic types of ornamentation are so few that it is not surprising that some unrelated stocks of pectinoids are similarly ornamented. Even in such instances generally there are characters by which different stocks of Pectinacea can be distinguished.

As a rule, the two valves in the ancient pectinoids are differently ornamented. In such instances, the ornamentation is somewhat subdued in the lower valve, but it may be also quite different in other respects. Much confusion has arisen in the past through failure to realize that the two valves of the same pectinoid individual may be, and generally are, very unlike. The problem of correlating two unlike valves of a species is not so difficult as might be supposed. Although the right valves are, as a rule, much scarcer than the left ones because of their greater fragility, it is nevertheless possible, with a few exceptions, to obtain some specimens of the right valve in any good collection of Paleozoic pectinoids. In my own field experience I have never found right valves without also discovering left valves at the same place, because the left valves are for some reason more abundant than right ones. If there are two sets of complementary valves in a collection from a given horizon and locality, the reasonable assumption is that they belong to a single species unless there is convincing evidence to the contrary.

The fact that the pectinoid invariably lies on one valve when at rest, has tended undoubtedly to modify the ornamentation of the lower valve. Such an idea, however, is not favored by observation of a number of instances in which the ornamentation of the two valves is very nearly alike.

To Davenport (1900, p. 869) belongs the discovery in his brilliant biometric studies, that the ornamentation of the lower valve in modern Pectinidae is more conservative than that of the upper or left valve:

> We may conclude that the right valve is the more conservative, or responds less to varying environmental conditions. This small variability of the lower valve is in accord with the fact that the young shell of *Pecten* is larger and better preserved on the right valve than on the left. Again in *P. squamosus,* in which the scales are becoming obsolete in the adult, they are found at a later stage on the right valve than on the left. In other cases the grooves of the left valve divide and become ornamented while the right valve remains simple. Here, then, the index of variability is an index of phylogenetic changeableness.

He found also that "the anterior, or notched ear is the more constant; it may be regarded as a generic character. The posterior ear may be regarded as a specific character." (1903a, p. 135). This statement originated from statistical studies in which he found the coefficient of variation to be 17 percent higher in the posterior than in the anterior ear of *Aequipecten irradians*. Certainly it is true in many types of Paleozoic Pectinacea that the right valves in two species cannot be distinquished. There is also less variability in the ornamentation of the anterior auricles than in the posterior ones. I have found that the number of costae in the anterior auricle of the left valve is much more constant in a suite of specimens than costae on other parts of the same valve. Consequently, this character has proved to be a valuable one for discriminating species.

The importance of surficial ornamentation in the taxonomy of the Paleozoic pectinoids has not been appreciated, in spite of the fact that ornamentation has long been employed in genetic classifications of brachiopods, cephalopods, gastropods, and even other pelecypod groups.

As shown by the ontogeny of an individual, the development of adult ornamentation in the pectinoid shell generally involves a series of changes, correlated with changes in form. If the principle of recapitulation is applicable in pelecypods, and I believe that it is, each fundamental type of ornamentation observed in an adult pectinoid shell represents the culmination of a series of evolutionary modifications. Although I am not prepared to argue that ornamentation in pectinoids is strictly nonadaptive, it appears that these shell features are less readily influenced by external environment than some others. Consequently, I have been impelled to set aside as separate genera, shells having certain fundamental and distinctive types of ornamentation.

MUSCULATURE

The muscle system in various genera of modern Pteriidae appears to be fairly uniform, and distinct from that of the Pectinidae. The Paleozoic pectinoids in this respect, as in some others, embody features of both Pteriidae and Pectinidae. The most striking distinction in musculature between the two modern groups lies in modifications of the pedal muscles and pallial muscle system.

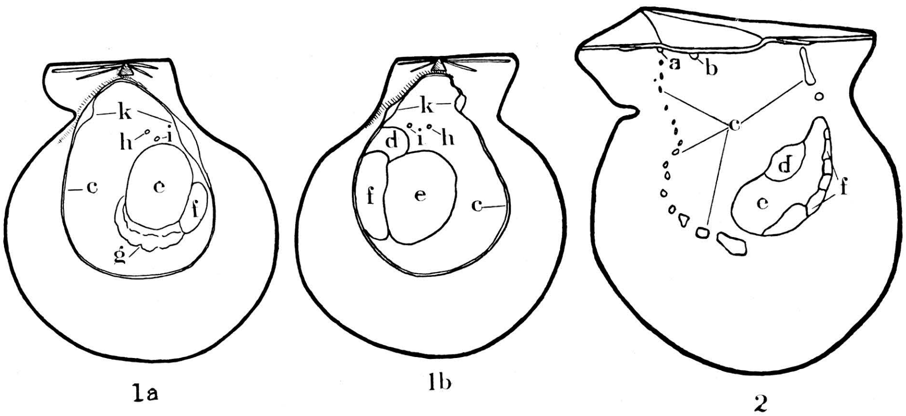

FIG. 1.—Musculature in modern *Pecten islandicus,* a typical representative of the Pectinidae, and *Pinctada vulgaris,* a typical species of the Pteriidae. 1a-b, *Pecten islandicus,* × 5/8, right and left valves, respectively; note that the musculature is not identical in the two valves. 2, Interior of right valve in *Pinctada vulgaris,* × 1; note the discontinuous pallial line, and the fact that the pallial line, unlike *Pecten,* is open dorsally, that is, U-shaped; the musculature in the two valves of *Pinctada* is almost identical.

a, b, Impressions of pedal levator muscles; *c,* pallial line; *d,* pedal retractor impression; *e, f,* adductor impression; *g,* gill suspensory, generally visible only on the right valve of *Pecten,* although the gills are attached to both valves of *Pecten* and *Pinctada; h,* superior suspensory for gills; *i,* impression of uncertain significance, possibly attachment for auricle of heart; *k,* impressions for circular pallial muscle.

In typical Pteriidae, such as *Pinctada*[1] and *Pteria,* the shell bears impressions of one adductor, one pair of retractors for the foot, two pairs of small pedal levator muscles (superior retractors), and a series of discontinuous pits marking the insertion centers of fanlike muscles of the orbicular or pallial system.

In the adult shell there is but one adductor muscle, morphologically equivalent to the posterior one of the primitive dimyarian shell. This adductor is located just back of the center of each valve. There are two distinct parts of the muscle—a narrow tendonous strip, forming the posterior border, and a thick, massive part, making up the remainder.

1. *Pinctada* and *Meleagrina* are synonomous names.

The chief retractor muscles of the foot are two in number, symmetrically disposed in reference to the two valves. They originate in the walls of the byssal gland of the foot, and then diverging, pass backwards in the form of a V to be inserted, one in the right valve, the other in the left at the anterodorsal part of the adductor impression. Generally, the retractor part of the impression cannot be distinguished from the remainder of the real adductor impression, the posterior edge of the retractor blending indistinguishably with the anterior edge of the adductor "scar."

There are four levator muscles of the foot, two anterior and two posterior. Both muscles of the anterior pair have their insertion at the innermost point of the umbonal recess, directly dorsal to the mouth region. From this place the fibers pass downward at right angles to the hinge, on either side of the mouth spreading laterally, fanlike, until they join the mass of the foot. The left anterior levator is the stronger of the two. By contraction of this muscle, the foot is drawn over to the left side, which is its normal position when in a state of rest. An explanation of this asymmetry is seen in the fact that the left valve is more convex, and, therefore, more spacious than the right, and so the foot is more readily accommodated on the left side.

The posterior levators are short, weak muscles, which originate high up in the fibers of the anterior levators at the level of the mouth. From their origin they extend backward and upward to an insertion behind and slightly below the impression of the anterior levators.

The orbicular system of the mantle in the Pteriidae consists of a series of fan-shaped retractor muscles radiating outward to the mantle edge from a number of insertion centers at the pallial line. The purpose of the orbicular system is the retraction of the mantle edge from the shell margin preparatory to the closing of the valves.

It will be seen that the shell musculature in the Pectinidae is considerably different from that outlined above (see fig. 1*a, b,*). The adductor impression is large and located just behind the center of either valve. This muscle corresponds to the posterior one in dimyarian pelecypods. In very young Pectinidae, as in other monomyarian forms, an anterior adductor muscle is present which for a time is the only functional one, but the posterior muscle soon makes its appearance and the anterior muscle is lost. In adult Pectinidae, the adductor has a greater area of attachment on the left, the upper, valve than on the right. The muscle impression is divided and crescent-shaped. The physiology of the two parts of the adductor is quite different. The large anterior part may be entirely severed in *Placopecten tenuicostatus* (Drew 1906, p. 31), and the posterior will close the shell with only slightly less vigor; but if the smaller posterior part is severed and the anterior portion not injured, the animal cannot close its shell.

There are no levator muscles and there is but one pedal retractor muscle. It is attached to the left valve of the shell along the dorsal border of the adductor muscle. The impression of the retractor cannot be distinguished from the scar of the adductor muscle in some forms, but in *Chlamys* there is a dorsal extension from the adductor impression, corresponding to the pedal retractor. The retractor muscle extends along the dorsal border of the foot and is about equally in evidence on its right and left sides. It extends from the foot over to the left side and is attached to the left valve. The right retractor has been lost, apparently during the phylogenetic development of the group.

The mantle is attached to each valve along a continuous pallial line that is farther removed from the shell margin than in Pteriidae. The muscles that are attached at the pallial line radiate toward the free edge of the mantle, but they are not gathered into insertion centers as is the case in the Pteriidae. The Pectinidae differ in another respect in that the mantle is also provided with circular muscle bands that are collected into large bundles near the hinge line and attached to the shell. The impressions on the shell caused by the attachment of these circular pallial muscles are commonly more distinct posteriorly than anteriorly. The mantle is attached to the shell continuously below the hinge and on both sides of the liver, whereas in the Pteriidae there is no attachment of the mantle between the extremities of the pallial line.

There are perhaps two factors that might have operated in establishing the pallial line in Pectinidae so far from the shell margin, (1) the active habits, and (2) specializations of the mantle margin. Obviously a high development of the orbicular system is essential in this group to insure a quick withdrawal of the mantle from the margin. An increase in the distance from the shell margin to the pallial line not only would permit a development of longer and more effective muscle strands, but also would produce a greater shell buoyancy compatible with rapid locomotion. Modern Pectinidae have extraordinary specializations of the mantle margin which have resulted in an unusually thick edge. The surprisingly complicated eyes and tactile organs of the thickened margin of the mantle require a distant withdrawal before the valves can be closed safely. According to Drew (1906, p. 12):

In specimens (of *Placopecten tenuicostatus*) that have been disturbed so the shell valves are closed together, the margins of the mantle lobes are drawn far back into the shell so there may be a strip three quarters of an inch or

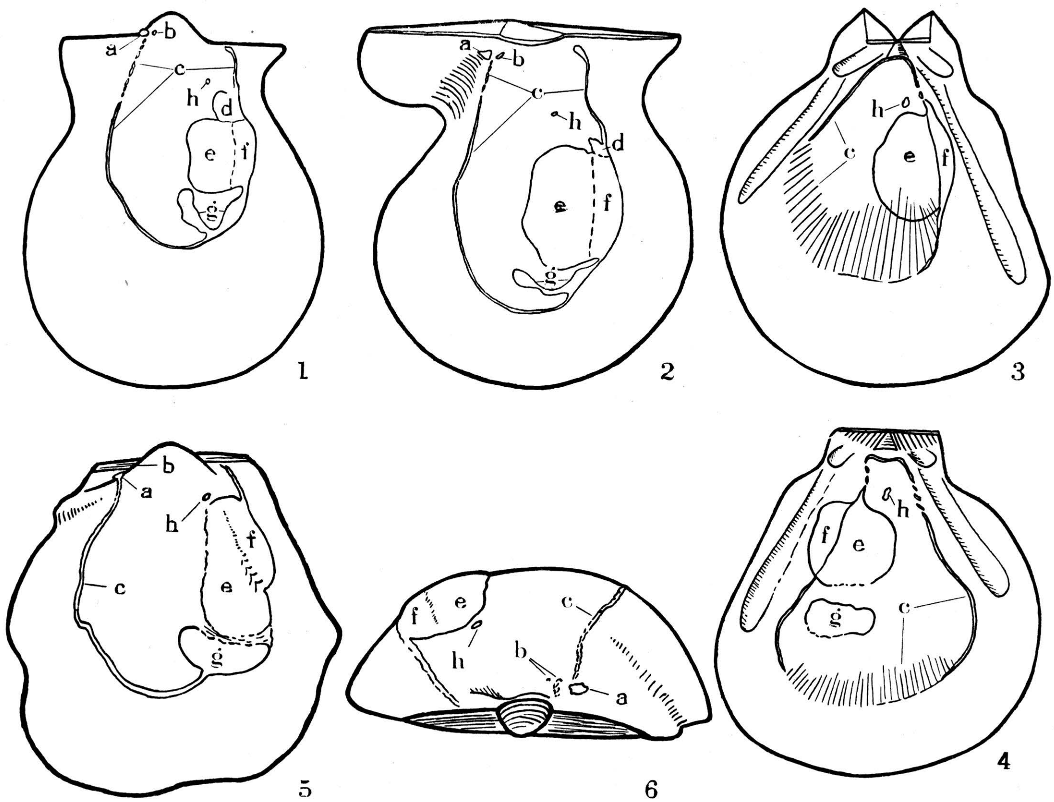

FIG. 2. Musculature in three types of Pennsylvanian pectinoids.

1. Aviculopecten exemplarius Newell, n. sp., camera lucida drawing of an internal mold of left valve, × 4.

2. Camera lucida drawing of the interior of a right valve of the same species, × 4. Note particularly the pterioid features of the U-shaped pallial line, impressions of levator muscles, and existence of a pedal retractor in both valves; the pallial line is not disconnected, however, being in this respect like modern Pectinidae.

3. Pernopecten clypeatus Newell, n. sp., camera lucida drawing, × 2, of the internal mold of a left valve. Note the peculiar pallial line, continuous dorsally, as in modern *Pecten* or *Amussium,* but giving way to a number of radial furrows ventrally, as though the pallial system had a marked development of radial muscles. The lack of apparent pedal retractors, like in modern *Amussium,* is correlative with the loss of a byssal notch and atrophy of the foot at the adult stage.

4. Camera lucida drawing of internal mold of a right valve of *Pernopecten clypeatus.* The muscle systems are like those of the opposite valve, except for the addition of a distinct scar made by gill suspensories.

5. Pseudomonotis equistriata Beede, camera lucida drawing of internal mold of left valve, × 4. This form has about the same musculature as *Aviculopecten* except for the absence of pedal retractor scars, fully in accord with the sessile habit of *Pseudomonotis,* consequent loss of the byssal notch, and atrophy of the foot at maturity.

6. Dorsal view of same specimen shown in 5, × 6. *a, b,* impressions of pedal levator muscles; *c,* pallial line; *d,* impressions of pedal retractor; *e, f,* adductor impressions; *g,* gill suspensory; *h,* superior suspensory for gills.

more of the inner border of each shell valve that is left uncovered. This retraction of the mantle is necessary in order that the thickened and highly modified margins of the mantle may not be injured by the closing of the shell.

In general, the pallial line in Paleozoic pectinoids is relatively closer to the margin than in modern Pectinidae and more nearly comparable to the Pteriidae in this respect. This fact suggests that the sense organs and habits of the Paleozoic pectinoids might have been more like those of modern Pteriidae, than of the Pectinidae. The mantle margin in Pteriidae, although somewhat thickened, bears only short tentacles.

In modern Pectinidae there is generally an indistinct line beneath the adductor impression that marks the attachment of the suspensory muscles of the gills. Similar, and presumably homologous impressions, occur in some Paleozoic forms.

In *Chlamys islandica* there are two small impressions in each valve just above the adductor system. It appeared to me, upon dissecting preserved specimens of this species, that the inner pair of gill lamellae is attached to the shell at one pair of the small impressions. The significance of the other pair of impressions was not so evident. It seems, however, that a connection extends from each auricle of the heart to the two valves at these impressions.

The muscle system in Aviculopectinidae does not correspond exactly to that of either the Pteriidae or Pectinidae (see fig. 2, Nos. 1, 2, and 5, 6). The pallial line is continuous except a short portion near the anterodorsal extremity of the line where, at least in some individuals, the line is broken into obscure pits, indicating a bundling of the fibers in insertion centers. This differentiation of an anterior part of the orbicular system takes on added interest when we recall that anterodorsal shell features appear to be more conservative than other parts of the shell (see page 20).

In Aviculopectinidae that have been investigated there are three muscle pits along the hinge line. Two of these are within the umbonal cavity and correspond in appearance and position to the levator impressions of the Pteriidae. The other impression is intermediate between the umbonal cavity and the posterior termination of the hinge, located at the end of the pallial line.

In *Aviculopecten* muscle impressions occur in both valves at the dorsal extremity of the adductor impressions, appearing to occupy the position of the retractor muscles of modern Pectinidae and Pteriidae. The fact that the retractor impression in the left valve is larger than in the right, is in accordance with the obsolete condition of the right retractor in modern *Pecten*. *Pseudomonotis* and *Pernopecten*, on the other hand, appear to have had no retractors, or at least the retractors were degenerate. In both of these genera the byssal notch is obsolete in adults, indicating a loss of the foot at maturity, and therefore a degeneration of the pedal retractors. A similar condition is seen in modern *Amussium*, which has a byssal notch and an active foot early in the ontogeny, but at maturity the foot, pedal muscles, and byssal notch are lost.

Although the characters of musculature are useful supplementary criteria for differentiation of groups of the ancient pectinoids, there are many puzzling questions that I cannot at present answer. For example, I suspect, but cannot yet demonstrate, that the modern Pteriidae are not closely related to many of the "pterioids" of the Paleozoic. In fact, it appears that the Paleozoic pterioids more closely resemble ancient pectinoids than modern Pteriidae. The fact that some of the aviculopectens possess musculature incorporating features of both modern Pectinidae and Pteriidae is not intelligible until we can determine the nature of the musculature in the Paleozoic pterioids. Obviously the Paleozoic pectinoids were not derived from modern kinds of Pteriidae, and it appears that most, if not all, of the Paleozoic pterioids should be placed in families other than the Pteriidae.

SHELL STRUCTURE

The microscopic structure of the molluscan shell has been poorly understood, and the recent treatise in English on the subject by Boggild (1930) should be enthusiastically received by students of mollusks. Although Boggild's biologic treatment is not entirely satisfactory, his work will prove a valuable tool in the hands of systematists.

There are several distinctive structural elements that may compose a pelecypod shell. The particular distribution of these elements, as pointed out by Boggild, is constant in some taxonomic groups, in other groups, variable. Consequently, the value of shell structure in classification of pelecypods has to be demonstrated separately for each group.

Contrary to the belief of Boggild and other workers, the preservation of original shell microstructure in Paleozoic mollusks is not a rare phenomenon—at least it is not rare in collections from the Pennsylvanian rocks. The condition of preservation can be determined readily by examining the shells under some liquid, such as xylol. In some instances the distribution of the shell elements can be studied satisfactorily without the need for thin sections.

The pelecypod shell may possess three parts. These are named, in order from the inner to the outer surface: hypostracum, ostracum, and periostracum. The hypostracum is a relatively thin layer of prismatic or fibrous aragonite, secreted by special glands at the muscle insertions. Commonly the hypostracum is negligible except at the insertions, or "scars," of the adductor muscles. Because the hypostracum is secreted only by the muscles, addition to this layer takes place in isolated areas that are bordered laterally by a different shell substance. As the body of the pelecypod migrates ventrally in the shell, due to increasing size, the muscles migrate, leaving abandoned areas of insertion, or "muscle tracks," imbedded under later deposits of shell material. Cross-sections of a shell show that each hypostracum layer (one for each muscle insertion) is a triangular layer having an acute apex directed toward the beaks of the shell, buried by later shell addition except at the last position of the muscle. In some forms, the hypostracum is exceedingly thin and easily overlooked; in some others, particularly large adults or gerontic individuals, the hypostracum is relatively thick.

The ostracum includes, with the exception of the hypostracum, all of the calcareous shell. This part is commonly composed of more than one layer of either calcite, aragonite, or combination of the two. In the majority of the Paleozoic forms, the ostracum consists of two layers, an outer thin one (outer ostracum), of either prismatic or homogeneous calcite, and an inner one (inner ostracum), either nacreous or crossed lamellar. A foliated structure characterizes the entire ostracum in modern Pectinidae, but this shell is probably homologous with only the inner ostracum of the Paleozoic shells.

Jackson (1890, pp 343, 348-350) has shown that the juvenile shell has a prismatic outer ostracum in lines of shell growth and never irregular like the calcite lamellae in the oyster or the foliaceous structure in modern Pectinidae. In the older fossils the organic lamellae are, of course, lacking, but the characteristic pearly luster is preserved in some cases. Nacreous structure is not found outside the mollusks and should not be confused with the pearly sheen shown on fresh fractures of some brachiopod shells. Nacreous structure is well exemplified by the pearly part of the shell in *Nautilus, Unio, Pteria,* and *Pinctada.*

Crossed-lamellar structure (see Boggild, 1930, p. 251) is found in all classes of Mollusca except the cephalopods, and is found in no other phylum. This structure generally occurs in aragonite, but is also found in calcite. It is made up of two elements, larger lamellae of the first order, and smaller ones, called lamellae of the second order. Only the first order lamellae, of which three are shown in figure 4 (lower), are readily visible at low magnification.

FIG. 3. Diagrammatic cross-section through a Paleozoic pectinoid showing the three fundamental shell constituents. a, Outer ostracum, composed of calcite; b, hypostracum, composed of aragonite; c, inner ostracum, composed of aragonite.

the right valve of modern Pectinidae, whereas the adult shell, except perhaps in a few deep sea amussiums, does not show prismatic structure in either valve. Apparently in these the outer ostracum is lacking, the valve being constructed of foliaceous calcite inner ostracum and an obscure fibrous hypostracum. In several, and probably all of the genera of Aviculopectininae, the outer ostracum of the right valve is prismatic at all observed growth stages, whereas the outer ostracum of the left valve is homogeneous calcite. This restriction of the prismatic structure to the right valve is clearly demonstrated in all of the Pennsylvanian species of *Limipecten* from America, and also in every well-preserved *Aviculopecten* that I have examined, except *Aviculopecten mazonensis* Worthen, which has a prismatic outer ostracum on each valve. In modern Pteriidae the outer ostracum in both valves is prismatic throughout all but the earliest growth stages.

The *nacreous structure* is characterized by thin, exceedingly uniform lamellae of aragonite, all of the same thickness, separated by equally thin leaves of some organic substance, probably conchiolin. The thickness of each lamella is slightly less than 1 micron. The lamellae are always parallel to the They are minute lath-shaped pieces, arranged either with the long axis parallel to growth lines (concentric crossed-lamellar structure), or radiating more or less regularly from the beak (radial crossed-lamellar structure). The intermediate dimension of the first order lamellae is either normal to the shell surface or slightly inclined to it. The short axis is parallel, or nearly so, to the surface of the shell. These lamellae are built up of smaller elements, lamellae of the second order, which are oriented normally to the broad faces of the first order lamellae, but form with their edge an angle of 41 degrees. In adjoining first order lamellae the second order lamellae are inclined in opposite directions, producing a characteristic crossing.

The lamellae of the first order produce a characteristic pattern when viewed in planes parallel to the shell surfaces. The lamellae usually branch and wedge out in the direction of their long axis and are replaced by others. The boundaries may be fairly rectilinear and parallel, or very irregular. In a type characteristic of many pelecypods the lamellae are grown together in a peculiar way to form a network of rhomboidal figures.

The breadth of a single lamella may equal or be less than the entire thickness of the crossed-lamellar layer of the shell, and its length, although commonly small, may reach several millimeters. As viewed

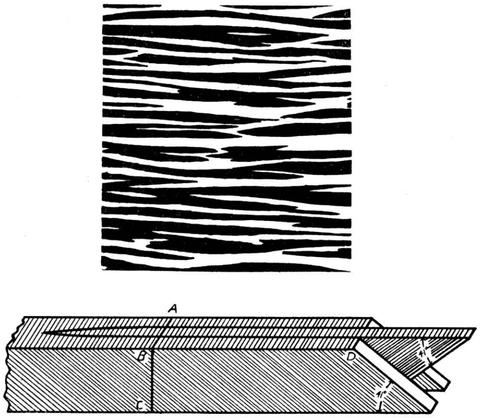

FIG. 4. Diagrams illustrating crossed-lamellar structure. Upper, a section of shell, about × 60, cut parallel to shell surface, showing edges (white and black) of branching and wedging first-order lamellae. Lower, three first-order lamellae greatly magnified, composed of second-order lamellae which are inclined differently in alternate lamellae of the first order; the surface, ABD, corresponds to a small part of the surface represented in the diagram above; BC may equal the entire thickness of the crossed lamellar layer as in *Aviculopecten,* or the layer may be built of successive tiers of first-order lamellae as in *Arca.*

in cross-sections the lamellae may be normal to the shell surfaces, oblique, curved, or have nearly a zigzag form.

Nacreous and crossed-lamellar structure occur in modern Pteriidae, but the latter is extremely rare. So far as I know, both are lacking in modern Pectinacea. In the Aviculopectinidae both kinds of structure are found to characterize the inner ostracum. The two kinds of structure are not found together in the same shell, however, and this rule appears to hold for modern shells. In the Pteriidae, as in the Aviculopectinidae, the outer ostracum is composed of calcite, whereas the inner is aragonite. There may be exceptions to this rule, of course, but it is a useful generalization. There are several reasons for believing that the inner ostracum in the Aviculopectinidae was made of aragonite. In many of the aviculopectens only the outer ostracum is preserved, suggesting that the inner ostracum was made of the less stable aragonite. If both layers were composed of the same substance, there would be no differential preservation. In other specimens the outer ostracum of the right valve retains the original prismatic structure, whereas the inner ostracum has been altered to coarsely crystalline calcite. Aragonite alters readily to calcite, and because of the notable differences in density of the two, the original microscopic structures are commonly destroyed completely when aragonite undergoes this change. A direct test by Meigen's method of staining aragonite showed that the inner ostracum of some exceptionally well-preserved specimens of *Limipecten* has not been altered from the original aragonite.

A very interesting outcome of my examination of shell microstructure in the Paleozoic pectinoids has been the discovery that easily recognizable and consistent differences in shell structure exist between tribes that are also separable on characters of form and ornamentation.

LIGAMENT

The ligament has been badly neglected by students of pelecypods and its usefulness in classification certainly has not generally been appreciated. Few extensive studies on the pelecypod ligament have been published. That of Reis (1902) is one of the most outstanding, but it leaves much to be desired.

Mr. F. Stearns MacNeil, of the United States Geological Survey, who is now engaged in comprehensive studies of pelecypod ligaments, is convinced of the importance of the ligament in working out the phylogeny of various pelecypod groups. I have had the pleasure of an extended correspondence with Mr. MacNeil concerning various problems of the pelecypod ligament, and our mutual coöperation has thus far proved very fruitful.

In many modern pelecypods the ligament is composed of two distinct parts that are structurally and mechanically unlike. In some kinds of shells the ligament is truly a complex mechanism composed of different parts. These separate elements commonly are inserted along the dorsal margin of the shell in characteristic arrangements. A reconnaissance of pelecypod ligaments in general suggests that there is a limited number of types of ligament, and that certain distinctive types appear, and have appeared in the geologic past, in apparently unrelated stocks of pelecypods. It would seem that the evolution of the pelecypod ligament has at least partly been in response to mechanical stimuli, thereby permitting a given ligament type to appear in widely separate pelecypod stocks. Nevertheless, it appears probable that there is a definite sequence of evolutionary stages through which some types of ligament have passed in order to have acquired their observed degree of complexity.

The insertion of the ligament structures into the ligament area of the shell invariably has an arrangement characteristic for a given tribe of pelecypods, and the nature of the ligament can be inferred by an inspection of the ligament area of a shell from which organic ligament structures have been stripped. The discovery of Paleozoic shells having ligament areas similar to or identical with ligament areas of modern shells invites conclusions regarding the character of the ligaments in certain Paleozoic forms.

Of the two differentiated types of material in the pelecypod ligament, one is composed of fibrous, calcified conchiolin, which is elastic to compressional stresses, but tears or parts readily when subjected to tensional stresses. Naturally this structure is a compressional ligament and the functional part is invariably at or below the hinge axis. If, during growth, the hinge axis migrates ventrally, as is normally the case, part of the compressional ligament may come to lie above, or dorsal to the actual axis of movement. The material above the hinge axis is subjected to tension when the animal closes the two valves, and being weak to tensional stresses, breaks and becomes nonfunctional. These relationships were observed by me in specimens of modern *Arca, Pteria,* and *Pinctada.* The calcareous material of this fibrous ligament appears to occur in the form of fibers or "spicules" imbedded in a matrix of conchiolin. The fibers lie at right angles to the hinge axis and parallel to the growing surface (*Arca, Pinctada*), or at right angles to it (*Yoldia*).

Primitively the "resilium" or internal ligament of some pelecypods, such as *Yoldia* and *Nucula,* is composed of the calcified fibrous ligament, but the main and only functional part of the internal ligament in *Pecten* appears not to be homologous to the fibrous ligament. As regards the nature of the *Pecten* ligament I am apparently at variance with Reis (1902), who mentions the presence of very fine calcareous spicules; and I am inclined to differ with MacNeil, who regards the vertical cleavage seen in the central part of dried specimens of *Pecten* resilium as a heritage of a former calcareous condition.

The second kind of ligament structure is a noncalcareous lamellar layer of conchiolin which is highly elastic to tensional, compressional, and torsional stresses. In most pelecypods this material makes up the "ligament proper" of authors, as contrasted to the "resilium." In *Pecten* and its relatives, however, the central part of the resilium is apparently composed of this noncalcareous, lamellar conchiolin. The lamellar ligament was inappropriately called by Reis the inelastic ligament. In many kinds of pelecypods the axis of rotation of the valves is actually contained within the substance of the lamellar ligament, so that the stresses within this part of the ligament are torsional.

For the present purpose, the material that is normally calcareous and compressional in function will be termed the *fibrous ligament.* The noncalcareous structure that is elastic to all kinds of stresses will be called the *lamellar ligament.* The fibrous and lamellar elements form the *ligament system.*

Kinds of ligament areas.—Four principal kinds of ligament areas are found in Paleozoic pectinoids. Each of these types was developed at various times in distantly related or unrelated groups of pelecypods and is represented in modern forms. It is desirable to examine the four types of ligaments as shown in living pelecypods.

Ligament of Type 1—*Arca.* The ligament area of such Devonian forms as *Pterinopecten* and *Lyriopecten* is identical with that of the modern *Arca.* A distinct, flat cardinal area extends from the hinge line to the beak of each valve, comparable in appearance to the cardinal areas of the brachiopod, *Spirifer.* There are no resilifers, but the area of each valve is provided with several chevron-shaped grooves extending across the area with their apices just below the beak. The significance of these chevron grooves has not been understood generally by paleontologists. Their true nature may be comprehended by an examination of the living *Arca.*

The ligament in modern *Arca transversa* Say, from the New England coast, is a complicated structure, having two elements. The cardinal area of each valve is covered by a thin sheet of fibrous conchiolin and the two valves are joined at the hinge line by this material. This fibrous structure is remarkably weak to tensile stresses and would be quite inadequate in itself to hold the valves together in *Arca.* Indeed, it is not easy to study the structure at the hinge axis in preserved specimens because of the difficulty in keeping it intact. This layer has the physiological and mechanical properties of the "internal" ligament or resilium of such forms as *Nucula* or *Pteria,* because the functional part of this layer is compressional, and restricted to a line just under the hinge axis.

The fibrous layer is not continuous over each cardinal area, but is interrupted at the chevron grooves by the insertion of a series of separate parallel sheets, one above another, of ligamentous material quite different in appearance and function from the fibrous ligament. The conchiolin sheets are laminar in structure and are not fibrous. Each sheet of the lamellar ligament is lonzenge-shaped. The last formed and smallest occurs at the center of the hinge line and the earlier ones lie at intervals above and parallel to it. Theoretically, all of the later-formed ligament sheets would be hidden from external view by the first-formed one, because new ligament bands make their first appearance only at the center of the hinge line. Growth carries the cardinal axis farther and farther away from the dorsal margin of the valves as the cardinal areas become broader. Since, however, addition to the ligament sheets occurs only at the hinge line where

and making direct examination of the behavior of the ligament and hinge teeth while the valves are slowly opened and closed. The axis of motion is not at the hinge teeth, but above them; *the fibrous ligament and not the teeth serves as a fulcrum,* and the axis of rotation of the valves is contained in

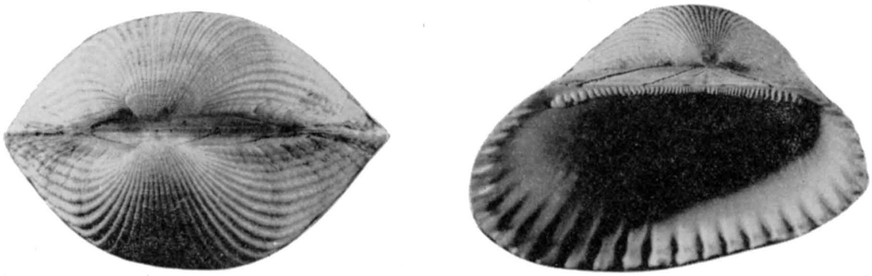

FIG. 5. *Arca transversa* Say. × 2. *Left,* Dorsal view with ligament removed to show the cardinal area; *Right,* left valve showing the chevron ligament grooves of the cardinal area.

the mantle extends between the hinge teeth to the ligamentary structures, there is no repair of the older parts of the ligament, which eventually become disrupted if shell growth forces the beaks sufficiently far apart. In an adult *Arca transversa* only the small central sheet is entire and the middle portions of the older sheets have broken away, exposing the inner sheets.

The only points at which an individual ligament sheet grows are at its insertions along the hinge line, because only at these places is the ligament in contact with the mantle. The addition is accomplished by a small group of specialized cells of a dorsal ridge of the mantle. During growth each cluster of ligament cells migrates slowly towards the ends of the hinge and new clusters appear at the approximate center of the hinge line. There can be no lateral addition to broaden these ligament sheets, their lateral extension being accomplished solely through stretching. The ligament sheets have incredible elasticity to the tensile stresses exerted by the adductor muscles. The lamellar material will stretch to an amazing degree before it loses its resiliency and ultimately breaks. It must be kept in mind that the ligament sheets are secreted along a narrow band about a millimeter or less across. In some instances I have observed sheets of lamellar ligament stretched out to a breadth of more than 1 centimeter by the gradual divergence of the shells during growth.

I believe it is commonly assumed by some paleontologists that the hinge teeth in *Arca* serve as a fulcrum around which the valves rotate in the process of opening and closing. The absurdity of this notion can be quickly demonstrated by sawing a fresh specimen across, transverse to the hinge,

this structure. The mantle extends between the hinge teeth and upward to a position in contact with the ventral surface of the ligament. When the valves are tightly closed there is ample space between adjoining teeth and sockets for a thin ex-

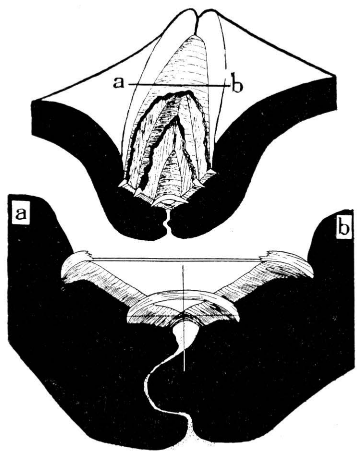

FIG. 6. Camera lucida drawings of *Arca transversa* Say, showing transverse sections through the hinge, back of the beaks. Upper, × 6, showing three elastic ligament sheets and the fibrous ligament sheet that surfaces the cardinal area. Lower, section, × 20, along a-b of the preceding diagram, showing two disconnected elastic ligament sheets inserted in the fibrous ligament; the cross shows the position of the hinge axis; stippled part is the dorsal extension of the mantle which secretes the teeth and ligament.

tension of the mantle, and it appears that the teeth and sockets are never in direct contact, but are invariably separated by an exceedingly thin layer of the mantle. The same situation occurs in *Yoldia,* and probably characterizes pelecypods in general.

The sheets of lamellar ligament in *Arca* are dark-amber colored and the lamellar structure is delicate and disposed in a horizontal direction. The material is entirely organic, containing apparently no appreciable content of calcium carbonate. In *Arca transversa* the first formed ligament groove is entirely posterior to the peaks. Whether this has any especial phylogenetic significance I cannot say.

In cross sections (see fig. 6) the fibrous layer appears to be laminated, but this effect is produced by the calcareous spicules which characterize this type of ligament. The fibrous ligament is iridescent through the outer third of the structure. The fibers are secreted parallel to the ventral or growing surface of the ligament and at right angles to the hinge line. That part of the fibrous layer in contact with the mantle is light-amber colored and is not iridescent, and the axis of motion lies within this part. When the cardinal axis migrates below a given part of the fibrous ligament, that part is subjected to tensile stress and soon parts along a line just above the axis. The reaction of the fibers after breaking is greater near the surface where there is more room to expand than next to the shell, and the resulting strain between adjoining fibers produces an iridescence. Addition to the fibrous ligament occurs along a midline at the inner surface between the valves where it is in contact with the mantle. There is an alternating series of lamellar ligament-forming and fibrous ligament-forming cell groups along a dorsal ridge of the mantle, and these sets of cells migrate toward the ends of the cardinal axis as new ones are introduced at the center.

In *Arca pexata* Say, from Long Island Sound, there is only one sheet of lamellar ligament, therefore, only one chevron groove occurs on each ligament. Here, as in *A. transversa,* the fibrous ligament serves the function of a fulcrum and the action on this structure is largely compression during the closing of the valves. When the valves are in tight apposition, as in the accompanying drawings, there is no undue pressure on the mantle where it extends between the teeth. In such a ligament system as that of *Arca pexata* the first-formed structure is the central part of the lamellar band secreted by a cluster of specialized cells at the center of the hinge line. This cluster divides and migrates toward both ends of the hinge as the ligament grows, and a new group of cells for the fibrous ligament appears at the center.

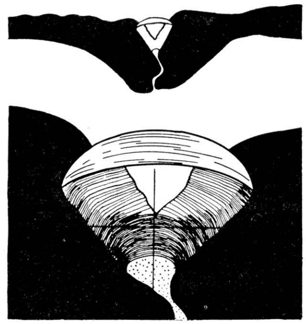

FIG. 7. Camera-lucida drawing of a section through the ligament in *Arca pexata; upper,* $\times$ 4; *lower,* $\times$ 12, showing the single elastic, lamellar ligament band above and the relatively massive fibrous ligament below; cardinal axis indicated by the cross lines; mantle by stippled area. As in the accompanying diagrams the sections were drawn while the valves were tightly closed.

There is no *a priori* reason for supposing that the type of ligament displayed by *Arca* is a relatively primitive one, or that it gave rise to other types of ligaments during the phylogeny of various tribes of pelecypods. There is geological evidence, however, that such is the case. Nearly all of the Devonian and Silurian pectinoids, as well as a few of the Carboniferous ones, possess a ligament area

FIG. 8. *Left.* Dorsal view of *Pinctada savignyi* (Monterosato), $\times$ 1, with ligament removed, showing diverging cardinal areas and resilifers. *Right.* Cardinal view, $\times$ 1, of *Pinctada vulgaris* showing the ligament area and large oblique resilifer.

ment area, occurring at the outer margin of the area. The single ligament sheet correlates with a more simple arrangement of the ligament-forming cells of the dorsal margin of the mantle. The single ligament band is commonly entire in adult specimens because the divergence of the cardinal margins is very slight and well within the stretching limit of the identical in plan with that of modern *Arca*. The assumption seems fair that these ancient shells had a ligament system like that seen in *Arca*. In the Carboniferous and Permian pectinoids the arcid type of ligament is suppressed overwhelmingly in favor of a ligament like that seen in *Pinctada*, next described. These Carboniferous and Permian forms are closely like the Devonian forms in characters other than the ligament, and I am disposed to believe that they were derived from the older forms. I regard, then, the type of ligament displayed by *Pinctada* and *Pteria* as being a second stage in ligament modification, derived from the arcid type just described.

Ligament of Type 2.—*Pinctada*. The second type of ligament system, found in *Limipecten, Aviculopecten,* and a host of similar forms characterizes modern Ostreidae, Limidae, Pteriidae, and several other groups. A species of *Pinctada* (usually called *Meleagrina*), a pearl oyster of commerce, was selected for the study because the general aspect of the shell as well as the hinge is similar to that of some of the aviculopectens. *Pinctada* is a typical representative of the modern Pteriidae, and, except for the abbreviated posterior auricles, is very like *Pteria*.

In *Pinctada savignyi* (Monterosato), from the Mediterranean region, as in *Arca*, there are two kinds of ligament structures, but their distribution is quite unlike that found in *Arca*. A broad, flat cardinal area occurs above the cardinal axis in both valves, diverging upward at about 60 to 70 degrees. At the middle of each area there is a large obliquely triangular fossette, or resilifer, which contains the fibrous ligament.

As in *Arca* (figs. 7, 9), the fibrous ligament consists of a thin straplike structure which joins the two valves together along the lower margin of the cardinal areas. Transverse sections show that the appearance of the fibrous ligament is similar to that found in *Arca*. There is an outer iridescent zone of nonfunctional, strained and broken fibers and an inner zone of functional, unbroken layers which lie almost wholly below the axis of movement so that the stresses applied are entirely compressional. As the hinge axis migrates downward during shell growth, the fibers are progressively subjected to tension and are broken. The fibrous ligament effervesces freely in dilute acid until the ligament structure is entirely broken up. I tried to discover the nature of the calcite bodies by crushing a dried specimen and mounting the fragments in Canada balsam. Each of the crushed fragments behaved optically like individual anisotropic crystals. It is obvious, though, that there must be a greater conchiolin than calcareous content in the fibrous ligament. When the material is pulverized individual fibers can be freed. The microscopic structure of the fibrous ligament of pelecypods needs to be thoroughly investigated.

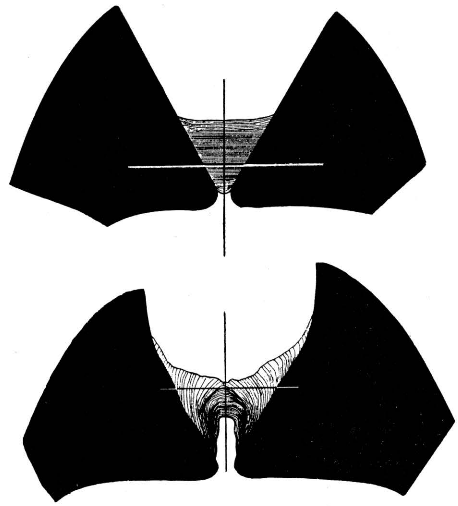

FIG. 9. *Pinctada savignyi*. *Upper*. A section through the lamellar elastic ligament just back of the resilifer, camera-lucida drawing, $\times 6$. *Lower*. Section through fibrous compressional ligament, camera-lucida drawing, $\times 6$. Both valves are in tight apposition; the cross indicates the position of the cardinal axis.

The lamellar ligament (fig. 9, *upper*) is a horizontally laminated, noncalcareous triangular prism of conchiolin. The axis of movement is near the center of the ligament so that the upper layers are subjected to stretching and the lower layers are probably under slight compression when the valves are closed. The upper layers are wrinkled and exfoliate readily. Instead of breaking when their strength is exceeded, as was the case in *Arca*, individual lamellae draw away from their attachments at the cardinal areas, and are progressively sloughed off. The new lamellae at the inner surface of the ligament are naturally somewhat thicker than the stretched ones at the top. Except for obscure growth lines on the cardinal area, there is no apparent special provision for the attachment of the lamellar ligament to the shell.

The fibrous ligament rests in two shallow, oblique resilifers, one in each valve. Both lateral borders of the resilifers are inclined backward so that the resilium lies entirely behind the beaks. This peculiar obliquity is apparently brought about by a posterior migration of the dorsal part of the mantle during shell growth. Unlike *Arca*, there is in *Pinctada* a progressive increase in size of the cell cluster along the dorsal ridge of the mantle so that there is a gradual increase in the size of the zone of active secretion of the fibrous ligament.

Ligament of Type 3—*Perna*. The ligament system in *Perna* is like that of *Pinctada* or *Pteria*, except that instead of having only one resilifer on each valve *Perna* is provided with a series of resilifers which are added successively at the posterior end of the hinge during growth. Jackson (1890, pp. 327-333) has shown that young individuals of *Perna* have only one resilifer on each valve, and at this stage the shell is closely similar to adult individuals of *Pteria*. As in *Pteria* the single resilifer of young *Perna* lies wholly behind the beaks. The additional resilifers are added during shell growth at the posterior extremity of the hinge. Each resilifer contains fibrous ligament material and the flat areas between are covered by lamellar ligament as in *Pteria* or *Pinctada*.

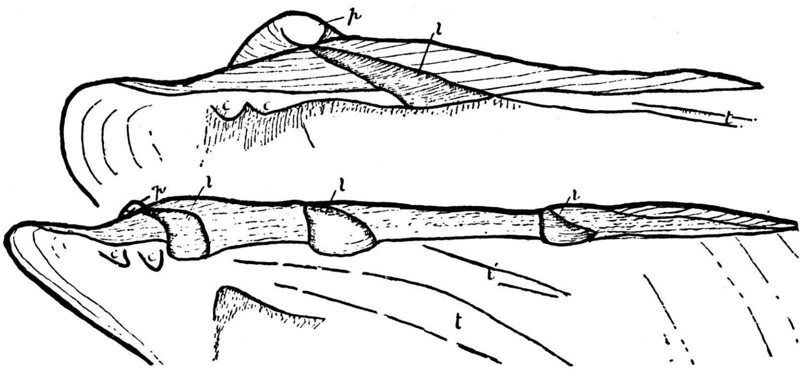

FIG. 10. *Perna ephippium*, (modern), after Jackson. *Upper*. Young individual, right valve; p, prodissoconch; l, single resilifer; c, cardinal, and t, lateral teeth, × 90. *Lower*. Older specimen with three resilifers, and two lateral teeth, × 24.

The Carboniferous genus *Euchondria*, and possibly the Devonian *Crenipecten*, had a ligament system comparable to that of *Perna*, with only one important difference. In *Euchondria* resilifers are added both in front and behind the beaks and the initial resilifer remains almost central along the hinge. Except for the supplementary resilifers in front and behind the central first resilifer, the ligament system in *Euchondria* is like that in other aviculopectens having but one resilifer. Apparently the hinge of *Euchondria* was derived from the type (pteriid) that characterized the true aviculopectens.

F. Stearns MacNeil, of the U. S. Geological Survey, a specialist in the study of pelecypod ligaments, has communicated to me that he doubts that the cardinal pits in front and behind the central large resilifers in *Euchondria* are actually resilifers. If these pits are not resilifers, then they are not homologous to any known structures of modern pelecypods. My reasoning is based on the following observations made on remarkably well-preserved specimens.

1. *Euchondria* possesses triangular cardinal areas and the hinge axis is at the base of the cardinal areas, as in *Arca* and *Perna*.
2. The central and subsidiary resilifers occur *above*, dorsal to, the hinge axis.
3. Unique, nearly perfect specimens were observed having the two valves in apposition. The cardinal areas diverge and can be viewed externally when the valves are closed.

Obviously the cardinal pits of *Euchondria* cannot be compared with any known type of dentition because the cardinal areas *diverge* when the valves are closed and the cardinal structures cannot serve the function of interlocking teeth.

Ligament of Type 4—*Pecten*. The parts of the ligament system in modern Pectinidae are not very much like those in the Pteriidae, and only after an inspection of modern *Limopsis* is it apparent how the pectinid type might have been derived from the pterioid type of ligament. (I am indebted to F. Stearns MacNeil and Hubert Schenck for calling my attention to the *Limopsis* type of ligament). There is no cardinal area in *Pecten*, except in gerontic individuals. The areas of attachment of the lamellar ligament and "resilium" are concealed, or "internal." The cardinal axis is located almost at the extreme dorsal margin of each valve and lies within lamellar ligament along the front and rear parts of the hinge. The resilium lies wholly underneath the cardinal axis, almost completely hidden from view. The resilium is attached on both sides in triangular resilifers, but the structure of the resilium is not homologous with the structure of the ligament contained in the resilifers of *Pinctada, Pteria, Yoldia, Perna*, etc. In these forms the resilifers are occupied only by fibrous ligament, and lamellar ligament does not extend into the resilifers. In *Pecten* the resilium consists of two unlike structures: (1) a pair of fibrous, tan- or cream-colored, triangular calcareous pieces which fit into the resilifers; and (2) a central mass of reddish-brown,

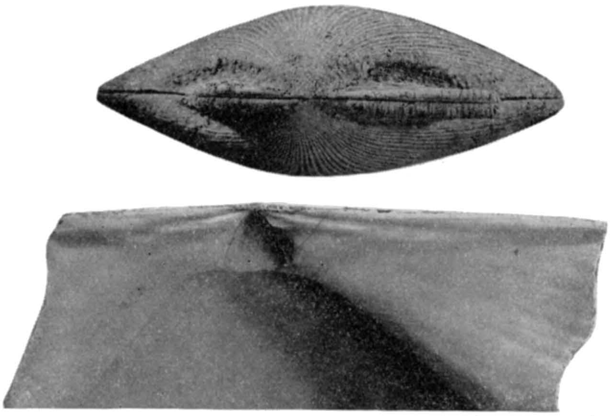

FIG. 11. *Pecten* (*Chlamys*) *islandicus;* (modern). *Upper.* Dorsal view, × 1, showing the tight apposition of the dorsal margins of the valves, effectively hiding the lamellar ligament and the resilium. *Lower.* Left valve, × 2, showing a kind of dentition radiating from the apex of the resilifer; the radial teeth occupy the position of the cardinal area of *Pinctada* or *Aviculopecten.*

lamellar, noncalcareous conchiolin with the lamellae parallel to the growing surface. The calcareous lateral pieces are silky in appearance, and fibrous. They are quite rigid, although they contain a considerable proportion of conchiolin, and do not aid in opening the valves, nor do they have any other obvious function. The elastic part of the resilium is bell-shaped if sectioned in the plane of the valves. In horizontal section it is transversely subrectangular, that is, flattened from front to back, with rounded corners. Upon drying, the lamellar central mass of the resilium tends to divide into vertical fibers, disposed at right angles to the lamellae.

These perpendicular fibers of the dried resilium are not homologous to the fibrous structure of the ligament in the resilifers of *Pinctada,* or on the cardinal area of *Arca.* The fibers in the last two are calcareous spicules and are very small, whereas in *Pecten* the aforementioned fibers are coarse and irregular and contain no calcareous material that I could discern. Furthermore, they are disposed at right angels to the inner or growing surface of the resilium, whereas it will be recalled that in *Arca* and *Pinctada* the calcareous spicules are secreted parallel to the growing surface, where the mantle is in contact with the ligament.

A cup-shaped depression in the mantle fits snugly over the ventral globular end of the resilium with long processes covering the front and rear surfaces.

The lamellar ligament, along the hinge margin in front of and behind the resilium, is a light-amber colored structure secreted by a dorsal ridge of the

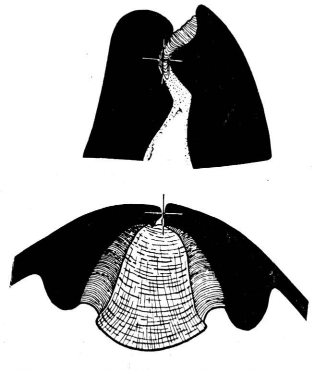

FIG. 12. *Pecten* (*Chlamys*) *islandicus. Upper.* Section through the lamellar ligament behind the beaks, showing how the convex lamellae of the ligament are progressively straightened out as they are subjected to more and more tension above the cardinal axis; the stippled area is the dorsal ridge of the mantle, camera-lucida drawing, × 12. *Lower.* Section, through resilium, showing the bell-shaped lamellar ligament flanked on both sides by the calcareous vestigial fibrous-ligament, camera-lucida drawing, × 12. The position of the cardinal axis is shown by the cross, in both figures the right valve is on the right.

mantle. It is not calcified and is horizontally lamellar. The lateral surfaces of the ligament are nearly parallel so there is no tendency for the older parts to cleave medially, nor is there any regular loss of older lamellae by sloughing as in *Pinctada,* but parting occurs along one side or the other where the ligament joins the shell. This part of the lamellar ligament outside of the resilifers is very weak, insufficient to hold the valves together if the muscle and resilium are removed. Its weakness is partly compensated for by a kind of dentition common to *Pecten, Amussium,* and kindred forms. There are narrow ridges on the inner surface of both valves, diverging from the apex of the resilifers, which fit into grooves in the opposite valve.

It is likely that the *Pecten* ligament system was derived from a pteriid one, such as that possessed by many of the aviculopectens, yet there appears to be little direct evidence that such was the case. Among the Paleozoic pectinoids apparently only *Pernopecten* and its relatives possessed a ligament like that of *Pecten.*

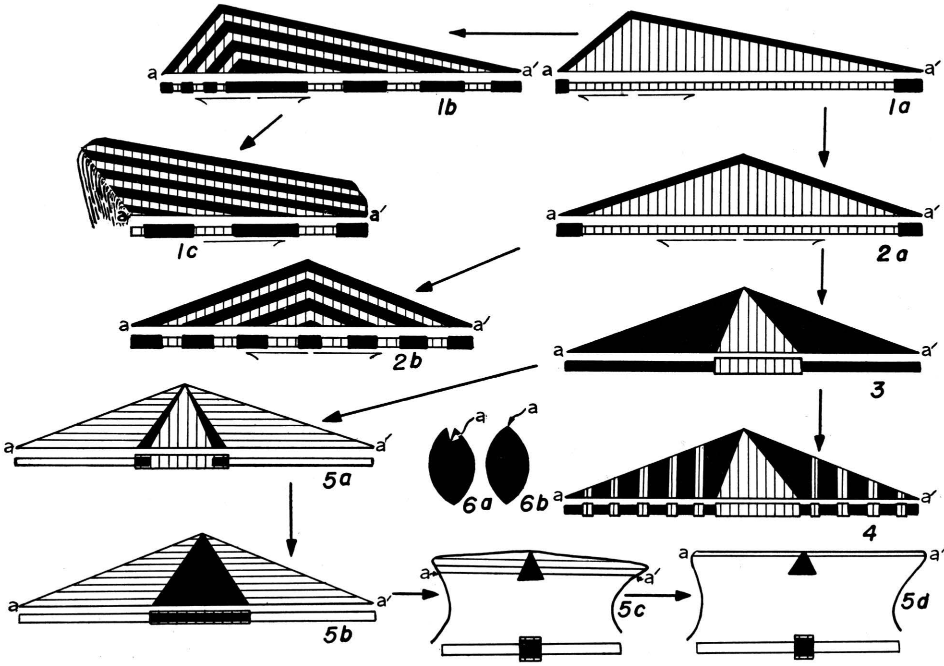

FIG. 13. Hypothetical development of pectinid and pteriid types of ligament from the arcid type of ligament.

Solid black, except 6, represents lamellar ligament; horizontal ruling, essentially the same, but is thin, relatively unimportant lamellar ligament occurring outside the resilifers; vertical ruling represents fibrous, calcified ligament.

In *1a-5c,* inclusive, cardinal areas are developed and the hinge axis (*a-a′*) is located below them, as shown in the end view of a complete shell in *6a*. In *5d* the hinge axis (*a-a′*) corresponds to the dorsal margin of the shell as *6b,* and there are no cardinal areas. Two diagrams, an upper and a lower, are given for each type of ligament. The upper is a plan view of the cardinal area of a right valve (anterior to the left) with ligament structures intact, or (in *5d*) a view of the inner surface of the valve retaining the ligament structures. The lower diagram in each case represents a ventral (internal) view of the ligament as though seen between the partly opened valves. This view reflects the arrangement of differentiated clusters of cells on the mantle whose sole function is the secretion of new additions to the ligament. In *1a-2b* there obviously is no change in the size of the clusters of ligament-secreting cells during shell growth. Growth in the dorsal margin of the mantle takes place by a curious insertion of new cells at a single point along the hinge line, causing previously formed parts of the dorsal margin of the mantle (and also ligament structures in the process of development) to migrate away from the single point of growth. This migration of developing ligament structures, together with the normal addition on the ventral or growing surface of the ligament, produces an oblique arrangement of the parts of the ligament, either in the form of chevrons (*1a, 1b, 2a, 2b*) or oblique bands (*1c*). In *3-5d* there is no evidence that the parts of the ligament, or the differentiated clusters of ligament-forming cells along the dorsal margin of the mantle migrate during growth toward the poles of the hinge axis except inasmuch as there is a general increase in size of cell clusters during growth. Triangular resilifers, absent in the previous types, occur in *3* to *5d* and ordinarily the fibrous ligament is restricted to the resilifers, but in *4,* small subsidiary resilifers may be added during growth at each (or only one) end of the hinge line.

1a represents the ligament of juvenile *Liopteria, Ptychodesma,* and the hypothetical ancestral type; *1b* represents adult *Liopteria, Ptychodesma,* etc.; *1c* represents adult *Myalina,* characterized by the complete loss of the anterior part of the shell; *2a* represents species of modern *Arca,* juvenile *Pseudaviculopecten,* and juvenile *Pterinopecten; 2b* represents species of modern *Arca,* adult *Pseudaviculopecten, Pterinopecten,* etc.; it is possible that the symmetrical forms like *2a* and *2b* were ancestral to the asymmetrical ones like *1a* and *1b* but the paleontologic record suggests the reverse; *3* represents *Aviculopecten, Limipecten,* etc., and modern *Pinctada* and *Pteria,* the first two differing from the latter two only in being a little more symmetrical; *4* represents *Euchondria* which differs from modern *Perna* in having one resilifer much larger than the others, and in the fact that new resilifers are added at both ends of the hinge instead of only at the rear end as in *Perna; 5a* represents the ligament of modern *Limopsis* which differs from *Pinctada* chiefly in the fact that part of the lamellar ligament is incorporated in the resilifer and is partly overlapped by fibrous ligament; *5b* is a strictly hypothetical stage intermediate between the *limopsid* type of ligament and the *pectinid* type; *5c,* gerontic *Pecten* in which there are cardinal areas; this type of ligament differs from that of *Limopsis* chiefly in the separation of the fibrous ligament into two nonfunctional vestigial structures; *5d,* modern adult *Pecten,* in which the hinge axis occupies the dorsal margin of the shell; the resilifers are entirely below the hinge and there are no cardinal areas.

EVOLUTION OF THE PECTINOID LIGAMENT

In figure 13 I have attempted to illustrate my hypothesis as to how the evolution of certain types of ligament systems *might* have proceeded. The diagrams show that the postulated sequence of stages is mechanically possible. Each stage (except *5b*) can be compared to or is identical with modern or fossil types. I do not hold that the possession of identical ligament systems in different groups of pelecypods implies close relationship. For example, the close resemblance of the ligament system of some Devonian pectinoids with that of modern *Arca* does not suggest to me that the arcas are closely related to the Devonian pectinoids. Nor does the similarity between the ligament in *Lima* or *Ostrea* with that of *Pteria* suggest near relationship, for we know that these genera have had a very different history. The stages of ligament development illustrated in figure 13 are stages in the modification of certain types of ligaments and were certainly developed independently in unrelated groups of pelecypods.

A number of Middle Paleozoic pelecypods, such as *Ptychodesma, Posidonia, Liopteria; Palaeopecten, Pseudaviculopecten* Newell, n. gen., and *Pterinopecten,* illustrate the types represented by *1a, 1b, 2a,* and *2b* (fig. 13). Various modern arcas, *Glycimeris* and others illustrate *2a,* and *2b.* In *1a-1c* the beaks are at or near the front end of the shell and there is a corresponding asymmetry of the insertion grooves for the lamellar ligament bands. Whether or not the asymmetrical type (*1a, 1b*) preceded the symmetrical type (*2a, 2b*) cannot be determined. Either condition appears equally possible.

All of the better known Devonian pectinoids are equipped with chevron ligament grooves of the arcid type. In the Mississippian rocks and the later Paleozoic, the dominant type of ligament is illustrated by *Aviculopecten, Limipecten, Deltopecten* (*3,* fig. 13). This type of ligament is possessed by modern *Pteria, Pinctada, Ostrea, Lima,* and many other genera. In the modern forms the type of ligament in any one compact family appears to be constant.

Now, because of the dominance of this latter type of ligament in the Carboniferous periods and the suppression of the arcid type, which certainly had been dominant in the Devonian, I am disposed to believe that the pteriid ligament is a natural derivative of the arcid ligament. In comparing *2a* (arcid) with *3* (pteriid) it is seen that there are several important differences which may be summarized in the following manner:

Arcid type	*Pteriid type*
1. Lamellar ligament attached in a groove.	1. Lamellar ligament raised on a pedestal.
2. Lamellar ligament length constant at hinge.	2. Lamellar ligament length increases at hinge.
3. Fibrous ligament on pedestal.	3. Fibrous ligament in triangular pit.
4. First formed ligament lamellar.	4. First formed ligament both lamellar and fibrous.

I do not understand why the fibrous ligament of the pteriid type should be depressed in a resilifer and that of the arcid type raised on the general surface of the cardinal area. It appears that the difference indicated in the fourth point, listed above, might be explained by acceleration of development in the pteriid type so that the initial all-lamellar stage of the arcid type might be skipped in the development of the pteriid ligament.

The most serious obstacle lies in the difference suggested in the second point above. The dorsal ridge of the mantle in the arcid type (*2a, 2b* lower) increases in length by inserting new cells at a single mid-point almost directly under the beaks. This peculiar serial addition causes a poleward migration of ligament structures during growth, without causing any anteroposterior increase in their dimensions. Because of this circumstance the lamellar ligament bands or sheets of the arcid ligament are uniformly the same thickness, and the chevron grooves into which they are inserted are of a uniform breadth.

The pteriid ligament system appears to be fundamentally different in mode of growth. All ligament structures progressively increase in anteroposterior dimensions during growth. Apparently new cells appear uniformly along the entire dorsal margin of the mantle so that there is a uniform increase in the size of the clusters of ligament-secreting cells.

There are no recognized forms intermediate between *2a* and *3,* and I admit the possibility that the pteriid ligament was not derived from the arcid type. Nevertheless the remarkable similarity between some of the Devonian pectinoids (*Pseudaviculopecten* Newell, n. gen.) having an arcid ligament area, with Carboniferous forms (*Aviculopecten*) having a pteriid ligament area, leaves little choice but to believe that the Devonian and Carboniferous forms are closely related.

There is no difficulty deriving the *Perna* type of ligament from the pteriid type, as has been admir-

TABLE III.—Proposed Classification of Paleozoic Pectinacea

Hinge.	Family.	Obliquity.	Outer Ostracum. Left.	Outer Ostracum. Right.	Relative length auricles.	Subfamily.	Genus.	Ornamentation. Left valve.	Ornamentation. Right valve.	Posterior auricle.	Special features.	Geologic range.
							Pterinopecten	Intercalate costae	Intercalate costae	Subquadrate		Devonian
							Pseudaviculopecten	Intercalate costae	Intercalate costae	Alate		Devonian—L. Carboniferous
							Lyriopecten	Intercalate costae	Intercalate costae	Alate	Anterior auricle obsolete	Devonian
							Vertumnia	Intercalate costae	Intercalate costae	Alate	Left flat, right convex, front ear acuminate	Devonian
	Pterinopectinidae	Prosocline	Homogeneous?	Irregular prismatic	Subequal		*Dunbarella*	Intercalate costae	Bifurcate costae	Subquadrate		Upper Carboniferous
							Pterinopectinella	Intercalate costae	Bifurcate costae	Alate	Costae regularly spinose	Carboniferous—L. Permian
							Palaeopecten	Intercalate costae	....	Alate	Auricular crura	Silurian
							Rhombopteria	Lirae in quincunx	....	Subquadrate		Silurian
							Posidonia	Concentric folds		Subquadrate		Carboniferous
							Aviculopecten	Intercalate costae	Bifurcate costae	Alate		Carboniferous—Permian
							Deltopecten	Large equal plicae		Alate		Permian
							Fasciculiconcha	Intercalate costae		Alate	Fascicled costae on left valve	Upper Carboniferous
		Prosocline to Opisthocline	Homogeneous	Irregular prismatic	Subequal	Aviculopectininae	*Limipecten*	Intercalate costae		Alate	Pointed scale-lamellae between costae	Carboniferous—Permian
							Acanthopecten	Large equal costae	Small equal costae	Alate	Pointed scale-lamellae between costae	Carboniferous—Permian
							Annuliconcha	Two ranks concentric fila		Alate	Left outer ostracum made of concentric increments normal to shell surface	Carboniferous—Permian
	Aviculopectinidae						*Girtypecten*	Few equal costae and coarse concentric ridges		Alate	Spines at juncture costae and fila	Permian
							Clavicosta	Costae intercalate in pairs		Alate	Valves equally convex	Upper Carboniferous—Permian
		Irregular	Homogeneous	Irregular prismatic	Posterior ear obsolescent	Pseudomonotinae	*Pseudomonotis*	Intercalate costae		Subquadrate	Right valve commonly cemented	Upper Carboniferous—Permian
							Streblochondria	Intercalate costae and concentric fila		Subquadrate	Resilifers extended anteriorly	Carboniferous—Permian
		Acline to Opisthocline	Radial crossed lamellar	Radial crossed lamellar	Anterior ear longer than posterior	Streblochondriinae	*Obliquipecten*	Nearly smooth		Obsolete	Right front auricle extended above hinge	Lower Carboniferous
							"*Camptonectes*"	Radial lirae in quincunx		Subquadrate		Permian
							Streblopteria	Smooth		Subquadrate		Carboniferous
	Euchondriidae	Prosocline	Homogeneous	Quadrate prisms in radial rows	Subequal		*Euchondria*	Intercalate costae	Smooth	Alate		Devonian?—U. Carboniferous
							?*Crenipecten*	Smooth		Subquadrate	Poorly developed byssal notch	Devonian
	Amussiidae	Prosocline	Radial crossed lamellar	Hexagonal prisms in concentric rows	Subequal	Pernopectininae	*Pernopecten*	Smooth			Left auricles extend above hinge, byssal notch obsolete, auricular crura	Carboniferous—Permian

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ably illustrated by Jackson (1890), and I believe that *Euchondria* (fig. 13, *4*) was derived from one of the aviculopectens (*3*) by the aquisition of subsidiary resilifers that were progressively added during growth at each end of the hinge.

I am indebted to F. Stearns MacNeil for acquainting me with the nature of the ligament in modern *Limopsis* (fig. 13, *5a*) and for suggesting that the *Limopsis* ligament may represent a key to the solution of some questions regarding the development of the pectinid ligament from more primitive kinds. The lamellar ligament outside the resilifers is thought by MacNeil not to be homologous to the lamellar ligament of the pteriid system, so we are not in accord as regards the significance of the limopsid type of ligament. It appears to me that the limopsid ligament is very nearly like the pteriid ligament, differing from it only in the fact that the lamellar ligament extends a short distance into the resilifers at their margins. The limopsid ligament appears to be intermediate between the pteriid and pectinid ligament (*5c, 5d*). In gerontic *Pecten* a cardinal area, lacking in adult *Pecten*, is developed. An intermediate stage between *Limopsis* and normal *Pecten* necessarily must involve the reduction of the cardinal area. In *Pecten* and its near relatives the lamellar ligament has invaded the entire area of the resilifers, separating into two separate halves the nonfunctional and vestigial parts of the fibrous ligament. The only Paleozoic representative of the pectinid type of ligament so far recognized is *Pernopecten*, which was first developed in its typical form in the Mississippian period. Because of various shell features, I regard *Pernopecten* as ancestral to the modern amussiums and not directly ancestral to other modern pectinoids. The latter, probably derived from the aviculopectens, apparently did not acquire the *Pecten*-type of ligament until the Triassic period, or less probably, the Permian.

SYSTEMATIC PALEONTOLOGY

THE EARLIEST PECTINOIDS

It was set forth clearly by Jackson, in his monumental "Phylogeny of the Pelecypoda," that modern Pteriidae and Pectinidae pass through a series of growth stages in which the shell form in the two groups is identical. The early growth stages in the modern forms correspond, at least superficially, to the adult form of several Paleozoic genera. It was Jackson's belief that the genus *Rhombopteria*, from the Silurian of Bohemia, represents the ancestral radical which gave rise on one hand to the Pteriidae through such genera as *Leptodesma*, and on the other hand to the Pectinidae (Pectinacea) through forms like *Pterinopecten* and *Aviculopecten*. In general, the consecutive form stages of a modern *Pecten* are similar in outline to the adults respectively of *Rhombopteria, Pterinopecten, Aviculopecten,* and *Pecten*. This growth sequence is so characteristic of modern Pectinacea that its phylogenetic significance cannot be lightly passed over. The evidence of ontogeny suggests that a form resembling *Rhombopteria* in general shape gave rise to one having the shape of *Pterinopecten*, which in turn evolved respectively into an *Aviculopecten*-like shell and one having the shape of a true *Pecten*. This phylogeny needs to be examined more closely in light of the paleontological evidence.

In a broad way, there are two kinds of ligament structures in Paleozoic pectinoid shells, otherwise quite similar, separating an older from a younger Paleozoic group. In the older group the ligament area of the shell is structurally like that of modern Arcidae, although there is no necessary implication of close relationship with the arcas. The *Arca* kind of ligament, described on previous pages, is very distinctive and there is a good basis for supposing these older Paleozoic pectinoids had such a ligament. The genera *Lyriopecten* Hall, *Pseudaviculopecten* Newell, n. gen., *Posidonia* Brown, *Palaeopecten* Williams, and *Pterinopecten* Hall, are alike in having the *Arca* type of ligament area. These genera characterize beds ranging from Silurian to Mississippian age, inclusive, but there are a few stragglers that extended into the Pennsylvanian. In the following pages I propose to classify these Mid-Paleozoic pectinoids as a separate family in the Pectinacea, called the Pterinopectinidae.

In the Mississippian faunas another kind of ligament, similar to that in the modern Pteriidae, began to supplant the pterinopectinid structure, and apparently completely replaced it before Permian time. This later Paleozoic group, diversified into several subfamilies, I propose to class as the Aviculopectinidae. Presumably the Aviculopectinidae were derived from the Pterinopectinidae, because the latter group is, in general, older than the Aviculopectinidae, and because there is nothing in the older faunas so nearly like the Aviculopectinidae as are the Pterinopectinidae. It is appropriate now to give a diagnosis of the family Pterinopectinidae, and some brief comments on genera of the family known to me. Further characteristics of the family can be defined in the future, when more has been learned about this group. In seeking an ancestral radical of the Pterinopectinidae, I should expect, on theoretical grounds, a form organized like the equivalve *Ptychodesma* Hall and Whitfield. This genus is probably dimyarian and lacks a distinct byssal notch, but there is a slight tendency toward an anterior lobation prophetic of such a notch. Of course *Ptychodesma* itself probably should not seriously be considered because it is supposed to be restricted to the Devonian, whereas *Rhombopteria* was described from the Silurian.

FAMILY PTERINOPECTINIDAE Newell, n. fam.

Commonly prosocline, rarely acline, smooth or ornamented, more or less pectiniform shells in which the right valve is primitively the less convex of the two; ligament area similar to that in some Arcidae, i. e., without resilifers but bearing one or a series of asymmetrical chevron grooves below the beaks; posterior auricle longer than anterior, but commonly conspicuously less well differentiated.

Phylogeny

Presumably these earliest of all pectinoids originated in noncostate, prosocline, Early Silurian forms like *Rhombopteria,* probably structurally like the Devonian *Ptychodesma.* Neither *Rhombopteria* nor *Ptychodesma* are "pectinoid" in general physiognomy, but they agree well, at least in form, with the earliest growth stages of later Pterinopectinidae.

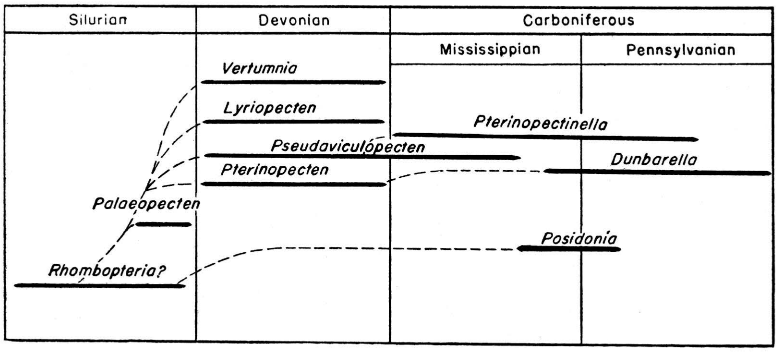


FIG. 14. Hypothetical phylogeny of the family Pterinopectinidae; entirely tentative and subject to revision.

The exact derivation of the Silurian genus *Palaeopecten* and the Devonian genera *Pterinopecten, Pseudaviculopecten, Lyriopecten* and *Vertumnia* is not yet known to me. It is obvious that *Vertumnia,* with its resupinate convexity, and *Lyriopecten,* with the aborted anterior auricles, are both highly specialized genera, apparently leaving no descendants.

Half-grown individuals of *Posidonia* have the general form of *Rhombopteria* and suggest that *Posidonia* is a direct descendant of the Silurian genus.

Except for the bifurcate costae on the right valve *Dunbarella* Newell, n. gen., is very similar to *Pterinopecten,* indicating that *Dunbarella* is an immediate derivative from *Pterinopecten.* Stratigraphic evidence for this relationship should be sought in early representatives of *Dunbarella papyraceus* from the Carboniferous of western Europe.

Pterinopectinella is like *Pseudaviculopecten* except for a curious spinose ornamentation and bifurcate costae on the right valve. In view of the fact that *Pterinopectinella* is not now known in the Devonian, where *Pseudaviculopecten* reaches its acme of development, it seems probable that *Pterinopectinella* is a descendant of *Pseudaviculopecten.*

Genus PTERINOPECTEN Hall, 1883

Pterinopecten HALL, *1883,* Paleontology of New York, vol. 5, part 1, Lamellibranchiata 1 (advance copy), p. 3.

Genolectotype *Pterinopecten undosus* (Hall), Middle Devonian, designated by S. A. MILLER, *1889,* North American Geology and Paleontology, p. 507.

Plate 2, figures 4 *a-c*

Shell elongate, subquadrate, prosocline; hinge line shorter than shell length, met by the rear margin at an obtuse angle; umbonal folds low, obscure, diverging at 100 degrees or more; auricular sulci obscure, the left anterior being more pronounced than the others; in some specimens the umbonal folds are scarcely distinguishable; posterior auricular sinus obscure or lacking; both valves ornamented alike by fine intercalate costae and finer concentric fila, spaced about the same distance apart as the costae; ornamentation of auricles similar but slightly less prominent than that of the shell body; a well-defined cardinal costa on each valve; ligament area narrow, flat, with chevron grooves extending the length of the area and having their apex below the beaks; one or two of the earliest formed grooves do not form complete chevrons in some instances, but extend only behind the beaks.

This diagnosis is drawn up from nine specimens of the genotype species, from the Hamilton group of western New York. Two or three specimens show traces of a thin lamellar shell layer that included at least the outer ostracum. However, further observations will have to be made before this shell structure can be described properly and evaluated.

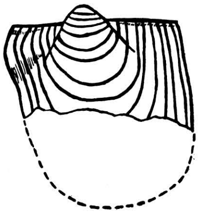


FIG. 15. Camera-lucida drawing of the juvenile stages of a left valve of *Pterinopecten undosus* (Hall), genotype of *Pterinopecten,* showing the rhombic form and protuberant beak.

Genus RHOMBOPTERIA Jackson, 1890

Rhombopteria JACKSON, *1890,* Phylogeny of the Pelecypoda, Boston Soc. Nat. Hist., Mem., vol. 4, p. 380.

Genotype, *Avicula mira* Barrande, Silurian.

Because *Rhombopteria mira* conforms quite well in shape with a very early growth stage in Pectinacea, it has been generally assumed that this particular genus is the ancestral form from which later Pectinacea and Pteriacea were derived. As far as I am aware, nothing is known of the ligament area or hinge structures in the genotype species. Weigelt (1922) and Kegel (1925) have discussed the genus at length, but their personal observations did not include the type species. Weigelt (1922, p. 59) has shown how similar *Rhombopteria* is externally to young specimens of *Posidonia.* He demonstrated a ligament area of the pterinopectinid type in *Posidonia.* If *Rhombopteria* is in reality closely related to *Posidonia,* it must have a similar hinge structure.

Genus PALAEOPECTEN Williams, 1913

Palaeopecten WILLIAMS, *1913,* U. S. Nat. Mus. Proc., vol. 45, p. 331.

Genotype, *Palaeopecten cobscooki* Williams, Silurian.

Range, Silurian.

This curious genus clearly is distinct from all other Pterinopectinidae in possessing slender, but distinct auricular crura. Williams described this form as possessing a central resilifer, but after examining the type specimens of *P. cobscooki* at the U. S. National Museum I believe that the specimens, which are internal molds, are not sufficiently well preserved below the beaks to determine whether or not there was a central resilifer. The chevron grooves of the Pterinopectinidae are well shown and it seems improbable that both kinds of ligament were combined in *Palaeopecten.*

Genus POSIDONIA Bronn, 1828

Posidonia BRONN, *1828,* Zeitsch. f. Min., vol. 1, p. 262.

Genotype, *Posidonia becheri* Bronn, Lower Carboniferous.

Range; Lower Carboniferous (Mississippian) to upper Carboniferous (Pennsylvanian, Des Moines subseries).

Weigelt (1922) has made an important contribution to the study of *Posidonia* and similar forms. He has shown that an early stage *Posidonia becheri* has an incipient byssal notch, and a shape like *Rhombopteria.* The ligament area is that of the Pterinopectinidae. Weigelt is inclined to give the genus *Posidonia* very wide limits and to suppress terms like *Rhombopteria* Jackson and *Caneyella* Girty as subjective synonyms. The adult *Posidonia* is not auriculate nor does it have a byssal notch. It would appear to be a side specialization from the main pterinopectinid stem. I doubt the propriety of placing *Caneyella* Girty, as represented by the costate genoholotype *C. richardsoni* Girty, with the noncostate and otherwise quite different *Posidonia.*

Of the various American Pennsylvanian posidonias that have come to my attention, only *Posidonia fracta* (Meek) is a valid species, all other names being synonyms or referring to other genera.

Three Pennsylvanian species were described by Lea (1853) and referred provisionally to *Posidonia*: *Posidonia? clathrata, Posidonia? distans,* and *Posidonia? perstriata.* Girty (1908) has shown that the first of these is a costate pectinoid, but otherwise unidentifiable, the second is a gastropod, and the third possibly an *Edmondia.*

Posidonia moorei Gabb (1860) is probably an *Astartella,* and *Posidonomya striata* Stevens is probably the right valve of *Aviculopecten.* A cursory examination of the types of *Posidonomya? recurva* and *Posidonomya? pertenuis* Beede (1899) from upper Pennsylvanian (Virgil) rocks shows that these species are not posidonias.

POSIDONIA FRACTA (Meek)

Plate 3, figures 15-17

Posidonomya fracta MEEK, *1875,* Paleontology, Ohio, vol. 2, p. 333, pl. 19, figs. 7 *a, b.* Lower Mercer limestone (upper Pottsville), Flint Ridge, Ohio.

Posidonia girtyi MORNINGSTAR, *1922,* Ohio Geol. Survey, Bull. 25, p. 214, pl. 12, figs. 1-4. Lower Mercer limestone (upper Pottsville), Rock Hollow, Vinton county, Ohio.

Posidonia vintonensis MORNINGSTAR, *1922,* Ohio Geol. Survey, Bull. 25, p. 216, pl. 12, figs. 5, 6. Lower Mercer limestone (upper Pottsville), Rock Hollow, Elk township, Vinton county, Ohio.

Meek's description:

Shell obliquely subovate, compressed, very thin; posterior basal margin regularly rounded; posterior dorsal edge ascending obliquely forward to the hinder extremity of the hinge, which it meets at an obtuse angle; anterior margin descending or truncated more or less nearly vertically from the beaks above, and rounding obliquely into the base below; hinge line straight, very short, and ranging at an angle of about 45° to 60° above the longer oblique axis of the valves; beaks terminal, very oblique, and projecting very little or not at all above the hinge margin; surface marked by regular concentric undulations, with intermediate parallel striae.

Length of a narrow right valve, 0.72 inch; breadth of same, 0.43 inch; length of hinge, 0.22 inch.

There is no doubt that Morningstar's material of *Posidonia girtyi* and *P. vintonensis* came from the same horizon as Meek's types of *P. fracta*, and being in all respects like the previously described *fracta*, I am placing the three names in synonymy. An examination of the growth lines of mature *P. girtyi* shows that the associated *P. vintonensis* represents merely a juvenile growth stage of the former species.

Material.—Only Morningstar's types were examined, and under circumstances that precluded a detailed study.

Occurrence.—Upper Carboniferous, in black carbonaceous, somewhat calcareous shale at top of the lower Mercer limestone (upper Pottsville), Vinton county, Ohio.

Genus LYRIOPECTEN Hall, 1877

Plate 2, figure 11

Lyriopecten HALL, *1877*, in S. A. Miller, Am. Paleozoic Fossils, p. 13.

Genotype, by monotypy, *Avicula orbiculata* Hall, Middle Devonian.

Range, Devonian.

The genotype of *Lyriopecten* generally has been thought to be *L. magnificus* Hall, dating from S. A. Miller's designation in 1889 (p. 487). In 1877 Miller published a list of manuscript names of Hall's species under the manuscript genus *Lyriopecten*. Included in the list was a single previously published species *Lyriopecten orbiculatus* (Hall). Since all of the other species were *nomina nuda* the species *orbiculatus* automatically becomes the type. Frech (1891, p. 27) introduced the term *Orbipecten* for Hall's *Lyriopecten* on the grounds that *Lyriopecten* is a homonym of the older *Lyropecten* Conrad. His arguments are not correctly founded because the two terms are compounded from different stems: *lyrion*, and *lyra*.

Genus VERTUMNIA Hall, 1884

Vertumnia HALL, *1884*, Palaeontology of New York, vol. 5, part 1, Lamellibranchiata I, p. xii.

Genolectotype, *Vertumnia reversa* (Hall), Middle Devonian, designated by Pohl, Devonian of Wisconsin, Lamellibranchiata I, Milwaukee, Public Mus., Bull., p. 59, 1929.

Range, Devonian.

The hinge structures of this genus are unknown, but the general expression is pterinopectinoid. *Vertumnia* is exceptional in having a flat or concave left valve and a convex right valve.

Genus PSEUDAVICULOPECTEN Newell, n. gen.

Plate 2, figures 1-3, 19, 20

Prosocline, costate, Pterinopectinidae, in which the subequal auricles are well differentiated from the shell body, both in form and ornamentation, umbonal folds and auricular sulci clearly defined; hinge margin shorter than the shell length; a broad and deep sinus present at the outer margin of each auricle; ornamentation similar on both valves, consisting of moderately fine intercalate costae crossed by finer fila.

Genotype, *Aviculopecten princeps* (Conrad), Middle Devonian.

Range, Devonian, Mississippian?

Remarks.—It seems highly probable that many of the species classed by Hall (1884) as *Aviculopecten* belong here. The hinge characters of several of the Devonian species are not yet known. The Mississippian *Aviculopecten amplus* Meek and Worthen is a pterinopectinid and probably belongs here.

Genus DUNBARELLA Newell, n. gen.

Orbicular or subquadrate, prosocline Pterinopectinidae having costate ornamentation on both valves, intercalate on the left and bifurcate on the right, and with or without costae on the auricles; concentric fila absent or very subdued: distinct posterior umbonal fold lacking, anterior one obscure; anterior sulcus narrow and well defined, posterior one broad and obscure, or lacking, auricles subquadrate, except the anterior one of the right valve, which is rounded; outer ostracum of both valves prismatic with the prisms of irregular size and not regularly arranged in a pattern; inner ostracum unknown; right valve slightly flatter than the left, cardinal costae obscure or lacking. The name is given in honor of Dr. C. O. Dunbar, of Yale University.

Genotype, *Aviculopecten whitei* Meek, upper Pennsylvanian.

Range, Mississippian, Pennsylvanian.

Remarks.—This group is obviously closely related to *Pterinopecten* and very likely is a direct descendent from the Devonian genus. The only conspicuous difference lies in the bifurcate costae of the right valve. The juvenile stages of *Dunbarella* are strikingly like that of *Pterinopecten*. The well-known *Aviculopecten papyraceus* (Sowerby) from the Coal Measures of western Europe is a member of this genus.

Three species of *Dunbarella* can thus far be profitably distinguished in the American Pennsylvanian rocks, although I am sure that several more species can eventually be discriminated. *Dunbarella rectalaterarea* characterizes the older Des Moines rocks and does not extend above the Des Moines subseries. Most of the occurrences appear to be in the Cherokee shale or equivalent horizons.

Dunbarella knighti, n. sp., is known thus far from the uppermost part of the Cherokee shale (Allegheny equivalent), above the Bevier coal horizon. This species is intermediate in character between *Dunbarella rectalaterarea* and *D. whitei*, of which the latter characterizes Virgil (upper Pennsylvanian) rocks.

Probably future discoveries will bring to light additional evidence that the species of *Dunbarella* can be arranged in simple, stratigraphically useful genetic series.

DUNBARELLA WHITEI (Meek)

Plate 1, figures 9-11; Plate 2, figures 12-18

Aviculopecten whitei MEEK, *1872*, U. S. Geol. Survey, Nebraska, Final Rept., p. 195, pl. 4, figs. 11 *a-c*.

Shell orbicular, prosocline, flattened; hinge slightly shorter than the shell length; posterior auricle twice as long as anterior, flat, and smooth, generally not set off from the shell body by a fold, or by more than an almost indistinguishable broad sulcus; anterior fold absent, but the small triangular auricle is distinctly set off by a shallow, narrow sulcus; costae lacking on both auricles; body of left valve ornamented by a few low, rather closely spaced, intercalate costae arranged in commonly two, rarely three ranks; right valve with similar costae that increase by bifurcation, the first splitting taking place

MEASUREMENTS IN SPECIES OF *Dunbarella* Newell, n. gen.

Species.	Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Umbonal angle, degrees.	Body costae.	Costae on front auricle.
whitei	L 1[a]	16	15	11	105	28	....
	L 2	16	15	12	110	27	....
	L 3	16	16	12	95	31	....
	L 4	21	20	17	99	27	....
	R 5	22	21	19	110	24	....
	R 6	24	21	20	115	26	....
	R 7	16	14	13	106	32	....
knighti	L 1[b]	25	22	17	....	78	7±
	L 2	24	23	16	....	....	5
	R 3	24	22	17.5	....	....	3
rectalaterarea	L 1	25	27	21	....	77±	8+
	L 2	22±	23	18	....	....	6
	L 3	21±	22	16	....	78±	5
	L 4	22	23	18	....	83	7

a. Lectotype. *b*. Holotype. L. Left valves. R. Right valves.

at a shell height of 4 to 7 mm., commonly about 5 mm.; outer ostracum in both valves composed of polygonal prisms of irregular shape and size, averaging about 25 to 30 microns in diameter in adult

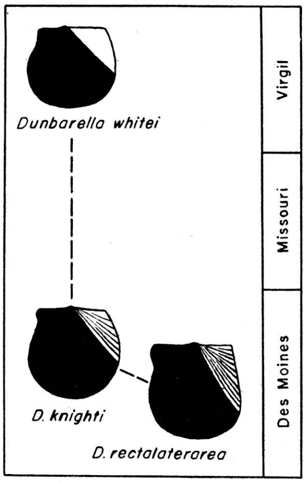


FIG. 16. American species of the new genus *Dunbarella*. Evolution in the genus appears to be expressed in (1) increasing posterodorsal angle of the rear auricle, (2) reduction and loss of costae on the rear auricle, and (3) forward migration of the beaks.

shell. The rear shell margin meets the cardinal margin at about 120 degrees. A single one of my specimens shows traces of the chevron grooves of the pterinopectinid hinge.

Measurements for specimens of *Dunbarella whitei* are given in the table on page 39.

Comparison.—This species can be distinguished readily by the noncostate auricles and relatively broad flattened costae on the shell body.

Material.—This description was based on the original types studied at the U. S. Nat. Mus., No. 6,983, and some other characteristic specimens (Yale Univ., Peabody Mus., No. 14,462) from beds of nearly the same age as those from which the types were collected. These specimens in every case retain only the outer prismatic ostracum, the inner part having been dissolved away. Although the external ornamentation is very subdued, it is reflected rather well on molds of the inner surface of the prismatic layer.

Occurrence.—Upper Carboniferous. The types were collected by Meek from fine argillaceous gray shale near the level of the boat landing at Nebraska City, Neb. This is near the level of the Willard shale (Wabaunsee). Other specimens in our collections came from the Pierson Point shale, one mile south of Falls City, Neb., Severy shale, Church farm, a short distance east of Du Bois, Neb. Virgil subseries.

DUNBARELLA KNIGHTI Newell, n. sp.

Plate 2, figures 8-10

This species is very much like *D. whitei* (Meek) in size and shape, but is distinguished by the occurrence of costae on both auricles and by a subcentral location of the beaks along the hinge. The costae uniformly are smaller and less distinct toward the hinge so that the rear auricle in each valve is not sharply defined by differences in ornamentation. Since the rear auricles are so poorly defined, it is not possible to measure the umbonal angle. Whereas there are rarely over 30 costae on either valve in *D. whitei,* there are generally between 70 and 90 on each valve of *D. knighti.* The angle between the cardinal margin and the posterior margin of the shell is uniformly about 120 degrees. The outer prismatic ostracum is like that of *D. whitei.*

The name is given in honor of Dr. J. Brookes Knight who collected and donated the type material.

Measurements of specimens of *Dunbarella knighti* are given in the table on page 39.

Comparison.—In the characters of ornamentation *Dunbarella knighti* resembles *D. rectalaterarea* (Cox). From that species, however, it is easily distinguished by its orbicular shape and obtuse posterodorsal angle. The costate auricles and the nearly median position of the beaks distinguish this species from *D. whitei.*

Material.—The types, Kansas Univ. Paleont. Type Coll., No. 237, about 20 in number, were presented to me by Dr. J. Brookes Knight as part of a very fine collection of pelecypods from the Pennsylvanian beds of the St. Louis outlier. The specimens are chiefly molds of the inner surface of the prismatic ostracum (subinternal), the inner ostracum with hinge and musculature having been dissolved.

Occurrence.—Upper Carboniferous. The holotype and several topoparatypes were collected from fine bluish-gray argillaceous shale, and black, platy, carbonaceous shale of the Cherokee shale, at the Prospect Hill shale pit of the Missouri Portland Cement Company, Riverview Drive, St. Louis Mo. (Knight's locality 8, cycle A, member 8, lower part). Several paratypes, all in black shale are from the Cherokee shale, Abingdon, Ill. Des Moines subseries.

DUNBARELLA RECTALATERAREA (Cox)

Plate 2, figures 5-7

Avicula rectalaterarea Cox, *1857,* Kentucky Geol. Survey, Paleont. Rept., vol. 3, p. 571, pl. 9, fig. 2.

Subquadrate dunbarellas, higher than long, with numerous crowded costae on auricles and shell body; ornamentation of auricles not well differentiated from that of shell body; posterodorsal angle abrupt, only slightly more than a right angle (less than 110 degrees); commonly there is an obscure sinus just below the posterior termination of the hinge so that the tip of the rear auricle is truly quadrate. A single specimen in my collection shows an imprint of the chevron grooves characteristic of the pterinopectinid hinge.

Measurements of specimens of *Dunbarella rectalaterarea* are given in the table on page 39.

Apparently the original types of this species are lost. It is such a distinctive form, however, that I have but little doubt that my specimens are conspecific with or very closely related to those described by Cox.

Comparison.—The relatively great height and quadrate form of this species serve to distinguish it from other known American dunbarellas.

Material.—The above description was drawn up chiefly from a collection from Oakland City, Ind. (Yale Univ., Peabody Mus., No. 14,463). In addition there are three or four other collections of material, undoubtedly conspecific with the Indiana specimens, so that in spite of the rather fragmentary condition characteristic of specimens of the genus, the limits of variability are fairly well known.

Occurrence.—Upper Carboniferous. Cox's types were said to have come from the black roof shale of No. 9 coal at the Kentucky Coal and Curlew mines, Union county, Kentucky. This horizon is in the Des Moines subseries, thought to be equivalent to the hard black shale under the upper Fort Scott limestone. In the collections at hand the species was found at Oakland City, Ind., 8 feet above the 4-foot coal at that place, probably in the roof of the Petersburg coal which is the same age as the preceding; "Coal Measures." Henry county, Missouri; Des Moines beds, Vermillion county, Indiana; Des Moines beds, Schuyler county, Illinois; probably just below the upper Fort Scott limestone. There are three specimens from the coal shaft at Leavenworth, Kan., probably from the Cherokee shale.

Genus PTERINOPECTINELLA Newell, n. gen.

Pterinopecten (in part) of authors.

Prosocline subquadrangular Pterinopectinidae having broad, poorly defined posterior auricles and well-defined small, anterior auricles; a small marginal sinus occurs just under the acute posterodorsal angle; ornamentation characterized by rather coarse spinose costae which increase by implantation in the left valve and by fission in the right valve; costae of the auricles slightly finer but otherwise undifferentiated from the body costae; spines relatively short, cylindrical, inclined toward the ventral surface at almost 45 degrees to the shell surface; left valve inflated, right valve nearly flat; fila absent or inconspicuous.

Genotype, *Pterinopectinella welleri* Newell, n. sp., middle and upper Pennsylvanian.

Range of genus, Mississippian to upper Pennsylvanian inclusive.

The so-called *Pterinopecten granosus* (Sowerby) and *Pterinopecten eximius* (Koninck) from the Lower Carboniferous of western Europe are characteristic species of *Pterinopectinella,* as is the *Pterinopecten spinosus* Fedotov from the Lower Carboniferous of the Donetz Basin in Russia (D4 limestone of series C4). In the Pennsylvanian the genus is as yet known only in the Missouri and lower Virgil subseries of the Mid-Continent region, and as far as I know this is its highest occurrence.

PTERINOPECTINELLA WELLERI Newell, n. sp.

Plate 3, figures 14, 18-24

Adult shell prosocline, about as long as high, subquadrangular; hinge nearly but not quite as long as the greatest length of the shell; beaks distinctly anterior to a mid-point on the hinge line, that of the left valve broad and gibbous in accordance with a subhemispherical form of the valve; right valve nearly flat except for a moderate convexity of the umbo; distinct umbonal folds lacking; anterior sulcus rather deep and moderately narrow, being depressed slightly below the general surface of the auricle; posterior sulcus very broad and poorly defined, about coextensive with the auricle; both valves ornamented on body and auricles with numerous spinose costae in three ranks, becoming uniformly a little less coarse on the posterior auricles; anterior sulcus without costae; concentric ornamentation obscure or lacking; spines relatively short, cylindrical, probably originally hollow, containing in the fossil state a large central core of calcite; in ontogenetic development spines appear nearly as early as the first appearance of the first order costae, occurring chiefly on the first and second order costae.

The name is given in honor of Dr. J. Marvin Weller of the Illinois Geological Survey.

Comparison.—It would be difficult to distinguish this species from several of the Mississippian forms solely on the basis of the published illustrations and descriptions. The limits of variability within the genus appear to be rather slight. It is highly probable that other species in the Pennsylvanian can be discriminated when further material is discovered.

Material.—Description of the species is based on eight specimens, six left valves, and two right valves, showing quite well the characters of ornamentation.

MEASUREMENTS OF *Pterinopectinella welleri* Newell, n. sp.

Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Convexity, mm.	Chevron grooves, No.	Costae on anterior auricle.	Total costae.
L 1	43	41	....	10	5	3	43
L 2	32	32	30	7	4 ±	2+	40 ±

L. Left valve

The holotype, an internal mold, shows satisfactorily the ligament area. Holotype and two topoparatypes, Kansas Univ. Paleont. Type Coll., No. 358; paratypes, Kansas Univ. Paleont. Type Coll., Nos. 356 and 357; paratype, U. S. Nat. Mus., No. 27,881.

Occurrence.—Upper Carboniferous. The holotype and some topoparatypes were found in the uppermost sandy layers of the Stanton limestone (South Bend limestone member) at a cement plant, Fredonia, Kan. Two paratypes came from the Argentine limestone, Kansas City, Mo., and one from the oölitic Westerville limestone at Kansas City, Mo. Other specimens, too fragmentary for a positive identification, came from the Palo Pinto limestone, 3 miles west of Strawn, Tex.; Kansas City, Mo., exact horizon unknown; Farley limestone, Bonner Springs, Kan. All of these horizons are in the Missouri subseries. Several other paratypes were found in the Plattsmouth member of the Oread limestone (Shawnee group), Virgil subseries at Melvern, Kan.

FAMILY AVICULOPECTINIDAE Etheridge, Jr., emend. Newell

Aviculopectenidae, MILLER, *1889,* North American Geology and Paleontology, p. 45, (not defined).

Aviculopectinidae, ETHERIDGE, JR., *1906,* Mon. Carb. and Permo-Carb. Invertebrata of New South Wales, vol. 2, Pelecypoda, p. 7.

Diagnosis.—Pectiniform smooth or ornamented shells, having the two valves more or less dissimilar in ornamentation and convexity; the right valve is the less convex of the two and invariably shows a byssal notch at some growth stage. There is a well defined, flat, smooth, external ligament area on each valve as in *Lima* or *Pinctada,* with an oblique subcentral resilifer beneath each beak; with or without additional resilia on either side of the central one. Musculature similar to that in Pectinidae, but lacking the large differentiated dorsal insertions of the circular pallial muscle; in addition, having supplementary pedal muscles in the umbonal cavity, and probably having a small right pedal retractor as well as a larger left one. In some, possibly all, of the genera the inner layer of ostracum is aragonite; ostracum composed of two layers, an outer and inner one neither of which has the foliaceous structure of modern Pectinidae.

Phylogeny of the Aviculopectinidae

The early history of the Aviculopectinidae is shrouded in mystery, and any statement made at the present time is partly speculative and subject to revision. Too little is known about the hinge characters and ontogeny of early Mississippian forms, and almost nothing is known about the Devonian progenitors of this race.

Most of the genera are well represented in Mississippian rocks. *Pernopecten, Annuliconcha, Acanthopecten, Aviculopecten, Limipecten, Streblopteria, Streblochondria,* and *Obliquipecten* are represented among the species described in the great monograph by Hind on the British Carboniferous pelecypods. It is true that almost nothing is generally known regarding the exact stratigraphic distribution of these genera in the Mississippian rocks, but at least it is certain that many of them originated in the Devonian period.

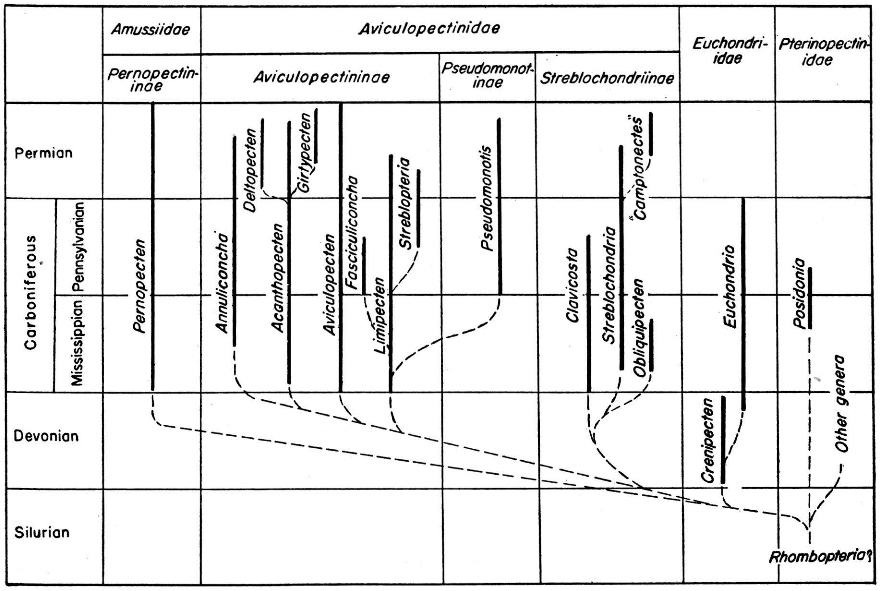
Notwithstanding the fact that Devonian pelecypod faunas in various parts of the world have been monographed, so little is known about the hinge characters of these pectinoids that I cannot recognize Devonian Aviculopectinidae in the literature.

Ontogeny of Pennsylvanian species furnishes a somewhat tenuous basis for the hypothetical family tree of figure 17.

Smooth shells, having poorly developed auricles, like *Streblopteria* s. s., are undoubtedly primitive forms, because they resemble the juvenile parts of so many Aviculopectinidae.

Limipecten and *Aviculopecten* probably evolved from a form in which at least the right valve was smooth, because the right valves in these two genera are smooth up to a slightly later growth stage than the left valves. It is improbable that either genus gave rise to the other, because the ornamentation of the right valves is different, even at a very early stage. *Pseudomonotis,* in view of the similar ornamentation on the two valves, was probably derived from a primitive *Limipecten* lacking well-developed auricles, as suggested by the similarity of juvenile *Limipecten* to mature *Pseudomonotis*. The ancestry of *Clavicosta* is in doubt, owing to the unique ornamentation. In the genus, new costae are added on both valves, during growth, by being inserted or intercalated in pairs. In *Limipecten* new costae are intercalated singly between preëxisting costae. Theoretically the ornamentation of *Clavicosta* could be developed from *Limipecten* by the fission of costae that had been intercalated between older costae.

Acanthopecten had a long history despite my conviction that it is a highly specialized genus. It is well represented in the Mississippian rocks and possibly had ancestors in simplicicostate forms, like the Upper Devonian *Aviculopecten ellipticus* Hall. The simplicicostate ornamentation, so extraordinary in Paleozoic faunas, points to *Acanthopecten* as a probable ancestor to the Permian *Deltopecten* s. s. Likewise, but with less reason, *Girtypecten* may be a descendant of *Acanthopecten*.



* FIG. 17. Hypothetical phylogeny of the Aviculopectinidae, Amussiidae, and Euchondriidae

Subfamily AVICULOPECTININAE Meek and Hayden, emend. Newell

Aviculopectininae MEEK and HAYDEN, *1864*, Paleontology, upper Missouri, Smithsonian Contr. Knowledge, vol. 14, No. 172, p. 49.

Acline or prosocline ornamented Aviculopectinidae with a single oblique resilifer located between and mainly behind each beak; in the characteristic genera the outer ostracum in the right valve is prismatic, in the left homogeneous; the inner ostracum is aragonite, either nacreous or crossed-lamellar; prisms of the outer ostracum in the right valve irregular in size and distribution, although there is a gradual increase in size during shell growth; posterior auricle longer than the anterior.

Genus AVICULOPECTEN McCoy, emend. Newell

Aviculopecten, MCCOY, *1851,* Annals and Mag. Nat. History, 2d ser., vol. 7, p. 171.

Deltopecten, part, of authors.

Acline or only slightly oblique Aviculopectinidae in which the costae on the shell body increase in number on the left valve by implantation, and on the right valve by bifurcation; auricular costae increase only by implantation; new costae appear nearly simultaneously in more or less regular ranks or orders, being introduced at successive stages; costae on auricles and left valve variable in form and spacing, but those of the shell body of the right valve invariably obscure, flat, broad, and closely spaced; number of costae in the two valves about the same; cardinal costae present in both valves of all species, but somewhat variable in prominence; costae when present on the left anterior fold are weaker, irregular and crowded, forming a transitional zone between the ornamentation of the auricle and shell body; ornamentation of left posterior auricle generally set off abruptly by a somewhat coarser posterior costa of the shell body.

* For *Streblopteria,* in this diagram, read *Clavicosta,* and for *Clavicosta* read *Streblopteria.*

The left valve is generally ornamented in unworn specimens with fine, more or less regularly spaced fila which swing slightly hingewards between costae, or else extend directly across costae and interspaces; acute ventral projections between costae are never present but vaulted spinelike processes arising from imbricating lamellae may occur on the costae, never between them; spines, or concentric ornamentation, save for fila on the auricles, lacking on the right valve. The right valve is nearly flat, rarely concave, left valve markedly convex; posterior auricles generally slightly longer than anterior ones; umbonal folds are more or less distinct, subequal, broadly rounded, the anterior ones being slightly more prominent than the posterior ones and curved forward; posterior umbonal fold of both valves generally nearly straight. Anterior and posterior auricular sulci subequal, those of the right valve being shallower than those of the left.

A comparatively narrow, flat, smooth cardinal area with a subcentral shallow, triangular resilifer occurs on both valves, the two resilifers joining at the hinge axis at an angle of 45 degrees, more or less; front and rear margins of resilifers nearly straight and the latter margin is much longer than the former, so that most, but not all of the resilifers lie behind the beaks.

Musculature consists of (1) a relatively large adductor impression with a posterodorsal lobe probably corresponding to a pedal retractor in both valves; (2) a narrow crescentic impression of the gill suspensories below each adductor impression; (3) pallial line unbroken except near its anterior extremity, where it is broken into a series of small pits; (4) two levator pits lying in the umbones; and (5) a very small pit above the adductor impression of the right valve, probably representing a point of attachment of the gills.

Apparently the right valve fits slightly inside the left one because right valves are in many instances smaller than left ones of equal hinge length; furthermore the pallial line and adductor of right valves are closer to the ventral margin than in left ones.

There are two kinds of ostracum in both valves, a thin outer ostracum of calcite, and a thicker, inner ostracum, probably aragonite; outer ostracum apparently homogeneous in left valves, prismatic in right ones; prisms irregularly arranged and somewhat irregular in size, although there is an increase in size from very small ones in juveniles to a diameter of about 30 microns or more in adults; the inner ostracum exhibits two kinds of crossed lamellar structure in exceptionally well-preserved Pennsylvanian specimens; (1) a concentric crossed lamellar layer which extends to the shell border, externally visible only near the margin of the inner surface of the shell, and (2) an irregular radial crossed lamellar layer covering all the inner surface within the pallial line except the muscle areas; hypostracum part of the shell exceedingly thin. In one species (*A. mazonensis* Worthen) there is evidence of a periostracum. This species is extraordinary in having a prismatic outer ostracum in the left valve as well as the right one.

The genolectotype is *Aviculopecten planoradiatus* McCoy, from the Carboniferous limestone of Derbyshire, England.

Range.—So far as I can learn, undoubted aviculopectens are not yet known in the Devonian rocks. The demonstrated range of *Aviculopecten* is early Lower Carboniferous (Mississippian) to Late Permian, inclusive. The so-called aviculopectens that I have seen from the Triassic rocks of the western United States do not show a byssal notch at any stage, and, therefore, belong to some very different group from the Aviculopectinidae.

Discussion.—There has been some confusion regarding the identity of the genotype species of *Aviculopecten.* McCoy clearly intended *Aviculopecten docens* McCoy to be the type species as pointed out by Girty (1904, pp. 291-296), and practically stated that it was upon this species that the genus was founded (see McCoy 1855, p. 392). However, McCoy's intentions can have no legal bearing in establishing the type of *Aviculopecten* because he made no mention of the name *docens* in the original diagnosis of his genus. According to Article 30, Case IIa, paragraph *a* of the International Rules of Zoölogical 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. McCoy included with the original diagnosis the names of the two species, *Aviculopecten planoradiatus* and *A. ruthveni.* The latter has never been designated as the type species so it need not be further considered here. Included in the first diagnosis of the genus was a line drawing of an internal mold labeled *Aviculopecten.* In a subsequent publication, McCoy (1855, p. 392) explained that this line drawing was made from the type specimen of *Aviculopecten docens* McCoy, and that it was *A. docens* that taught him the characters of the genus. In 1889, S. A. Miller (1889, p. 465) made the first unequivocal designation of a type for *Aviculopecten,* naming *A. docens.* It appears, however, that *A. docens* has never been available as the type of the genus, inasmuch as it was not mentioned by *name* in the first diagnosis of the genus. Zoölogical nomenclature is not concerned with the biological concept of species,

Chart for Comparison of American Species of *Aviculopecten**

Aviculopecten s. s.	Maximum height, mm.	H/L	HL/L	C/H	U	Body costae.	Auricular costae. A.	Auricular costae. P.	Special features.	Age.
exemplarius	24	1.14	0.91	0.21	75	43	7	5	Ratio breadth to length ligament area, 0.12	Missouri
arctisulcatus	26	1.08	0.87	0.21	83	38	9	3	Subhemispherical, axis of left rear sulcus near shell body	Virgil
occidentalis	29	1.07	0.88	0.17	82	46	9	10	Ratio breadth to length ligament area, 0.07	Missouri
moorei	35	1.07	0.95	0.14	86	46	10	9	Spines numerous	Virgil
basilicus	43	1.03	0.79	0.18	85	54	11	7	Costae generally broad, flattened	Virgil
sumnerensis	47	1.02	0.73	0.20	93	54	9	12	Umbonal angle	Big Blue
mazonensis	34.5	1.01	0.73	....	90	58	15	20	Ill-defined umbonal folds	Des Moines
nodocosta	29	1.15	0.88	0.19	86	52	10	6	Three to five coarse, nodose costae	Big Blue
mccoyi	22	1.15	0.73	0.22	85	42	9	......	Eight or nine coarse, scaly costae	Big Blue
vanvleeti	28	1.31	0.80	0.14	71	46	8	6	Small rear auricle, three to five coarse, nodose costae	Whitehorse
gryphus	43	1.19	1.03	0.26	80	63	6	6	Acute beak, posterior lobation	Word
gradicosta	22	0.98	0.91	0.23	81	64	13	9	Gradation of fine rounded costae in three or four orders	Missouri
bellatulus	25	1.08	0.95	0.20	80	93	11	9	Gradation of fine rounded costae in three ranks	Kaibab
girtyi	35	1.00	0.77	0.20	87	65	9	8	Five coarse costae, separated by fine ones	Word
kaibabensis	60	1.00	....	0.21	91	85	......	13	Subhemispherical, posterior fold absent	Kaibab
coxanus	14	1.07	0.92	....	80	46	8	6	Rather shallow marginal sinuses under auricles	Des Moines
flabellum	15.5	0.93	0.71	....	111	38	5	3	Shallow marginal sinuses under auricles	Des Moines
germanus	12	1.05	0.81	....	81	26	6	......	Shallow marginal sinuses under auricles	Des Moines
halensis	7.5	1.05	0.90	0.28	89	24	5	5	Flaring umbonal angle at small size	Morrow
phosphaticus	6.2+	0.84	1.00	....	90	21	8	6	Large auricles, distinctive shape	Phosphoria
peculiaris	40	....	....	....	......	42	......	......	Globular left valve, concave right valve	Big Blue

* Mean values for mature left valves: H, height; L, length; HL, hinge length; C, convexity; U, umbonal angle in degrees; A, anterior; P, posterior. *Aviculopecten? ballingeranda* (Beede), *Aviculopecten? coreyanus* (White), and *Aviculpecten eaglensis* (Price) are omitted.

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but with the names of species. In 1903, Hind (1903, p. 66) designated *A. planoradiatus* as the type of *Aviculopecten,* and this designation appears to be the first legal selection of an available species for the type of the genus.

Through the courtesy of the curators of Sedgwick Museum, at Cambridge, England, I have been given an opportunity of examining paratypes of *A. docens* McCoy and the primary types of *A. planoradiatus* McCoy. *A. docens* appears to be a *Limipecten,* as nearly as I can judge in the absence of any right valves (see pl. 11, figs. 6*a*-8*b*).

McCoy's diagnosis of *Aviculopecten,* based upon this species, is incorrect. It was his belief that a resilifer is absent in *Aviculopecten,* and subsequent students have accepted McCoy's statement. There is no well authenticated case in the literature of any Paleozoic pectinoid having a smooth ligament area devoid of a resilifer; consequently there is no good reason to suppose that such a hinge structure exists.

The material of *A. planoradiatus* before me (see pl. 5, figs. 12-15) is too poorly preserved to develop any characters of shell structure, hinge, or musculature, and to that extent the genus *Aviculopecten* is not well established. The characters of form and ornamentation that can be determined from this type collection correspond so well, however, to the Pennsylvanian group of *A. occidentalis* Shumard, that I feel justified in drawing a generic diagnosis of the genus based on Pennsylvanian forms as well as the Lower Carboniferous type species. Besides a greater size of its individuals there are two particulars in which *A. planoradiatus* differs from the Pennsylvanian forms. Introduction of new costae in the British form ceases at a very early ontogenetic stage, whereas, new costae are introduced throughout life in most of the Pennsylvanian species. In *A. planoradiatus,* the anterior umbonal fold (left valve) overhangs the anterior auricle slightly as in some species of *Acanthopecten.* It seems hardly likely that these differences alone warrant separating the Pennsylvanian forms from *Aviculopecten* as a distinct subgenus. I have not been able to see authentic right valves of *A. planoradiatus* from Derbyshire, England. Hind (1903, p. 68) believed that *A. planoradiatus,* known only from left valves, is a synonym of *A. tabulatus* McCoy, described from a right valve. It does not appear that the similarity of ornamentation alone on the type specimens of the two species indicated by Hind is sufficient to class them together, because generally the ornamentation of right and left valves in Aviculopectinidae is conspicuously different. *A. tabulatus,* however, is clearly congeneric with the American group of *A. occidentalis.* The only way to show that *A. planoradiatus* is a synonym of *A. tabulatus* is to find them associated together in the same beds of Derbyshire, or Parkhill, England.

The characters of hinge, musculature and shell structure given in the preceding diagnosis were taken largely from *Aviculopecten exemplarius,* n. sp., but were observed also in some other species.

Of recent years, the term *Deltopecten,* originally applied to Australian Permian pectiniform shells, has been used for characteristic species of *Aviculopecten.* This erroneous usage has arisen from the prevailing belief that resilifers are lacking in typical *Aviculopecten,* whereas they were clearly demonstrated in *Deltopecten.* Paleontologists have thought to classify most of the Carboniferous pectinoids as *Deltopecten* or *Aviculopecten,* depending upon whether or not resilifers could be demonstrated in them. Consequently, a large number of species in which the hinge characters are not known have been classified as *Aviculopecten.* Since *Deltopecten* was the only genus of aviculopectinid aspect known to have resilifers, it seemed logical to classify as *Deltopecten* all Carboniferous and Permian species known to possess resilifers. In the present work it was discovered that almost all of the Carboniferous forms have resilifers which vary only in detail. The genus *Deltopecten,* still poorly known, is discussed more fully on another page. Unlike any other Paleozoic form excepting *Acanthopecten,* the two valves in the type species of *Deltopecten* are simplicicostate, and furthermore are remarkable in having almost identical ornamentation.

Thus far, the attempts to recognize evolutionary trends in *Aviculopecten* have been somewhat discouraging. However, the chief difficulty appears to lie in the very large number of genetic lines and the difficulty in obtaining fairly complete stratigraphic series of specimens representative of one line of affinity. For example, I have not been able thus far to secure representative collections of the *Avicculopecten occidentalis* s. s. gens from Des Moines or Morrow rocks, or post-Des Moines representatives of the distinctive *Aviculopecten germanus* gens. My results are indicative of untold scores of undiscovered species (or mutations) of *Aviculopecten* that are to be sought in Pennsylvanian and Permian rocks.

Some suggestion of progressive change within a single gens is suggested by the species *Aviculopecten occidentalis, A. basilicus,* and *A. sumnerensis,* named in ascending stratigraphic order. This series, whether or not fortuitous I cannot now say, exhibits increasing average size of individuals and increase in the umbonal angle. During ontogenetic development of any *Aviculopecten* there is a progressive increase in the umbonal angle, due to the outward curvature of the anterior umbonal fold. Theoretically one might expect to discover evidence that this type of ontogenetic change might be reflected, at least in some series, as a phylogenetic modification.

The species *Aviculopecten gradicosta* and *A. bellatulus* are exceedingly alike except that the latter and younger one has a larger number of costae than the former. Since increase in number of costae is an ontogenetic character common to all aviculopectens, we might hope to find that this type of change is also a phylogenetic character.

However, for the greater part, species of *Aviculopecten* seem to be so isolated and disconnected from each other that the construction of convincing evolutionary series is still a goal to be sought in the future.

MEASUREMENTS OF SPECIMENS IN SEVERAL SPECIES OF *AVICULOPECTEN*

Species.	Specimen No.	Length, mm.	Height, mm.	Height / Length.	Hinge length, mm.	Hinge length / Length.	Convexity, mm.	Convexity / Height.	Umbonal angle, degrees.	No. auricular costae. Anterior.	No. auricular costae. Posterior.	No. body costae at given height. Costae.	No. body costae at given height. Height, mm.	Breadth ligament area, mm.	Breadth / Length of ligament area.
exemplarius	L1	17	20.5	1.21	15	0.88	4	0.19	74	6	5	36	20.5	2	0.13
	L2	19	23	1.21	18±	0.95±	....	....	73±	6	5	36	23	....	....
	L3	15±	18.5	1.23	14	0.93	4	0.21	78—	6	4	20	11	....	....
	L4	23	24	1.04	20	0.87	4.7	0.20	77	....	6	51	24	....	....
	L5	18±	21	1.17	15.5	0.86	4.8	0.23	74+	6	5	34	21	1.7	0.11
	L6	20	22.5	1.13	....	....	4.9	0.22	75	7	....	37	22.5	....	....
	L7	20	21.5	1.07	17.5	0.88	....	....	75	6	5	47	21.5	....	....
	L8	....	....	....	10	....	....	....	....	....	....	....	....	1.2	0.12
	R9	12	13	1.08	14.5	1.21	flat	....	72±	3	5	....	....	....	....
	R10	....	....	....	14.5	....	flat	....	....	2	....	....	....	....	....
	R11	13	13	1.00	13	1.00	flat	....	90	3	5	....	....	....	....
	R12	8	10	1.25	10	1.25	flat	....	....	3	....	....	....	0.9	0.09
	R13	8.5	9.2	1.08	10	1.18	flat	....	73±	3	8	....	....	....	....
	R14	7	8.5	1.21	8	1.14	flat	....	....	5	....	....	....	....	....
	R15	4	5	1.25	4.5	1.13	flat	....	65	4	....	....	....	....	....
	R16	9.5	10.5	1.12	11	1.16	flat	....	....	3	5	....	....	....	....
	R17	13±	17	1.31	14	1.08	flat	....	....	....	....	....	....	1.3	0.11
	R18	14	17	1.22	17	1.22	flat	....	....	4	....	....	....	....	....
	R19	15	16	1.07	15±	1.00	flat	....	....	4	....	....	....	....	....
occidentalis	L1	23.5	23.5	1.00	18.5	0.79	3.5	0.15	88	10±	10	51	21	1.5	0.08
	L2	26.5	27.5	1.03	....	....	5	0.18	80.5	....	8	42	24	....	....
	L3	25	26.5	1.06	23	0.92	....	....	81.5	10	10	42	26.5	....	....
	L4	24	25	1.04	23+	0.96	4	0.16	81	10+	10	47	25	....	....
	L5	24	27	1.12	....	....	....	....	75+	....	....	36+	27	....	....
	L6	15.5	17.5	1.13	13.5	0.88	....	....	73	....	9	39	18	0.67	0.05
	L7	17	19	1.12	16	0.94	....	....	75	....	12	42	19	1.0	0.06
	L8	28.5	29	1.02	....	....	....	....	84	....	....	....	....	....	....
	L9	24.5	25.5	1.04	....	....	....	....	86.5	9±	9+	42	26	....	....
	L10	25	26	1.04	23.5	0.94	....	....	82.5	8+	9±	41	26	1.7	0.07
	R11	15.7	17	1.08	19.5	1.24	....	....	82.5	4	7	....	....	1.5	0.07
	R12	23	23	1.00	24	1.04	....	....	94	3+	....	....	....	1.7	0.07
	R13	9	11	1.22	13.5	1.50	....	....	78	4	5+	....	....	....	....
	R14	14.5	16.5	1.14	16+	1.10	....	....	64	4	4	....	....	....	....
	R15	11±	11±	1.00	....	....	....	....	64	....	7+	....	....	....	....

MEASUREMENTS OF SPECIMENS IN SEVERAL SPECIES OF *AVICULOPECTEN*—CONTINUED

Species.	Specimen No.	Length, mm.	Height, mm.	Height / Length.	Hinge length, mm.	Hinge length / Length.	Convexity, mm.	Convexity / Height.	Umbonal angle, degrees.	No. auricular costae.		No. body costae at given height.		Breadth ligament area, mm.	Breadth / Length of ligament area.
										Anterior.	Posterior.	Costae.	Height, mm.		
arctisulcatus	L1	23	23	1.00	21	0.91	5.1	0.22	81	8	....	38	23	....	....
	L2	23±	24.5	1.06	17±	0.74	5.4	0.22	81±	8±	....	38	24.5	....	....
	L3	22	25	1.09	19	0.86	....	....	81	8±	....	39±	25	....	....
	L4	20	23	1.15	19	0.95	4.6	0.20	80	10±	....	38	23	....	....
	L5	20	22	1.10	20	1.00	....	....	80	8±	....	30	22	....	....
	L6	26	26+	1.00	....	....	....	....	83	....	5	44±	26	....	....
	L7	23	24	1.04	....	....	....	....	83±	9±	2	46±	24	....	....
	L8	16+	20±	1.25	16	1.00	4.0	0.20	73	8	3	30±	20	....	....
	L9	22.5	23.5	1.04	19	0.85	....	....	84	9±	4+	34	23.5	....	....
	L10	19	22	1.16	....	....	....	....	....	7	....	44±	22	....	....
	L11	....	....	....	15	....	....	....	72	7	3	....	....	....	....
mazonensis	L1	36	34.5	0.96	26	0.72	....	....	90	several	several	55+	34.5	....	....
	L2	29	28.5	0.98	19	0.66	....	....	90±	several	18–20	61±	28.5	....	....
	L3	23	23	1.00	14.7	0.64	....	....	85+	18±	16±	49±	23	....	....
	L4	29	31	1.07	20	0.69	....	....	89	17	18±	70	31	....	....
	L5	24.5	23	0.94	19	0.78	....	....	92	13±	13+	45+	23	....	....
	L6	17+	18	1.06	12	0.71	....	....	84	11+	11+	33+	18	....	....
	L7	19.5	20	1.03	14	0.72	....	....	88	11+	8+	30+	20	....	....
	L8	33±	31	0.94	22	0.67	....	....	95	12±	26±	50±	31	....	....
	L9	17	18	1.06	14	0.82	....	....	90	13	10±	50±	18	....	....
basilicus	L1	42	43	1.02	32±	0.76±	7	0.16	80.5	11	8	50	43	....	....
	L2	27	27+	1.00	24	0.89	5	0.19	78	11	....	40±	27+	....	....
	L3	35	35	1.00	28	0.80	7	0.20	90	....	5	40	35	....	....
	L4	37+	40	1.04	30±	0.81	7±	0.17	90	11	7	68	40	....	....
	L5	38.5	40	1.04	....	....	6	0.15	81	....	....	54	40	....	....
	R6	21	21	1.00	24	1.14	....	....	88	6	11	....	....	1.5	0.06
moorei	L1	....	....	....	30	....	....	....	85	11	11	37	25	....	....
	L2	....	30	....	....	....	4	0.13	....	9	....	....	....	....	....
	L3	20	21	1.05	19	0.95	3	0.14	82	8	10±	37	21	....	....
	L4	....	32	....	24	....	....	....	81	9	....	45±	32	....	....
	L5	32	35	1.09	30	0.94	4.5	0.13	90	8	6+	55	35	....	....
sumnerensis	L1	39	38	0.97	29	0.74	8	0.20	94	8	....	48	38	....	....
	L2	39	....	....	32	0.82	....	....	96	12±	....	52	....	....	....
	L3	35	40	1.14	....	....	....	....	88	9	....	52	40	....	....
	L4	33	36	1.09	....	....	7	0.21	89	9	....	51	36	....	....
	L5	42	44	1.04	29	0.69	....	....	96	8	9±	50	44	....	....
	L6	46	46	1.00	30	0.65	....	....	98	9	....	41	46	....	....
	L7	....	45	....	....	....	....	....	....	8	....	....	45	....	....
	L8	43	47	1.09	28	0.65	8	0.18	96	8	....	64	47	....	....
	L9	52	47±	0.90	....	....	....	....	....	....	....	62	47±	....	....
	L10	39	36	0.92	26±	0.66	8	0.20	91	8	14	67	36	....	....

MEASUREMENTS OF SPECIMENS IN SEVERAL SPECIES OF *AVICULOPECTEN*—CONCLUDED

Species.	Specimen No.	Length, mm.	Height, mm.	Height / Length.	Hinge length, mm.	Hinge length / Length.	Convexity, mm.	Convexity / Height.	Umbonal angle, degrees.	No. auricular costae.		No. body costae at given height.		Breadth ligament area, mm.	Breadth / Length of ligament area.
										Anterior.	Posterior.	Costae.	Height, mm.		
nodocosta	L1	26.5	27.5	1.04	22±	0.83	5.5	0.20	90	9	1	53	27.5	...	...
	L2	23	26	1.13	21±	0.92	5.2	0.20	86	...	8	64	26	...	...
	L3	16	20	1.25	14.5	0.91	3.5	0.17	80	10±	...	38±	20	...	...
	L4	27	29	1.08	23	0.85	6	0.20	91	11	...	40	29	...	...
	L5	26	...	...	...	...	...	...	90±	11	11	49	...	...	...
halensis	L1	7±	7±	1.00	7±	1.00	2	0.28	94	5	7	27	7	...	...
	L2	...	...	...	...	...	...	...	...	5	...	...	...	...	...
	L3	7.5	7.5	1.00	6+	0.80+	...	...	98±	...	...	...	...	...	...
	L4	5	5.5	1.10	5+	1.00	...	...	80±	5	...	...	...	...	...
	L5	...	6.5	...	...	...	...	...	...	...	3+	...	...	...	...
	L6	7	...	...	...	...	...	...	...	...	...	21+	...	...	...
vanvleeti	L1	25	34	1.36	23	0.92	5	0.14	72	...	6+	50	34	...	...
	L2	28	30	1.07	25±	0.89	4+	0.13	74±	10+	...	50+	30	...	...
	L3	16	19	1.09	11	0.68	3	0.15	76	7+	5+	46	19	...	...
	L4	27	37	1.37	20	0.74	4	0.10	67	...	...	42+	37	...	...
	L5	25	30	1.20	17	0.68	4	0.13	66	...	...	...	...	...	...
	L6	20	22	1.10	16±	0.80	...	...	77	...	5+	46+	22	...	...
	L7	17	24	1.41	14	0.82	4.5	0.18	65	6	...	42+	24	...	...
gradicosta	L1	14+	15	1.00±	13	0.93	3.5	0.23	80	13	12	62	15	...	...
	L2	21	22	0.96	18.5	0.88	...	...	82	13±	5+	66	22	...	...
gryphus	L1	26	33	1.26	27±	1.03	7.5	0.22	80	6+	6+	63	33	...	...
	L2	33	43	1.30	...	...	...	...	...	...	...	...	...	...	...
	L3	25	27	1.08	...	...	8	0.29	...	...	...	...	...	...	...
flabellum	L1	14	12	0.85	9	0.64	...	...	114	4	3	36+	12	...	...
	L2	5	4.9	0.98	4.8	0.96	...	...	94	3	...	23	4.9	...	...
	L3	13	13	1.00	10	0.77	...	...	112	3	...	39	13	...	...
	L4	17	15.5	0.91	13+	0.76	...	...	...	...	...	36±	15.5	...	...
	L5	12	11	0.91	...	...	...	...	113	6	...	36	11	...	...
	L6	11	10	0.91	8	0.72	...	...	107	...	3	37	10	...	...
germanus	L1	11	12	1.09	8	0.72	...	...	79±	6		30	12	...	...
	L2	10	11	1.10	9	0.90	...	...	75–82	7		25	11	...	...
	L3	5	5+	1.00	4.5	0.90	...	...	83	5+		22±	5+	...	...
	L4	...	10	...	7	...	...	...	...	...	...	...	10	...	...

L. Left valves. R. Right valves.

AVICULOPECTEN EXEMPLARIUS Newell, n. sp.

Plate 1, figures 12, 17; Plate 3, figures 1-12; Plate 4, figures 10-12

Moderate sized aviculopectens, rarely higher than 25 mm., as a rule less than 20 mm., generally slightly higher than long and moderately incised below the auricles; obliquity, acline or slightly prosocline; axis of left posterior sulcus nearly bisecting auricles; left umbonal angle about 75 degrees; convexity ratio $\left(\frac{\text{convexity}}{\text{height}}\right)$ in mature undistorted left valves, 0.19 to 0.23. There are five to seven, generally six, rounded costae on the left anterior auricle, four or five of which are primary ones and the others secondary, grading into two to four small, irregular, crowded, transitional costae on the outer slope of the umbonal fold. Costae of the shell body rounded, low, generally as broad or broader than the interspaces, 34 to 50 of them, in

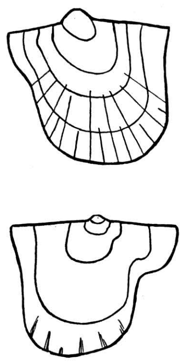

FIG. 18. Early growth stages of the beaks of *Aviculopecten exemplarius* Newell, n. sp. *Upper,* left valve, × 12; the concentric lines represent those growth lines which were sufficiently prominent to be followed; the radial costae do not appear until a shell height of 0.5 mm. is attained. *Lower,* right valve, × 12; the shell is practically smooth until the broad, flat costae appear at a height of about 1 mm.

mature specimens, including transitional costae in left valves, distributed in three or four ranks of intercalaries; four to six fine costae occur on the left posterior auricle, becoming obsolete at an intermediate growth stage, so that, except in rare cases (two out of twenty specimens), the mature part of the auricle is smooth; spines absent, imbrications may or may not occur on the anterior part of the shell body and on the anterior auricle of the left valve.

The fila are fine, about 10 in a space of 1 mm., occurring on the juvenile parts of the shell body in exceptionally well-preserved specimens, but give way to irregular growth lines at a height of 20 mm. or so; ligament area extraordinarily broad, attaining as much as 2 mm. at a shell height of 20 mm. Shell substance of either valve divisible into four layers (1) a thin outer layer, homogeneous in the left valve, prismatic in the right valve; (2) a concentrically crossed lamellar layer which extends to the border of the shell; (3) an irregular radially crossed lamellar layer covering the inner surface within the pallial line except that part occupied by (4) a thin hypostracum layer of the adductor impression. Musculature: large retractor impression

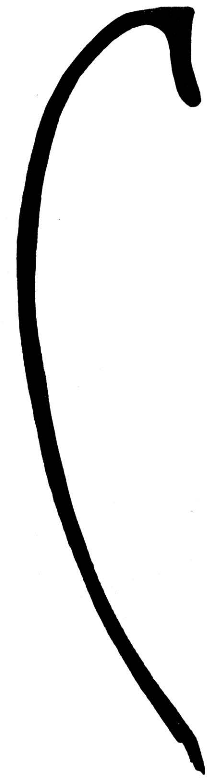

FIG. 19. Dorsoventral section, × 5, through a mature left valve of *A. exemplarius* Newell, n. sp. The complete shell thickness is represented.

with a postero-dorsal lobe corresponding to the pedal retractors, narrow imprint of the gill suspensories below and to the front of either adductor; pallial line unbroken expanding into a relatively broad impression under the adductor; two levator pits in the umbones; a small pit of the superior gill suspensories above either adductor.

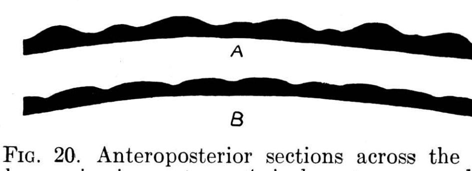

FIG. 20. Anteroposterior sections across the ventral margin in mature *Aviculopecten exemplarius* Newell, n. sp., × 10. *A,* Left valve; *B,* right valve.

Measurements of specimens of *Aviculopecten exemplarius* are given in the table on page 46.

Comparison.—This species is closely similar to *Aviculopecten arctisulcatus*, n. sp., found at a higher horizon, but well-preserved specimens of the two species generally can be distinguished. The following differences are the more obvious ones for undistorted specimens:

A. exemplarius, n. sp.	*A. arctisulcatus,* n. sp.
a. Axis of left posterior sulcus bisects auricle.	*a.* Axis of sulcus close to posterior costa of shell body. Left posterior auricle flattened.
b. Beaks and umbonal slopes slightly compressed, convexity decreasing rapidly toward center in left valves.	*b.* Left valves slightly tumid to hemispherical.
c. Spines and imbrications rare.	*c.* Posterior spines common on left valve, imbrications common on left anterior auricle.
d. Posterior auricular costae become obsolete at an intermediate growth stage.	*d.* Posterior auricular costae either faint, extending to margin, or entirely absent.
e. Umbonal angle commonly about 75 degrees in adults.	*e.* Umbonal angle as a rule about 80 degrees in adults.
f. Filose ornamentation restricted to juvenile parts of shell.	*f.* Filose ornamentation extends into mature stage.

It can be most readily distinguished from *A. mazonensis* by the ornamentation of the left rear auricle and the angularity of the posterior umbonal fold on the left valve.

Material.—The species *A. exemplarius* is founded upon several scores of fine specimens of both right and left valves (Kansas Univ. Paleont. Type Coll., No. 233) obtained at a single locality and horizon. The preservation of the shell substance is not excellent, although the various elements characteristic of *Aviculopecten* can be recognized.

Occurrence.—Upper Carboniferous. The type lot was collected from a cross-bedded limestone consisting of brown limestone pebbles, comminuted shells, and oölite grains, a local limestone in the Bonner Springs shale (Missouri subseries) near Bonner Springs, Kansas. There are rare pebbles of a greenish rock resembling glauconite, and grains of sphalerite that appear to be worn. Other specimens were found in oölite, impure limestones, and limy shales. The limestone bed, occurring just below the Plattsburg formation, is a basal conglomerate and marks an unconformity at the top of the Bonner Springs shale.

Other specimens referred to this species have been found in the oölitic Drum limestone near Independence, Kan.; Vilas shale, Louisville, Neb. (Murphy quarry); Captain Creek limestone, (Kiewitz quarry) Louisville, Neb.; South Bend limestone, 2 miles northwest of Nehawka, Neb.; questionably from the Rock Lake shale, 2 miles east of Louisville, Neb.; Rock Lake shale near Bonner Springs, Kan.; and South Bend limestone near Lansing, Kan.; Graford formation, McKenzie Mt., Palo Pinto county, Texas; and Graford formation near Brownwood cemetery, Brown county, Texas. All of these occurrences are of Kansas City or Lansing age (Missouri subseries, Pennsylvanian).

AVICULOPECTEN ARCTISULCATUS Newell, n. sp.

Plate 4, figures 1-3

Medium-sized aviculopectens ranging in height up to 26 mm., suborbicular, with moderately deep auricular sinuses; obliquity acline; axis of left posterior sulcus relatively close to the umbonal fold, that is in every case below (ventral to) the bisectrix of the auricle; left umbonal angle generally slightly above eighty degrees; convexity ratio $\left(\frac{\text{convexity}}{\text{height}}\right)$ in well preserved adult specimens 0.20 to 0.22; costae of left anterior auricle rounded and closely spaced, 7 to 10 in number, most commonly 8. In a single right valve in which the anterior auricle could be studied, there were four costae; generally two or three irregular crowded costae on the left anterior umbonal fold that form an ill-defined transitional zone between the slightly coarser

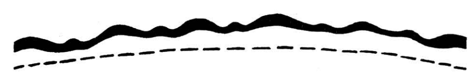

FIG. 21. Anteroposterior section across ventral margin in left valve of mature *Aviculopecten arctisulcatus* Newell, n. sp., × 12. Only the outer ostracum is preserved, the inner, aragonitic layer having been dissolved.

ornamentation of the shell body and front auricle; 30 to 46 broadly rounded low costae on the shell body, as broad and generally broader than the interspaces, distributed in three or four successive orders; posterior auricles either entirely smooth or there may be two to five faint broad costae that extend completely across the auricle; spines occur in many instances along the distal parts of the posterior costae in the shell body of the left valve, less commonly on other parts of the left valve; roughened imbricated lamellae common on the left anterior auricle and adjoining parts of the left valve; surface of unworn left valves covered with fine fila numbering, in the specimens measured, from about 10 to 15 in the space of 1 mm., those fila near the ventral margin being progressively more widely spaced; ligament area, observed in only one specimen, broad, ratio of breadth to length about 0.10; prisms at ventral margin of outer shell layer in full grown right valve range from 15 to 25 microns in diameter.

Measurements of specimens of *Aviculopecten arctisulcatus* are given in the table on page 47.

Comparisons.—From similar species, such as *A. exemplarius,* the present form is distinguished by the following characters: the posterior sulcus has its axis almost against the posterior costa of the shell body; the form is more tumid in undistorted shells, in some instances nearly hemispherical; posteroventral spines are commonly present; posterior auricular costae are few and faint or entirely absent, in no case becoming obsolete at an intermediate growth stage; the number of costae on the anterior auricle of the left valve is uniformly high; unworn shells exhibit regular filose ornamentation on auricles and shell body of left valve.

Material.—The species *A. arctisulcatus* is based on several scores of specimens, mostly incomplete, from a single locality (Kansas Univ. Paleont. Type Coll., Nos. 234, 235). The preservation of these specimens is such that only the thin outer shell layer remains, all inner structures having been lost by solution of the crossed-lamellar and hypostracum layers of the shell.

Occurrence.—Upper Carboniferous. The type collection was found at or near the horizon of the Brownville limestone (upper Wabaunsee), 1 mile north of Reece, Kan., on U. S. highway 54. The rock is a gray to buff, fine-grained, hard, argillaceous limestone in which shells of various kinds are common. Right valves are rare and poorly preserved, but in almost every instance the existing right valves are nearly in apposition with left valves, indicating quiet water conditions. Other specimens referred to the same species were found at Brownville, Neb., exact horizon unknown; Houchen Creek limestone, 1½ miles east of Paxico, Kan.; Aspinwall shale south of Nemaha City, Neb., and 1½ miles north of Brownville, Neb.; a single specimen said to come from the Florena shale at Grand Summit, Kan., is a characteristic representative of the species. Questioned identifications were made of specimens from the Rock Bluff limestone member of the Deer Creek limestone, Big Springs, Kan.; Fort Riley limestone member of the Barneston limestone, Marysville, and Junction City, Kan.; Neva limestone, member of the Grenola limestone, sec. 30, T. 7 N., R. 30 E., Nebraska; Florena shale member of the Beattie limestone, Beaumont, Kan. These horizons are in the Virgil (Shawnee, Wabaunsee) and lower Big Blue beds.

AVICULOPECTEN OCCIDENTALIS (Shumard)

Plate 4, figures 4-9; Plate 5, figure 7

Pecten occidentalis SHUMARD, *1855,* Missouri Geol. Survey, Ann. Rept., p. 207, pl. c, fig. 18.

Shell ranging in height up to 28 mm. in large adults; suborbicular, slightly higher than long, with rather deeply incised sinuses at the margin of each auricle; acline, rarely with distinct prosocline obliquity; axis of posterior sulcus approximately bisecting the rear auricles; umbonal angle in full-sized specimens generally more than 80 and less than 85 degrees; convexity ratio in undistorted left valves $\left(\frac{\text{convexity}}{\text{height}}\right)$ ordinarily between 0.15 and 0.18; from 8 to 10 rounded costae occur on the left anterior auricle, half of which are of the first order, the remainder, second order; there are generally 40 to 50 moderately narrow and elevated costae on the body of the shell, which are crowded and irregular over the anterior umbonal fold forming a transition to the more regular ornamentation of the auricle; 9 or 10 fine costae occur across the posterior auricle; commonly there are small stublike spines on the coarse posterior costae of the shell body in the left

FIG. 22. Anteroposterior section across the ventral margin of the left valve in mature *A. occidentalis* (Shumard), × 12.

valve, and small spines and projecting imbricate lamellae are usually found on the front umbonal fold and anterior auricle of the left valve, less commonly on the posterior auricle; fine regular fila occur on all parts of an unabraded shell, spaced about 15 in 1 mm. over mature areas of the shell body; ligament area narrow, less than 2 mm. in large shells.

Measurements of specimens of *Aviculopecten occidentalis* are given in the table on page 46.

It is with little hesitation that I have employed Shumard's name for this species, even though the original types, formerly located at Washington University, St. Louis, were long since destroyed by fire. Insofar as the species is not based upon existing types, it is poorly founded. On the other hand, Shumard illustrated the original type specimen and stated that it was found "by Mr. Hawn, in the Coal Measures, near Plattsburg, in Clinton County," Mo. The rocks near Plattsburg, Mo., are included in the Kansas City and Lansing groups. In the collections before me there is a well-defined species corresponding fairly well to Shumard's illustration. This form is common in beds of Kansas City age, and in Kansas is replaced above by another form, *A. exemplarius,* n. sp. There appears to be good basis for the continued recognition of the name *occidentalis,* and consequently I do not now feel justified in abandoning it.

Comparison.—This species is distinguished by its upright form, acuminate posterior auricles, moderate size, orbicular shape, low convexity, rather large umbonal angle (75 to 88 degrees), large number of costae on the left anterior auricle, by the common occurrence of projecting imbrications over the surface of the anterior part of the left valve, by the narrowness of the ligament area, and by the moderately slender costae. The form most like *A. oc-*

cidentalis is *A. moorei*. The latter is distinguished by a much greater profusion of spines and by a considerably greater average size.

Material.—The above description was drawn up from more than 100 specimens from the Westerville oölite (Kansas City group) at several localities near Kansas City.

Occurrence.—Upper Carboniferous. The species is abundant in the oölitic division of the Westerville formation (Kansas City group) near Kansas City, but rare in nonoölitic parts of the division; common in the oölitic Farley limestone (Kansas City group) of the same area; Captain Creek limestone (Lansing group) in the quarries near Louisville, Neb. Right valves are not uncommon in the oölite occurrences, but are not found in apposition to left valves. The separation of the valves, in harmony with the pronounced cross-bedding of the oölite, indicates an environment of marked current action and shifting sediments. It is questionably identified because of insufficient material from the Bethany Falls limestone (Bronson group) at Birmingham, Mo., and Lane shale (Kansas City group), Kansas City, Mo.

AVICULOPECTEN MOOREI Newell, n. sp.

Plate 6, figures 4-6

This form is very like *A. occidentalis* (Shumard), and is to be distinguished from the latter by a considerably larger size and a greater development of spines along the anteroventral part of the left valve.

FIG. 23. Anteroposterior section across the ventral margin of left valve in mature *A. moorei* Newell, n. sp., × 12. Only the outer ostracum is preserved.

The costae are moderately high and rounded in most specimens, but a few individuals have somewhat depressed and broad costae. During the development of a shell, spines appear first on costae along the anterior and posterior margins of the shell body in the left valve, and on the anterior auricle.

During continued growth more spines are added on these areas and appear on costae progressively farther and farther inward from the front and rear margin. Generally, only the larger and older costae bear spines. Near the ventral margin every third or fifth costa on the front part of the shell has spines. Spines occur in some cases across the middle part of the ventral edge. The average height in a number of the largest specimens is 35 mm., or slightly more. The prisms of the outer ostracum at the ventral border in a right valve 23 mm. high, range from 10 to 25 microns in diameter.

The name of this species is given in honor of Dr. R. C. Moore.

Measurements of specimens of *Aviculopecten moorei* are given in the table on page 47.

Comparison.—This species is very much like *A. occidentalis* (Shumard) and actually may be a descendent of it. The characteristic development of spines and large size distinguish *A. moorei* from *A. occidentalis.* The spiny ornamentation and usually fewer costae separate *A. moorei* from *A. basilicus.* There is some variation in spinosity in both *A. occidentalis* and *A. moorei.* Occasional specimens of the former species exhibit a few spines along the front margin of the left valve, but smooth individuals are more common. Entirely smooth specimens of *A. moorei* are rare.

Material.—The new species is based on some 30 specimens from the Oread formation at several localities in Nebraska. The inner ostracum has been dissolved from all of the specimens, leaving only the film of outer ostracum of both valves. (Types, Yale Univ., Peabody Mus., No. 14,452.)

Occurrence.—Upper Carboniferous. The type specimens were obtained in gray and buff argillaceous limestone filled with shell fragments of various kind of pelecypods. This limestone occurs as lenses just above the Plattsmouth member of the Oread formation (lower Shawnee group) near Nehawka, Neb., a horizon probably equivalent to the Kereford limestone. Other specimens were found in the Plattsmouth member of the Oread formation at Lecompton, Kan.; Lawrence shale, Lawrence, Kan.; Iatan limestone, and Tecumseh shale, both near Nehawka, Neb.; Kereford limestone, Amazonia, Mo. All of these occurrences are in the Douglas and lower Shawnee groups, Virgil subseries, Pennsylvanian.

AVICULOPECTEN BASILICUS Newell, n. sp.

Plate 6, figures 13-16*b*

This robust species is similar to *A. moorei* and *A. occidentalis* (Shumard) in general aspect, but is readily distinguished by a greater average size,

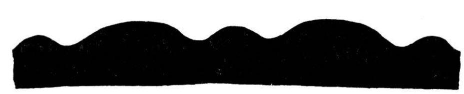

FIG. 24. Anteroposterior section across the ventral margin of left valve in mature *A. basilicus*, n. sp., × 12.

generally broad, flattened costae, and an almost complete absence of spines or projecting imbrications. I have several specimens having a height of at least 35 mm. The holotype and one paratype, both left valves, show an extraordinary tendency for the broader ribs to split distally into two or three smaller ones. The fission of the costae occurs at a late ontogenetic stage and may be regarded as a gerontic character.

Measurements of specimens of *Aviculopecten basilicus* are given in the table on page 47.

Material.—The species is based on nine specimens representing two collections from widely separated localities. Holotype and topoparatypes, Kansas Univ. Paleont. Type Coll., No. 369. Paratypes, Yale Univ., Peabody Mus., No. 14,451.

Occurrence.—Upper Carboniferous. The holotype and some paratypes retaining the complete ostracum occur in a gray, fine, sandy oölitic limestone of the Haskell limestone (Douglas group) at a spring on Cameron's Bluff near Lawrence, Kan. Other paratypes, in which only the outer ostracum is preserved, were collected from an argillaceous and ferruginous calcareous rock of the Graham formation (Cisco), 2½ miles west of Lacos, Tex. The Graham shale is probably of Douglas or Shawnee age, Virgil subseries, Pennsylvanian.

AVICULOPECTEN NODOCOSTA Newell, n. sp.

Plate 6, figures 7-10

This form is very like *A. arctisulcatus* in many particulars. It differs conspicuously in having from three to five of the first order costae much coarser than the others, these costae being provided with one or two coarse spines, the bases of which produce knotty protuberances, broader than the costae on which they occur. The umbonal angle is flared outward and relatively large in mature specimens because of an excessive outcurving of the anterior umbonal fold. The costae are either elevated and narrow, or broad and flattened, and in either case are somewhat more numerous than in similar species.

Measurements of specimens of *Aviculopecten nodocosta* are given in the table on page 48.

Comparison.—This species is similar to *A. arctisulcatus*, its differences from that species being indicated in the foregoing description. From *A. mccoyi* M. and H. it differs in having a large umbonal angle, more costae, and fewer coarse spinose costae.

Material.—The new species is based on seven specimens, six from one locality and horizon, and one from another horizon. (Holotype and topoparatypes, Yale Univ., Peabody Mus., No. 14,453. Paratype, Kansas Univ. Paleont. Type Coll., No. 367.)

Occurrence.—Lower Permian. The holotype and topotype were found in fine-grained, ferruginous, argillaceous limestone belonging to the Burr member of the Grenola limestone (Council Grove group, Big Blue series), at the southwest edge of Burbank, Okla. A paratype was found in fine, calcareous, gray shale of the Florena member of the Beattie limestone (Council Grove group), at Grand Summit, Kan.

AVICULOPECTEN GRADICOSTA Newell, n. sp.

Plate 6, figures 1, 2

Suborbicular, acline, medium sized aviculopectens with a very acute posterior auricle; umbonal angle about 80 degrees, with both umbonal folds of the left valve nearly straight; convexity ratio $\left(\frac{\text{convexity}}{\text{height}}\right)$ 0.23 or slightly less; 13 high and rounded costae, of which 6 are primary ones, occur on the left anterior auricle and about the same number ornament the posterior auricle; left anterior fold well defined,

FIG. 25. Anteroposterior profile across the surface of the ventral margin in left valve of *A. gradicosta* Newell, n. sp.

subangular, body of shell smooth or occupied by three or four transitional costae, including transitional ribs with 62 to 66 narrow and high costae of which the posterior one is a coarse one of the first order; introduction of new costae exceedingly regular, each costa increasing rapidly in height so that there is a marked gradation in coarseness from first order costae down to those of the fourth order; costae crossed by fine regular fila which produce small scalelike projections on the smaller costae and rise into coarser scales over the larger ones.

Measurements of specimens of *A. gradicosta* are given in the table on page 48.

This form belongs to the heterogeneous group generally classified as *Aviculopecten mccoyi* M. and H., but is readily distinguished from that form by the numerous and high costae.

Material.—The species is described from two specimens collected at two different horizons (Kansas Univ. Paleont. Type Coll., holotype, No. 365; paratype, No. 366).

Occurrence.—Upper Carboniferous. Paratype in cross-bedded, sandy, oölitic limestone of the South Bend limestone member (Stanton limestone) Lansing group), Fredonia, Kan.; holotype found in cross-bedded, oölitic limestone, Westerville oölite (Kansas City group), Turner, Kan. Missouri subseries, Pennsylvanian.

AVICULOPECTEN EAGLENSIS (Price)

Plate 4, figures 15, 16

Deltopecten eaglensis PRICE, *1916*, West Virginia Geol. Survey, Rept. on Raleigh, Mercer, and Summers counties, p. 719, pl. 31, figs. 1, 2.

Price's description:

Shell small, suboval, slightly oblique and inequilateral, height equal to or a little more than the greatest length of the shell below, length of hinge line unknown, probably two thirds to three fourths of this dimension, which is measured in a direction such that its prolongation would meet the extension of the hinge line at a point about 30 millimeters in front of the beak; left valve depressed, convexity greatest at the midheight, beak small, pointed, extending slightly beyond the hinge line, separated from the ears by a sinus on each side; the anterior ear wedge-shaped, raised above the narrow, deep sinus, its surface slightly convex, its lateral margin curved inward from the hinge line at an angle of about 65°; posterior ear depressed, its surface flat, not raised above the bottom of the sinus which separates it from the body of the shell, its lateral margin concave, posteriorly acuminate at the hinge line, larger than the anterior ear. Posterior sinus curving slightly inward, one fifth longer than the anterior sinus, which also curves slightly inward. Ventral margin broadly rounded, very nearly semicircular. Surface of this valve ornamented by sixteen fine, raised, rounded costae, half of which originate within one or two millimeters, and the other half within five millimeters, of the beak; costae separated by broad, flat spaces from two or three times their width, beyond which at the ventral margin they are slightly produced, giving the border a scalloped appearance, but without any evidence of spines at the extremities of the costae; crossing the latter are extremely fine, concentric striae, slightly imbricated, incurved and crescentic on each intercostal space, occasionally more prominent than the average with small protuberances where they cross the costae, in this respect resembling *Acanthopecten carboniferus*, but with no evidence of spines. Two radiating costae appear upon the anterior ear and the fine concentric striae cross the posterior ear parallel to its outer margin. On this ear the radiating costae are almost obsolete.

This species very nearly resembles in size, configuration, and ornamentation *Aviculopecten arkansanus* Mather, with the following differences, noted after a comparison with Mather's type specimen, kindly loaned by the Walker Museum of the University of Chicago. Our shell is depressed, its beak not full, its convexity about one half that of *arkansanus*, no concentric striae appearing on Mather's specimen, which is a cast, in a limestone matrix, of the exterior of a left valve. The absence of these striae may be due merely to their not having been preserved on the exfoliated shell. Our shell is slightly broader, proportionately, at the ventral extremity, but the ventral margin of Mather's specimen is not entire and may not exhibit the true outline. . . .

DIMENSIONS OF TWO SPECIMENS:

Height, mm.	Length, mm.	Thickness, mm.	Hinge line, mm.
7	8	1	..
9	..	1	5.5

The types of *A. eaglensis* are lost, at least temporarily. Mr. Dana Wells generously made an extensive search for them at West Virginia University, where they are supposed to be located. Price's comparison of *A. eaglensis* with *A. arkansanus* Mather was rather futile because he thought that the type of *A. arkansanus* is an external mold. It is, however, a complete left valve buried in matrix so that only the inner surface is exposed. This was particularly obvious when the holotype of *A. arkansanus* was examined under xylol. Naturally, a squeeze of the interior of the type specimen of *A. arkansanus* does not show the external shell ornamentation. *A. eaglensis* is like *A. halensis* Mather, differing principally in having a smaller angle and fewer costae. It may be that the three species *A. halensis*, *A. arkansanus*, and particularly *A. eaglensis*, were based on juvenile specimens. An exact understanding of these forms must await the discovery of further topotypes.

Occurrence.—The figured syntypes of *Aviculopecten eaglensis* (Price) are said to have been found in the Eagle limestone, of Pottsville age, at Eagle, Fayette County, West Virginia.

According to Dr. Harold Wanless (personal communication),

the Eagle limestone is in the upper Pottsville (lower Pennsylvanian) several hundred feet below the horizon of the Seville limestone of Illinois. It is considerably older than the Bevier coal section and may not be represented in the northern Mid-Continent region.

AVICULOPECTEN PHOSPHATICUS Girty

Plate 6, figure 3

Aviculopecten phosphaticus GIRTY, *1910*, U. S. Geol. Survey, Bull. 436, p. 43, pl. 4, fig. 11.

Girty's description:

Shell small, subquadrate, slightly wider than high and somewhat oblique. Hinge line longer than the greatest width.

Left valve rather strongly convex. The ears are triangular, depressed. Anterior ear oblique, more depressed than the posterior, defined in outline by a deep sinus. The posterior ear is defined from the rest of the shell by an angulation and in outline by a moderately strong sinus.

The sculpture consists of rather thin, high, abruptly elevated, subequal costae, separated by relatively very broad, flat striae. On the body of the shell the costae are 21 in number. Toward the anterior side they become more closely arranged or rather, perhaps, one or two alternating ones are introduced. The anterior ear has seven or eight fine, rather closely arranged radiating costae, but there is a space between the ear and the body of the shell which is not thus ornamented. The same is true of the posterior ear, only the space is broader and the ear is sharply defined on the body of the shell by the angulation above mentioned. The posterior ear bears six costae not so closely arranged as those on the anterior. There is also a concentric ornamentation of fine lirae much more crowded than the costae. These are conspicuous on the noncostate strip which defines or forms part of the posterior ear. They are present on the latter as well, and also on the anterior ear, but only traces of them can be seen crossing the body of the shell in the only specimens examined.

Right valve unknown.

After studying a squeeze of the holotype, there is nothing that I can add to Doctor Girty's description. The shape of this species is distinctive.

Whether or not the holotype is a normal representative of the species cannot be ascertained until additional topotypes can be obtained and described. (Holotype, U. S. Geol. Survey, No. 1,737.)

Occurrence.—Permian. The type specimen came from the phosphate beds of the Phosphoria formation, Thomas Fork, Wyo. U. S. Geol. Survey, sta. 988c.

AVICULOPECTEN? BALLINGERANA (Beede)

Deltopecten ballingerana BEEDE, *1916*, Indiana Univ. Studies, vol. 3, p. 10 (not figured).

Beede's description:

> The shell is large, nearly as high as long, rather convex, slightly oblique, with the hinge nearly as long as the shell. The ears of the left valve are large, the anterior one being separated from the shell by a rounded, rather indefinite sulcus, with considerable marginal construction below it. The posterior ear is apparently somewhat longer than the anterior one, and terminates with a sharper angle. It is less sharply separated from the shell and has a broader marginal sinus below it. The anterior ear of the right valve is separated from the shell by a deep marginal sinus extending more than half way to the beak.
>
> The body of the right valve is ovate in outline, most convex above the middle, with the beak projecting slightly above the hinge. The anterior part of the larger specimens possesses a wide zone of stronger growth marks and fainter radiating sculpturing than is found on the rest of the valve. The surface of the valve is covered with three ranks of radiating costae. The largest, eight to twelve in number, appearing at rather wide intervals, reach the beak. Between the larger costae there are from two to six smaller costae. All these ribs are split, each one being doubly carinated at its crest, or it is formed of two similar ones, giving the shell a unique appearance. These costae extend over the ears, being much stronger on the anterior one, on which seven or eight can be counted while four or five faint ones appear on the posterior ear. Both coarse and fine growth lines ornament the valve. The former are rather conspicuous and are rather widely spaced. The larger costae are very indistinctly developed on the posterior half of the shell and are quite prominent on the anterior half. There seems to be some evidence that the surface was roughened by vaulted lamellae, but not markedly so.
>
> A faint impression of the right valve shows it to be very flat. and to be marked by nearly even radiating costae of moderate size. Other characters are not well shown. Length of shell about 60 mm.; height. 51 mm.; convexity of left valve, 7 mm. Smaller specimen. hinge is 31 mm.; height of same specimen, 40 mm.; length of shell, 39 mm.
>
> This species is similar in outline and superficial appearance to *D. texanus,* Girty. from the rocks below, but its unique split-rib ornamentation and probably thinner shell separate it at once from that shell.
>
> Quarries in the west part of Ballinger, Texas, on the north side of the Colorado river.

Comparison.—There is no described species with which I am acquainted having the above characters of ornamentation. Indeed. lacking authentic specimens and illustrations of the species, it cannot be placed in any of the known generic groups.

Material.—The types appear to be lost, at least temporarily, although I have made every effort to locate them. On the other hand, the exact locality from which the types were secured is known and eventually the species may be redescribed and adequately figured on the basis of topotype specimens.

Occurrence.—Permian. Arroyo formation, quarries in the west part of Ballinger, Tex., on the north side of the Colorado river.

AVICULOPECTEN GERMANUS Miller and Faber

Plate 4, figures 13 *a, b,* 14

Aviculopecten germanus MILLER and FABER, *1892,* Cincinnati Soc. Nat. History, Jour., vol. 15, p. 81, pl. 1, fig. 9.

Small subquadrate, acline or slightly prosocline shells with large distant costae of which there are at least two orders, the second order being introduced by intercalation. The most distinguishing feature is the very shallow posterior sinus bounding the rear auricle and the resulting quadrate form of the auricle. An extraordinary fold and faint crest occurs about midway along the posterior margin of the posterior auricle. There is no distinction between the ornamentation of the posterior auricle and the shell body, but there appears to be a transition zone of ornamentation in the well-defined anterior auricular sulcus where the costae become crowded and obsolescent. No well-defined posterior sulcus, the flattening of the auricular area taking place rather gradually. The shell substance shows distinctly a rather coarse concentric crossed-lamellar structure with a poorly defined rhombic pattern.

There are growth lines in the lectotype on the outer surface of the crossed-lamellar layer, suggesting that this was the original surface of the shell and that there was no outer ostracum layer. This would be an anomalous condition in a Paleozoic pectinoid, and since the shells are somewhat worn, their original structure cannot be positively determined. One badly exfoliated specimen appears to show traces of an oblique resilifer, like that in the Aviculopectinidae, and for that reason these shells are classed as *Aviculopecten,* although their peculiar shape suggests that they might eventually prove to belong to some other group.

The lectotype exhibits a few spines along the ventral margin and particularly along the posterior part of the ventral edge. The spines are short, blunt, and are continuations of the costae. The abrupt appearance of the spines, together with a marginal weakening of the sculpture, suggests that the lectotype is a mature or even gerontic individual. The convexity on the lectotype is 2 mm. Right valve unknown.

Measurements of specimens of *Aviculopecten germanus* are given in the table on page 48.

Comparison.—There is no described American Pennsylvanian species that is likely to be confused with this one. The curious shape of the rear auricle suggests some of the Pterinopectinidae, and it is possible that better preserved specimens will show that the species belongs to that group.

Material.—The specimens before me are four syntypes (Chicago Univ., No. 8,778) generously lent me from Walker Museum by Dr. Carey Croneis. The specimens are badly preserved left valves. The best specimen, plate 4, fig. 13, is here selected as the lectotype.

Occurrence.—Upper Carboniferous. The types occur in a matrix of black, pyritiferous, fine-grained, possibly concretionary limestone. According to the labels accompanying the type specimens, they were found by Faber in Pennsylvanian rocks (lower Pennsylvanian) along Elkhorn Greek, Kentucky.

Dr. Harold Wanless writes as follows:

> I presume this refers to Elkhorn Creek in the Eastern Kentucky Coal field. This is in Letcher and Pike counties, eastern Kentucky. The marine horizons exposed there are a dark shale of the Amburgy coal, which probably corresponds with our Seville limestone of coal No. 1, Illinois, and one or two lower marine horizons. They are all upper Pottsville.

AVICULOPECTEN COXANUS Meek and Worthen

Plate 4, figure 23

Aviculopecten coxanus MEEK and WORTHEN, *1860*, Philadelphia Acad. Nat. Sci., Proc., p. 453; *1866*, Illinois Geol. Survey, vol. 2, p. 326, pl. 26, figs. 6*a*, *b*.

The holotype is a small, acline left valve especially distinguished by having an unusually long hinge extending nearly the length of the shell, and by the marked shallowness of the subauricular sinuses. The holotype has a height of 14 mm.; length, 13 mm.; hinge length, 12 mm. There are five or six costae on the rear auricle extending from the apex of the shell across the posterior auricle. There are light costae on the anterior auricle, half of which are second order intercalaries. The anterior auricular sulcus is quite smooth with no trace of costae. About 46 costae occur on the shell body in at least two and probably three orders. The umbonal angle is about 80 degrees.

Comparison.—There is no other described species that combines the small size and shallow marginal sinuses of this form. Inasmuch as it is quite rare, nothing is known of the variability of the species.

Material.—Through the generosity of Dr. J. Marvin Weller, I have had an opportunity to examine the holotype (Illinois Univ., No. 10,931) and a paratype (Illinois State Mus., No. 3,009). The paratype is apparently distorted and is too poorly preserved to be used in describing the species. Both specimens are somewhat crushed and do not retain any of the shell except traces of the outer ostracum.

Occurrence.—Upper Carboniferous. The holotype was collected from a soft, argillaceous, dark-gray shale in Adams county, Illinois, in beds of Des Moines age. According to Dr. Harold Wanless (personal communication),

> the marine section in Adams county, Illinois, includes several horizons. The highest of these would be slightly below the Pawnee limestone (of the northern Mid-Continent) and the lowest would probably be above the Tebo coal equivalent. I believe the latter horizon is more likely to have yielded this species, though I may be mistaken.

In the collections before me there is a single specimen from the Willard shale (Wabaunsee) at Nebraska City, Neb., that is remarkably like *A. coxanus*. My hesitancy in classing the Willard form as *coxanus* is based on the great age difference between the two, and the fact that I cannot be sure, in the absence of other specimens from the Willard shale, that my one specimen is a normal adult.

AVICULOPECTEN MAZONENSIS Worthen

Plate 4, figures 19-22

Aviculopecten mazonensis WORTHEN, *1890*, Illinois Geol. Survey, vol. 8, p. 117, pl. 22, fig. 9.

Moderate sized slightly prosocline aviculopectens characterized by a dorsoventral arching of the plane of the left valve indicative of a marked anterior and posterior gape; number of costae on shell body and auricles rather high; costae either narrow and separated by spaces as broad as the costae or relatively broad and closely spaced; umbonal angle rather large for the genus, ranging between 85 and 95 degrees in mature specimens; full-sized individuals commonly longer than high; immature ones higher than long. The umbonal folds and auricular sulci ill-defined, the anterior ones being somewhat more distinct than the posterior ones; surface entirely devoid of spines or projecting imbrications but ornamented throughout by unusually distinct, fine fila, 10 to 20 occurring in one millimeter; extraordinary in having a prismatic outer ostracum in both valves with the individual polygonal prisms separated rather widely by a matrix of what must have been originally conchiolin; prisms of the same order of size in both valves increasing in size with maturity. In one left valve the prisms along a mid-dorsoventral line measured 20 microns at a shell height of 3 mm., and 35 microns in diameter at a shell height of 11 mm. The convexity is moderate, of the same order as in similar species.

Measurements of specimens of *Aviculopecten mazonensis* are given in the table on page 47.

Comparison.—This species scarcely can be confused with other similar forms. The more striking features are the persistent prosocline obliquity, anterior and posterior shell gape, flatness of the umbonal folds and auricular sulci, and the high costal count. The shell structure and breadth of cardinal area are distinctive features, although these characters are less easily observed.

Material.—Through the courtesy of Dr. J. Marvin Weller and the Illinois State Museum, I have studied the holotype and a topo-paratype (Illinois State Mus., No. 2592), and a topotype (Illinois State Mus., No. 13,190). In the collections of Yale University, Peabody Mus., there are 12 topotypes of the species (Nos. 14,454-14,458). The specimens are all preserved alike, being more or less distorted and crushed. Except for an outer ostracum and traces of a periostracum, the shell substance is altered or lacking.

Occurrence.—Upper Carboniferous. The specimens occur in silty ironstone concretions associated with the famous brackish water and terrestrial fauna and flora of the Mazon Creek beds (Des Moines age), Mazon Creek, Grundy county, Illinois. Doctor Harold Wanless writes me that "these shales, with their famous fossil plants, probably belong slightly above your Tebo coal" (of the northern Mid-Continent).

AVICULOPECTEN MCCOYI Meek and Hayden

Plate 5, figure 3

Aviculopecten mccoyi MEEK and HAYDEN, *1864,* Paleontology Upper Missouri, p. 50, pl. 2, fig. 9.

The holotype is a rather small, acline left valve in which the costae rapidly increase in size during growth so that there is a very pronounced differentiation in size between alternate costae on the marginal part of the shell. On the posterior auricle there are 8 distinct costae on the dorsal half of the auricle and 9 crowded fine ones on the ventral half, making 17 in all. There are 42 costae on the shell body, of which 8 or 9 are conspicuously larger, particularly those on the middle part of the shell, and have vaulted imbrications or spine bases at irregular widely spaced intervals. The first order costae are separated by 3 or 7 smaller costae on the shell body which are introduced quite regularly. There are 9 costae on the anterior auricle, 4 of which are of the first order, the others second order. Imbricating growth near the shell margin suggests that the holotype is a full sized individual. There are traces of very fine fila on the less worn parts of the shell, about 50 occupying the space of 1 mm. near the ventral margin. The height of the holotype is 22 mm.; length, 19 mm.; hinge length, 14 mm.; umbonal angle, 85 degrees; convexity, about 5 mm.

Comparison.—Unfortunately, this species was founded on insufficient material so that the range of variability is not known. Until authentic topotypes can be obtained better to establish the characters of the species, the relative importance of the features shown by the holotype cannot be definitely established. The features which especially distinguish the holotype are the rapidly expanding spinose costae.

Material.—A single specimen, the holotype, is kept at the U. S. Nat. Mus. (No. 2,521) where I was permitted to study it by the curators of that institution. The shell is fairly well preserved, retaining most of the original shell substance.

Occurrence.—Permian. The holotype occurs in a light-gray to white oölite matrix in which there are many molds of shells. It is said to have been obtained from South Cottonwood Creek, Kansas. The horizon is probably near the Fort Riley limestone of Lower Permian age.

AVICULOPECTEN VANVLEETI Beede

Plate 5, figures 8-10

Aviculopecten vanvleeti BEEDE, *1902,* Oklahoma Geological Survey, Advance Bull., First Bien. Rept. p. 6, pl. 1, figs. 8-8*b*; *1907,* Kansas Univ. Sci. Bull., vol. 4, p. 159, pl. 5, figs. 2-2*e*.

Aviculopecten oklahomaensis BEEDE, *1907,* Kansas Univ. Sci. Bull., vol. 4, p. 158, pl. 5, figs. 3-3*c*; pl. 6, figs. 11-11*c*.

Shell of moderate size, higher than long, variable in form and obliquity from slightly prosocline to slightly opisthocline; posterior auricle slightly shorter and distinctly smaller than the anterior one; beak of left valve small, narrow and extended slightly above the hinge; umbonal angle small; posterior umbonal fold poorly defined, although there is a rather sharply defined sulcus at the inner margin of the rear auricle setting it off from the highly convex umbo; anterior umbonal fold and sulcus well defined and nearly straight in most of the specimens; an obscure radial sulcus or flattening occurs just within the posterior margin of the left valve recalling a similar but more pronounced feature in *Pseudomonotis;* from three to five of the first order costae across the middle of the shell body in many specimens are very much coarser than the others and have a knobby appearance where spines or projecting imbrications formerly occurred; the marginal costae of the shell body are not particularly coarse; spaces between coarse costae occupied by 6 to 10 closely spaced fine subequal costae; auricles covered with fine, subequal costae; hinge as in *Aviculopecten.*

Measurements of specimens of *Aviculopecten vanvleeti* are given on page 48.

Comparison.—This striking form is not very like any other species with which I am familiar. The ornamentation is similar to *A. girtyi,* but the narrow beaks, great height, small posterior auricle, and posterior sulcus on the shell body readily distinguishes the present form. *A. vanvleeti* is an

Aviculopecten, but it is certainly a nontypical one. The species *A. oklahomaensis* Beede is included in the synonymy of *A. vanvleeti* in which the ornamentation is poorly preserved and consequently indistinct. However, the first order costae in some of the types of *A. oklahomaensis* were actually finer than in *A. vanvleeti* and in some of the specimens the body costae are nearly uniform in size. The circumstance that all of the type specimens of the two species were found together, and the fact that there appears to be a gradation from forms having a few very large first order costae to those having little or no differentiation of costae into coarse and fine ones, suggests that only one species is involved.

Material.—The holotype of *A. vanvleeti* is destroyed. In the original publication of the species Beede (1902, p. 11) designated his figure 8 of plate I as the type and this specimen was subsequently destroyed (see Beede 1907, p. 142). There are three metatypes (Kansas Univ., Paleont. Type Coll., No. 363) left valves, that are clearly conspecific with his original holotype. In addition there are nine other specimens, including the type of *A. oklahomaensis*, (Kansas Univ., Paleont. Type Coll., No. 363.3) all of which I regard as representatives of *A. vanvleeti.*

Occurrence.—Permian. The specimens were found in a red calcareous sandstone composed chiefly of well-rounded and sized quartz grains. The shells are chiefly internal molds with traces of the outer ostracum preserved on one or two specimens, from Whitehorse sandstone of the Marlow formation (upper Permian), 2 miles or more southeast of Whitehorse post office, and 18 miles due west of Alva, Okla. They were taken from the top of a hill just west of the spring.

AVICULOPECTEN GIRTYI Newell, n. sp.

Plate 5, figure 4

Aviculopecten mccoyi WHITE, *1877*, U. S. Geol. Surveys W. 100th Mer., Rept., vol. 4, p. 149, pl. 11, fig. 2*a*.

Deltopecten vanvleeti GIRTY, *1909*, U. S. Geol. Survey, Bull. 3089, p. 86, pl. 9, figs. 5, 5a.

Shell rather large, having an estimated length and height of 35 mm. in the holotype; acline, orbicular; left valve moderately ventricose, subhemispherical, with large subequal auricles; umbonal folds nearly straight, the anterior one being particularly prominent and curved outward almost imperceptibly; anterior sulcus deep and broad, posterior one shallow, and narrow with its axis quite close to the body of the shell; shell body ornamented by costae of three distinct sizes corresponding to the oldest three ranks of costae, later costae are scarcely differentiated; there are on the holotype about 65 costae on the body of the shell of which 5 are quite coarse, 5 are intermediate in size, and the remaining ones are very fine and closely spaced, generally 6 of the finer ones separating the coarse first order costae from the second order; about 9 costae occur on the dorsal part of the anterior auricle and the anterior sulcus appears to be ornamented with much more obscure costae; posterior auricles with at least 8 small costae; umbonal angle 87 degrees; convexity about 7 mm.; hinge length, about 27 mm.

Comparison.—I have no hesitation in classing Girty's *Deltopecten vanvleeti* from the Manzano group of New Mexico with this species. Girty (1909, p. 86) speaks of "fine concentric, lamellose lines which tend to form scalelike spines upon the costae, the size and frequency of the costae bearing a direct relationship to the size of the costae themselves. Those upon the large primary ribs are large, producing nodes upon them, and they are a long distance apart." The single specimen on which *A. girtyi* is founded is not sufficiently well preserved to exhibit these details of concentric ornamentation. *Aviculopecten girtyi* differs from *A. vanvleeti* in the extended posterior auricles. Furthermore, *A. vanvleeti* has a markedly higher form, whereas *A. girtyi* is more nearly subcircular. *Aviculopecten kaibabensis* is similar to *A. girtyi*, but is distinguished by a large number of subequal costae, whereas *A. girtyi* exhibits a marked differentiation of coarse and fine costae.

Material.—The holotype (Texas Univ., No. 12,-310) is an incomplete left valve exhibiting very well the general character of form and ornamentation. The shell substance appears to be completely altered.

Occurrence.—Permian. The holotype was found in a gray, highly calcareous quartz sandstone, in which the separate grains are rather well rounded. This rock belongs in the middle Permian Word formation, Glass Mountains, West Texas, about 1.5 miles north 55° west of the old Hess Ranch House. Other material, described by Girty, was collected from the Permian Manzano group of New Mexico. The species is doubtfully identified in the Kaibab limestone (Permian), lower Kanab canyon, Arizona.

AVICULOPECTEN GRYPHUS Newell, n. sp.

Plate 5, figures 11*a*, *b*

This extraordinary form bears a striking resemblance to some of the Ostreidae or *Pseudomonotis*, but it is certainly a member of Aviculopectinidae. The shell is acline, with subequal auricles and deeply impressed auricular sulci, both of which curve outward slightly and equally. Well-defined umbonal folds are lacking because of the uniform and low convexity of the umbonal slopes. The remarkably convex beak is acute and narrow, extending distinctly above the hinge. A striking sulcus extends from beak to shell margin along the posterior part of the shell body, producing a posterior lobation like that of *Pseudomonotis* and most Ostreidae. The ornamentation consists of 9 or 10 coarse first order costae separated by conspicuously smaller costae of two or three higher orders.

Measurements of *Aviculopecten gryphus* are given in the table on page 48.

Comparison.—This species is like *A. vanvleeti* Beede in having a narrow, projecting beak. It may be readily distinguished from the latter by the very deep and curved auricular sulci, greater convexity, larger posterior auricle, and more numerous coarse first order costae. Furthermore, the anomalous posterior sulcus of the shell body is very much more pronounced in *A. gryphus* than in *A. vanvleeti.* The form of the auricles and character of the ornamentation in *A. gryphus* are typical for *Aviculopecten.* The extraordinary production of the beak, and the posterior sulcus of the shell body, together with the rather high convexity, suggests some genus like *Pseudomonotis. Pseudomonotis* is especially distinguished by the absence of an extended posterior auricle, which in the present species is acute and fully developed.

Material.—The species is based on a dozen fragmentary specimens, all of which belong to left valves (Texas Univ., No. 12,311). The preservation is not good; consequently further details of the finer ornamentation may be discovered when better material is collected.

Occurrence.—Middle Permian. The types occur in a gray matrix of hard siliceous limestone with fragments of brachiopods and fusulinids, Word formation, Glass Mountains, West Texas, 1.5 miles north 55° west of the old Hess Ranch House.

AVICULOPECTEN? COREYANUS White

Plate 5, figures 1, 2

Aviculopecten coreyana WHITE, *1874,* U. S. Geog. Surveys W. 100th Mer., Prelim. Rept. Invertebrate Fossils, p. 21.

Aviculopecten coreyanus WHITE, *1877,* U. S. Geog. Surveys W. 100th Mer., Rept., vol. 4, p. 147, p. 11, figs. 2*a*, 6.

Deltopecten coreyanus GIRTY, *1909,* U. S. Geol. Survey, Bull. 389, p. 87.

Shell large, acline, orbicular, with an extraordinarily long hinge margin for an *Aviculopecten;* umbonal slopes, particularly the posterior one, poorly defined; anterior sulcus well differentiated, but the posterior one broad and shallow, with its axis near the middle of the auricle; shell surface of the left valve ornamented by a large number of intercalate, closely spaced costae, about 65 occurring on the shell body, 8 to 12 on the anterior auricle and somewhat less on the posterior auricle; umbonal angle in the type specimens about 85 degrees. Regarding the right valve, specimens of which are lacking in the type collection, Girty (1909, p. 88) says, "This is considerably less convex than the left, but by no means entirely flat. It has almost the same shape as the other, the byssal sinus being not as deep as in some species. The surface, I am inclined to believe, is destitute of any radial markings but crossed by fine lines of growth, some of which are sublamellose." Girty (1909, p. 88) was also able to examine the hinge of some specimens of *A. coreyanus* from the Permian Manzano group of New Mexico. "*D. coreyanus* proves to have a broad beveled cardinal area, with triangular cartilage pit beneath the beaks."

Comparison.—This species recalls some of the elongate Pterinopectinidae in the great shell extension below the auricles. However, Girty's observation on the hinge characters of the species indicate that it is in reality one of the aviculopectinids. I have not seen a right valve of the species, but if the right valve is truly devoid of any radial ornamentation, the species cannot be a true *Aviculopecten.*

Occurrence. — Permian, Manzano group, New Mexico. The types (U. S. Nat. Mus., No. 8,522) are said to have been collected 1 mile south of Pajuate, N. M., east of Mount Taylor.

AVICULOPECTEN HALENSIS Mather

Plate 5, figures 5, 6

Aviculopecten halensis MATHER, *1915,* Denison Univ., Sci. Lab. Bull., vol. 18, p. 223, pl. 15, fig. 17.

Aviculopecten arkansanus MATHER, *1915,* Denison Univ., Sci. Lab., Bull., vol. 18, p. 226, pl. 15, fig. 13.

This species is known from very small gibbous left valves, which, because of their small size, inflation, and a very marked yet fine filose ornamentation, resemble somewhat the juveniles of other species, and, indeed, lacking sufficient material, it is not easy to prove that they are not juveniles. The flaring curvature of the anterior umbonal slope, however, suggests that the types are approaching maturity. These shells appear to be acline and are ornamented with narrow high costae arranged in three ranks, separated by interspaces three to four times their own width. The posterior body costae is no larger than the other first order costae so that the posterior umbonal fold is rather obscure and broad. The costae are capped by imbricating scales produced where fine fila cross them. Costae are almost completely absent along the inner part of the anterior sulcus.

Through the courtesy of Dr. Carey Corneis of the University of Chicago, I have been able to compare directly the types of *A. arkansanus* and *A. halensis,* and it seems probable that they belong to the same species.

The holotype of *A. arkansanus* Mather, Walker Museum, Univ. Chicago (No. 16,053), is a nearly complete left valve with the outer surface imbedded in a matrix of dark-gray oölitic limestone. It was implied from Mather's description, and stated by Price (1916, p. 720), that this specimen is an external mold. This interpretation is incorrect as even a cursory examination of the specimen under xylol shows. The valve is truly a plicate one, and the original inner surface retaining the hinge is intact. An examination of the ventral margin shows that the outer ornamentation consists of at least two orders of distant, elevated costae. With the aid of xylol 20 body costae, of which at least 9 are intercalaries, can be seen. At least 4 costae on the anterior auricle and 5 on the posterior one are visible through the shell. There is a well-defined cardinal area, like that of other aviculopectens, and the margin of a resilifer can be seen at the middle of the exposed part of the area. The specimen was found in the Hale formation, East Mountain, Fayetteville, Ark., at nearly the same horizon as the types of *A. halensis*. Although it cannot be proved that *A. arkansanus* is synonymous with *A. halensis*, it seems quite likely that the two are the same.

Measurements of specimens of *Aviculopecten halensis* are given in the table on page 48.

Comparison.—*Aviculopecten halensis* Mather is distinguished especially by the combination of the following characters: number and character of the costae, the imbricating scales of the costae, number of anterior costae, ill-defined posterior umbonal slope, absence of costae on the inner part of the anterior auricular sulcus, and the small size of the shell. The larger number of costae and greater umbonal angle distinguishes this species from the similar *A. eaglensis* (Price).

Material. — The types of *A. halensis* Mather (Walker Museum, Univ. Chicago, No. 16,051) consist of six fragmentary specimens, external molds of left valves, in a silty, black and gray, noncalcareous shale, associated with molds of Bryozoa.

Occurrence.—Upper Carboniferous. Hale formation, Morrow subseries, East Mountain, Fayetteville, Ark.

AVICULOPECTEN FLABELLUM (Price)

Plate 11, figures 1-4

Deltopecten flabellum PRICE, *1916,* West Virginia Geol. Survey, Rept. on Raleigh, Mercer, and Summers counties, p. 720, pl. 31, figs. 3-6.

Shell rather small for the genus, acline or only slightly prosocline, suborbicular, slightly longer than high; anterior auricle quadrate or acute, sharply depressed below the shell body, set off by a narrow sulcus in which there are rarely any transitional costae; posterior auricle poorly differentiated from the shell body by a shallow and broad sulcus which nearly covers the entire auricle; outer margins of each auricle indented in a broad, shallow sinus; surface ornamented with broad costae, closely spaced, which increase by implantation on the left valve, by bifurcation on the right; crossed by obscure fine fila spaced up to 0.1 mm. apart; costae on shell body tend to be coarser across the middle area, progressively become weaker toward the front and rear margins of the shell, and curve slightly outward from a mid-line of either valve; anterior auricle generally with two to four costae, posterior one possessing up to three. There is a well-defined cardinal costa on either auricle.

Measurements of *Aviculopecten flabellum* are given in the table on page 48.

Comparison.—This species has the general expression of a *Dunbarella,* but differs in the extended and acute rear auricle and in possessing filose ornamentation on the better preserved shells. Since the hinge structures are unknown, this species may conceivably belong with the Pterinopectinidae.

The salient features that most readily distinguish this species from similar aviculopectens are: the angular anterior auricle of the left valve, coarse costae, and the elongate form of the shell.

Material.—The figured types of this species could not be located, but through the generosity of Mr. Dana Wells at West Virginia University, I have had an opportunity to study 30 of the syntypes of the species. The types are at West Virginia Univ., Coll. Nos. 507, 509, 638, 634, 637, 635 and 636. They are for the most part poorly preserved molds of the inner surface of the outer ostracum layer. A few specimens retain part of the outer ostracum, but in no instance is there any trace of the inner ostracum. Several localities and horizons are represented in the collection.

Occurrence. — Upper Carboniferous. Kanawha group, upper Pottsville, roof shale of the Little Eagle Coal, hillside northwest of Oceana, and along Cedar Creek of the Clear Fork of the Guyandot, Wyoming county, West Virginia; Cannelton limestone, roof of the Matewan coal, Kanawha group, Huff Creek, 0.5 mile north of the mouth of Laurel Branch, 1.4 miles south of the corner of Wyoming, Logan, and Boone counties, West Virginia. The specimens occur in a matrix of light- to dark-gray silty shale somewhat carbonaceous.

AVICULOPECTEN KAIBABENSIS Newell, n. sp.

Plate 4, figures 17, 18

This is a robust orbicular *Aviculopecten,* easily distinguished from other North American species. The individuals attain a relatively large size with a maximum height and length of at least 60 mm. The convexity is quite marked, so that mature left valves are subhemispherical. The right valve is unknown. In addition to the large size, the species, unlike most aviculopectens, is characterized by an almost complete absence of a posterior umbonal fold. The ornamentation is characteristic, consisting of a relatively large number of moderately coarse, closely spaced costae, numbering at least 85 on the shell body of a specimen having a height of 60 mm. The anterior umbonal fold is only slightly curved outwardly so that the umbonal angle is only moderately flaring. Both auricles are costate, but the anterior one is poorly shown in the material at hand. The posterior auricle is ornamented differently from the shell body, and the juncture of the posterior auricle with the shell body defines the rear margin of the umbonal angle. The costae on the rear auricle, numbering 12 or 15, are widely spaced and relatively narrower than those on the general shell surface.

Measurements for the holotype

Height	60 mm.
Length	60 mm.
Umbonal angle	91 degrees
Convexity	13 mm.
Body costae	85

Material.—The species is based on three specimens, including the holotype, all from a single locality. Types, Kansas Univ. Paleont. Type Coll., Nos. 361.1, 361.2.

Occurrence.—Permian, upper part of the Kaibab limestone in yellowish, porous dolomitic limestone associated with innumerable molds of other mollusks, (*Bellerophon* beds), Padre Canyon, on main highway east of Flagstaff, Ariz.

AVICULOPECTEN BELLATULUS Newell, n. sp.

Plate 5, figure 16

This species is very like *A. gradicosta* and, indeed, probably is a descendent of the Pennsylvanian form. Although there is only a single specimen, a left valve, of the new species at hand, its characters are such that it can be readily recognized. It differs from *A. gradicosta* in the greater number of costae at a comparable growth stage. At a height of 22 mm. there are 93 costae of which 6 are transitional on the anterior umbonal fold, whereas in *A. gradicosta* there are only 62 to 66. There are 8 relatively coarse first order costae which are coarsely spinose, separated by 14 or 15 finer costae in two orders. The holotype has a height of about 25 mm., length about 23, and a hinge length of around 22 mm. There are 9 distinct costae on the posterior auricle and at least 11 on the incomplete anterior auricle. The umbonal folds are nearly straight and diverge at 80 degrees. The convexity ratio is about 0.20.

Material.—This beautiful little species is based on a good external mold of a left valve. The holotype is Kansas Univ. Paleont. Type Coll., No. 364.

Occurrence.—Permian, upper part of Kaibab limestone in brown dolomitic limestone, filled with molds of shells, chiefly mollusks, (*Bellerophon* beds), Padre canyon, at highway east of Flagstaff, Ariz.

AVICULOPECTEN SUMNERENSIS Newell, n. sp.

Plate 6, figures 17, 18

A robust *Aviculopecten* is common in the Summer group of the Big Blue series in Kansas. For a time, I was disposed to class this form with *Aviculopecten basilicus*, n. sp., which it closely resembles. There are a few specimens associated with typical representatives of the new species which could not be readily distinguished from *A. basilicus,* and I am open to criticism in establishing two new names for forms which many discriminating paleontologists would prefer to class as a single species. *Aviculopecten basilicus* is found several hundred feet below *A. sumnerensis,* in the Douglas group, and similar forms have not been found in the intervening Shawnee and Wabaunsee groups. A dozen specimens of *A. sumnerensis* from the Sumner group could be distinguished from a like number of specimens of *A. basilicus* from the Douglas group.

Superficially the two forms are exceedingly alike. Both are relatively large and robust, commonly having a height and length of about 40 mm.

Measurements of specimens of *A. sumnerensis* are given in the table on page 47.

In most of the left valves of *A. sumnerensis* there are but 8 or 9 costae visible on the front auricle, whereas there are generally 11 on specimens of *A. basilicus.* This distinction is not emphasized here, however, because all of the specimens of *A. sumnerensis* are subinternal molds and the ornamentation is correspondingly weak so that costae cannot accurately be counted. Many of the specimens of left valves show incipient bifurcation of the coarser costae at a height of more than 30 mm., but this habit is not constant and there are many specimens in which there is no trace of such bifurcation.

The chief character by which good collections of *A. sumnerensis* can be distinguished from *A. basilicus* is the size of the umbonal angle. In my specimens of *A. basilicus* a maximum of 90 degrees was measured, whereas an angle of more than 95 degrees was measured in a number of specimens of *A. sumnerensis.* It seems proper that the average size of the umbonal angle should be greatest in those specimens which are geologically youngest because during the ontogenetic change of any *Aviculopecten,* there is a continuous increase or flare in the umbonal angle reaching a maximum at maturity.

Through the generosity of the Texas Bureau of Economic Geology, I have before me five fragmentary specimens of a large *Aviculopecten* that I am tentatively identifying with *A. sumnerensis*. The specimens are labeled *Limipecten* n. sp. Beede, 1909. These specimens came from limestone quarries in the Arroyo formation at Ballinger, Runnels county, Texas. These specimens were at first regarded as topotypes of *Aviculopecten ballingerana* Beede, the primary types of which are lost. Unfortunately, Beede's specimens were never illustrated. He sought to distinguish his species by a marked bifurcation of the costae of the left valve. The material at hand from Ballinger is well enough preserved to show that none of the costae of the left valves bifurcate. There are no specimens of *A. sumnerensis* before me in which the bifurcation is at all marked, and partly for that reason, in addition to the fact that too little is known of Beede's species, I have deemed it unwise to revive the term *ballingerana* when there is no assurance that the original types were even members of *Aviculopecten* s. s.

Material.—The species is based on a large number of subinternal molds, chiefly from one horizon, the Herington limestone. Holotype, Kansas Univ. Paleont. Type Coll., No. 371.1.

Occurrence.—Lower Permian. Common in the Herington limestone (Big Blue series) in Kansas and Nebraska. The holotype was found by M. K. Elias at this horizon 1½ miles southeast of Spence siding, Washington county, Kansas. Other specimens were found in the Arroyo (lower Permian) formation at Ballinger, Tex. (Texas Bur. Econ. Geology, No. 9,876), and in the Krider, Burr, and Fort Riley limestone, and doubtfully from the Florena shale, all from the lower Permian Big Blue series.

AVICULOPECTEN PECULIARIS Newell, n. sp.

Plate 6, figures 11-12*b*

There is no form to my knowledge that might be confused with this unorthodox *Aviculopecten.* It is remarkable in having an extraordinarily convex left valve when viewed dorsally, whereas the right valve is markedly concave when viewed dorsally or ventrally. There is no other *Aviculopecten* that has a concave right valve, but I have no hesitancy in assigning this form to the genus. Although the specimens at hand are internal and subinternal molds, there are low prominences marking the former site of rather coarse spines that originated from the larger costae. The posterior umbonal slope is so ill-defined that a measurement of the umbonal angle is impracticable. There is no evidence of costae on the rear right and left auricles. Owing to poor preservation, a precise count of the body costae is difficult, but in several specimens the count ranges between 40 and 50 for specimens having a height of around 3 to 4 cm. The ligament area is relatively broad, having a breadth of nearly 2 mm. in one specimen having a hinge length of about 23 mm.

Material.—The species is based on nearly a score of specimens, all internal or subinternal molds, and all from one horizon, but representing several localities in northern Kansas. The holotype, (Kansas Univ. Paleont. Type Coll., No. 368.1), as well as most of the paratypes, come from the Fort Riley limestone 1 mile east of Marysville, Kan.

Comparison.—There is no other *Aviculopecten* with which this form may be confused. The high antero-posterior convexity of the left valve, and corresponding convexity of the right valve, are distinctive.

Occurrence. — Lower Permian. Buff, dolomitic limestone, filled with molds of shells chiefly mollusks, Fort Riley limestone, Big Blue series, Kansas.

Genus LIMATULINA De Koninck, 1885

Limatulina De Koninck, *1885,* Faune des Calcaire Carbonifère de la Belgique, Lamellibranches, p. 243.

Genolectotype, *Limatulina radula* (De Koninck), Viséan, Belgium.

Original diagnosis: Coquille inéquivalve, obliquement ovale, plus haute que longue; valve droite un peu moins convexe et un peu plus petite que la gauche; crochets distants, faiblement bombés séparés par une aréa occupant toute la longueur du bord cardinal; oreillettes antérieures petites, nettement définies; celle de la valve gauche plus ou moins renflée, tandis que celle de la valve droite est plane et accompagnée d'une fente étroite destinée au passage du byssus; le restant des bords libres des valves hermétiquement clos; surface garnie de côtes rayonnantes plus or moins épaisses, ordinairement rugueuses ou traversées par des plis concentriques formant avec elles un réseau plus ou moins régulier.

A genotype was not selected by De Koninck, nor, as far as I can learn, by later writers. The genosyntypes were *Limatulina etheridgei* De Koninck, *L. selecta* De Koninck, *L. linguata* De Koninck, *L. heberti* De Koninck, *L. radula* De Koninck, and *L. loricata* De Koninck. It does not appear to me that all of these shells are congeneric, even allowing for De Koninck's unsatisfactory descriptions and misleading illustrations. It has not been possible for me to examine authentic specimens of any one of these species. One species, *L. radula,* resembles the juvenile stage of *Aviculopecten,* and, according to De Koninck's description, the type of this species possesses intercalate costae on the left valve and bifurcate costae on the right valve. He described the ligament area as being smooth, so, in all probability, it is one of the Aviculopectinidae. Highly probable, also, is the conclusion that *L. radula* is a true *Aviculopecten,* whereas some of the other species most certainly are not. I propose here to designate *L. radula* (De Koninck) (see fig. 9, pl. 7) as the genolectotype of *Limatulina*, thus placing a poorly known and troublesome genus in synonymy with *Aviculopecten*. When De Koninck's material is critically restudied, it may develop that *L. radula* is not an *Aviculopecten*, but at the present time it appears to me very probable that *L. radula* was based on juveniles of some larger species of *Aviculopecten*.

Genus DELTOPECTEN Etheridge, Jr., 1892

Plate 8, figures *6a-d*

Deltopecten Etheridge, Jr., 1892, in Jack and Etheridge, Jr., Geology and Palaeontology of Queensland and New Guinea, p. 269.

Genotype, *Pecten illawarensis* Morris, Permian, New South Wales, Australia.

Original diagnosis: Shell possessing the general structure of *Aviculopecten*, but the valves are very inequivalve, the larger or convex valve with a high overcurved umbo, overhanging a long triangular hinge area, with longitudinal cartilage furrows, and a large deltoid-triangular cartilage pit.

The term *Deltopecten* has come to be applied in recent years, incorrectly I believe, to a large proportion of the Carboniferous Pectinacea. For the past 80 years, following McCoy's diagnosis of *Aviculopecten*, paleontologists have thought that *Aviculopecten* is characterized by the presence in each valve of a smooth, flat, ligament area devoid of a resilifer. No such structure is known in any of the modern Pectinacea or Pteriacea, nor in any other modern or fossil group. Confusion was added when James Hall amended the original diagnosis to include pectinoid forms with or without resilifers or having a grooved ligament area. According to Hall's interpretation, the genus *Aviculopecten* was classified largely on the basis of form and ornamentation, with no regard to the cardinal structures. The presence of a median resilifer in an aviculopectinid shell was regarded as such a novelty, even 40 years after McCoy's diagnosis, that Etheridge was impelled to erect the genus *Deltopecten*, distinguished mainly by having a large median resilifer below each beak. As early as 1866, Meek (Meek and Worthen, 1866, p. 331) had noted a similar hinge arrangement in *Aviculopecten occidentalis* (Shumard), but he had placed no particular importance on his discovery, and, consequently, it did not become generally known. In 1904, Girty (p. 721) described some exceptional specimens from Texas showing a broad, smooth ligament area and central resilifer. He based the new genus *Limipecten* on these specimens, supposing it to be distinguished from *Aviculopecten* by the presence of the resilifers. On learning that *Deltopecten* previously had been erected on the same basis, he abandoned *Limipecten* and referred many of the Carboniferous and Permian species of pectinoids to *Deltopecten*.

As a result of the present investigation, it has developed that all of the true aviculopectens, including many quite diverse shells, have a shallow central resilifer, similar to that of modern *Lima* or *Pinctada*. Obviously, other characters than the mere presence or absence of resilifers are needed to differentiate the Paleozoic pectinoids.

No reasonable effort has been spared in attempting to learn the exact characters of *Deltopecten*. Yet, in absence of specimens of the genotype species, some of the significant features still remain unknown. Through the generous coöperation of the curators at the British Museum, I have been enabled to study excellent casts (see pl. 8, figs. *6a-d*) of the holotype of *Pecten illawarensis* Morris. A restudy of the type specimen seemed important because Etheridge (Etheridge and Dun, 1906, p. 25) himself was not sure of his identification of the species on which he based *Deltopecten*. The type specimen shows that the shell was extraordinary in being truly plicate, having a few large, simple, rounded plications that normally do not increase in number during growth. The ornamentation is nearly alike on both valves, and the plications interlocking at the margin, as in many modern Pectinidae. No American Carboniferous shell of my acquaintance has this kind of ornamentation. Another feature, not shown by the fragmentary holotype, but one which seems to exist in many of the Australian pectinoids, is the coarse linear ligament furrows that occur on the ligament area of each valve. It seems curious that several of the Australian shells with diverse ornamentation have been described as having ligament grooves in addition to resilifers. It is futile to speculate on these characters until detailed descriptions and figures are available to show the ligament area in several of the species, especially *Deltopecten illawarensis*, or one of the other species having simple plications.

Dr. Leslie Bairstow, of the British Museum, has generously supplied the following observations on the type specimen of *Deltopecten illawarensis* (Morris):

We have the type specimen of *Pecten illawarensis* Morris, registered No. 96,893. The two valves are in apposition. The specimen is incomplete, as represented in Pl. XIV, Fig. 3, of Morris in Strzelecki; being truncated where it reaches the eroded surface of the containing rock. The specimen is in three portions: an internal mold, with some flakes of shell adherent to it, and two counterparts, with much of the flaky lamellar shell adherent to them. Pl. XIV, Fig. 3, represents the internal mold, together with the pair of apposed ears, which are both adherent to one of the counterparts, and not attached to the internal cast. Most of the hinge-line is missing, only the one ear of each valve being preserved; and as these two ears are in apposition, their internal surfaces are concealed.

The ribs are folds of the shell, and show strongly both on internal and external molds. To a first approximation, the number of ribs remains constant through the successive growth stages, from a very early stage. In the later growth layers, some of the ribs come to have flattened crests; and further, in one or two cases, a faint longitudinal hollow develops along this flattening, suggesting incipient bifurcation. The two or three ribs that start in closest proximity to the preserved ear of each valve are undulations of smaller amplitude than that of the other ribs visible, and one or two of these "lateral" ribs seem to have arisen by intercalation. Judging from those parts of the external molds that are free from flakes of shell, the external surface of the shell shows the growth layers, and (scarcely visible to the unaided eye) a finely granular pattern resembling engine-turning. The internal mold is smooth and polished.

The matrix of the counterparts contains portions of two other valves of *Pecten,* apparently of the same species; but neither of these is more completely preserved than the type specimen.

As so much, e. g. of the hinge-line, is missing, the type-specimen of *Pecten illawarensis,* taken alone, does not exhibit all the characters required for a complete diagnosis of *Deltopecten.* But, in my opinion (for what it is worth—I have not worked on lamellibranchs), if further material could be obtained from the type locality, it should be possible to decide its identity or otherwise with the type-specimen of *P. illawarensis,* which seems fairly distinctive.

The only provenance-information on the original label with the specimen is "Illawara." The matrix is a reddish-brown to grey, slightly micaceous, finely granular, impure limestone, with some still finer textured inclusions. The Pecten shells are of flaky calcite, colour variable from white to yellowish-brown and brown. In the matrix of one counterpart there is a minute gastropod.

Several large pectinoids from the Permian of southeastern Australia occur in the Dana collection at the U. S. National Museum. Although these forms all fall in the genus *Deltopecten* as generally employed, I believe that they represent several genera, because they display several fundamentally different types of ornamentation.

Some of the National Museum specimens exhibit striated or deeply grooved ligament areas. In order to learn whether or not these grooves are chevron grooves, comparable to those of *Arca,* or are merely irregular varices of growth, I appealed to Mr. F. Stearns MacNeil of the U. S. Geological Survey. Mr. MacNeil has communicated this opinion:

> In the forms you inquired about the grooves on either side of the chondrophore are not ligament grooves. The chondrophore is very large and slightly oblique, and the grooves, although not exactly horizontal, are clearly growth lines—or rather, say, the eroded edges of successively deposited layers.

As far as I can learn, *Deltopecten* s. s. is restricted to Middle and Upper Permian rocks of the eastern hemisphere. In addition to the genotype *D. illawarensis* (Morris), *Aviculopecten mitchelli* Etheridge and Dun, and *A. squamuliferus* Morris, from the Middle Permian of Australia, are representatives of *Deltopecten.* The Upper Permian species, *Aviculopecten jabiensis* Waagen, *A. derajatensis* Waagen, *A. subexoticus* Waagen, and *A. pseudoctenostreon* Waagen, from the Salt Range of India, are representatives of *Deltopecten.*

Probably *Deltopecten* had its origin during the Pennsylvanian or Early Permian in *Acanthopecten,* the only other Paleozoic pectinoid thus far recognized that has a constant number of costae during growth.

Genus FASCICULICONCHA Newell, n. gen.

Acline, truly pectiniform, symmetrical shells characterized by having the intercalate costae of the adult left valve arranged in fascicles that are separated by broad, generally smooth interspaces, rarely having faint costellae within them. Costae commonly arranged in three ranks, less commonly four, of which the first two are like those in *Aviculopecten,* showing no tendency towards fasciculation; third and fourth series introduced by intercalation in close position to the older series, producing the bundling characteristic of the genus. Auricles ornamented by fine, widely spaced nonfascicled costae which increase by intercalation; auricle sulci broad, shallow, with axis close to the shell body. Umbonal folds subangular, narrow, prominent. Surface of shell body covered with fine, somewhat irregular fila which generally lose their distinctness on the auricles and over the adult part of the shell; these fila produce small projecting imbrications where they cross the costae. Musculature apparently like that of *Aviculopecten.* Resilifers similar to that of *Aviculopecten,* but differing slightly in the shape of its front margin, which diverges outward from the beak until an intermediate growth stage is reached; then the margin is recurved posteriorly so that the anterior termination of the resilifer is a rounded V-shaped margin, midway between the dorsal and ventral edges of the ligament area. There is a very marked dorsoventral curvature of the shell margin in the type species, which is suggestive of either a pronounced anterior and posterior gape. Right valve ornamented similarly to *Limipecten,* with relatively fine costae which increase in number during ontogeny by implantation of new costae at the shell margin. Shell micro-structure like that of *Limipecten,* from which the genus apparently was derived.

Genotype.—Fasciculiconcha knighti Newell, n. sp.

Range.—Des Moines to lower Virgil subseries, Upper Carboniferous (Pennsylvanian series).

MEASUREMENTS OF SPECIMENS IN SPECIES OF *Fasciculiconcha*

Species.	Specimen.	Length, mm.	Height, mm.	Hinge length, mm.	Umbonal angle, degrees.	Convexity, mm.	Auricular costae. Anterior.	Auricular costae. Posterior.	No. fascicles.	No. body costae.
knighti	L1	67	70	41	96±	23	12	7	23	72±
	L2	60	62	....	90±	16	....	8	21	72±
	L3	75	75	....	89±	16	....	10	26	87±
	L4	54	57	31	85±	15.5	13	13	24	72±
	L5	68	70	38	100	17	9+	8±	31±	100±
	L6	64	61	38.5	95	16	....	....	25±	....
	L7	67	61	44	89	15	....	....	27±	....
	L8	70±	75	49	94	20	13	10	26±	109±
	L9	27	29.5	19	86	6	12	8	20	59±
providencensis	L1	47	44±	28±	94	10	....	....	30	95±
	L2	48	48	....	90	....	....	....	25±	....
scalaris	L1	21	23	17	89	low	8	7±	24±	56±

FASCICULICONCHA KNIGHTI Newell, n. sp.

Plate 6, figures 19*a-c*; Plate 7, figures 1-3, 5, 6; Plate 8, figure 2*a*, *b*

Aviculopecten fasciculatus KEYES, *1894*, Missouri Geol. Survey, vol. 5, p. 113, pl. 42, fig. 7 (not *A. fasciculatus* Hall, 1883).

Orbicular large shells, about as high as wide; hinge slightly shorter than the shell length; anterior umbonal fold curved outward moderately, posterior one nearly straight, curved very slightly inward or outward but never markedly so; margin of anterior auricle rounded in a broad sinus, sigmoidally recurved at hinge; rear auricle angular, with the form of an inverted isosceles triangle, the hinge margin being slightly longer than its sides; especially characterized by a marked dorsoventral outward curvature of the valve margin, suggestive of a strong anterior and posterior gape; arching so marked in some specimens as to make them subhemispherical, with the dorsal part of the auricles curved inward at a steep angle to the plane of the valve margin; umbonal angle generally between 90 and 100 degrees, commonly 10 or 12 slender costellae with wide interspaces on the anterior auricle and 8 or 10 on the posterior auricle; axis of auricle sulci is close to the shell body, marked by smooth areas, devoid of costellae; right valve unknown.

The largest specimen known to me, a topoparatype (U. S. Nat. Mus., No. 89,092), has a length of 92 mm. and a height of 100 mm.

The species is dedicated to Dr. J. Brookes Knight.

Measurements of specimens of *Fasciculiconcha knighti* are given in the table above.

Comparison.—This species is readily distinguished by its pronounced gape, straight or nearly straight posterior fold, high convexity, and relatively broad interspaces between fascicles.

Material.—The species is based on 17 fine specimens, left valves, from the Westerville oölite at Kansas City. The preservation is good, but the original shell substance appears to be altered. Holotype, Kansas Univ. Paleont. Type Coll., No. 372.1; topoparatypes, Kansas Univ. Paleont. Type Coll., No. 372, and Yale Univ. Peabody Mus., No. 8,147, 14,466M, and U. S. Nat. Mus., Nos. 80,337, 46,377.

Occurrence.—Upper Carboniferous. Westerville oölite, Kansas City region; Sniabar limestone, 1 mile south of Harrisonville, Mo.; Bethany Falls limestone, 2 miles west of Oreapolis, Neb.; Cherryvale shale, 4½ miles south of Bethany, Mo.; Merriam limestone, sec. 8, T. 10 S., R. 23 E., Kan. The species is most common in the Westerville oölite, but it is nowhere abundant. One or two fragments, provisionally referred to the species, were found in the Oread limestone, but all other occurrences are in the Missouri subseries, Pennsylvanian.

FASCICULICONCHA SCALARIS (Herrick)

Plate 7, figure 4

Aviculopecten scalaris HERRICK, *1887,* Denison Univ. Sci. Lab., Bull., vol. 2, p. 26, pl. 1, fig. 8.

The holotype of *F. scalaris,* which I have seen, appears to preserve the original surface of the shell, and there are conspicuous differences in ornamentation between this and other fasciculiconchas. The ornamentation in *F. scalaris* has the fascicled costae of the genus, but the regular concentric fila, so characteristic of *F. providencensis,* are lacking in this shell. *F. scalaris* has a relatively low convexity, the general form of the shell suggesting *Aviculopecten* rather than *Fasciculiconcha.* I am not satisfied that the lateral costae of individual fascicles are intercalaries, as they are in other fasciculiconchas. The lateral costae appear to rise from the older ones by fission, but this cannot be determined positively from the single specimen at hand. The species *Aviculopecten basilicus,* n. sp. shows a tendency toward such a fission of first order costae at a late growth stage, and it is possible that a similar kind of ornamentation characterizes *F. scalaris.* A character shown by the holotype, probably accentuated by distortion, is an extraordinarily abrupt, narrow sulcus at the base of the anterior auricle, and the auricle rises abruptly above the depressed sulcus. A further study of this species, based on topotype specimens, is needed.

Measurements of the holotype of *F. scalaris* are given in the table on page 65.

Comparison.—This species, if restricted to forms like the holotype, is characterized by a nearly straight posterior umbonal slope, and by very irregularly fascicled, apparently smooth costae. The concentric undulations, thought by Herrick to distinguish the species particularly are probably abnormalities of growth or preservation.

Material.—A collection of Flint Ridge (Ohio) fossils, presented to the National Museum by the late Dr. August Foerste, contains a specimen that is almost certainly the holotype of *A. scalaris.* The original figure of the holotype indicates a nearly complete left valve, whereas the present specimen is broken and fragmentary, otherwise the specimen is like the figure in having the same shape and size. A label, fastened to the specimen, reads: "Plate 1, Fig. 8, *Av. scalaris* Herr., Bald Hill."

Occurrence.—Upper Carboniferous. Lower Mercer limestone, Pottsville, at Bald Knob (formerly called Bald Hill) about 2 miles southeast of Newark, Ohio.

FASCICULICONCHA PROVIDENCENSIS (Cox)

Plate 7, figures 7, 8; Plate 8, figures 1*a, b*

Pecten providencensis Cox, *1857,* Geol. Rept. Kentucky, vol. 3, p. 566, pl. 8, fig. 1.

This species is similar to *F. knighti* but can be distinguished readily by certain distinctive characters. The posterior umbonal fold flares outward about equally with the anterior one and the costae tend to swing outward on either side of a midline; there is no marked dorsoventral arching of the shell margin, and if there was originally a shell gape, it must have been slight; increase of costae in the adult stage becomes irregular, so that the fascicles are not uniform, a fanning or spreading out of the component elements of each fascicle occurring near the margin; fine but prominent, regular fila cross both costae and interspaces on the shell; interspaces between fascicles distinctly narrower and shell size ordinarily less than in *F. knighti;* convexity only moderate.

This description is particularly incomplete because the specimens of this species available for the present study are all fragmentary and poorly preserved. All of the material at hand, which is from Des Moines beds, and the published descriptions of specimens of this age, appear to have the above characters. It is highly probable that better material would permit distinction of several species of Des Moines age, but all can be distinguished readily from younger forms by the above characters. Cox's type is lost, but its locality and exact horizon (Allegheny) are known, so that topotypes may be secured.

Measurements of specimens of *F. providencensis* from Brazil, Ind., are given in the table on page 65.

Comparison.—This species is so distinctive that it need not be confused with the other two American forms, *F. knighti,* n. sp., and *F. scalaris* (Herrick).

Material.—The type of *F. providencensis* is lost and topotypes have not been available for the present study. Hypotypes that furnished basis for part of the above description are three poorly preserved specimens in the U. S. National Museum (No. 80,-338) retaining part of the outer ostracum, and several fragmentary specimens collected from Des Moines beds at widely separated localities.

Occurrence.—Upper Carboniferous. According to present information, the species is restricted to the Des Moines subseries, Pennsylvanian series. The holotype was found at Providence, Hopkins county, Kentucky, in the limestone which overlies the main coal (No. 11) at that place. This horizon belongs in the upper part of the Allegheny formation. Dr. Harold Wanless, of the University of Illinois, writes me that "this is the same as the cap of the Lexington coal (Labette shale) in western Missouri."

Material that I have seen came from Des Moines beds at the following places: Brazil, Ind. (label reads "V shale Otter"); regarding this locality Doctor Wanless reports, "I have measured a section along Otter Creek near Brazil, Ind., and there are several marine horizons. They range from the horizon of the Seville limestone up to the horizon of our Coal No. 2, probably the roof of your Tebo coal." All of these are in the lower Pennsylvanian. Lower Fort Scott limestone, Fort Scott, Kan. (Kansas Univ. Paleont. Type Coll., No. 2,314); same as last, (Yale Univ., Peabody Mus., No. 14,468); upper Fort Scott limestone, near St. Louis, Mo., (Knight's loc. 3, St. Louis, outlier; Pawnee limestone, east bank of Verdigris River, 4 miles east of Talala, Okla. (Yale Univ., Peabody Mus., No. 14,469); shale near top of Wewoka formation, 5½ miles west of Okmulgee, Okla.; Cherokee shale (?), Henry county, Missouri (Yale Univ., Peabody Mus., No. 14,467); Millsap Lake formation, north-central Texas. All of these horizons are of late Des Moines age.

Genus LIMIPECTEN Girty, 1904

Limipecten GIRTY, *1904*, U. S. Nat. Mus., Proc., vol 27, p. 721.

Deltopecten (part) of authors.

Robust, acline, symmetrical, pectiniform Aviculopectininae, especially characterized by a peculiar ornamentation; left valve with intercalate costae, crossed by the edges of regular lamellae which swing downward toward the margin between costae in short, flattened, pointed projections similar to those of *Acanthopecten*, somewhat more numerous and prominent on the posterior part of the shell; right valve with numerous slender intercalate costellae, which are crossed by more or less prominent fila, spaced about the same distance or closer than the costae; auricles subequal in length, ornamented with intercalate costae, lamellose projections, or both. Inner ostracum of nacreous aragonite, outer and much thinner ostracum layer composed of calcite, homogeneous in the left valve, prismatic in the

MEASUREMENTS OF SPECIMENS OF THREE SPECIES OF *Limipecten*

Species.	Specimen.	Left valve.						Right valve.			
		Length.	Height.	Umbonal angle, degrees.	Auricular costae.		Body costae.	Umbonal angle, degrees.	Auricular costae.		Body costae.
					Anterior.	Posterior.			Anterior.	Posterior.	
texanus	1[a]	50+	55+	97+	....	7	31	....	....	....	55+
	2	55+	62+	100+	3–4	5+	27+	100+	6	7	50±
	3	....	....	....	....	7	....	....	....	13	....
	4	....	....	....	5	6	....	....	....	....	....
grandicostatus	1[a]	66+	70	....	6±	....	26±	....	....	....	65+
	2	....	62	....	2+	....	23	....	....	....	....
morsei	1[a]	95	96	105±	....	....	40	100–110	....	....	....
	2	72±	74	95±	....	....	38	100±	....	....	52±

a. Holotype.

right, with irregularly sized and arranged prisms. Ligament area like that of *Aviculopecten;* there is no shell gape; right valve nearly flat, left valve very much more convex.

Genotype.—Limipecten texanus Girty, lower Cisco, upper Pennsylvanian (Upper Carboniferous).

Range.—Lower Carboniferous to Lower Permian.

This genus is closely similar to *Aviculopecten,* but the ornamentation is so distinctive that well-preserved and typical species of the two can be separated by even small fragments of either valve. Some unique specimens of *Limipecten morsei* n. sp. from the Kendrick shale in Kentucky preserve beautifully the original shell structure, with even a faint suggestion of nacreous luster. Some other specimens of *Limipecten,* including the type species, show the delicate lamination of the inner ostracum of nacreous structure, but some change from the original aragonite has occurred.

The only Lower Carboniferous species known to me that is probably a *Limipecten* is *Aviculopecten docens* (McCoy) (see pl. 11, figs. 6*a*-8*b*) from Great Britain. This is the species which was used to illustrate the genus *Aviculopecten* in McCoy's original diagnosis, and the one which has erroneously been considered as the type of *Aviculopecten.*

LIMIPECTEN TEXANUS Girty, 1904

Plate 9, figures 2-6; Plate 10, figures 2*a*, *c*

Limipecten texanus GIRTY, *1904,* U. S. Nat. Mus., Proc., vol. 27, p. 722, pl. 45, figs. 1-3; pl. 47, figs. 1-3.

Shell large, orbicular, symmetrical. Left valve ornamented with high, rounded, intercalate costae that are separated by equally broad interspaces, the posterior costae not differentiated in size from the others; costae crossed by the edges of imbricate lamellae, spaced about the same as the costae; lamellae become prominent on the auricles, rising abruptly at a high angle above the general shell surface; flattened spinelike prolongations of the lamellae project from a third to a half of the distance between adjoining imbrications, and generally are obsolete on the auricles. Body of right valve nearly smooth except for fine numerous intercalate costellae, spaced lightly more distant than their breadth; they are crossed by nonprojecting obscure fila, or more properly, regular edges of lamellae more closely spaced than the costae; the edges of the lamellae become prominent and projecting on the auricles, although less than on the left valve; between every fourth or fifth costa there is a slightly broader interspace, so that there is an obscure fasciation of the costae that is most noticeable across the middle of the shell. Anterior fold of the left valve nearly straight, angular, prominent, overhanging slightly the adjoining sulcus; rear fold straight, poorly defined, in both valves; anterior auricular sulcus of left valve narrow, without costae, deep; posterior one broad, poorly defined with axis near the middle of the auricle; inner half of the sulcus characterized by faintly and more widely spread costae; cardinal costae large and prominent on both valves; crossed by projecting imbrications. Convexity of both valves in apposition 18 mm. in the holotype, a specimen 55 mm. high; outer ostracum in left valve made up of imbricating lamellae of homogeneous calcite, in the right valve composed of short polygonal prisms of variable breadth ranging up to about 35 or 40 mm. in the adult part of a shell, and having no regular arrangement in rows;

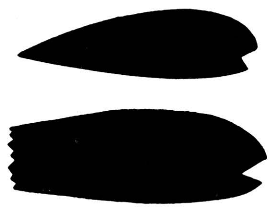

FIG. 26. Comparison of profiles of *Limipecten texanus* (*upper*) with *Limipecten morsei* (*lower*), showing difference in divergence of ligament areas; the left valve in both diagrams is uppermost, × ½.

the inner ostracum is delicately laminar, suggesting nacreous structure; the ligament area is underlain by a thin film of differentiated material that has a suggestion of crossed lamellar structure, but this is not certain; the ligament area of the holotype has a breadth of slightly over 2 mm.; ligament areas diverge at an angle of around 80 degrees.

Measurements of specimens of *Limipecten texanus* are given in the table on page 67.

Comparison.—This species appears to be distinguished most readily from others of the genus by the number and character of the costae, ornamentation of the auricles, and the subdued character of the concentric ornamentation on the right valve. The widely diverging cardinal areas of the two valves form a greater angle than in *L. morsei.*

Material.—Through courtesy of the curators at the National Museum I have been able to study the type specimens of *Limipecten texanus* (U. S. Nat. Mus., No. 27,102), which are five in number, including the holotype. All are fragmentary but well preserved, and the valves are in apposition in several of the specimens. A single fragmentary specimen at Yale Univ., Peabody Mus. (No. 14,470) is about the same age as the types.

Occurrence.—Upper Carboniferous. The types were found at Graham, Tex., associated with ironstone nodules in argillaceous, buff shale of lower Cisco age. The fact that the valves are commonly in apposition indicates that there was little or no current action during deposition of the inclosing sediments. The famous collecting horizon at Graham is in the Wayland shale member of the Graham formation and there is little doubt but that the types of *L. texanus* came from this member. The single hypotype at Peabody Museum was found in the middle shale of the Jacksboro limestone 3½ miles southeast of Jacksboro, Tex.

LIMIPECTEN GRANDICOSTATUS Girty

Plate 9, figures 1*a*, *b*

Limipecten texanus var. *grandicostatus* GIRTY, *1904*, U. S. Nat. Mus., Proc., vol. 27, p. 23, pl. 46, figs. 1-3.

This form differs from the preceding chiefly in having broader and coarser costae on the left valve, separated by correspondingly broader interspaces. The costae on the right valve are somewhat more numerous than in *L. texanus*, but are otherwise quite similar. The convexity of the two valves in apposition, of a specimen 70 mm. high, is about 20 mm. In a specimen 62 mm. high, the ligament area is 5 mm. high. The angle formed by the divergence of the ligament areas of two valves in apposition is about 80 degrees.

Measurements of specimens of *L. grandicostatus* are given in the table on page 67.

Comparison.—The ornamentation of the left valve in this form is similar to that of *L. koninckii* (Meek and Worthen) in having rather broad costae, but, as in *L. texanus*, spines are obscure or lacking on the auricles. The right valves of *L. koninckii* and *L. grandicostatus* differ in the possession of prominent fila in the former species.

Material.—This description is based on two of the four types (U. S. Nat. Mus., No. 27,103), two specimens being too badly weathered to be of much aid. The two valves are in apposition, and the material is well preserved, retaining the entire ostracum. The shell substance is stained a limonite brown throughout.

Occurence.—Upper Carboniferous. Argillaceous buff shale, associated with ironstone concretions. Wayland shale, Graham formation, lower Cisco, at Graham, Tex.

LIMIPECTEN KONINCKII (Meek and Worthen)

Plate 10, figure 1

Aviculopecten koninckii MEEK and WORTHEN, *1860*, Philadelphia Acad. Nat. Sci., Proc., p. 453; *1866*, Illinois Geol. Survey, vol. 2, p. 328, pl. 26, fig. 8.

Shell large, orbicular, longer than high; right valve slightly flatter than the left, ornamented with at least 80 slender, closely spaced intercalate costellae crossed by fine raised fila, about 10 of which occupy a distance of 4 mm. on the anterior slope of the mid part of the shell; besides a moderately prominent cardinal costa, there are six costae on the posterior auricle; umbonal angle in the holotype (right valve) 109 degrees; height,78 mm.; length, 87 mm.; convexity, 8 mm.; hinge length, about 77 mm.; the posterior sulcus, like that of *L. texanus*, is broad, illdefined and nearly or quite noncostate over the inner half of the sulcus; axis of the sulcus nearly bisects the posterior auricle which is set off by narrow obscure, nearly straight umbonal fold; anterior fold essentially straight; outer ostracum prismatic, inner ostracum macreous; costae of the left valve are coarser than those of the right, spaced 14 to 20 mm. apart near the ventral margin where the shell was 80 mm. high.

The species is known from only one specimen, a right valve, to which is clinging a small fragment of the complementary valve. It is always difficult to recognize a pectinid species from the right valve, because the right valves in similar species of a genus are likely to look alike. It seems, however, that this form is sufficiently distinct from other limipectens to permit recognition.

Comparison.—This form is distinguished by the wide umbonal angle, large number of costellae on the right valve, and by its elongate form.

Material.—The holotype, a right valve, (Univ. Ill., No. 12,877) was made accessible to me through the generosity of Dr. J. Marvin Weller. The specimen is well preserved, showing the complete ostracum of the shell, with the characteristic structure of *Limipecten*.

Occurrence.—Upper Carboniferous, in black, pyritiferous, fine-grained limestone, apparently of the concretionary kind sometimes found in black fissile shales, Des Moines subseries, Pennsylvanian, Alpine, Iowa. According to Doctor Marvin Weller (personal communication) this horizon may be about the same as the Illinois Coal No. 1.

LIMIPECTEN MORSEI Newell, n. sp.

Plate 1, figures 8, 16; Plate 10, figures 5-7*b*

Deltopecten texanus MORSE, *1931*, Kentucky Geol. Survey, vol. 36, p. 317, pl. 51, fig. 1.

Shell large, orbicular, about as long as high; left valve with rather broad, irregular intercalate costae, of which there are about 40, spaced approximately as far apart as the breadth of the coarsest costae; costae crossed by the edges of somewhat irregular imbricating lamellae, spaced about the same distance as the ribs; the intercostal projections commonly reach less than half of the distance between adjoining edges of the lamellae, becoming progressively more prominent from front to rear on the shell surface; anterior auricle abruptly set off by an acute, slightly overhanging fold which curves outward almost imperceptibly; there is no posterior fold; right valve ornamented in the adult with 55 or more slender, closely spaced, intercalate costellae crossed by prominent rather irregularly spaced fine fila, spaced about the same as the costellae across the middle of the valve, but becoming crowded over the marginal areas of the shell; anterior umbonal fold nearly straight, angular; posterior one obscure, straight; ligament area as in *L. texanus,* except that the area of left valves makes a small angle with the plane of the valves, instead of being nearly parallel to it; in *L. morsei* the plane of the valves nearly bisects the angle between the diverging ligament area of the two valves; valves of subequal convexity, the right being only very slightly less convex than the left. There are at least three costellae on each rear auricle of the holotype; costae lacking near the inner part of the angular auricular sulcus, this area being covered only by fine imbrications; the projecting short spines on the inner part of the very broad posterior sulcus of the left valve become somewhat more sparse across the auricle toward the hinge margin.

The preservation in the type specimens of *L. morsei* is exceptionally good. The inner ostracum shows a faint iridescence suggestive of the original mother-of-pearl luster, and exhibits in thin sections the exceedingly delicate lamination of nacre. By means of Meigen's method for identification of aragonite, the inner ostracum was found to be unaltered aragonite. The outer ostracum is perfectly preserved in both valves, consisting in the left valve of thin imbricating lamellae of homogeneous calcite, and in the right valve of short polygonal prisms having a maximum diameter of about 30 microns. The hypostracum layer is well-preserved aragonite. It is fibrous rather than prismatic, and cross sections of the fibers are much too irregular to be called polygonal. The convexity of a specimen 74 mm. high with both valves in apposition is 25 mm. The hinge length of a specimen 96 mm. high is 80 mm.

Measurements of specimens of *L. morsei* are given in the table on page 67.

Comparison.—This species differs from *L. koninckii* in being less elongate, markedly higher, and in having a smaller number of costae on the right valve. It is distinguished from *L. texanus* and *L. grandicostatus* by having a greater development of the short spines on the posterior part of the left valve, and in having prominent fila on the right valve, rather than only the obscure flattened edges of lamellae. Furthermore, the right valve in *L. morsei,* as well as in *L. koninckii,* is somewhat more convex than in *L. texanus* and *grandicostatus,* so that the ligament area in the two valves of the present species are about equally disposed in relation to the plane of the valves. In the two latter species, from the Graham shale, on the other hand, the ligament area in the left valve is more nearly parallel to the plane of the valves. The body costae of the left valve are more numerous in the present species than in the Texas forms. The name is given in honor of Prof. William C. Morse.

FIG. 27. Profile of *Limipecten morsei,* × ½.

Material.—I am indebted to Professor Morse for the loan of the remarkable specimen from Kentucky, selected as the holotype. The specimen is now at Mississippi State College. Two other specimens, topoparatypes (Yale Univ., Peabody Mus., No. 8,146) were used in formulating the description. This material is the finest that I have seen of Paleozoic Pectinacea in the remarkable preservation of the original aragonite of the inner ostracum.

Occurrence. — Upper Carboniferous. The two topoparatypes are labeled Kendrick shale, Cow Creek, Floyd county, Kentucky. The holotype was found at the same horizon at the Kendrick homestead at the head of Cow Creek. This horizon is high in the Pottsville, Des Moines subseries, Pennsylvanian.

LIMIPECTEN LATIFORMIS (Shimer)

Plate 10, figures 3, 4

Deltopecten occidentalis var. *latiformis* SHIMER, *1926,* Canada Geol. Survey, Bull. 42, p. 76, pl. 7, figs. 11a, b, 12.

Shimer's description:

Shell flabelliform, with transverse diameter (from anterior to posterior border) slightly greater than the distance from the hinge-line to the basal border; in consequence, the angle formed at the beak between the anterior and the posterior umbonal slopes is broad, slightly exceeding a right angle. Hinge-line nearly or quite equalling the greatest length of the valves. Length, the diameter from the anterior to the posterior margin, 30 mm.; height from hinge-line to basal margin, 23 mm.; greatest thickness of the conjoined valves 8 mm. Angle to divergence of the umbonal slopes at the beaks 100 degrees (in one specimen 90 degrees).

Left valve sloping broadly and flatly in all directions from the slightly convex umbonal region. Ears nearly equal in size, the anterior the more obtuse and defined by a deeper sinus from the body of the shell; it is marked by six or seven radiating ribs which are finely crenulated by concentric striae. Posterior ear separated from the body of the valve by a broad and shallow depression; on this ear the concentric markings are the more conspicuous and the radiating striae are fine and numerous—18 or 20 in number. Surface of valve marked by strong radiating costae between which are from one to three intercalated weaker striae; only the stronger costae are present at the beak, whereas at the ventral margin there are, in a space of 6 mm., about ten striae, of which four are strong.

Right valve nearly flat and much more faintly ribbed than the left, with finer striae of nearly equal size. Sinus separating the anterior ear from the body of the shell much sharper and deeper than on the left valve.

Through the courtesy of Dr. E. M. Kindle of the Canada Geological Survey, I have had an opportunity to study the paratypes and a squeeze of the holotype of this species. The material is preserved as impressions in a hard, white, quartzose sandstone or quartzite. The details of ornamentation are very poorly preserved. I have not seen the left valve, said to be preserved in the holotype, and the best paratypes are right valves, so I cannot add anything to Shimer's description. It is not possible to make an accurate count of costae in the material at hand, but it appears that there are about 65 or 70 costae on the shell body of the right valve. The costae are slender and crowded; they appear to be intercalate, although this is not certain. A poorly preserved fragment of a left valve, originally having a height of at least 32 mm., shows at least 10 evenly spaced intercalate costae. They are crossed by fine regular fila. The anterior auricle of the right valve in one specimen has 5 or 6 costae, including the cardinal costa. The right valve is by no means flat, but it appears to be less convex than the left. The umbonal folds are nearly straight in right valves, diverging at 90 to 100 degrees.

Comparison.—The general aspect of the species suggests *Limipecten*, but assignment to this genus is by no means certain, considering the imperfections of the types. In no known *Aviculopecten*, however, are the costae of the right valve so numerous. In the more typical species of *Aviculopecten*, the umbonal slopes flare outward in a decided curve, whereas in the present forms they are nearly straight. The only *Limipecten* that has approximately the shape of the *L. latiformis* is *L. koninckii* (Meeks and Worthen), of Des Moines age. It is hardly possible to confuse these forms, in view of their great difference in age.

Material.—The type collection (Victoria Memorial Mus., No. 4,863, Ottawa) includes several specimens, six of which I have seen, all poorly preserved, as molds and casts in coarse quartzite.

Occurrence.—Permian of the Lake Minnewanka region, Alberta, (Shimer's loc. 14, section 1).

LIMIPECTEN WEWOKANUS Newell, n. sp.

Plate 11, figures *5a, b*

Shell large, about 50 mm. long and high; orbicular; acline and symmetrical; umbonal folds hardly distinguishable, curving outward equally; sulci broad and ill-defined, coinciding in breadth to the entire area of either auricle; shell body ornamented in the holotype with 62 slender crowded costae in four ranks, spaced slightly closer than their breadth; costae crossed by a rather striking concentric ornamentation; up to a shell height of 8 mm. the costae are smooth, from thence to a height of about 17 mm. the ornamentation, although finer, becoming like that of typical *Limipecten*, having acute downward projections of the fila, or imbricating lamellae, between costae, and finally toward maturity the lamellae becoming vaulted into short prominences on the costae while the pointed projections between the costae become less conspicuous; ornamentation of the two auricles similar and clearly set off from that of the shell body by abrupt widening of the interspaces between costae, and decrease in size of the costae to faint costellae; on the anterior auricle there are about 10 costellae which are crossed by the edges of irregular imbricating lamellae, giving rise to short vaulted projections on the costellae; dorsal margin of each valve occupied by a relatively enormous cardinal costa having transverse, scale-like projections where it is crossed by the imbricating lamellae; umbonal angle in the holotype about 105 degrees.

Comparison.—This curious form does not need to be compared with any other American species. It certainly is not a typical *Limipecten*, as is especially indicated by the obsolescent character of the anterior umbonal fold. A deep anterior sulcus and overhanging angular fold is characteristic of most limipectens. The ornamentation, however, is similar to that of *Limipecten*, and there is now no more appropriate genus in which to place it.

Material.—Only one specimen of *L. wewokanus*, a well-preserved left valve, is known. I consider it a poor practice to describe a new species from only one specimen, but the present form seems so distinctive that there should be no difficulty in recognizing it. The holotype is Kansas Univ. Paleont. Type Coll., No. 374.

Occurrence.—Upper Carboniferous, very thin ferruginous, highly fossiliferous lens of limestone in gray argillaceous shale. Wewoka formation, near top of middle shale, quarry at spillway, east end of Lake Okmulgee, 5½ miles west of Okmulgee, Okla. Des Moines subseries.

Genus ACANTHOPECTEN Girty, 1903

Acanthopecten, GIRTY, *1903*, U. S. Geol. Survey, Prof. Paper 16, p. 417.

Orbicular, acline or slightly prosocline Aviculopectininae, about as long as high, with moderately long, slender auricles, the posterior only slightly longer than the anterior; simplicicostate, *i. e.*, without increase in number of costae after a very early stage; left valve with from about 15 to 50, rarely more than 25, broad closely spaced costae, separated by angular shallow grooves; along the crest of each costa there is a more or less distinct narrow, rounded ridge or keel, very obscure in some forms, which may be considered as the primitive costa (because, as traced toward the beak, the angular grooves of the interspaces disappear, leaving only the narrow costellae, which if continued to their origin, are seen in some instances to be intercalated between others, as in *Aviculopecten*); at a juvenile stage the costae are crossed at right angles by regular raised fila, which later become extended downward between costae in sharp projections; with increasing maturity, particularly coarse fila are introduced on auricles and shell body at regular wide intervals, and these ridges extend downward between costae in short, stout spines having a U-shaped cross section, with the convex surface inward; right valve nearly flat, almost smooth, except for widely spaced slender costellae that correspond in number and position to the interspaces of the opposite valve; structure of inner ostracum unknown, outer film of ostracum apparently homogeneous or granular in the left, and definitely prismatic in the right valve, with the prisms somewhat more regular in form and size than is commonly the case in the subfamily, ranging in diameter up to 25 microns; hinge as in *Aviculopecten;* musculature unknown; posterior umbonal folds outcurved, poorly developed, nearly obsolete in right valve; anterior folds curved outward, sharply angular, that of the left valve overhanging an equally narrow and angular anterior sulcus; sulcus of rear auricle in each valve broad, shallow, corresponding in breadth with the auricle; auricular costae few, widely spaced; cardinal costae particularly coarse, rugose where crossed by fila, particularly on the anterior auricle.

Genotype.—Pecten carboniferus Stevens, from the Centralia formation, Missouri subseries, Illinois.

Range.—Mississippian to Permian.

Remarks.—This genus has been widely misunderstood because of the rarity of specimens retaining the inner ostracum and hinge. Meek, with his usual keen perception, suspected the true relationships when he wrote of *Acanthopecten carboniferus:*

> The only specimens of this species I have seen consist entirely of what seems to be the thin outer layer of the shell, in which there appears to be a prismatic structure, as seen by the aid of a microscope and a strong transmitted light. They show no flattened cardinal plate, but a furrow along the inner side of the hinge margin of each valve. The cardinal plate or area was doubtless composed, as in other cases, of the inner laminated portion of the shell, that has been destroyed during the fossilizing process; if not, it would seem to be a new genus. (Meek, 1872, p. 194.)

I have been able to recognize the oblique resilifer and ligament area of the Aviculopectininae in specimens from the Westerville oölite at Kansas City, and in certain other specimens. Every specimen that I have seen preserved in shale has lost the inner ostracum, with the characters of musculature and hinge, while only a thin outer film of calcite remains. On the other hand, the inner ostracum of shells preserved in limestone is, in most instances, so badly recrystallized that the rock matrix cannot be readily separated from the inner part of the shell.

The difficulties in the discrimination of species in this genus are manifold. In the first place, the range of specific variation in the genus seems to be small, *i. e.,* all of the several described species of *Acanthopecten,* the world over, are surprisingly alike in general features, so that the species must be differentiated on more or less obscure characters. Secondly, collections containing as many as two or three well-preserved specimens from one locality are rare. There are only two lots at my disposal in which there are enough specimens to attempt a statistical study. One of these occurs in a fine clay matrix, the other in oölitic limestone, and the preservation of the ornamentation is so different in the two that they can scarcely be compared. Specimens from limestone are almost always misleading because the spines and vaulted frills are generally broken away with the matrix. On the other hand, shale specimens are commonly distorted through compression.

ACANTHOPECTEN CARBONIFERUS (Stevens)

Plate 12, figures 8*a*-10

Pecten carboniferus STEVENS, *1858,* Am. Jour. Sci., (2), vol. 25, p. 261.

Pecten Hawni GEINITZ, *1866,* Garb. und Dyas in Neb., p. 36, taf. 2, figs. 19*a, b*.

The original types of this species appear to have been lost, but there are very good grounds for its continued recognition. Two topotypes were lent to me by Dr. J. Marvin Weller, and one of these specimens, a left valve, is the basis for the following description.

Shell acline, orbicular, with 16 broad flattened costae, separated by narrow, angular furrows which become less angular with growth; crest of each costa surmounted by a high and narrow costella which becomes hemicylindrical near the ventral margin; slopes of the costae on either side of the median costellae, or keels, are slightly convex; surface covered with two sets of fila—coarse, widely spaced first order ones separated by many fine second order ones; at a very early stage the second order fila probably extended directly across the costae, but throughout the preserved part of the shell at hand, the fila are curved downward between costae into short pointed projections. Up to a height of about 7 mm., two or three of the small fila are fascicled over the costae to form a single coarser one; these modified fascicles are separated by three to four normal fila; the first coarse filum originates at a shell height of 6 or 7 mm. and thereafter the large fila periodically appear at progressively increasing intervals; they project ventrally into stout spines between the costae, extending about one third to one half of the interval between successive coarse fila; spines U-shaped in cross section, with concave surface directed outward; large fila in the specimen at hand are not vaulted into projections over the costae; posterior auricle has a large, oddly angular cardinal costa, which is apparently nearly quadrate in cross section; there are five obscure costellae on this auricle and the inner one is recognized only with difficulty. Where the large fila cross the auricular costellae, a large channeled spine is developed like those on the shell body, but it was not possible to illustrate them in the figured squeeze; anterior auricle and umbonal fold lacking in the specimen at hand; internal mold exhibits a narrow but distinct, smooth, flat ligament area and the poorly exposed impression of a resilifer; intervals between the last five coarse fila, measured across the middle of the shell: 1.5 mm., 2.6 mm., 3.0 mm., 3.5 mm.

Of 15 left valves from the Willard shale at Rockford, near Nebraska City, Neb. (U. S. Nat. Mus., No. 6,508), 6 have 17 body costae, 7 have 16 body costae, and there is one each with 15 and 18 costae. In this lot the number of anterior costae ranges from one to three, and the posterior ones from two to three. In five right valves from this suite there are three with 15 costellae and one with 17; in every one there are three anterior costae and no posterior ones.

The following measurements were obtained in the topotype, a left valve, from the Centralia formation, in Illinois: length, 19 mm., height, 17 mm; umbonal angle, 98 degrees.

The topotype specimen at hand is preserved in shale, and has been flattened slightly. Apparently the original convexity was about 3 or 4 mm. Other specimens retaining the anterior part of the shell have a slender anterior auricle, a deep angular sulcus, crossed by projecting imbricating lamellae, and a narrow overhanging anterior umbonal fold.

It is very probable that more than one species is included here under *A. carboniferus*. Most of my specimens occur in shale and the preservation generally is poor. When it is possible to compare directly a representative collection from the horizon of the topotypes with large collections from other horizons undoubtedly a further discrimination of species will be found desirable.

The types of Geinitz's *Pecten hawni* came from about the horizon of the Willard shale at Nebraska City. If it is possible to separate *A. carboniferus* from the Nebraska City material, when better collections of typical *carboniferus* are secured, the name *Acanthopecten hawni* (Geinitz) will have to be applied to the Nebraska City form.

Both of the species *Pecten broadheadi* Swallow (St. Louis Acad. Sci., Trans., vol. 2, p. 97) and *Pecten armigerus* Conrad (Pennsylvania Geol. Soc., Trans., vol. 1, pt. 2, p. 268, pl. 12, fig. 3) are acanthopectens, but they are too poorly described for recognition, except through the unwarranted assumption that there is only one species of the genus in our Pennsylvanian rocks. The types of these species are lost or destroyed and their original localities and horizons are unknown.

Comparison.—This species, on the basis of several rather poor specimens, chiefly from the Missouri and Virgil subseries of Kansas and adjacent states, appears to be distinguished by low convexity, rather large number of coarse fila, particularly narrow and distinct keels or costellae on the crests of the costae; also, there seems to be no tendency for the coarse fila to form vaulted projections over the costae. The topotype described above is nearly as large as any specimen of the species in the collections at hand.

Material.—Two topotypes were available to me, but only one is sufficiently well preserved to be of value. It is a left valve preserved in shale, retaining an exceptionally fine external mold and a rather poor internal mold upon which some of the external ornamentation appears to have been impressed. The specimens belong to the Illinois Geological Survey.

Occurrence.—Upper Carboniferous. This species, as here classified, occurs through much of the Pennsylvanian section, from beds of Des Moines to Wabaunsee age, through the Mid-Continent region. The type specimens are from the Centralia formation, Missouri subseries, Crooked Creek, near Centralia, Marion county, Illinois. Other specimens in the Mid-Continent region have been found in Des Moines beds (Altamont limestone), Missouri beds (Raytown limestone, Jacksboro limestone, Francis formation), and in Virgil beds (Kereford limestone, Ervine Creek limestone, White Cloud shale, Haskell limestone, Howard limestone, Maple Hill limestone, Willard shale, Graham formation).

ACANTHOPECTEN MEEKI Newell, n. sp.

Plate 12, figures 1*a*-5

Acanthopecten carboniferus Sayre, *1930,* Kansas Geol. Survey, Bull. 17, p. 121, pl. 12, figs. 5, 6.

Left valve acline, symetrical, markedly convex, nearly hemispherical in full-sized specimens; costae broad, rounded, commonly with only an obscure keel on the younger stages; small fila absent except on the very young parts of the shell at the umbo; coarse fila (more properly, the edges of imbricating lamellae) numerous, the first one appearing generally at a shell height of 4 to 6 mm., extended generally into strongly protruding vaulted projections over the costae, most prominent over the anterior part of the shell body; anterior fold narrow, sharply angular, projecting distinctly out over the deep and angular noncostate auricular sulcus; posterior fold small, angular, and distinct; posterior sulcus broad, right valve unknown; in the holotype the concentric lamellae are added respectively at the following shell heights; 4, 6, 7, 8, 9, 11, 13.5 16.5, 20, 24, 28, and 31.5 mm.

Moderate variation occurs in the prominence of the vaulted lamellae on the costae, and in the prominence and breadth of the more or less obscure ridge or keel on the costae. Far more confusing is the condition of preservation, because the details of surface ornamentation generally are broken away when the specimens are removed from limestone matrix. If allowances are made for preservation, there is little difficulty in recognizing this species.

Comparison.—This species is readily distinguished from *A. carboniferus* (Stevens) by its great convexity, rounded costae, with broad, generally obscure costellae along their summits, and the projecting rounded and vaulted imbrications over the costae. The coarse fila are projected in such a way that they are more accurately described in *A. meeki* as the edges of imbricating lamellae, whereas in *A. carboniferus* they are vertically elevated ridges or fila.

Material.—The species is based on a large number of left valves from the Westerville oölite of the Kansas City region, and one particularly fine specimen from an unknown locality in Douglas county, Kans. Holotype and three topoparatypes, Yale Univ., Peabody Mus., No. 8,148; five topoparatypes, Yale Univ., Peabody Mus., Nos. 14,471, 14,472; 25 topoparatypes, Kansas Univ., Paleont. Type Coll., No. 375; paratype, Kansas Univ., Paleont. Type Coll., No. 376.

Occurrence.—Upper Carboniferous. The species appears especially to characterize the limestones of the middle and upper part of the Missouri subseries. Many individuals, including nearly all of the types, were found in the Westerville oölite, at various places around Kansas City. One fine paratype, the best specimen in the collection, came from an unknown locality in Douglas county. The matrix of this specimen is identical with a peculiar kind of limestone which occurs at the top of the Captain Creek limestone (Lansing) in Douglas county. On the other hand, the horizons represented in the county range from upper Lansing to lower Shawnee, and this specimen might have come from any one of several limestone formations. Other specimens were found in the Argentine limestone, Kansas City; Drum oölite, 1 mile east of Independence, Kan.; Captain Creek limestone near Eudora, Kan., and north edge sec. 10, T. 13 S., R. 21 E., Kansas; Merriam limestone, south line sec. 17, T. 17 S., R. 22 E., Kansas; Iatan limestone, 2 miles northwest of Nehawka, Neb.; Iola limestone, Iola, Kan.; Farley limestone, south of DeSoto, Kan.; Olathe limestone, Fredonia, Kan.

MEASUREMENTS OF LEFT VALVES OF *Acanthopecten meeki* Newell, n. sp.

Specimen No.	Length. mm.	Height, mm.	Hinge length, mm.	Convexity, mm.	Umbonal angle, degrees.	Auricular costae.		Body costae.	No. coarse fila.
						Anterior.	Posterior.		
1[a]	34	32	....	8	98	....	....	18	10
2	16	16	12±	2.5	95	2	....	18	7
3	19	20	....	3.5	96	....	5	16	7
4	16	16	13±	3+	90±	2	5	15	6
5	21.5	20	13	4.5	100	3	....	18	11
6	19	18.5	....	4.5	85	....	4	18	8
7	26.5	24	....	6	103	....	....	18	10

a. Holotype

MEASUREMENTS OF LEFT VALVES OF *Acanthopecten coloradoensis* (Newberry)

Horizon.	Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Convexity, mm.	Umbonal angle, degrees.	Auricular costae.		Body costae.
							Anterior.	Posterior.	
Kaibab..........	1	....	51	....	10	....	....	....	....
Kaibab.........	2	25	27	23±	6	115±	....	2	23
Word...........	3	26	27	24	6	115±	....	....	21

ACANTHOPECTEN COLORADOENSIS (Newberry)

Plate 12, figures 7*a*, *b*, 13-15*b*

Pecten (*Monotis*?) *Coloradoensis* NEWBERRY, *1861*, Ives Colo. Expl. Exped., p. 129, pl. 1, figs. 6, 6*a*.

Shell characterized by a relatively large number of costae, 23 in a nearly complete hypotype; a large number of closely spaced coarse, raised fila that extend across shell body and auricles, extended into spines between the costae, as long or longer on the mature part of the shell than the distance between successive fila. Posterior umbonal fold low, obscure, bounded on the inside by an almost indistinguishable flattening or sulcus; anterior one angular; but low and not overhanging the sulcus; auricular sulci broad, rounded; posterior auricle poorly defined, possessing one or two obscure costellae; anterior one without costellae. Only one order of fila is observed; at a shell height of 6 mm. the fila are slightly finer and more widely spaced than the costae, extending straight across costae and interspaces; subsequent fila become extended ventrally into sharp points between costae and take on progressively the appearance of the thickened edges of imbricating lamellae, but they generally are not projected outward from the main surface as vaulted protuberances; the fila continue to be much finer than the costae and their spacing progressively increases at a lower rate than the divergence of adjoining costae, so that at a mature stage the costae are wider apart at their crests than one or two successive fila; between a shell height of 6 mm. and 27 mm. 16 of these spinose fila are added, the last two being spaced about 2 mm. apart; shell of moderate convexity, nearly even in all directions. Dimensions for a well preserved external mold of a left valve; height, 27 mm.; length, 25 mm.; hinge length, about 23 mm.; convexity, about 6 mm.; number of body costae, 23. The umbonal angle cannot be measured satisfactorily because of the poorly defined posterior fold, but it may be estimated at about 115 degrees. The species attains a large size, one topotype measuring 50 mm. in height.

Comparison.—This species is so distinctive that it scarcely needs comparison with Pennsylvanian forms. The large number of costae, closely spaced and numerous concentric ridges, and poorly defined rear umbonal fold are the most obvious characters by which the species may be recognized.

Material.—The two figured syntypes (Columbia Univ., Nos. 6,392G and 14,203), generously lent to me by Dr. Marshall Kay, are fragments of left valves preserved in drab dolomitic limestone in which are the altered remains of many fenestrate and fistuliporid bryozoans. The better preserved, though more fragmentary specimen (14,203) is here designated as the lectotype. Two other specimens from the same horizon and region as the types are preserved in chert concretions, one as a nearly complete external mold (Yale Univ., Peabody Mus., Nos. 14,473, 14,474). Six fragmentary hypotypes, occurring in drab, soft dolomitic limestone of the Word formation, belong to the Texas Bureau of Economic Geology.

Occurrence.—Permian. The types of *A. coloradoensis* are labeled "Upper Carboniferous, north of Little Colorado River, New Mexico," this area now being included in Arizona. The dolomitic limestone is the Kaibab. Two of our hypotypes came from the Kaibab limestone at Bass Ranch, Grand Canyon, Ariz., and at Arden, Las Vegas quadrangle, Nev. Other specimens are from the Word formation, Glass Mountains, western Texas. Both the Kaibab and Word formations are well up in the Permian.

ACANTHOPECTEN DELAWARENSIS (Girty)

Plate 12, figure 12

Aviculopecten delawarensis GIRTY, *1908*, U. S. Geol. Survey, Prof. Paper 58, p. 437, pl. 23, figs. 2, 2*a*.

Through the kindness of Doctor Girty I have had opportunity to study the type specimen of *A. delawarensis*. It appears to be a typical *Acanthopecten*, as evidenced by its symmetry, form, grooved interspaces, keeled costae, and constant number of costae during ontogeny. The characteristic spines of this genus are not visible, but the holotype is so poorly preserved that the ornamentation is not distinct. Although the species was originally described as being oblique it appears to me that the present outline of the specimen is misleading as the result of being slightly broken away at the rear margin. There are 18 or 19 costae on the shell body. Probably this species cannot be recognized widely until topotype specimens are secured and detailed study made.

Comparison.—*Acanthopecten delawarensis* is comparable in general to *A. coloradoensis*, but appears to have fewer costae, the latter having 21 to 23 costae (probably, also, more and less), whereas the single specimen of *A. delawarensis* has only 18 or 19.

Material.—A single specimen, the holotype, U. S. Geol. Survey, Type Coll., No. 417, furnished the basis for my observations.

Occurrence.—Middle Permian, drab dolomitic limestone of the Delaware Mountain formation, Guadalupe Mountains, western Texas.

ACANTHOPECTEN LAQUEATUS (Girty)

Plate 12, figure 11

Aviculopecten laqueatus GIRTY, *1908*, U. S. Geol. Survey, Prof. Paper 58, p. 439, pl. 9, fig. 11.

Shell of moderate size, suborbicular, slightly extended anteriorly to produce a very slight opisthocline obliquity; auricular costae absent, shell body with 21 broad, flattened costae, each surmounted by a narrow, distinct keel or costella; interspaces narrow, trough-shaped or grooved, distance between keels about four times their breadth; eight or more concentric, coarse fila extend directly across interspaces and costae without deflection, producing a striking panelled ornamentation, each rectangle being about twice as high as broad; spinose ornamentation characteristic of most acanthopectens absent. Measurements of holotype: length, 20 mm.; height, 21 mm.; hinge line, 16 mm.; convexity, 5 mm.; umbonal angle, 110 degrees; body costae, 21.

Comparison.—No other American species resembles this one. The absence of the intercostal spines which are characteristic of *Acanthopecten*, taken with the proportions of the shell, distinguish this form. However, the peculiar keeled costae are found only in *Acanthopecten* and the orbicular shape and symmetry of *A. laqueatus* identify the species with *Acanthopecten*.

Material.—The holotype, U. S. Geol. Survey, Type Coll., No. 416, served as the basis for my observations.

Occurrence—Upper Permian, drab dolomite of the Capitan limestone, Guadalupe Mountains, western Texas.

Genus ANNULICONCHA Newell, n. gen.

Orbicular, acline or slightly prosocline Aviculopectininae, ornamented on auricles and shell body by two ranks of distinct fila; at a mature stage a few irregular, ill-defined radial ridges appear, but they do not occur on young individuals; auricles of nearly equal size and shape, with acute terminations; anterior umbonal fold of left valve narrow, subangular, posterior one lacking; anterior sulcus deep, narrow, with a steep or perpendicular inner boundary; posterior sulcus, broad, shallow; cardinal costae absent; right valve apparently similar to the left in ornamentation, but slightly less convex; shell structure and musculature unknown.

Genotype.—*Aviculopecten interlineatus* Meek and Worthen, LaSalle limestone, Missouri subseries, LaSalle, Ill.

Range.—Mississippian (Lower Carboniferous) to Permian.

This genus is similar in form to species of *Acanthopecten* and *Girtypecten*, and the very early growth stages of the three genera are similar in form and ornamentation. It seems rather probable that these three genera are more closely related to each other than to other Aviculopectininae.

Owing to the extreme rarity of specimens of *Annuliconcha*, no satisfactory basis has yet been discovered for recognition of more than one species in the American Pennsylvanian rocks. Ordinarily, too, the specimens are found in hard limestone and much of the projecting ornamentation is lost when the matrix is broken away, so that limestone specimens commonly give an erroneous idea of the ornamentation.

Undoubted representatives of the genus occur in the Word formation (Permian) of the Glass Mountains, but these specimens are too poorly preserved to warrant specific identification.

ANNULICONCHA INTERLINEATA (Meek and Worthen)

Plate 13, figures 6a-10

Aviculopecten interlineatus MEEK and WORTHEN, *1860*, Philadelphia Acad. Nat. Sci., Proc., p. 454; *1866*, Ill. Geol. Survey, vol. 2, p. 329, pl. 26, figs. *7a, b*.

Posidonomya lasallensis MILLER and GURLEY, *1896*, Illinois State Mus. Nat. History, Bull. 11, p. 12, pl. 1, figs. 17, 18.

Shell, exclusive of auricles, circular; there are two ranks of fila, very coarse ones separated by several fine ones, the coarse fila becoming progressively small on the umbonal area, where they appear at a shell height no greater than 0.5 mm., the fine fila being first visible between the coarse ones at about 1 mm. In a well-preserved topotype 14 mm. high, there are 15 of the large fila, and there are at least two more in the holotype having a height of 18 mm.; the tenth coarse filum is introduced at a shell height of 4 mm., the eleventh at 5 mm., twelfth at 6.5 mm., thirteenth at 8 mm., fourteenth at 10.5 mm., fifteenth at 14 mm. Between the twelfth and thirteenth fila there are 9 or 10 of the small closely spaced ones; in the following interspaces between the coarse fila there are respectively 10, 14, 14, and 16 of the small ones.

The large fila have rounded summits and parallel, perpendicular sides. At a height of 8 mm., in one specimen, and 10 mm. in another, about 24 radial low, rounded ridges appear and extend outward toward the shell margin, but they do not occur on the auricles. At each large filum they are interrupted without modifying the filum, and commonly they are offset slightly at successive fila. At a mature stage the outer surface of the coarse fila

MEASUREMENTS OF LEFT VALVES OF *Annuliconcha interlineata* (Meek and Worthen)

Specimen No.	Height, mm.	Length mm.	Convexity, mm.	Hinge length, mm.	Umbonal angle, degrees.
1[a]..........	18	20	3±	16	100
2...........	14	....	2±	....	103

a. Holotype

is obscurely crenulated, without, however, any necessary correspondence to the radial ridges. One specimen, showing part of the inner margin, has a series of papillae along the inner surface of the margin. In a shell 14 mm. high, the papillae are spaced a little less than 1 mm. apart along the ventral margin. Beyond a height of 13 or 14 mm., each successive interspace between the large fila is depressed distinctly below the level of the previous one, like the steps of stairs. The shell gapes distinctly at both ends.

Through the courtesy of Drs. Carey Croneis and J. Marvin Weller, I have had opportunity to examine and directly compare the holotypes of *Avic-*

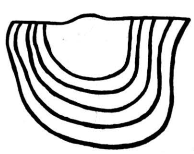

FIG. 28. Juvenile growth stages of *Annuliconcha interlineata* (camera lucida drawing, × 15).

ulopecten interlineatus Meek and Worthen and *Posidonomya lasallensis* Miller and Gurley. The latter proves to be a distorted juvenile of the former. The two come from the same locality and horizon.

Comparison.—This is the only species of *Annuliconcha* that I have been able to recognize in the material at hand. However, each one of our few specimens is poorly preserved, and I was forced to depend chiefly on two borrowed specimens to describe the species.

Material.—A fine topotype figure was lent me by the curators of the National Museum (No. 80,348). The holotype is Univ. Illinois, No. 10,922, and the holotype of *Posidonomya lasallensis,* Univ. Chicago, No. 6,612.

Occurrence.—Upper Carboniferous. The type came from the Lasalle limestone, Missouri subseries, Lasalle, Ill. Other specimens were found in the Des Moines subseries (Cherokee shale, sec. 1, T. 31 S., R. 23 E., Cherokee county, Kansas; Oologah limestone, Garnett quarry, northeast of Tulsa, Okla.); in the Missouri subseries (Argentine limestone at Kansas City; Stoner limestone, Farley, Mo.; Dewey limestone, Dewey, Okla.; Adams Branch limestone, quarry, 3 miles northwest of Bridgeport, Tex.); and in the Virgil subseries (Willard shale, one half mile north of the mouth of Weeping Water Creek, Nebraska.) All belong to the Pennsylvanian series, Upper Carboniferous.

Genus GIRTYPECTEN Newell, n. gen.

Prosocline or acline, suborbicular Aviculopectininae, ornamented on the left valve with coarse, widely spaced costae which are intersected by almost equally and similarly spaced concentric ridges that continue across the subequal acute auricles; long, cylindrical, erect spines rise from the intersections of the coarse radial and concentric ornamentation; interspaces between the coarse costae, and surface of the auricles ornamented with fine, widely spaced, intercalate costellae; there is a distinct cardinal costa on the left valve; auricular sulci well defined, and umbonal folds prominent, corresponding to marginal, first order costae of the shell body, the posterior fold being distinctly longer than the anterior one; byssal sinus obsolescent; ligament area aviculopectinid with the greater part of the resilifer lying behind the beaks; early juvenile stages like corresponding stages of *Acanthopecten* and *Annuliconcha* in having an elongate subquadrate shape and an ornamentation of regular fila; right valve unknown; shell structure unknown.

Genotype.—*Aviculopecten sublaqueatus* Girty, from the Permian of western Texas.

Remarks.—The genus is represented in the Permian of Sicily by *Pseudomonotis fimbriata* Gemmellaro. The genus is not yet recognized in Pennsylvanian rocks. *Pterinopecten tesselatus* (Phillips), as figured by Hind, from Lower Carboniferous beds of Great Britain, and *Aviculopecten tesselatus* (Phillips) from the Lower Carboniferous of New South Wales, Australia, bear a resemblance to *Girtypecten,* but I am not convinced that they belong to this genus.

MEASUREMENTS OF LEFT VALVES OF *Girtypecten sublaqueatus* (Girty)

Specimen No.	Length, mm.	Height, mm.	Height / Length.	Hinge Length, mm.	Hinge length / Length.	Con-vexity, mm.	Convexity / Height.	Umbonal angle, degrees.	No. auricular costae.		Body costae.	
									Anterior.	Posterior.	First order.	Total.
1..........	17	17	1.00	17	1.00	2.5	0.14	84	3	5	7	13
2..........	....	30	....	....	....	4.5	0.15	78	....	....	8	15
3..........	44	40±	0.91	35	0.79	5.5	0.14	93	....	....	7	30+

GIRTYPECTEN SUBLAQUEATUS (Girty)

Plate 13, figures 11-14*b*

Aviculopecten sublaqueatus GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 440, pl. 9, fig. 12 (actual date Feb., 1909).

Acline, or slightly prosocline shells with nearly equal, extended auricles; the anterior auricular sulcus sharply incised, bounded within by a nearly perpendicular slope of the adjoining umbonal fold that corresponds to the anterior first order costa of the shell body; posterior sulcus broad, its axis nearly bisecting the auricle, bounded within by a

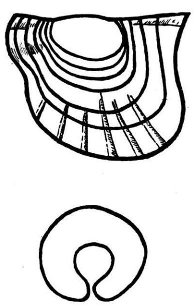

FIG. 29. *Girtypecten sublaqueatus* (Girty); upper, juvenile growth stages in a left valve, × 15; lower, cross-section of a spine 3 mm. from spine base, × 15 (camera lucida drawings).

well defined, narrow umbonal fold which coincides with the posterior first order costa of the shell body; shell body ornamented by six to eight coarse, widely spaced costae which are intersected by almost equally coarse concentric ridges or fila which extend across the auricles as well as shell body; spaced a little more widely than the costae; auricles and spaces between first order costae ornamented by widely spaced, fine, subequal intercalate costellae, distributed in as many as five ranks in full-sized shells; in a shell 40 mm. high there are five small costellae near the margin between the large first order ones; in a shell 7 mm. high there are only three supplementary costellae in the interspaces between first order costae; the first order costae appear simultaneously 0.5 mm. from the end of the beak, the second order costellae appearing somewhat irregularly between 5 and 7 mm. from the beak; there are four of the coarse fila at a shell height of 0.5 mm. where the costae originate, at 17 mm. there is a total of 17 fila, and at 40 mm. about 25 fila; long heavy, cylindrical spines rise almost perpendicularly from the points of intersection of fila and first order costae, but the spines are almost always broken away when the rock matrix is removed, so that their distribution on the juvenile parts of the shell has not yet been observed. The spines in the material at hand are circular in cross section save for an obscure groove along the ventral side, and they are quite solid. A central core of clear calcite extends out on the ventral side to the groove of the spine. The appearance of these spines in section suggests that in life the spines may have had the form of a thick-walled cylinder, split along the ventral side so that the long projection of the mantle within the spine was in contact with the sea water. It is equally possible that the differentiated calcite core represents a final secretion of the mantle, permanently closing the interior of the spine and converting it into a solid structure. The right valve is unknown.

Comparison.—There is no described species known to me that is likely to be confused with this one.

Material.—In addition to the holotype (U. S. Geol. Survey, No. 1,211), eight specimens were used in making the description, one hypotype belonging to Yale Univ., Peabody Museum, (No. 14,459), and the other seven belonging to the University of Texas (No. 12,313). The shell substance is altered.

Occurrence.—Permian. The species was recorded by Girty from the middle and basal parts of the Capitan formation, Upper Permian, and the Delaware Mountain formation, Middle Permian, western Texas. The hypotypes before me were collected in the Middle Permian Word formation, Glass Mountains, western Texas.

Genus CLAVICOSTA Newell, n. gen.

Orbicular subequivalve, symmetrical, acline, subglobose pectiniform shells, characterized by coarse, nearly identical ornamentation on each valve; coarse, spinose first order costae separated by a pair of smaller intercalate second order costae; auricles subequal, differentiated from the shell body by different ornamentation; spines U-shaped in cross section, arranged more or less regularly in concentric rows.

Genotype.—*Clavicosta echinata* Newell, n. sp.

Range.—Westerville limestone, Missouri subseries, Pennsylvanian, to the Big Blue series, Lower Permian.

Remarks.—This genus is so dissimilar to all other forms with which I am familiar that it is difficult to classify it properly. The hinge structure observed in two individuals is that of the Aviculopectininae. No other known Paleozoic genus shows intercalaries that are added in pairs as in this one. There is no evidence of a prismatic outer ostracum in the right valve in any of my material, in spite of the fact that some of the specimens are rather well preserved. The equal convexity and nearly identical ornamentation on the two valves is unknown elsewhere in the Aviculopectinidae, except perhaps in the genus *Deltopecten*.

CLAVICOSTA ECHINATA Newell, n. sp.

Plate 13, figures 1-5

Subglobose, orbicular shells, with deeply depressed auricles, separated from the shell body by rather deep auricular sulci and well defined, outwardly curved, subangular umbonal folds; margin of left anterior auricle rounded, indented at the extremity of the sulcus by a shallow sinus, margin of the rear auricles indented by a broad and fairly deep sinus, so that the posterior auricles are acute; auricles costate, with short vaulted projections extending from the costae, particularly those of the anterior auricles; dorsal half of posterior auricles nearly smooth, or with relatively obscure costae; coarse rugose cardinal costae present. Anterior auricular sulci devoid of costae; shell body of both valves with two sets of costae—prominent rounded first order costae with numerous tangential spines arranged in irregular concentric rows, and depressed second order costae as broad as those of the first order, intercalated in pairs between the larger ones; each second order costa on the right valve ornamented with three rows of fine vaulted, erect scaly protuberances, two lateral rows and a median one, the second order costae of the left valve being provided generally with only a median row of such projections extending along the crest of each costa, rarely with three rows; concentric fila lacking, growth lines swing downward between costae as in *Acanthopecten*, except that they form rounded, instead of pointed, projections.

Material.—The species is based on 13 specimens, all more or less worn and fragmentary, from several localities and horizons. In view of the fact that such a long stratigraphic range is included in the

MEASUREMENTS OF *Clavicosta echinata* Newell, n. sp.

Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Convexity, mm.	Umbonal angle.		Auricular costae.		Body costae.		
					Maximum.	At beak.	Anterior.	Posterior.	First order.	Second order.	Total.
L1[a]	31	29+	....	8	110	86	....	3+	10+	20	30+
L2	26±	26.5	18	7	108±	93	8	9	11	20	31
L3	13.5	14.5	10.5	3.5	95	83	6±	8	10	20	30
R4	31	29±	....	7	105±	95±	4+	3±	10	21±	31±
R5	19	19	14.5	4.5	....	86	4	2+	10	19–20	30±

a. The holotype. *L,* left valve; *R,* right valve.

collection, it is possible that additional material will furnish basis for dividing the group into more than one species. The types are Kansas Univ., Paleont. Type Coll., No. 377; Yale Univ., Peabody Mus., Nos. 14,480 (holotype) to 14,483.

Occurrence.—Upper Carboniferous and Lower Permian. The holotype and some topoparatypes were found in the lower Eiss limestone (Council Grove group) just west of the cemetery northwest of Strong City, Kan. Other specimens are from the Hughes Creek shale (Council Grove) on the east bank of Cottonwood river, east of Elmdale, Kan.; Crouse limestone (Council Grove), NE 1/4 sec. 22, T. 34 S., R. 7 E., Cowley county, Kansas; White Cloud shale (?) (classed by Condra as Auburn shale), (Wabaunsee group); Barroum Ranch, Osage county, Okla.; Americus limestone (Council Grove), Elmdale, Kan.; Brownville limestone (Wabaunsee group), 1 mile south of Unadilla, Neb.; one specimen from the Oread formation (Shawnee group), at Snyderville, Neb., seems to be a member of the species.

Fragmental material, probably representing several species, comes from the Westerville limestone (Missouri subseries), Kansas; Weeping Water limestone (Shawnee group), Nebraska; "South Bend" shale (Virgil subseries), Texas; Saddle Creek limestone (Big Blue series), Texas; Graham formation (Virgil), Texas; Calhoun shale (Shawnee), Kansas; Topeka formation (Shawnee), Kansas; Biel limestone (Shawnee), Kansas; and Stine shale (Admire group), Kansas.

SUBFAMILY STREBLOCHONDRIINAE Newell, n. subfamily

Smooth or sculptured opisthocline shells having a relatively broad and long anterior auricle, and a small or obsolete posterior one; ligament area similar to that of *Aviculopecten*, except that in some of the genera the obliquity of the resilifer is backward; outer ostracum in most genera radial crossed-lamellar in both valves, prismatic structure unknown; inner ostracum concentric crossed-lamellar in some genera; both valves of nearly the same convexity, the right one being only slightly flatter than the left. Figure 17 indicates the inferred phylogeny of the subfamily.

Genus STREBLOCHONDRIA Newell, n. gen.

Streblopteria (part) of authors.

Shell slightly but persistently opisthocline, nearly equivalve, the right valve being slightly flatter—especially over the umbo—than the left; shell ornamented with numerous radiating intercalate costae on both valves, crossed by fine regular fila so that the surface has a regular latticed ornamentation; in some species the ornamentation becomes obsolete across the posterior part of the shell, or across the middle, in others the lattice ornamentation is preserved only at the umbones; resilifer with a marked backward obliquity, most pronounced in young individuals, even at a stage prior to the opisthocline obliquity of the shell, becoming less oblique in large

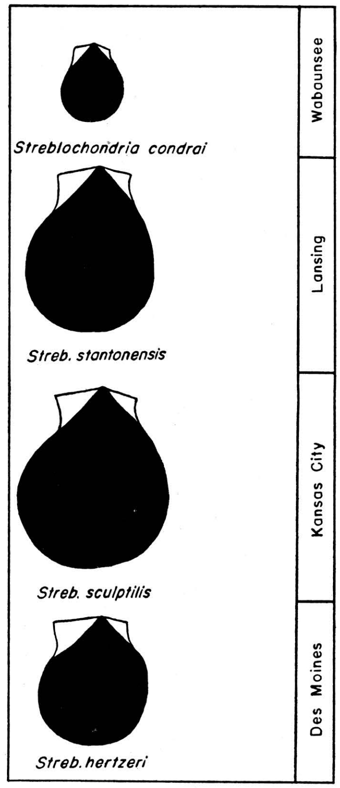

FIG. 30. Comparison of some American species of *Streblochondria,* showing relative geologic age, × ½.

adults, resilifer supported within the umbonal cavity by a buttress extending from middle of the inner surface of the "hinge plate" to the ridge on the inner surface corresponding to the external anterior auricular sulcus; shell substance in each valve composed of two layers, an outer thin film of radial crossed-lamellar calcite, and an inner ostracum of very much finer concentric crossed-lamellar aragonite; anterior auricle about twice as long as the posterior, both auricles having rectangular terminations; umbonal folds rounded, rather poorly defined; auricular sulci very well defined, narrow; surface of auricles above the sulci nearly flat.

Genotype.—*Aviculopecten sculptilis* Miller, Westervlle oölite, Missouri subseries, Pennsylvanian (Upper Carboniferous), Kansas City, Mo.

Range.—Mississippian (Lower Carboniferous) to Permian. It is possible that Upper Devonian species like *Aviculopecten cancellatus* (Hall) represent the ancestral radicle of *Streblochondria.*

MEASUREMENTS IN SPECIES OF *Streblochondria*

Species.	Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Convexity, mm.	Maximum umbonal angle.	Umbonal angle, at beak.	Body costae.	Anterior auricular costae.
hertzeri	L1..............	30	33	....	4.5	97	89	73	11
	L2..............	24	28	13.5	....	96	85	73	12
	L3..............	16	18	9.5	1.5+	93	....	....	....
	L4..............	10.5	12	7	....	94±	....	56	11
	R5..............	17	20.5	....	....	94±	....	86	....
	R6..............	8	10	5+	....	....	....	41	6±
sculptilis	L1..............	41.5	48.5	21	7	87	80	50±	2
	L2..............	9.5	12	6±	1±	80±	80±	42	2–3
	R3[a]..............	29	33	17	....	92	82	70–75	8
	R4..............	10	....	6	....	82±	82±	55	7
stantonensis	Li[a]..............	33	43.5	17	5	80	73	59	8
	L2..............	27	33	15	4	83	75	58±	5+
	L3..............	37.5	47	....	6	81	79	....	....
condrai	L1[a]..............	15	20	8.5	3.5+	93	87	40	8
	L2..............	18	22	....	....	....	....	40	....
	R3..............	15	....	10±	....	85±	75+	52	7
guadalupensis	L1[a]..............	11	13	7.5	....	88	....	....	....
	R2..............	18	20	9.5	....	93	....	....	....
tenuilineata	L1..............	10	12	5.6	1	85	....	....	....
	R2[a]..............	14	15	7	2	105	....	....	....

a. The holotype. *L,* left valve; *R,* right valve.

STREBLOCHONDRIA SCULPTILIS (Miller)

Plate 16, figures 5*a*-*c*, 7, 9*a*, *b*, 11

Aviculopecten sculptilis MILLER, *1891*, Ind. Geol. Survey, Adv. sheets, 17th Rept., p. 92, pl. 20, fig. 5. ———, BEEDE, *1900*, Kan. Univ. Geol. Survey, vol. 6, p. 122, pl. 13, figs. 3-3*b*. ———, SAYRE, *1930*, Kan. Geol. Survey, Bull. 17, p. 119, pl. 11, figs. 9, 10.

Shell, distinctly higher than long, slightly opisthocline, with a slightly arcuate, rounded anterior umbonal fold and a nearly straight, well defined posterior one; beaks sharp, narrow; maximum umbonal angle in adult about 90 degrees; anterior auricular sulcus narrow, quadrate, so that the flat auricle meets the high inner wall of the sulcus at nearly a right angle; surface exclusive of auricles finely cancellated on both valves by intercalate radiating costellae, crossed by fila of about the same order of size; there are three to four ranks of costellae on a large adult and they are only about 70 percent as numerous on the left as on the right valve; toward the ventral and front margins the fila become lamellose in adult shells and become relatively less prominent than the costellae; at the posterior margin of the shell body, the costellae become narrow and obscure; small scale-like projections occur at the intersections of costellae and fila at a mature stage; rear auricle of both valves nearly smooth save for ordinary growth lines, and on the anterior auricle of the left valve there commonly are two or three faint costellae, crossed only by coarse growth lines; cardinal costae obscure or lacking, except for a large rugose costa on the anterior auricle of the right valve; and there are in addition six to eight closely spaced costellae on the surface of this auricle, the one bounding the byssal notch being commonly somewhat larger than the others, and the costellae are crossed by regular fila such as those on the shell body; anterior auricle of each valve twice as long as the posterior; terminations of all excepting the anterior right auricle quadrate, the latter being rounded; anterior marginal sinus of the left valve subangular; outer thin ostracum in each valve with radial crossed-lamellar structure; structures of inner ostracum unknown.

Measurements of *Streblochondria sculptilis* are given in the table on page 81.

Comparison.—This beautiful species is similar to *Streblochondria hertzeri* (Meek) and *S. stantonensis*, n. sp. From the former it differs especially in having a smaller umbonal angle, nearly smooth, rather than sculptured auricles, and in having the auricles depressed much farther below the general shell surface. A larger number of costae occur on *S. hertzeri*. *Streblochondria stantonensis* is a relatively higher form, with costate left anterior auricle, and almost, but not quite, straight umbonal slopes. Furthermore, the sinus at the margin of the left anterior auricle is rounded instead of angular as it is in *S. sculptilis*.

Material.—Through the kindness of Prof. N. M. Fenneman and Mr. M. S. Chappars of Cincinnati University, I have been enabled to restudy the holotype of *S. sculptilis* (Cincinnati Univ., No. 3,894). This is a well-preserved right valve, embedded in a white oölite matrix. The locality from which it came is Kansas City. There can be no doubt that the original horizon was the Westerville oölite, because the species is common only at that horizon at Kansas City. In addition, I have a large left valve, the same figured by both Beede and Sayre (Kansas Univ., Paleont. Type Coll., No. 386.1), (Kansas Univ., Paleont. Type Coll., No. 386.3); one small left valve and one small right one (Kansas Univ., Paleont. Type Coll., No. 386.2). All of these are topotypes.

Occurrence.—Upper Carboniferous. Kansas City group, Missouri subseries, Pennsylvanian. Several specimens of the species have been found in the oölitic part of the Westerville limestone at and near Kansas City; Drum oölite, cement plant, southeast of Independence, Kan.; lower oölitic bed of the Farley limestone, quarry NW cor. sec. 11, T. 10 S., R. 23 E., Kansas.

STREBLOCHONDRIA HERTZERI (Meek)

Plate 16, figures 6, 10, 12-15

Aviculopecten (*Streblopteria?*) *hertzeri* MEEK, *1871*, Philadelphia Acad. Nat. Sci., Proc., p. 61; *1875*, Paleontology, Ohio. vol. 2, p. 330, pl. 19, figs. 13*a*-*c*.

Aviculopecten hertzeri MORNINGSTAR, *1922*, Ohio Geol. Survey, Bull. 25, p. 226, pl. 13, fig. 4 (not fig. 3).

This species is similar to *S. sculptilis* (Miller) and the two often have been considered synonyms. In fact, they can be distinguished readily by the more numerous costellae on the left front auricle as well as the shell body in *S. hertzeri,* by the greater umbonal angle, greater proportion of length to height, and ornate auricles of this form. There are 11 or 12 narrow, high costellae on the left anterior auricle, crossed by even higher regular fila that are continuous with those of the shell body. The posterior auricles are without distinct costellae, but they are ornamented by high, narrow fila. The anterior umbonal fold is narrow, rounded, curved outward slightly more than in *S. sculptilis,* and the rear fold is nearly straight. The anterior sulcus of the left valve is rounded instead of angular, producing a rounded sinus at the edge of the shell. The auricles are not depressed so markedly beneath the general shell surface as in *S. sculptilis*. Radial crossed-lamellar structure of the outer ostracum is well shown in several specimens, both right and left valve.

Measurements of specimens of *Streblochondria hertzeri* are given in the table on page 81.

Comparison.—The characters of form and ornamentation of auricles that distinguish this form from *S. sculptilis* (Miller) have been indicated. From *S. stantonensis,* this species is easily distinguished by its greater umbonal angle and greater proportion of length to height.

Material.—It has not been possible to locate Meek's types of *Aviculopecten hertzeri.* They were said to have been borrowed from Rev. H. Hertzer of the Ohio Geological Survey, and it is possible that some day they will be recognized in the collections of that institution. Fortunately the approximate locality and horizon of the types are known, so that it is possible to recognize the species. The above description is based on several specimens: an external mold from the McArthur member of the Pottsville formation, Moore mine, Elk Township, Vinton county, Ohio (Ohio St. Univ., No. 15,246); four molds from the lower Mercer limestone, Pottsville, Flint Ridge, Licking county, Ohio (U. S. Nat. Mus., No. 89,790); three other specimens from the same horizon and locality as the last (Kansas Univ., Paleont. Type Coll., No. 387); one squeeze of a right valve from the same place and horizon as the preceding two collections (Yale Univ., Peabody Mus., No. 14,457). Two of the specimens are fine internal molds, showing well the cardinal structures of *Streblochondria.*

Occurrence.—Upper Carboniferous, Des Moines subseries, Pennsylvanian. Meek's types are said to have come from Newark, Ohio, in the Lower Coal Measures. His specimens might have been obtained from either the lower Mercer or McArthur members of the Pottsville formation where the species is said to be abundant (Morningstar, 1922, p. 226). Specimens from both horizons show close agreement. Authentic specimens from the Mid-Continent region do not occur in our collections.

STREBLOCHONDRIA STANTONENSIS Newell, n. sp.

Plate 15, figures 1*a, b,* 3, 4

Shell high, narrow, with acute beaks; slightly opisthocline, nearly acline; anterior and posterior auricular sulci and corresponding sinuses broadly rounded; anterior fold of the left valve narrow, rounded, curved outward only very slightly; auricles ornamented by irregular growth lines; anterior auricle of the left valve with low, relatively broad costae. Right valve unknown.

Measurements of specimens of *S. stantonensis* are given in the table on page 81.

Comparison.—This species is distinctive, although at first sight it might be mistaken for *S. sculptilis* (Miller). It is especially characterized by the small umbonal angle and nearly straight umbonal folds, and by the fact that the left anterior sulcus, although deeply impressed as in *S. sculptilis,* is rounded and broad instead of angular.

Material.—Description of *S. stantonensis* is based on 12 specimens from a single locality. Most of them are fragments and none are well preserved, but in each instance there is a close correspondence in form, indicating a surprisingly small range in variation. The holotype and topoparatypes are in the Kansas Univ., Paleont. Type Coll., No. 381.

Occurrence.—Upper Carboniferous, in arenaceous, cross-bedded, oölitic limestone of the South Bend member of the Stanton formation (Lansing group, Missouri subseries), Pennsylvanian, cement plant quarry, Fredonia, Kan.

STREBLOCHONDRIA? MONTPELIERENSIS (Girty)

Plate 14, figures 6, 7

Aviculopecten? montpelierensis GIRTY, *1910,* U. S. Geol. Survey, Bull. 436, p. 42, pl. 4, figs. 9, 10.

Girty's description:

Shell sometimes attaining a medium or rather large size, subcircular, somewhat longer than wide; axis perpendicular to the hinge which is somewhat shorter than the width below. The convexity of both valves is about the same and rather high for the genus. In the right valve the anterior wing is depressed, sharply defined, auricular, with a deep byssal sinus. The posterior wing is small, narrowly triangular, and much depressed below the body of the shell, which arises abruptly from it. The outline rounds out strongly on the anterior side beneath the ear and to a less degree on the posterior side.

The shape of the left valve is somewhat similar to that of the right, though the anterior wing is not auricular and it has no sinus beneath it. It is more sharply defined than the posterior wing, though both are rather abruptly depressed.

In most specimens the surface of both valves appears to be smooth, with no markings except very obscure growth lines. In a few, however, there are traces of regular closely arranged, concentric lirae. These probably are a constant character of the shell and would be seen on all specimens if well preserved. Whether they are confined to the left valve or are common to both valves, however, has not been determined.

The largest specimen referred to here has a length of 33 mm., but the average is much smaller. In some examples the anterior side projects considerably more than the posterior, but usually the axis is about perpendicular to the cardinal line and the two sides are approximately symmetrical. Always, however, the anterior wing is larger and more sharply defined than the posterior. In the left valve the anterior wing often descends abruptly from the general convexity. The depression of the posterior wing is more gradual, but depends on the convexity of the medial portion, which varies in different individuals. The size of the wing is also subject to variation.

In addition it should be noted that there are almost invisible traces of radiating costellae on the umbonal area of the left valve. The concentric ornamentation alluded to above appears to me to be irregular undulations and varices of growth. There are no cardinal or other costae on the right valve. The anterior umbonal fold slightly overhangs the anterior sulcus in the left valve.

Remarks.—It is impossible to determine the affinities of this species from the material at hand. It was provisionally placed here because of the close similarity that it bears to *Streblochondria? tenuilineata* (Meek and Worthen). There is no reason to believe that this type of shell is one of the Pectinidae, as some of the Europeans have suggested by classing such shells with *Pseudamusium* or the poorly known *Syncyclonema.* On the other hand, the extreme simplicity of Carboniferous and Permian shells like the present species makes their discrimination difficult.

Comparison.—This form is similar to *Streblochondria? tenuilineata,* but is more nearly circular and lacks auricular costae. Furthermore, there is no trace in the material at hand of the umbonal fila of *tenuilineata.*

Material.—Two type specimens (U. S. Geol. Survey, Nos. 1,714, 1,713) are the basis for the above comments. I was permitted to study them through the courtesy of Doctor Girty.

Occurrence. — Permian, in black, carbonaceous limestone of the Phosphoria formation, Montpelier, Idaho, U. S. Geol. Survey station 3,511, Crawford Mountains, Wyo.; Thomas Fork, Wyo.; Bear Lake, Idaho.

STREBLOCHONDRIA? TENUILINEATA (Meek and Worthen)

Plate 1, figure 3; Plate 15, figures 10-16

Pecten tenuilineatus MEEK and WORTHEN, *1860,* Philadelphia Acad. Nat. Sci., Proc., p. 452.

Streblopteria? tenuilineata MEEK and WORTHEN, *1866,* Illinois Geol. Survey, vol. 2, p. 334, pl. 26, figs. 9*a, b.*

Crenipecten Foerstii HERRICK, *1887,* Denison Univ., Sci. Lab., Bull., vol. 2, p. 28, pl. 3, figs. 9, 9*a.*

Crenipecten foerstii MARK, *1922,* Ohio Geol. Survey, Bull. 25, p. 230, pl. 13, figs. 7, 8.

Streblopteria tenuilineata SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 121, pl. 11, figs. 3-3*a.*

Orbicular, slightly opisthocline, essentially smooth shells with the hinge margin about one half as long as the shell, and auricles of subequal length, the anterior only slightly longer than the posterior; valves moderately inflated, the right slightly flatter than the left; auricular sulci poorly defined, so that the angle at which they diverge is indefinite (the angle in the left valve at hand is approximately 85 degrees); shell body of the left valve smooth in the later stages, save for obscure growth lines, but covering the umbo to a shell height of about 3 mm. surface ornamented by relatively broad, flat and obscure fila separated by very narrow, sharply depressed interspaces; fila very uniform, increasing very gradually outward from the beak; along the vertical axis at a shell height of 2 to 3 mm., 18 fila occur in a space of 1 mm.; fila intersected by exceedingly fine, numerous costellae, producing a cancellated ornamentation that is scarcely visible without considerable magnification; costellae somewhat finer and more obscure than the fila, and distally fainter until there is no trace of them beyond a shell height of 2.5 mm.; depressions or pits occurring between the intersections of fila and cos-

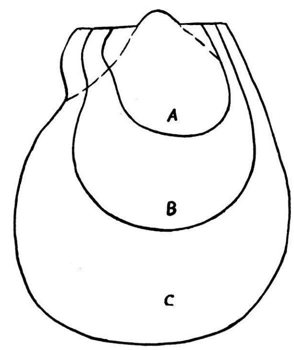

FIG. 31. *Streblochondria? tenuilineata.* Early growth stages in a paratype, showing progressive changes in form; camera lucida drawing of growth varices at shell height of 2.1 mm., 3.3 mm., and 5.0 mm., respectively.

tellae start to fade out so that the shell appears punctate over a small area; in addition to these juvenile characters the left valve shows a few faint, poorly defined radiating undulations. The auricles are set off by sulci, anterior fairly well defined and narrow, posterior broad, poorly defined; front margin of the flattened anterior auricle broadly sigmoid, with a broad and shallow byssal sinus below and a broad crest at the upper part of the anterior margin of the auricle; outer edge of the auricle meets the cardinal margin obliquely in a continuation of the marginal crest, but in juvenile stages, as shown by growth lines, there is a narrow, poorly defined sinus between the crest and cardinal margin, so that growth lines are somewhat recurved from the crest, intersecting the cardinal margin almost at right angles; posterior auricle only very slightly shorter than the anterior, but its area is very much less because the posterior umbonal slope curves inward, encroaching on the area of the auricle, whereas the anterior umbonal slope curves outward, giving the inner border of the anterior auricle a convex outline. The nearly straight dorsal part of the posterior margin of this valve meets the cardinal margin at an angle of about 130 degrees.

The holotype, a right valve, has a clearly defined groove corresponding to the trace of the byssal notch, but the posterior sulcus is poorly defined.

The umbonal angle approximates 105 degrees as a maximum, and about 85 degrees at the beak. A projection of the nearly straight dorsal part of the posterior margin meets the cardinal margin at about 130 degrees, but the posterior margin curves abruptly outward just under the hinge line, so that the angle is only a little greater than 90 degrees.

The body of the shell is smooth except for irregular fine growth lines in the adult parts of the shell and fine fila or regular growth lines on the slopes of the beak. The beak is slightly worn on this valve, as is generally the case in right valves, but apparently the ornamentation of this part of the shell was similar, although much finer than that of the left valve. Traces of obscure, irregularly spaced furrows radiate across the body of the shell from the beak. These are very narrow and can be seen only by proper illumination.

The anterior auricle is set off from the shell body by a narrow and deeply impressed sulcus which terminates distally at a narrow, sharply angular byssal notch. The anterior margin of this auricle is almost semicircular except for three slight crests corresponding to three narrow and shallow radiating sulci. The three sulci divide the auricle into four subequal areas. The cardinal and inner margins of the anterior auricle diverge from the beak at about 53 degrees in the adult, but the angle is larger at younger stages because of the outward flare of the anterior umbonal slope. The anterior auricle is ornamented by coarse irregular fila separated by shallow interspaces of about the same width as the fila. Up to a length (measured from the beak along the cardinal margin) of about 1 mm., the ornamentation is conspicuously finer than at later stages. This rather well-marked change occurs when the shell is about 4 mm. high. The fila extend dorsally beyond the cardinal margin in such a manner as to produce a regularly denticulate margin. There are 11 or 12 of these denticles on the anterior auricle of the holotype; about 5 denticles occupy the space of 1 mm. The relatively finer surface of the juvenile part of the auricle lacks well-defined projection at the cardinal margin, but after they appear, the spacing appears to be fairly uniform.

The posterior auricle is not arched dorsoventrally like the anterior one, but is nearly flat, and is set off from the umbo by an ill-defined sulcus. This sulcus is not depressed below the general surface of the auricle but nearly represents the indefinite juncture of the flat auricle and the convex umbonal slope. Because of the prosogyrate curvature of the umbo, the area of this auricle is less than it would be if the umbo were not curved. The posterior auricle is slightly shorter than the anterior, in a ratio of about ¾. The surface of the auricle is ornamented by two obscure, narrow sulci and several much fainter ones. At regular intervals along the cardinal margin the growth lines are gathered into angular fila which are abrupt on the posterior side and gentle on the anterior slope, like escarpments of gently dipping sedimentary beds. These fila extend dorsally beyond the main part of the auricle to form 10 or more acute denticles that are spaced about 10 in 2 mm. The fila and denticles are lacking in the juvenile shell near the beak. With the aid of xylol the radiating crossed-lamellar structure of the outer ostracum is readily seen in both valves.

Topotype specimens of Herrick's *Crenipecten foerstii* from Flint Ridge, Ohio, have been compared directly with the types of *S. tenuilineata* and there can be no doubt that they are the same. It was possible to examine the hinge in the specimens from Flint Ridge, and the character of the ligament area and resilifer appears to be the same as in *Streblochondria sculptilis* (Miller).

Measurements of *S. tenuilineata* are given in the table on page 81.

Comparison. — This shell differs from typical *Streblochondria* in being mostly smooth, in having a relatively long posterior auricle, and in the rounded, rather than angular left anterior auricle. The only reason indeed, for classifying it with the present genus instead of *Streblopteria* or similar forms is the cancellated ornamentation of the beaks. The character of the hinge is not even remotely like that of *Crenipecten* or the true pectinid *Pseudamusium,* as some of the European writers have classified such shells. Herrick was probably influenced in assigning this form to *Crenipecten* by the denticulate ornamentation of the dorsal margin in the right valve.

Material.—The original types of *Streblochondria? tenuilineata* (Univ. Ill., No. 12,880) were generously secured for me by Dr. J. Marvin Weller. The holotype is an exquisitely preserved right valve, and the topoparatype is a smaller, incomplete left valve, adherent to the same rock fragment as the holotype. Herrick's type of *Crenipecten foerstii* apparently has been destroyed, but I have examined several topotypes from Flint Ridge. Three of them, possibly paratypes, because they were in Herrick's possession when the species was described, are at the U. S. National Museum (No. 89,789). Other specimens from the same locality are in the Kansas Univ. Paleont. Type Coll. (No. 384). Other specimens of *Crenipecten foerstii,* described by Morningstar, (Ohio St. Univ., Nos. 15,288, 15,299) were examined, through the courtesy of Dr. J. E. Carman. There is some question as to the proper identification of these latter specimens because they do not conform well in shape to the Flint Ridge material.

Occurrence.—Upper Carboniferous. The types are said to have been found in the "Upper Coal Measures," south line of Clinton county, Illinois. A label accompanying the specimens bears the notation "L 86 t." Regarding this locality Dr. Harold Wanless writes, "the horizon here is probably our Shoal Creek limestone, which I believe is equivalent to your Hertha (lower Missouri subseries) or nearly so." The Flint Ridge material is from the lower Mercer limestone, Pottsville, lower Pennsylvanian, Licking county and southeast of Frazeysburg, Muskingum county, Ohio. Typical specimens occur in the black Hushpuckney shale, Swope formation, Devil's Backbone, near Winterset, Iowa. These horizons range in age from early Des Moines to Missouri in the Pennsylvanian series.

STREBLOCHONDRIA? GUADALUPENSIS (Girty)

Plate 15, figures 6, 7

Aviculopecten guadalupensis GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 436, pl. 16, figs. 20, 20*a*.

Aviculopecten sp. *a* GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 436, pl. 16, fig. 21.

Shell markedly opisthocline, anterior auricle about twice as long as the posterior; ornamentation of left valve consisting of coarse, intercalate costae, 23 on the shell body, in two or possibly three ranks, and 4 on the anterior auricle, at least one being a first order costa and the others second order costae; there appears to be in addition an obscure cardinal costa; anterior auricle with a few irregular coarse fila which might appear lamellose in unworn material; anterior sulcus of left valve deep, and there is no overhang of the adjoining fold, the outer slope of the fold being less than perpendicular to the plane of the auricle; posterior sulcus narrow, separating the flattened auricle from the broadly rounded umbo; terminations of the auricles quadrate, except in the front auricle of the right valve which is broadly rounded; ornamentation of the right valve consisting of 29 rounded prominent bifurcate costae and three additional costae on the upper part of the anterior auricle; shell structure not discernible.

Measurements of the types of *S. guadalupensis* are given in the table on page 81.

Comparison.—This species is unlike any described form known to me, and there is no established genus that includes a shell like this having bifurcate costae on the right valve. On the other hand, the material is much too poorly preserved to warrant erection of a new genus. There can be no question that this is a member of the Streblochondriinae, so that its general relations at least are definitely known.

Material.—Doctor Girty has very kindly invited me to examine his type specimens of this as well as other species. Holotype, U. S. Geol. Survey, No. 424; the other figured specimen is No. 425.

Occurrence. — Middle Permian. "Dark limestone," Bone Canyon limestone, Pine Spring, Guadalupe Mountains, Tex. (U. S. Geol. Survey sta. 2,930).

STREBLOCHONDRIA? INFELIX (Girty)

Plate 15, figures 17, 18

Aviculopecten infelix GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 438, pl. 9, figs. 9, 10.

Girty's description:

Shell small, length greater than breadth, erect or slightly inclined backward, cardinal line short. Ears nearly equal, quadrate, or somewhat extended. They are defined by reentrant angles on the outline and by grooves on the surface. The groove defining the anterior ear is more marked than that of the posterior. While without the deep byssal notch and specialized configuration of the anterior ear which is found in some species, the one ear is considerably more sharply defined than the other, and on this account I have regarded it as being the anterior ear of the right valve. The convexity is low. The inferior margin is broadly rounded.

Except for indistinct concentric markings, the surface is plain, without radiating ribs on any position.

The material on which this species is based, consisting of right valves, is too poor to be certain of the original shell surface. If there was originally any ornamentation, it is now lost from the type specimens. Altogether it seems probable that this species is congeneric with *Streblochondria? tenuilineata* (Meek and Worthen) and *S. ? montpelierensis* (Girty), this relationship cannot be determined beyond question. It is possible that a left valve of the present species would appear slightly more opisthocline than the nearly acline right valves at hand. *Euchondria* cannot be considered here, because in that genus the rear auricle is extended, and there is a pronounced prosocline obliquity in all of the known species.

Comparison.—From *S.? tenuilineata* and *S.? montpelierensis* the present form may be distinguished by its shape, being relatively higher.

Material.—The types (U. S. Geol. Survey, Nos. 414, 415), are poorly preserved right valves.

Occurrence.—Upper Permian, middle part of the Capitan limestone, Capitan Peak (U. S. Geol. Survey loc. 2,926) Guadalupe Mountains, Tex.

STREBLOCHONDRIA CONDRAI Newell, n. sp.

Plate 15, figures 8, 9

Slightly opisthocline, high streblochondrias, characterized by a relatively small number of fine, widely spaced radial costellae on the shell body and anterior auricle of the left valve; concentric fila, normal for the genus, replaced gradually at a shell height of about 7 mm. by irregularly spaced edges of imbricating lamellae, which are flat between costellae but become vaulted over them into small erect projections; auricles flattened, depressed markedly below the general shell surface, separated from the shell body by rather narrow rounded sulci, the inner slope of the left anterior sulcus being nearly perpendicular to the surface of the auricle; left anterior umbonal fold narrow, rounded distinctly, curved outward, posterior one obscure, nearly straight; auricles without distinct regular fila, except for obscure ones on the right anterior auricle; cardinal margins rugose; the rather marked curvature of the anterior umbonal folds suggests that these small forms are nearly full grown. In one left valve there are two or three costellae on the rear auricle, but some other specimens lack them.

Measurements of the types of *S. condrai* are given in the table on page 81.

Comparison.—The most distinctive thing about this form is the very slender, relatively wide-spaced costellae, which in the mature stage are not crossed by distinct fila. The specimens that I have, although rather small, are apparently mature, as evidenced by the marked curvature of the anterior umbonal folds, and the character of the ornamentation near the border of the shell.

Material.—There are six more or less fragmentary specimens in the collection before me. These exhibit such close agreement in size and distinctive ornamentation that it has seemed desirable to describe a new species on them. The inner ostracum has been dissolved from the specimens, but the outer film of ostracum, showing the radial crossed-lamellar structure, is still present in both valves. The holotype and five topotypes are catalogued as Yale Univ., Peabody Mus., No. 14,476.

Occurrence.—Upper Carboniferous, in arenaceous and shaly, gray to buff limestone of the Auburn shale (Wabaunsee group, Virgil subseries), Pennsylvanian series, Barroum Ranch, about 7.5 miles northeast of Foraker, Okla.

STREBLOCHONDRIA sp.

Plate 15, figure 5

A curious *Streblochondria* was found near Bartlesville, Okla., in the butte just west of town. This form is distinguished from the others by a very marked opisthocline obliquity and by an obsolescent character of the costellae over the posterior half of the shell. The horizon at Bartlesville is in the Lansing or Pedee group, Missouri subseries. A similar form is not uncommon at the Kereford limestone (Shawnee group, Virgil subseries) near Nehawka and Snyderville, Neb. Unfortunately, the material at hand is too fragmentary to warrant the application of a new name, or even to be positive that all of the several specimens are conspecific. The figured specimen is a squeeze of a fairly well-preserved mold from Bartlesville.

STREBLOCHONDRIA SUBEQUIVALVA (Beede)

Plate 15, figure 2

Aviculopecten subequivalva BEEDE, *1902,* Kansas Univ., Sci. Bull., vol. 1, p. 149, pl. 5, figs. 3, 3*a*.

Beede's description:

Shell thick, moderately large, subequivalvular, rather convex, quite oblique, ears well developed. The hinge is nearly straight, the beak does not project, the angle of divergence of its sides is about eighty to ninety degrees. The left valve, exclusive of the ears, is ovate; anterior ear well developed, obtusely angular, marked only by strong lines of growth; the rise from the ear to the body of the shell is abrupt; the marginal sinus separating the ear from the rest of the shell broad, shallow, and ill-defined. The posterior ear is unknown. The anterior margin below the ear forms an ovate curve, which is probably continued on the ventral and marked only by stronger and fainter concentric lines except on the front and back sides, where there are radiating rows of vaulted lamellae. It is entirely probable that these marks once extended over the entire surface, but have been worn off from the more convex portions. Judging from another specimen, the right valve is somewhat flatter than the left and quite as oblique. Posterior ear very small and obtuse; anterior ear quite large, marked by obscure, large radiating ribs and probably vaulted lamellae, as well as strong concentric markings; separated from the shell by a deep sulcus. Margin from the beak around the posterior to near the middle of the shell is a regular ovate curve, anter-ventral margin somewhat produced but rounded, extending obliquely toward the beak until the deep byssal sinus is reached. Ornamentation as in the other valve. In this specimen it seems that the radiating rows of scales covered the entire surface before being worn away. Length, 36 mm.; height, 32 mm.; hinge, 17 mm.; thickness, about 5 mm.

Position and locality: Thin limestone, south of Dover, Kan., in Upper Coal Measures. Type in author's collection.

It appears to me that Beede's description and illustrations do not distinguish this form sufficiently to permit recognition of the species. However, topotype specimens may be secured at some future date, serving as a basis for a revised description.

The rocks in the vicinity of Dover, Kan., belong mostly to the Wabaunsee group (Virgil subseries) of the upper Pennsylvanian.

Genus STREBLOPTERIA McCoy, 1851

Streblopteria MCCOY, *1851,* Annals Mag. Nat. History, vol. 7, p. 170.

Eumicrotis HIND, *1903,* Carb. Lamell., vol. 2, p. 43.

Shell acline to opisthocline, orbicular, valves of nearly equal convexity, smooth, with gibbous umbones; posterior umbonal fold lacking in either valve, anterior fold rounded, ill-defined; posterior auricular sulcus broad, coextensive with the poorly defined auricle, anterior sulcus of the left valve narrow, deep, rounded, curving outward markedly; anterior auricle well defined, small, with a rounded anterior margin; posterior auricle ill defined with obtuse terminal angle, as long or longer than the anterior.

Genolectotype. — *Streblopteria laevigata* (McCoy), Carboniferous limestone, Ireland. Designated by Meek and Worthen (1866, p. 333) and By S. A. Miller (1889, p. 514).

Range.—Lower Carboniferous to Permian (?).

Remarks.—Our knowledge of the genus *Streblopteria* is most unsatisfactory. McCoy described the hinge as having "one short narrow tooth slightly diverging from the hinge line in the posterior side of the beaks; ligament confined to a narrow, simple facet on the hinge-margin." These features of the articulus described by McCoy were not illustrated by him, or by any subsequent writer, so that we are left to interpret as best we can his almost unintelligible statement. No species known to me has the characters mentioned by McCoy.

An extended attempt has been made to secure authentic specimens of *Streblopteria laevigata* in order to examine and redescribe the hinge structure, but thus far it has not been possible to obtain such specimens. American Pennsylvanian rocks contain a small form that externally is like *S. laevigata,* and I believe that the two are congeneric. In the American form, *Streblopteria oklahomensis,* n. sp., I have not been able to make a wholly satisfactory study of the hinge, since the exact shape of the resilifer has not been determined. On the other hand, there is no question that the Pennsylvanian species has hinge structure like those of the Aviculopectinidae. This species is unlike any of the other Streblochondriinae in being devoid of any ornamentation at any stage, and apparently, in having a structureless outer ostracum in both valves.

Whatever may be the hinge characters of *Streblopteria,* it is absurd to believe that they diverge as greatly from the other Aviculopectinidae as McCoy's diagnosis would suggest. It generally is difficult to see the hinge structures in Paleozoic pectinoids, and it seems highly probable that McCoy mistook the ventral projecting shoulder of the ligament area for a lateral tooth. His failure to recognize a resilifer in *Streblopteria* is not surprising when we recall that he made such erroneous observation for *Aviculopecten.* As was pointed out elsewhere, the absence of resilifer pits in shells like this, except in the hinge type possessed by the Pterinopectinidae, would be an anomalous feature, quite incompatible with any of the modern groups that might conceivably be related to the ancient pectinoids. Even in *Pinna* and *Pteria* there is a special elongate triangular groove for the reception of the resilium, whereas the nonfibrous ligament in front and behind the resilium is not inserted in such a groove, but is confined to a flattened area on either valve.

Hind (1903, p. 43, 47) has confused the issue greatly. He supposed that Meek's *Eumicrotis* (type *Pseudomonotis hawni*) was a smooth, biconvex shell. Accordingly, he placed De Koninck's genus *Rutotia* in synonomy with *Eumicrotis.* Hind's classification of *Eumicrotis* and *Rutotia,* as far as I can tell from the literature, does not differ materially from *Streblopteria.* In spite of the similarity, amounting almost to identity, between Hind's descriptions and illustrations of *Streblopteria* and *Eumicrotis,* he apparently considered the two groups, as classified by him, entirely distinct.

The genus *Rutotia* as classed by De Koninck (Mus. royale histoire nat. Belgique Ann., tome 11, p. 196) is a smooth suborbicular shell, with poorly defined rear auricles, resembling *Streblopteria* in most respects but lacking, according to De Koninck's figures, a byssal notch in either valve, and possessing a marked prosocline obliquity. If De Koninck's interpretation of his material was correct, *Rutotia* is not a member of the Pectinacea.

According to Hind, *Rutotia hemisphaerica* (Phillips) has a well-defined byssal notch. This species, one of the genosyntypes of *Rutotia,* as described on authentic material by Hind, looks like a *Streblopteria.* De Koninck's *Rutotia grandis,* another genosyntype of *Rutotia,* looks so different from any other genus that I am disposed to think that someone familiar with De Koninck's specimens should designate it as the genolectotype, if it really has the characters ascribed to it by De Koninck. However, if *Rutotia* cannot be made known more fully, apparently it could be placed in synonymy with *Streblopteria* by designating Phillip's *Pecten hemisphaericus* as the type. It seems unwise to follow either course at the present time, since I have no knowledge of the location or condition of the types, nor any assurance that either De Koninck's or Hind's descriptions are satisfactory.

STREBLOPTERIA OKLAHOMENSIS Newell, n. sp.

Plate 14, figures 8a-12

Orbicular, acline or slightly opisthocline, smooth shells, with equally convex, gibbous valves; hinge margin about half as long as the shell length; anterior auricle equal or sligthly shorter than posterior, which is a simple undifferentiated flattening from the umbones, terminating in a definite obtuse angle of about 140 to 145 degrees; posterior umbonal fold lacking, sulcus broad, ill-defined, corresponding in area to the auricle; anterior fold distinct, rounded, curving rather markedly outward, bounding on the left valve a deep, narrow sulcus; byssal notch on the right valve ornamented by rugose irregular growth-lines, conforming to the semicircular anterior margin, crossed in some specimens by two or three faint radial grooves, which divide the auricle, so to speak, into three or four broad obscure costae, —— radial ornamentation in other specimens, however, being absent. Thin sections of the shells at hand indicate that the outer ostracum in each valve is homogeneous. Such evidence might at the present time be taken as tentative until other specimens, preserved differently, can be discovered. This outer ostracum of the right valve was definitely not prismatic, however, because species of *Aviculopecten* and *Limipecten* having the same clay-ironstone kind of matrix have perfectly preserved polygonal prisms in the right valve. One specimen, an internal mold, shows definitely the divergent ligament area of the Aviculopectinidae. It appears, although this is not certain, that the resilifer is long—one third as long as the hinge margin—and most of it lies behind the beaks. There is no cardinal costa on either valve.

MEASUREMENTS OF BIVALVE SPECIMENS OF *Streblopteria oklahomensis* Newell, n. sp.

Specimen No.	Length, mm.	Height, mm.	Convexity of both valves, mm.	Hinge length, mm.
1[a]	17±	17	7	8±
2	15	16	7.5	8±
3	19	21	9.5	10±
4	15	19	8.5	8

a. Holotype

Comparison.—This species is similar to *Streblochondria? tenuilineata* (Meek and Worthen), but it seems proper to place these species in different genera on the basis of umbonal ornamentation, which is present in *tenuilineata* and absent in *oklahomensis*. Our specimens of *Streblopteria oklahomensis* show the outer ostracum apparently perfectly preserved and unworn, yet there is no discernible ornamentation other than ordinary growth lines, nor is there any visible distinctive shell structure in either valve. Right valves of the two species can be readily distinguished by the peculiar ridge or costa bounding the inner margin of the byssal notch in *S. oklahomensis*. The size of the angle between the posterior margin of the shell and the hinge line is slightly greater in the present species than in *S.? tenuilineata*. I am quite confident that the reticulose ornamentation seen on the beaks of *tenuilineata* would be visible on the present specimens if it ever occurred, because it is readily distinguished in somewhat worn or crushed specimens of the former species, and the specimens of *oklahomensis* at hand appear to be quite unworn.

Material.—The species is based on 10 specimens, well preserved but more or less fragmentary, in every instance with both valves fixed in apposition. Holotype and six topoparatypes, Kansas Univ., Paleont. Type Coll., No. 380; topoparatypes, Yale Univ., Peabody Mus., No. 14,477; and one paratype, Kansas Univ., Paleont. Type Coll., No. 381. All of the specimens are free individuals, from argillaceous gray or buff shale. The interiors contain an exceedingly hard, tough, clay-ironstone matrix.

Occurrence. — Upper Carboniferous. A single paratype was collected in the Boggy shale (Des Moines), sec. 18, T. 35 S., R. 7 E., Oklahoma; the other specimens are from a horizon correlated with the basal Eudora shale (Lansing), 2½ miles west of Wann, Okla., and five miles northeast of Copan, Okla.

Genus OBLIQUIPECTEN Hind, 1903

Obliquipecten HIND, *1903,* Carboniferous Lamellibranchiata, vol. 2, Palaeont. Soc., p. 114.

Markedly opisthocline Aviculopectinidae with flattened valves, nearly smooth save for a few fine radiating costae on the anterior part of each valve and a few coarse fila on the anterior auricle of the right valve; hinge short, about half as long as the shell body; posterior auricle obsolete, very small and obscure, smaller on the right than left valve, with a very obtuse posterodorsal angle; anterior auricle of right valve subcircular, higher than long, projecting above the hinge axis; umbonal convexity in the right valve projected ventrally in a broad ridge that extends from beak to an obscure angularity at the posteroventral margin, sloping abruptly along its course down to the posterior edge of the shell; central and anterior part of right valve peculiarly flat, without an anterior umbonal fold; left valve with a well-developed anterior fold and an obscure posterior one; posterior area of shell body flattened along an axis corresponding to the posterior ridge of the right valve; posteroventral margin subangular as in the right valve; ligament area comparatively narrow, with a triangular resilifer, the posterior part of which is extended; outer ostracum in each valve radially crossed-lamellar, most readily observed on the auricles; cardinal costa absent.

Genotype.—*Obliquipecten laevis* Hind, Carboniferous limestone, Settle, England.

Range.—Lower Carboniferous.

Remarks.—This genus has not been recorded as yet outside of England. The remarkable extent to which the opisthocline obliquity has been carried, and the nearly complete loss of the posterior auricle characterizes this form from all others.

I must acknowledge the very great generosity of the curators at Sedgwick Museum, Cambridge, England, in entrusting to me the types of *Obliquipecten laevis* Hind, and with their consent I have been able to prepare the ligament area in the holotype. The ligament area proves to be that of the Aviculopectinidae, and the resilifer has a forward obliquity as in Aviculopecten, rather than a backward obliquity as in *Streblochondria.*

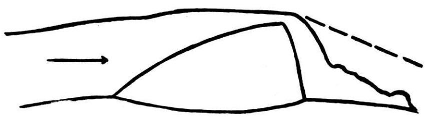

FIG. 32. Plan view of part of the ligament area in left valve of the lectotype of *Obliquipecten laevis* Hind, × 7, showing the oblique resilifer pit; the arrow points toward the anterior end of the shell.

The types of *Obliquipecten laevis* (see pl. 8, figs. 3-5*b*) before me are seven in number, six right valves and one left valve, here designated the lectotype. The specimens are preserved in a fine-grained, hard, gray limestone.

Genus CAMPTONECTES Agassiz?

Camptonectes GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 432.

I am tentatively following the course adopted by Girty in dealing with a group of Permian pectinoids from western Texas, although it is my opinion that the species under consideration belong to an undescribed genus of the Streblochondriinae. However, since I am unable, in the absence of good material, to discover any characters of the hinge or significant structures of the shell substance by which this group can be placed in the proper family, I would rather not propose a new genus at this time. The statements made by Doctor Girty on this interesting group of Permian forms are quoted:

This title is used for a peculiar group of forms which occurs in abundance in the Capitan formation of the Guadalupian series. Among its distinguishing characteristics the most striking are its forward obliquity, the large anterior and small posterior ear, the lack of definition of the posterior ear, and the surface ornamentation. The latter character proves to be the very variable. It seems to consist primarily of nodes or papillae which are arranged in curved diagonal lines outwardly concave. These nodes, which distinguish the surface of *C.? papillatus,* appear to have been connected with tubules traversing the shell at a strongly acute angle with the surface, and probably were continued outward into spines, which lay nearly flat along the shell in a radial direction.

With this character is probably connected an observation made on a shell related to those under consideration. In this instance the test was seen to be minutely and abundantly punctate, somewhat as in *Terebratula* or *Eumetria.* This is the only example in which punctation was observed, and it is on a much finer scale than the tubules in *C.? papillatus;* but as will later appear, this group shows wide variations in the scale of its ornamentation. Toward the circumference the rows of nodes tend to pass into continuous lirae, a circumstance which connects this species with *C.? sculptilis.* There the lirae tend to diverge pinnately from a median line, curving outward as they go. In *C.? asperatus* the two types of surface are more or less combined, but on a greatly reduced scale and with some modifications. Minute tubulous papillae cover the surface, but over the peripheral portions tend to form continuous lirae, which, however, are not in two sets with a pinnate arrangement, but in multiple groups and with a zigzag direction. It is probable with an ornamentation of this type that the punctate shell above referred to is most easily to be compared. Another factor which may be of importance is that on internal molds of the right valve the anterior ear shows obscure traces of radiating ribs, which are not seen on the exterior.

These shells in some respects can be appropriately compared with McCoy's genus *Streblopteria.* The forward prolongation of the shell is a rather striking character of both, and still further agreement can be traced in the fact that the anterior ear is defined and the posterior undefined. On the other hand, the type species of *Streblopteria* is smooth, while these Guadalupian shells have the peculiar ornamentation above described. Furthermore, typical *Streblopteria* has a large posterior and a small anterior ear. This is one of the diagnostic characters mentioned by McCoy. Unfortunately, in the case of *Streblopteria,* as well as in *Camptonectes?,* no comparison can be made in the matter of internal characters.

Camptonectes seems to agree with the Guadalupian forms in having a large, well-defined anterior ear and small, undefined posterior ear. In some species, at least, it has the same forward prolongation. The characteristic external feature of *Camptonectes* consists, however, in the radiating lines which diverge along a median line. This peculiar type of sculpture is repeated in *C.? sculptilis,* but the singular surface features of the other Guadalupian forms which are manifestly closely related to *C.? sculptilis* are unknown in *Camptonectes* proper. The punctate structure, which can hardly prove an erroneous observation, is altogether an anomalous character. Of the two genera considered, the Guadalupian forms appear to present points of closer similarity with *Camptonectes.* If the observations recorded here are established by further research, it seems certain, however, that they belong to a genus yet undefined.

It has not been possible for me to confirm Girty's observations on shell structure in any of the type specimens, but I have not seen very many of these shells, and those that I have examined are rather badly altered.

CAMPTONECTES? PAPILLATUS Girty

Plate 14, figures 4, 5

Camptonectes? papillatus GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 433, pl. 9, figs. 3-3*a*, 5-5*a*.

Girty's description:

The type specimen of this species is a left valve, and from it the following description is taken:

Shell small, rather oblique, and inclined forward. Convexity low and broad, hinge line short. Posterior ear probably small and undefined, anterior ear large and defined both by a notch in the outline and by being sharply depressed below the curvature of the body of the shell. The axis is curved, concave toward the anterior side. The surface is marked with papillae, which increase in size proportionally to the dimensions of the shell. Over the upper half they are small, and the surface appears to be almost smooth. They have a sort of quincunx arrangement such that they tend to form two sets of curved lines intersecting at an acute angle. Their lines are concave toward the anterior and posterior sides of the shell. Their curvature is greatest near the margins, especially near the lateral margins. In this region also the linear arrangement is more strongly marked, and tends to develop into connected ribs. The papillae appear to have been the bases of small spines pointing radially and almost tangential to the surface.

In addition to the type specimen, four other examples have come to hand, all left valves. They are small and more or less imperfect both as to shape and surface ornamentation, and it can not be told with certainty whether they belong here or with *C.? sculptilis.* The right valve is unknown, though probably among a number of right valves whose surface has been destroyed by exfoliation representatives of this species are found. It is probable that the right valve is the counterpart of the other in surface and configuration.

It appears to me after examining the types that the preservation is such that no satisfactory conclusions as to the original shell structure can be made, although thin sections might aid. The ornamentation appears to be largely confined to a surficial film of calcite, now granular. I cannot confirm the tubular character of the papillae, but certainly some of them suggest vaulted lamellae, as seen in *Pseudomonotis.* The preservation is such that the growth lines are not sharp and distinct, and it may be that perfect material would show vaulted projections from the edges of imbricating growth lamellae. No evidence of punctae was seen. The auricles appear to have been smooth, but the preservation is not wholly satisfactory in this particular.

Comparison.—This species is distinguished from similar ones by the rather coarsely papillate nature of the ornamentation.

Material.—Holotype, U. S. Geol. Survey, No. 351, a nearly complete left valve, but preserved rather imperfectly.

Occurrence.—Upper Permian, middle Capitan limestone, Capitan Peak (U. S. Geol. Survey sta. 2,926) Guadalupe Mountains, Tex.

CAMPTONECTES? SCULPTILIS Girty

Plate 14, figure 1

Camptonectes? sculptilis GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 434, pl. 9, figs. 4, 4*a*.

The ornamentation consists of "two sets of curved lirae apparently developed pinnately along the median line" rather than the rows of papillae such as occur in *C.? papillatus.*

The holotype is a fragment of a right valve, showing well the surface ornamentation, but illustrating very little else.

Comparison.—This form is distinct from similar ones in the character of ornamentation. Other means by which it might be distinguished from species having the same type of ornamentation must await discovery of more complete material.

Material.—Holotype, a fragmentary right valve, U. S. Geol. Survey, No. 352.

Occurrence.—Upper Permian, middle Capitan limestone, Capitan Peak, Guadalupe Mountains, Tex. (U. S. Geol. Survey sta. 2,926); questionably identified in the Word formation of the Glass Mountains, 1.5 mile N. 55 degrees W. of the old Hess ranch house, western Texas.

CAMPTONECTES? ASPERATUS Girty

Plate 14, figures 2, 3

Camptonectes? asperatus GIRTY, *1908,* U. S. Geol. Survey, Prof. Paper 58, p. 434, pl. 9, figs. 1, 2.

Girty's description:

This species much resembles *Camptonectes? papillatus,* the chief difference being in the surface ornamentation. The shape appears to be almost identically the same, but as the typical examples are right valves there is a deep notch under the anterior ear. The surface is of the same character as *C.? papillatus,* but on a very much finer scale. Apparently two types of surface are found to occur on the same shell, one consisting of intersecting rows of papillae and the other of intersecting lirae. I am inclined to believe that the two kinds of surface are more or less alternating. The scale is so small in the case of this species that it is difficult to tell whether the lines are continuous or interrupted; and it seems probable that preservation might alter the appearance to some degree. The lines have a more or less zigzag appearance on a portion of the surface.

All of these specimens are right valves, and as they occur in the same beds with *C.? papillatus,* which is represented by left valves, the presumptive evidence is certainly considerable that they belong together. On the other hand, the surface ornamentation though of the same general character as in *C.? papillatus* is yet so different in effect that the greater probability seems to favor regarding them as distinct. Furthermore, in *C.? sculptilis* both valves seem to have the same and not different ornamentation, though this fact, which would be important if proved, cannot be insisted on, because some uncertainty exists as to whether all the shells referred to *sculptilis* really are of the same species.

The fossils representing these species indicate that the two valves are practically equal, and that they have similar if not the same surface ornamentation.

Comparison.—The distinguishing features of the species have been stated in the above description.

Material.—The holotype (U. S. Geol. Survey, No. 355) and one other type specimen (U. S. Geol. Survey, No. 354) were examined through the kindness of Doctor Girty. These specimens are somewhat better preserved than is commonly the case in the group.

Occurrence.—Upper Permian, middle Capitan formation, Capitan Peak, Guadalupe Mountains, Texas (U. S. Geol. Survey sta. 2,926); also questionably identified from the Word formation, Glass Mountains, 1.5 miles N. 55 degrees W. of the old Hess Ranch House, western Texas.

SUBFAMILY PSEUDOMONOTINAE Newell, n. subfamily

Aviculopectinidae having a nearly flat or concave right valve, a very convex left valve, and retaining a primitive prosocline rhombic form until a relatively advanced ontogenetic stage; posterior auricle not extended nor set off from the shell body by a marginal sinus; retractors lost in sessile forms; right outer ostracum irregularly prismatic; left outer ostracum structureless. Figure 17 indicates the inferred relationships.

Genus PSEUDOMONOTIS Beyrich, 1862

Pseudomonotis E. BEYRICH, *1862,* Zeitschr. d. deutsch. geol. Gesell. Bd. 14, S. 10; genolectotype, *Gryphites speluncaria* Schlotheim, from the German Zechstein, selected by Stoliczka (Geol. Survey India, p. 389, 1871).

Eumicrotis MEEK, *1864,* Am. Jour. Sci. 2d ser., vol. 37, p. 216; genoholotype, *Monotis hawni* Meek and Hayden, from Big Blue series of Kansas.

Prospondylus ZIMMERMANN, *1886,* Jahrb. d. h. preuss. geol. Land., S. 109; genoholotype, *Prospondylus liebeanus* Zimmerman, from the German Zechstein.

Aviculomonotis GRABAU, *1931,* Nat. Hist. Central Asia, vol. 4 Permian of Mongolia, p. 322; genoholotype, *Aviculomonotis mongoliensis* Grabau. from the Permian Jisu Honguer limestone of Mongolia.

In addition to the family and subfamily characters, the genus is characterized by simple costate ornamentation on both valves, increase in ornamentation being by implantation; right valve attached at the umbo to extraneous objects throughout life, or only during maturity; retractor muscles obsolete in adults, correlative with an invariably obsolescent or obsolete byssal notch. The outer ostracum of the right valve is irregularly prismatic calcite exactly as in *Aviculopecten,* the left, homogeneous calcite; inner ostracum aragonite, microstructure unknown; in most species the shell passes through a curious cycle of form changes, beginning with the primitive prosocline shape, passing through acline and opisthocline form stages respectively, and finally reverting at full maturity to a secondarily acquired prosocline obliquity.

Remarks.—Great confusion has long existed regarding the nature of *Pseudomonotis,* most of the difficulty arising from lack of agreement as to the genotype species. One modern school, following M. Cossmann (1902, p. 75,194), has accepted *Gryphites speluncaria* Schlotheim of the Zechstein as the genotype. A second school, under the leadership of C. Diener (1902, p. 342; 1903, p. 17; 1923, p. 35), regards the Triassic form, *Avicula ochotica* Keyserling, as the type species of *Pseudomonotis.* In my opinion, as well as that of some other paleontologists, the Zechstein and Triassic species are not congeneric, and therefore the issue should receive a solution that may be accepted by all.

Pseudomonotis was established by Beyrich in 1862 as a subgenus of *Avicula.* The following is a free translation of the reference from which *Pseudomonotis* must date:

The second species from L. von Buch's collection from Schwerfen, near Kommern, is similar to *Avicula contorta* of the Kössen beds, but the preservation prevents a complete comparison. *A. contorta* is not a *Cassianella,* although the associated beautiful *Avicula speciosa* of the Alps belongs to this genus. *A. contorta* belongs in the group of inequivalve *Avicula* species which begins with the Zechstein *Avicula speluncaria* and is frequently quite erroneously classified with Bronn's *Monotis.* The *Monotis* (type *M. salinaria*) is almost equivalve, without a byssal ear. The inequivalve true Aviculae of the indicated affinities can be named as a subgenus *Pseudomonotis,* to which *Aucella* might be related by virtue of the reduction of the posterior ear as compared to the characteristic *Avicula* form. (Beyrich, 1862, p. 10.)

According to legal procedure *Avicula contorta* Portlock, from the Rhaetic beds, and *Avicula speluncaria* (Schlotheim) from the Zechstein, are the genosyntypes, and the subsequent designation of a genolectotype for *Pseudomonotis,* in order to be valid under the code of International Zoölogical Nomenclature, must apply to one of these two species, and no other.

In 1871, Stoliczka (1871, p. 389) designated *Gryphites speluncaria* Schlotheim as genolectotype for *Pseudomonotis,* and as far as I can learn this was the first published selection of a type for the genus.

The selection of *Avicula ochotica* Keyserling by Diener as the type of *Pseudomonotis* violates the rules, which provide that only those species listed in the original reference to the genus, and which fall within the generic diagnosis are to be considered in the selection of a genolectotype.

In 1864, Meek (1864, p. 216) proposed the new genus *Eumicrotis,* with the genotype *Monotis hawni* Meek and Hayden, recognizing the close relationship of *M. hawni* and *Monotis speluncaria* (Schlotheim). As soon as Meek learned that his genus was antedated by *Pseudomonotis* Beyrich by two years, he immediately and properly abandoned *Eumicrotis* for the former genus.

In 1903. Hind (1903, p. 43) proposed to distinguish *Eumicrotis* from *Pseudomonotis* on the grounds that *Eumicrotis,* as exemplified by *E. hawni,* was thought to be less convex than the genotype of *Pseudomonotis, P. speluncaria,* and to lack the peculiar posterior lobe separated from the remainder of the shell by an oblique sulcus on the left valve. Unfortunately, Hind completely misinterpreted the nature of *E. hawni,* for he applied the term *Eumicrotis* to British Lower Carboniferous smooth forms that probably should be classed as *Streblopteria.*

The lobation referred to by Hind is not useful, even as a specific character, because it is encountered in almost every known species of *Pseudomonotis* s. s. The lobation is not a constant feature of any species known to me, because many specimens exhibit no trace of lobation, but are associated with lobed specimens which in other respects they resemble.

Many kinds of pelecypods exhibit a lobation like that shown in some *Pseudomonotis*. Regarding the origin of the posterior lobation in oysters Jackson (1890, p. 307) says:

The sinuosity of the right valve is apparently due to the constantly retracted condition of the right mantle border at this point. It is constantly retracted to admit of the passage of the excurrent water and being so retracted, as a necessary result, the shell is not built at this area as rapidly as at other places where the mantle is fully extended. It might be considered that the peculiar excurrent opening was due to the mechanical conditions under which the oyster lives, an opening being necessary on account of the close relation of the shell to the object of fixation, and it is possible that this is the case; but against it may be urged the fact that no such character is found in *Anomia* which is subject to similar conditions. I think that this excurrent passage and the correlated sinuosity of the right valve are of hereditary significance. Examining the fossils, we find a similar sinuosity of the left and right valve characteristic in marked degree of the genus *Gryphaea;* it is also found frequently in *Exogyra* and in many fossil members of the Aviculidae, from which last group the Ostreidae were doubtless evolved.

I am inclined at the present time to take exception to the last suggestion concerning the possible derivation of the oysters from the pterioids (or pectinoids). Oysters are invariably attached by the *left* valve, whereas all pterioids and pectinoids lie on, or attached by the *right* valve. Furthermore, there is no byssal notch at any stage in any of the oysters. In spite of the striking resemblance of form and ligament between *Gryphaea* and *Pseudomonotis* there appears to be little liklihood that they were closely related.

Further controversies regarding *Pseudomonotis* center around the genus *Prospondylus,* established in 1886 by Zimmerman on the basis of the Zechstein *Prospondylus liebeanus* Zimmermann (1886, p. 109). At present I have no original observations regarding *Prospondylus* because authentic representatives of *P. liebeanus* have not been available to me. The problem is well summed up by Licharew (1931, p. 35) who states that:

Prospondylus was placed by Zimmerman between the Spondylidae and Pectinidae. Frech in 1891 identified it with *Hinnites*. Netchaev referred *Prospondylus* to the Ostreidae, but in 1898 Philippi again considered it as a representative of the group of edentulous Spondylidae and gave it the following diagnosis: "Formen mit massig breiter, Austernähnlicher Ligamentgrube, die linke Klappe meist tiefer als die rechte. Vorn und hinten deutlich ausgebildete Ohren. Skulptur besteht aus dichtstehenden Rippen erster und zweiter Ordnung. Zechstein-Deutsche Trias."

In 1912 Frech returned to the question of *Prospondylus*. Having discovered the presence of a notch for the issue of byssus in the anterior auricle of one of the specimens of this form from the Zechstein of Murom, determined by him as *Prospondylus liebeanus* Frech, he concluded that *Prospondylus* is to be considered as a subgenus of *Pseudomonotis sensu lato*. He gives the following diagnosis of *Prospondylus*: "Wölbung der beiden kraftigen Schalen annähernd gleich; die recht festgewachsene Klappe ein wenig konvexer, als die linke. Byssusohr sehr deutlich abgegrenzt. Radialskulptur kraftig. Ligamentgrube subcentral, gross."

According to Frech, *Prospondylus* differs from *Pseudomonotis sensu lato* in a sharply pronounced ornamentation, a greater thickness of the attached valve and a backwardly inclined ligament. Besides *Prospondylus liebeanus* Zimmerman, Frech refers to this genus five other species from the Triassic deposits of Hungary.

It is obvious that *Prospondylus,* as employed by Frech and Licharew, is synonymous in all respects with *Pseudomonotis*. The resilifers in American species range from symmetrical to very oblique. Licharew, like many other writers, has stressed the importance of shell thickness for distinguishing species and genera. I suspect that many of the Paleozoic pelecypods described as having very thin shells owe their apparent thinness to the fact that the inner orstracum is commonly absent, the aragonite having been dissolved away so as to leave only a thin shell layer of the more resistant calcite outer ostracum.

The general confusion surrounding *Pseudomonotis* has not been lessened by introduction of the term *Aviculomonotis* (Grabau, 1931, p. 325) proposal of which was incidental to description of the type species, *A. mongoliensis* Grabau, from the Permian of Mongolia. *Aviculomonotis* was founded without diagnosis in the following terms:

The reference of our species to the genus *Pseudomonotis* is questionable; probably it and the British form (*Aviculopecten interstitialis* Phillips), as well as the two following species, should both be referred at least to a distinct subgenus, for which the name *Aviculomonotis* Grabau (subgen. nov.) is here proposed with *A. mongoliensis* as the genotype.

An examination of the figures of *A. mongoliensis* reveals no characters by which the species might be distinguished from a typical *Pseudomonotis* s. s., nor does Grabau state in the description how he would distinguish *Aviculomonotis* from typical *Pseudomonotis*. I cannot agree that *Aviculopecten interstitialis* (Phillips), a typical representative of *Aviculopecten* from the British Lower Carboniferous rocks, is closely related to *Aviculomonotis mongoliensis* Grabau. Until satisfactory means for distinguishing *Aviculomonotis* from *Pseudomonotis* are made known, it seems best to place *Aviculomonotis* in the synonymy of *Pseudomonotis* s. s.

Geologic range.—A few decades ago *Pseudomonotis* was regarded as an index to Permian or later rocks. This supposition resulted from the fact that *Pseudomonotis* is not found below the Permian in western Europe where the genus was first made known. The fact that marine Upper Carboniferous rocks are mostly lacking in this region, however, makes this observation of the lower limit of geologic range of little significance.

Typical *Pseudomonotis* appears in America in the Morrow subseries of the Pennsylvanian rocks (Upper Carboniferous) in Arkansas. This occurrence, represented by *precursor* Mather, *inflata* Mather, and *P. aurisculpta* Mather, is apparently the earliest recorded appearance of the genus. It is possible that the habit of fixation had not been acquired in this tribe before Pennsylvanian time, in which case the Mississippian ancestors of *Pseudomonotis* would very likely have more nearly the characteristic pectinid form than the later species. A specimen of *Pseudomonotis sayrei,* n. sp., shows the curious feature of a smooth left valve and a costate right valve at a juvenile stage preceding fixation. *P. hawni* and some other species of *Pseudomonotis* became attached so early in life that right valves do not exhibit any recognizable prefixation stage. If *Pseudomonotis,* as defined here, is monophyletic we must look for an ancestor having a smooth left valve of marked convexity and a nearly flat costate right valve, in which the costae increase in number by intercalation. There should be no marginal sinus below the posterior auricles. The outer ostracum of the right valve should be irregularly prismatic, as in *Pseudomonotis,* and the hinge characters should be like those of the Aviculopectinidae. Unfortunately, it is impossible at the present time to obtain this information from the literature on any Lower Carboniferous species.

The genus *Pseudomonotis* ranges completely through the Pennsylvanian series and Permian system. It is commonly recorded in the Mesozoic systems but many of these citations refer to the group of *"Pseudomonotis" ochotica,* which does not appear to me to be congeneric with the Paleozoic forms. It is highly probable that there are Triassic derivatives of *Pseudomonotis,* but to my knowledge such relationship has not yet been demonstrated.

PSEUDOMONOTIS HAWNI (Meek and Hayden)

Plate 17, figures 11*a, b;* Plate 18, figures 8-16

Monotis Hawni MEEK and HAYDEN, *1858,* Albany Inst., Trans., vol. 4, p. 76; *1859,* Philadelphia Acad. Nat. Sci., Proc., p. 28.

Eumicrotis Hawni MEEK and HAYDEN, *1864,* Paleontology Upper Missouri, p. 54, pl. 2, figs. 5*a-c*.

Eumicrotis Hawni var. *ovata* MEEK and HAYDEN, *1864,* Paleontology Upper Missouri, p. 55, pl. 2, figs. 5*a, b*.

Large numbers of *Pseudomonotis* occur at several horizons in the Big Blue series of Kansas and Nebraska. Locally limestone beds in some cases shaly, are filled with representatives of the genus. I am identifying these Big Blue forms with *P. hawni* Meek and Hayden. In spite of the local abundance of this species, well-preserved specimens are exceedingly rare, for almost all of these fossils are preserved as impressions or subinternal molds. In few instances is the shell substance completely retained.

P. hawni shows clearly the distinctive characters of the genus, additional features of specific nature being its variable form, ranging in plan from circular to subovate; left valve only moderately convex in most individuals, and having an only moderately inflated umbo with a relatively sharp beak; a large proportion of specimens exhibit an ill-defined posterolateral sulcus extending radially from the umbo of the left valve, producing an obscure posterior lobation of the shell; ornamentation relatively coarse, consisting in average specimens having a height of 3½ to 4 cm. of about 10 coarse scaly costae separated by 3, or rarely 5, finer, nearly smooth costae, of which the middle one is of intermediate size; the number of coarse, scaly costae is only relatively constant, because in individual lots I have observed occasional specimens having as few as 8 and as many as 14 of the coarse costae.

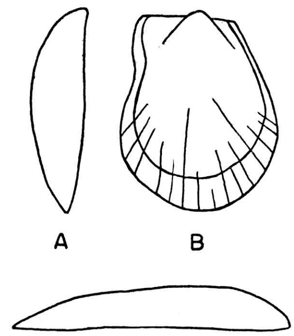

FIG. 33. *Pseudomonotis hawni* (Meek and Hayden). Upper figure, A-B, a juvenile left valve, showing narrow beak, convexity, form, and ornamentation, approximately × 4; lower figure, profile of a mature left valve, × 1, showing convexity from the beak (right) to the ventral margin (left); camera lucida drawings.

Remarks.—Probably the most constant and characteristic feature of the species is the distinctive form and convexity of the beak, which permits a ready distinction of this form from the similar *Pseudomonotis beedei,* n. sp. The posterior auricle in juvenile *P. hawni* is relatively short and more reduced than in *P. beedei,* and the beak is very much more pointed and pronounced in typical specimens. The largest observed specimen of *P. hawni* has a length and height of about 50 mm. Most individuals have only an obscure left anterior auricle and byssal sinus, differing in this respect from the well-defined byssal sinus found in the older species.

The right, or lower valve is flat or slightly convex, and except for the beak area is ornamented like the left with intercalculating costae, which are, however, noticeably finer than those of the opposite valve. A cicatrix of attachment appears to be present invariably at the umbonal area; in several specimens this scar measures 1 to 2½ cm. across. Radial ornamentation begins beyond the scar.

Comparison.—Adult specimens of *Pseudomonotis* commonly exhibit such variability that considerable difficulty has been experienced by paleontologists in discriminating species. It has been my experience that this difficulty of identification decreases where abundant well-preserved material is at hand. One cannot satisfactorily identify poorly preserved, or isolated specimens of *Pseudomonotis,* but I have found that collections containing a few good specimens of *P. hawni* from the upper half of the Big Blue series can be distinguished readily from adequate collections of the similar, much older, *P. beedei,* n. sp. Greater difficulty is experienced in dealing with specimens from the lower part of the Big Blue series, because this material consists chiefly of isolated or poorly preserved specimens. There appears to be considerable variation among these specimens, and I anticipate that it may ultimately be desirable to exclude some of them from *P. hawni.* The diagnosis given above concerns only the typical *P. hawni* from the Chase and Sumner groups. In addition to having a much more prominent and sharper beak on the left valve, *P. hawni* differs from *P. beedei* in being less gibbous and in having sparser and slightly coarser ornamentation.

Material.—The holotype of *P. hawni* (U. S. Nat. Mus., No. 3,958) is an internal mold retaining the impressions of both valves. The external ornamentation is not shown, but some paratypes from the same locality exhibit the essential features of the ornamentation of the left valve. The matrix is a grayish-buff, dolomitic limestone filled with the molds of tiny fossils. The length of the specimen is 37 mm.; height, 36 mm.; hinge length, 20 mm. The types of *P. hawni* var. *ovata* (U. S. Nat. Mus., Nos. 1,157, 1,158) occur in dense dolomitic limestone, and are preserved in the form of molds. These types of *ovata* came from "near Cottonwood Creek," Kansas. Prof. M. K. Elias, who is familiar with the stratigraphy of this region, informs me that the horizon of abundant *Pseudomonotis* along Cottonwood creek is the Herington limestone. After an examination of the type specimens and specimens from the Herington limestone supplied me by Professor Elias, I am convinced that the original types came from this horizon.

In addition to the types of *P. hawni* and the variety *ovata* a large number of fine specimens from the Herington limestone, as well as several dozens of isolated specimens from various horizons, were used as the foundation for the foregoing description.

Almost invariably, specimens of *P. hawni* that have come under my observation occur in a matrix of silty argillaceous limestone, or cavernous dolomitic limestone. Commonly, the only remaining part of the shell in argillaceous limestone is the outer ostracum of both valves. In dolomitic limestone, even this is generally gone, so that preservation is in the form of internal and external molds. At many horizons in the Big Blue series these shells are incrusted with a calcareous cover that resembles the alga, *Somphospongia multiformis* Beede. A number of shells show the effect of boring organisms and exhibit encrusting worn tubes, evidence of the inactive habits of the host. Generally the shells of *P. hawni* occur in large numbers in fairly thin, persistent zones, and they are commonly associated with species of *Aviculopecten, Bakewellia,* and *Myalina,* among pelecypods, and *Juresania* of the brachiopods. *P. hawni* is a gregarious species and locally the shells of this form are overwhelmingly predominant in the faunules.

Occurrence.—Lower Permian. *P. hawni* is especially characteristic of the upper part of the Big Blue series (Lower Permian), in the northern Mid-Continent region. Less typical forms identified with the species are common in the lower part of the Big Blue series, but are not found in older rocks. The holotype of *P. hawni* was collected from "near the mouth of Smoky Hill fork of Kansas river, Kansas." The entire Big Blue series is exposed in the vicinity of the mouth of the Smoky Hill, but it seems most likely from the appearance of the specimen that it came from one of the limestones in the Chase or Sumner groups, very probably the Herington limestone.

In the collections at hand the species has been identified in the Burr limestone, Florena shale, Middleburg limestone, Crouse limestone, Funston limestone, Wreford limestone, Krider limestone, and Herington limestone. Undoubtedly the species will be discovered at other horizons in the Big Blue series.

PSEUDOMONOTIS SUBLAEVIS Girty

Plate 18, figures 17, 18

Pseudomonotis sublaevis GIRTY, *1909,* U. S. Geol. Survey, Bull. 389, p. 80, pl. 9, figs. 1, 2 (not 3). Yeso formation, San Andreas, New Mexico.

Girty's description:

Shell large. Shape subovate, rather irregular. Hinge shorter than the width below, ears small.

Surface of the left valve with obsolescent sculpture. In the umbonal region it is marked by fine, irregular, more or less wavy costae, a few of which, arranged at rather regular intervals, are somewhat larger than the others. In the course of growth the smaller costae as a rule soon die out, while a few of the larger ones, from 1 to 12 or more in number, much increased in size, pass on to the ventral border. More rarely some of the smaller costae are persistent. The whole surface is also crossed by closely arranged, irregular, concentric, lamellose lines and wrinkles.

This species is related to *P. hawni,* but is distinguished by its obsolescent sculpture and by the rarity or absence of spinelike scales springing from the larger costae. These could hardly fail to be preserved upon our specimens if originally present, and they were apparently developed very rarely, perhaps not at all.

Comparison.—After examination of the type specimens of this species I am inclined to agree with Doctor Girty that this form is probably distinct from *P. hawni,* but the shell preservation is rather poor and it is possible that the radial ornamentation may be more pronounced in perfectly preserved specimens.

Material.—My observations were made on the three specimens figured by Girty in the original description of the species. His figure 3 is probably a *Pseudomonotis hawni,* and appears to belong to a different species from the other two. Figured types, U. S. Geol. Survey, Nos. 1,420 (holotype), 1,421, 1,422.

Occurrence.—Permian, Yeso formation, San Andreas Mountains, New Mexico, east of Engle, in red beds about 700 feet above the top of a massive red sandstone.

PSEUDOMONOTIS BEEDEI Newell, n. sp.

Plate 16, figures 2, 3

Pseudomonotis cf. *hawni* BEEDE, *1899,* Kansas Univ. Quart., vol. 8, p. 83, pl. 19, figs. 7*a-f*.

Pseudomonotis hawni (part) BEEDE, *1900,* Kansas Univ. Geol. Survey, vol. 6, p. 132, pl. 15, figs. 1*a-d*.

Pseudomonotis hawni SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 112, pl. 9, figs. 1, 2.

As early as 1899, Beede recognized the characters by which this form may be distinguished from the similar *P. hawni,* but he did not venture at that time, or subsequently, to propose a distinct name for the form under consideration. This is probably one of the most variable species of *Pseudomonotis.* In spite of this general lack of uniformity in adults, the characters of the juvenile shell, as recorded in the beak of the left valve, are surprisingly constant and are very distinctive. The end of the beak in *P. beedei* is relatively flattened, scarcely any more convex than the general surface of the umbo, and is rather poorly defined in most specimens. In this respect the species resembles *P. equistriata* Beede and *P. robusta* Beede, with which it is associated. The hinge is relatively long at the juvenile stage, so that the shell outline is subrhombic, with a distinct prosocline obliquity. In *P. hawni,* on the other hand, the beak is well defined even in juveniles, and the hinge is distinctly shorter than the body of the shell.

The more obvious but less constant distinguishing features of *P. beedei* are the marked convexity of the left valve and inflation of the umbo. Commonly the whole valve is arcuate, with a strongly incurved beak.

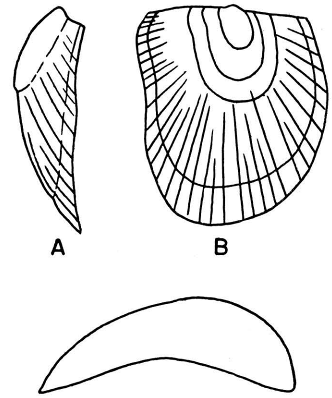

FIG. 34. *Pseudomonotis beedei* Newell. Upper figure, A-B, successive growth stages on the beak of a characteristic left valve, approximately × 4, showing the rhombic form, relatively flattened beak, and radial ornamentation; the constriction around the beak shown in A is an accident of growth. Lower figure, profile of the holotype, a left valve, beak at the right, ventral margin at left, × 1. Camera lucida drawings.

The ornamentation is generally, but not invariably, finer and more dense than in *P. hawni,* resulting in a greater number of costae in the former species. The number and coarseness of costae in *P. beedei* is highly variable. In general, there are two types of costae—coarse scaly or spinose costae, and fine costae, 3 to 7 or more of which are implanted between the coarse costae. The fine costae of a few specimens are also scaly, and there is a general tendency for imbricating scaly spines to be produced on all costae near the shell margin of mature specimens. The number of coarse scaly costae observed in various specimens ranges from about 12 to 21, but these figures probably do not represent the extreme range of variation.

Most specimens display a more or less well-defined sulcus extending from the umbonal region toward the posteroventral margin of the left valve, producing a sort of posterior lobation of the shell. This feature, however, is obscure or lacking in some specimens. The largest measured specimen has a height of 50 mm. and a length of about 45 mm.

Comparison.—Of the described American species of *Pseudomonotis, P. hawni* is most nearly like *P. beedei.* The latter differs from the former in the greater convexity shown by typical specimens, less prominent umbo and flattened beak of the left valve, more numerous costae, and greater variability in form.

Material.—The species is founded on several scores of fairly well-preserved specimens, most of which were obtained from the Westerville oölite in the Kansas City region. The holotype (Kansas Univ., Paleont. Type Coll., No. 385) was obtained from the Haskell limestone near Lawrence, Kan.

This species has been found in three kinds of sediments. The most common occurrence is in oölitic limestone, three fourths of my material having been found in such rock, representing several horizons. Sandstone and argillaceous limestone have yielded a few individuals. The known occurrences of *P. beedei* were all associated with other kinds of mollusks, chiefly pelecypods and gastropods.

Occurrence.—Upper Carboniferous, Drum oölite (Kansas City group) near Independence, Kan., has yielded a number of specimens of the species, most of which are preserved as internal molds. The Westerville oölite (Kansas City group), at Kansas City, is the most prolific source of specimens, and has furnished several scores of paratypes. Other horizons represented in my collections are: Springhill limestone (Lansing group), Captain Creek limestone (Lansing group), Haskell limestone (Douglas group) (holotype), Kereford limestone (Shawnee group), and Graham formation (Lower Cisco group, Texas).

PSEUDOMONOTIS EQUISTRIATA Beede

Plate 17, figures 3-7, 9, 10, 12-14

Pseudomonotis hawni equistriata BEEDE, *1899,* Kansas Univ. Quart., vol. 8, p. 82, pl. 18, figs. 3-3*b*.

Pseudomonotis tenuistriata BEEDE, *1899,* Kansas Univ. Quart., vol. 8, p. 81, pl. 18, figs. 1-1*d* (homonym of *P. tenuistriata* Bittner, 1899, supposed to have a few weeks priority).

Pseudomonotis kansasensis BEEDE, *1900,* Kansas Univ. Geol. Survey, vol. 6, p. 133, pl. 14, figs. 1-1*d* (proposed as a new name for the preoccupied *P. tenuistriata* Beede). ———, Girty, *1903,* U. S. Geol. Survey, Prof. Paper 16, p. 428, pl. 8, fig. 4; Girty, *1915,* U. S. Geol. Survey, Bull. 544, p. 129, pl. 17, figs. 4, 4*a*. ———, SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 113, pl. 10, figs. 6, 7.

Pseudomonotis equistriata GIRTY, *1903,* U. S. Geol. Survey, Prof. Paper 16, p. 428, pl. 8, fig. 5. ———, SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 114, pl. 9, figs. 10-12.

This form, because of variability in shape that exceeds even that of *P. beedei,* is one of the most perplexing of all American species of *Pseudomonotis.* The variability occurs even in relatively undistorted specimens and it affects the convexity of juvenile parts of the shell, although the form of growth lines in this part of the shell is fairly constant. I find it difficult to believe that the habit of attachment alone is responsible for the irregularity of this species. It also appears unlikely that the problem can be simplified by discriminatior of a larger number of separate species. Most, but not all, of my material comes from the Westerville oölite in the Kansas City region. In these collections the variation is so extreme and gradation so complete that I am disposed to bring together two of Beede's species P. *equistriata* and *P. kansasensis* under one name, *P. equistriata.*

The maximum size of mature growth varies, attaining a height and breadth in my largest specimen of about 60 mm. Some specimens, because of their extreme convexity and contortion, appear to have ceased their growth at a height of 20 mm. The larger specimens are relatively flattened and expanding.

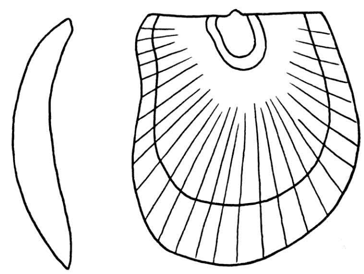

FIG. 35. A topotype specimen of *Pseudomonotis equistriata* Beede; ontogenetic changes on the umbo of a well-preserved, unworn left valve, and profile, showing the convexity, × 4 (camera lucida drawings).

The form of the juvenile parts of the shell is about the same as that in *P. beedei.* The single feature by which I have distinguished this variable form most definitely from others is the nature of the ornamentation. The body of the shell is covered by a very large number of fine, low, generally equal costae. The costae are not noticeably modified by scaly spines or projections, but are relatively smooth and regular. The species is not constant, however, even in character of ornamentation, because about half of my specimens show two or three orders of costae, one order being distinctly coarser than the other two. Even in these specimens the coarser costae are relatively fine and almost smooth.

At a shell height of about 25 mm. in several specimens, the costae range in number from about 100 to 125. The addition of new costae by implantation is very much more regular than is ordinarily the case in *Pseudomonotis,* so that in those specimens exhibiting two or three distinct sizes of costae, adjoining pairs of first order costae are generally separated by the same number of finer costae as other pairs.

Comparison.—This species is more nearly like *P. robusta* than any other form known to me, differing from that species principally in the form and convexity of the juvenile portions of the left valve, as exhibited at the umbo. The umbo in *P. robusta* is remarkably flat and the hinge is relatively long in the juvenile stage as compared with *P. equistriata*. There are occasional specimens of *P. beedei,* n. sp., that could easily be confused with this one. *P. beedei* typically has a few relatively coarse, invariably scaly costae at maturity, separated by finer smooth costae.

Material.—The material before me includes the holotype and several paratypes of *P. equistriata* and *P. kansasensis,* as well as scores of topotype specimens from the Westerville oölite at Turner, Kan., and Kansas City, Mo. The specimens are generally well preserved, but many of them are covered by a hard incrusting algal deposit that makes detailed study of the ornamentation difficult. Holotype of *P. equistriata,* Kansas Univ., Paleont. Type Coll., No. 389.1; holotype of *P. kansasensis,* Kansas Univ., Paleont. Type Coll., No. 370.1.

Specimens have been found mainly in oölitic and argillaceous limestones. The valves of *P. equistriata* are invariably separated in the oölitic occurrences, and other evidences of current action, such as cross-bedding, indicate that the shells have been transported more or less, perhaps from another environment.

Occurrence.—Upper Carboniferous. This species appears to be long ranging, for I have referred to it specimens from various parts of the Pennsylvanian series. By far the greater part of my material comes from the Westerville oölitic limestone in the Kansas City region, and it is possible that if large collections of the form could be obtained at other horizons some useful basis for further subdivision could be discovered. The species has been identified from the following formations: in Oklahoma, Wewoka; in Kansas, Missouri or Nebraska, Winterset, Drum, Westerville, Stoner, Kereford, Lecompton, Auburn, Florence; in Colorado, Rico; in Texas, Cisco (near Graham).

PSEUDOMONOTIS ROBUSTA Beede

Plate 17, figures 1*a*-2

Pseudomonotis? robusta BEEDE, *1899,* Kansas Univ. Quart., vol. 8, p. 82, pl. 18, figs. 2, 2*a* (not 2b, 2c); *1900,* Kansas Univ. Geol. Survey, vol. 6, p. 133, pl. 14, figs. 2, 2*a* (not 2*b*, 2*c*).

This is a relatively rare species, but there are five specimens in the collections at hand, all of which exhibit the diagnostic features. *P. robusta* is ornamented like *P. equistriata,* having a large number of fine, subequal costae, none of which is spinose or markedly roughened by imbricating layers of growth. The holotype, which is by far the largest known specimen, has about 180 costae at the margin. This individual has a height of 42 mm. and a width of 48 mm. If the shell were flattened out somewhat, it would have a height of 60 mm. The length of the hinge is 22 mm.

It appears to me that the critical character of the species is not the dorsoventral arching of the shell as illustrated by the holotype, and stressed by Beede, but rather the distinctive shape and convexity of the juvenile part of the left valve. The

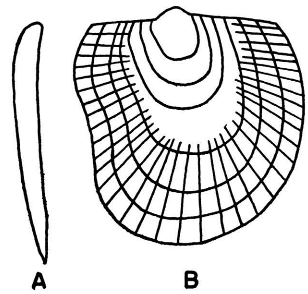

FIG. 36. Camera lucida drawings of the umbonal area of a topotype, a left valve, of *Pseudomonotis robusta* Beede, approximately × 4.

primitive rhombic prosocline form, illustrated in the earlier juvenile stage of all species of *Pseudomonotis,* is retained to a height of 15 or 20 mm., and the hinge is relatively long, lending an archaic aspect to the shell. The relatively great hinge length is retained in at least some adults, although cementation obviously could produce distortion of the hinge in some shells. One juvenile specimen has a height of 17 mm., length, 14 mm., and hinge length of about 13 mm. At this size the shell is nearly flat. The beak is small, obscure, and only very slightly more convex than the surrounding area of the umbo. The right valve is unknown.

Comparison.—The character of the ornamentation of this species appears to ally it with *P. equistriata,* from which it differs in the form and convexity of the juvenile stages. There is no other species that has come to my attention with which it might logically be confused.

Material.—The material at hand includes the holotype (Kansas Univ., Paleont. Type Coll., No. 388), two or three topotypes from the Westerville limestone near Kansas City, and in addition a specimen from the Winterset limestone. The Westerville specimens are all preserved in a matrix of oölite, whereas the Winterset specimen is associated with other mollusks in dark-gray, carbonaceous limestone.

Occurrence. — Upper Carboniferous, recognized thus far only in the Westerville (Kansas City group) (holotype) and Winterset (Bronson group) limestones, associated with other mollusks.

Group of PSEUDOMONOTIS SPINOSA Sayre

In the middle Pennsylvanian (Missourian) rocks of Kansas, and lower and middle Upper Carboniferous (C_2, C_3) of the Donetz Basin in Russia, there occurs a suite of *Pseudomonotis* species that differ somewhat from typical *Pseudomonotis*. These forms, including *P. spinosa* Sayre, *P. fredoniensis*, n. sp., *P. sayrei*, n. sp., and *P. mutabilis* Fedotov, form a closely related group of such distinctive character that I was at first disposed to erect a new genus or subgenus for it. This first impression was abandoned, however, when I sought to draw up a diagnosis by which these forms could be set apart from *Pseudomonotis*.

In the American species, and probably also in the Russian *P. mutabilis*, there are two distinct growth stages. The umbo of the left valve is sharply set off from the later part of the valve in being nearly smooth, and markedly more convex. Distinct ornamentation is acquired just beyond the margin of this part of the shell. The distinctive nuclear or juvenile part of the shell is rather uniform in size and shape, ranging in height from about 4 to 9 mm. in various specimens of the three American species. The most striking feature of the nuclear shell, however, is a marked opisthocline obliquity and a height distinctly greater than the length. I suspect that the two well defined growth stages—juvenile and adult—are correlated with the habits of the living animal. The juvenile portion of the shell is undistorted and uniform in quite a number of specimens, whereas the mature part of the shell is invariably irregular and contorted. The inference may be drawn from these observations that the habit of fixation was acquired when the shell had a height of 4 to 9 mm. This theory is substantiated by the fact that one of the specimens of *P. sayrei* retains both valves, and the nuclear stage of the right valve, unlike that of the left, is ornamented with distinct, unmodified fine costae, which are lost on the mature, presumably attached, part of the shell.

Judging from ontogeny, the ancestor of this group of *Pseudomonotis* was an opisthocline, or possibly acline, pectiniform shell with a smooth left valve and a costate right valve. A group of Russian species *P. gapeevi*, *P. jakovlevi*, *P. kumpani*, and *P. stepanovi*, recently described by Fedotov (1932), possess characters that appear to place them in the ancestry of this distinctive group of *P. spinosa*. They differ in form, however, from juvenile *P. spinosa* in being more nearly acline, and having an acute instead of obtuse rear auricle. They are too symmetrical to be attached forms, and they should probably be established in a new genus.

PSEUDOMONOTIS SPINOSA Sayre

Plate 18, figures 1*a*-2

Pseudomonotis spinosa (part) SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 114, pl. 10, figs. 3, 3*a* (not figs. 4, 4*a*).

The shell is relatively small for a *Pseudomonotis*, having a height and length of 25 mm. in the largest specimens at hand, with a hinge length of one third to one half of the length of the shell body. The beak of the left valve is very prominent and narrow, and somewhat incurved at the hinge. The umbo of the left valve is smooth and strongly inflated, changing markedly beyond a height of about 8 mm. At this size there is an abrupt decrease in convexity, and a curious ornamentation, consisting of numerous very fine, obscure costae intersected by closely spaced scaly growth varices, makes appearance. The intersecting radial and concentric lines produces a quincunxial arrangement of fine, depressed, scale-like projections. Beyond a shell height of about 17 mm. this striking ornamentation is modified by addition of 17 to 19 coarse plications which apparently have no relation to the fine costae. Right valve unknown.

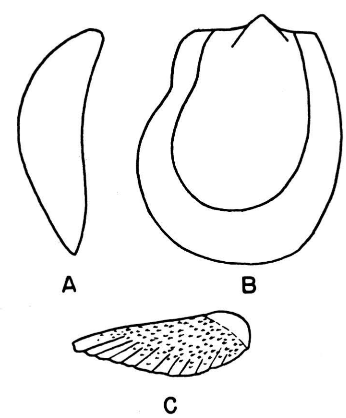

FIG. 37. Holotype of *Pseudomonotis spinosa* Sayre; A, rear view, beak at top, ventral edge below, ×4; B, plan view of the smooth nuclear part of the umbo, ×4; C, rear view, ×1, of the whole valve, showing three chief ontogenetic stages, differing in ornamentation; (camera lucida drawings).

Comparison.—Although there are only two specimens of this form in my collection, they are remarkably alike in all respects so that I do not doubt that this is a distinct species, although very closely related to *P. sayrei*, n. sp. From the latter species it differs chiefly in the late appearance of the plications, because in *P. sayrei* the folding extends to the margin of the nuclear part of the shell.

Material.—The above description is based on the lectotype (Kansas Univ., Paleont. Type Coll., No. 391.1) and a single paratype. I have separated a number of the original paratypes under the new name *P. sayrei.*

Occurrence.—Upper Carboniferous, known thus far only in the oölite part of the Westerville limestone (Kansas City group) in the Kansas City region, Pennsylvanian.

PSEUDOMONOTIS SAYREI Newell, n. sp.

Plate 18, figures 3, *5a, b*

Pseudomonotis spinosa (part) SAYRE, *1930,* Kansas Geol. Survey, Bull. 17, p. 114, pl. 10, figs. 4, 4*a* (not figs. 3, 3*a*).

This species appears to be more variable than the closely related *P. spinosa,* but this may be only apparent because I have a better representation of *P. sayrei* than of *P. spinosa.*

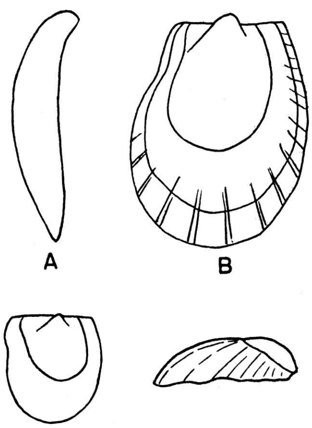

FIG. 38. Holotype of *Pseudomonotis sayrei* Newell; *A, B,* rear and side views respectively of the constricted area, showing the juvenile characters of convexity, form, and ornamentation of the nuclear part of the left valve, approximately × 4; *C,* an earlier stage, × 7.5, showing the abrupt change from the prosocline to acline obliquity; *D,* rear view of the entire left valve, × 1, showing the constricted umbonal area (shown in *A* and *B*) and the mature, plicate part of the shell; (camera lucida drawings).

This species is closely similar to *P. sayrei,* as evidenced by the same curious nuclear juvenile stage. In the present form, however, faint costae appear in some cases on the outer margins of the nuclear shell, becoming progressively coarser toward the periphery of the mature shell until they become distinct folds or plications. Some specimens, like the holotype, show very fine, almost invisible costae between the plications, and the fine costae are covered with scaly shell projections arranged in an obscure quincunx. Other specimens show no trace of the fine costae or the scales and some of these specimens are remarkably like a plicated *Platyceras* shell. It is possible that the non-scaly forms should be set aside as a distinct species, but I prefer to consider them as members of one variable species. The number of plications observed ranges from 13 to 21 in a few specimens in which a count can be made. The largest specimen is 30 mm. high. One small right valve in the collection is distinctly concave, and except for growth varices is nearly smooth in the mature part up to a height of 9 mm., where plications first appear; a nuclear area, deeply concave, occurs around the beak; this area is covered with very fine but distinct costae, of which 14 appear simultaneously. At a shell height of 8 mm., in this right valve, there are 24 of the costae, increase being by somewhat irregular implantation. The costae extend a short distance beyond the nuclear depression, which is only 6 mm. across in the direction of the shell height.

Comparison.—This species is quite similar to *P. mutabilis* Fedotov from the Donetz Basin in Russia —indeed, it is not easy to indicate a ready means by which the American forms can be distinguished from some of the specimens figured by Fedotov. In general, it appears that the radial plications of the Russian specimens are more numerous than in *P. sayrei,* but I cannot be certain because Fedotov makes no statement as to the number of plications in the Russian form. The Russian form is recorded from stages C_2 and C_3 of the Donetz Basin, from beds corresponding approximately to our Des Moines and Missouri series, and since *P. sayrei* has not yet been encountered outside of Missourian rocks, these two species occur in rocks of about the same age.

Material.—The collections before me include 14 specimens, several of which are syntypes of *P. spinosa* Sayre. The holotype (Kansas Univ., Paleont. Type Coll., No. 392.1) is a well-preserved specimen from the Westerville oölite. Most of the specimens occur in oölitic limestone, but one specimen was found by Prof. M. K. Elias in dark, carbonaceous limestone that is not oölitic, although associated with layers of oölitic limestone.

Occurrence.—Upper Carboniferous. The holotype and 12 paratypes were obtained from the Westerville oölite in the Kansas City region; one specimen was found in the Drum oölite near Independence, Kan., and a single specimen was discovered in the upper, molluscan part, of the Winterset limestone at Kansas City, Kan. All of these occurrences belong in the Missouri subseries, Pennsylvanian series.

PSEUDOMONOTIS FREDONIENSIS Newell, n. sp.

Plate 18, figures 4, 6, 7

A curious fauna occurs in the Stanton limestone (Stoner member) at Fredonia, Kan. This fauna is unlike that of the same or other formations elsewhere in Kansas in that many of the species and a few genera of invertebrates are unlike those found elsewhere in the Kansas section. It appears probable that this fauna is an exotic one, incorporating elements from some basin that was not ordinarily in free communication with the Kansas area. One of these exotic species is a peculiar *Pseudomonotis*, somewhat similar to the striking *P. spinosa* Sayre and *P. sayrei*, n. sp. My collection contains about 15 specimens, all left valves, of which the largest has a height and length of 50 mm. As in the preceding two species, there is an opisthocline, unornamented juvenile part of the shell at the umbo. Ordinarily this part of the shell is markedly more convex than the mature shell, and has a height of 8 or 9 mm.

The species is especially characterized by peculiarities of the costae on the mature part of the shell. The costae are numerous, subequal, and relatively narrow, ranging from 65 to 90 at a shell height of 30 mm. They are not modified by scaly projections, but are remarkable for their abundance and for the presence of local swelling and pinching that produces a marked rugose effect. The costae are relatively high and narrow and commonly are quite irregular in their course across the shell. Increase in numbers of costae is effected by irregular implantation. Right valve unknown.

Comparison.—No species known to me can be confused with this one. Although obviously closely akin to *P. spinosa* and *P. sayrei,* it can be distinguished readily by the larger number of subequal, narrow and prominent costae. The little collection at hand exhibits more contortion of form than is shown in the adults of the two mentioned species, but this difference is probably not distinctive.

Material.—The collection at hand contains 15 specimens including the holotype (Kansas Univ., Paleont. Type Coll., No. 393.1), all from a single locality and horizon. The types were obtained from a peculiar, granular suboölitic limestone, associated with a mixed brachiopod and molluscan fauna.

Occurrence.—Upper Carboniferous. Confined, so far as known, to the Stoner member of the Stanton limestone, found at a cement plant quarry in Fredonia, Kan. Lansing group, Missouri subseries, Pennsylvanian series.

Miscellaneous Species of PSEUDOMONOTIS

PSEUDOMONOTIS AURISCULPTA (Mather)

Plate 17, figure 15

Aviculopecten aurisculptus MATHER, *1915,* Denison Univ., Sci. Lab., Bull., p. 224, pl. 15, fig. 12. Hale formation, East Mountain, Fayetteville, Ark.

This curious species was founded on a single specimen, the characters of which are so striking that the species may be easily recognized. The left valve is subhemispherical, symmetrical, and not in the least contorted. The regularity in form suggests that this was not a cemented shell. The byssal sulcus and anterior auricle are covered with fine intercalate costae which become progressively fainter toward the ventral margin and toward the shell body. Except for the 18 or more anterior costae and distinct lines of growth, the shell is quite smooth. The distinctness of the growth lines proves conclusively that the absence of costae over the shell body is not due to abrasion. Although the posterior part of the shell is missing, its outline can be inferred from the growth lines of the umbonal area. The posterior auricle was apparently obtuse, as in *Pseudomonotis.* The marked convexity of the single known specimen, a left valve, suggests a much flatter right valve, like that of *Pseudomonotis,* rather than one of the subequivalve Streblochondriinae.

Comparison.—This species appears to be unique in the curious obsolescent character of the ornamentation.

Material.—The only known specimen of this species is the holotype, Univ. Chicago, Walker Mus., No. 16,050.

Occurrence.—Upper Carboniferous. Hale formation, Morrow subseries, East Mountain, near Klyce Spring, Fayetteville, Ark., Pennsylvanian series.

PSEUDOMONOTIS PRECURSOR Mather

Plate 17, figures 8*a-c*

Pseudomonotis precursor MATHER, *1915,* Denison Univ., Sci. Lab., Bull., p. 217, pl. 15, figs. 1, 1*a*. Brentwood limestone, northeast of Fayetteville, Ark.

In many respects this form is like *Pseudomonotis? auriculpta* (Mather), and it is probable that they are rather closely related. The shell is subhemispherical, with an evenly inflated left valve and a shallowly concave right valve. The surface of the left valve in the holotype is covered with about 90 very fine intercalate costae which do not extend to the beaks, but leave a smooth area 3 or 4 mm. high on the umbo. The right valve is similarly ornamented up to a height of about 12 mm. where, in the holotype, there appears to be a cicatrix of fixation. The marginal area of the valve is devoid of costae and exhibits only lines and wrinkles of growth. The holotype has a height and length of about 13 mm.

Comparison.—This species is characterized by its regular form and convexity, and by the remarkably fine costae.

Material.—The species was based on two specimens, one of which, the holotype (Univ. Chicago, Walker Mus., No. 16,059), has formed the basis of my remarks.

Occurrence.—Pennsylvanian series (Upper Carboniferous). Brentwood limestone, Morrow subseries, northeast of Fayetteville, Ark.

Unrecognizable Species of PSEUDOMONOTIS

PSEUDOMONOTIS INFLATA Mather

Plate 16, figures 4*a*-*c*

Pseudomonotis inflata MATHER, *1915,* Denison Univ., Sci. Bull., p. 218, pl. 15, figs. 15, 15*a*. Kessler limestone, East Mountain, near city water reservoir, Fayetteville, Ark.

This species is based upon an internal cast (mold) of a left valve from the Kessler limestone and differs markedly from the members of this genus described from the Coal Measures in its greater inflation and peculiar outline.—Mather.

No species of *Pseudomonotis* known to me can be recognized solely from internal molds. Until topotypes of *P. inflata* showing the external ornamentation are described this species cannot be utilized.

Material.—Holotype, Univ. Chicago, Walker Mus., No. 16,057. Found in oölitic limonite in which various shells are preserved as external and internal molds.

Occurrence.—Pennsylvanian series (Upper Carboniferous). Kessler limestone, Morrow subseries, East Mountain, near city water works, Fayetteville, Ark.

PSEUDOMONOTIS HAWNI var. SINUATA (Meek and Worthen)

Plate 16, figures 1*a*, *b*

Eumicrotis hawni var. *sinuata* MEEK and WORTHEN, *1866,* Illinois Geol. Survey, vol. 2, p. 338, pl. 27, figs. 12-14. Upper Coal Measures, bridge of north branch of Saline River, Gallatin county, Illinois.

This variety is not well founded, for the holotype and most of the paratypes are internal molds which do not display diagnostic features of the beaks. Possibly authentic topotypes can be obtained in the future and the variety (or species) finally may be placed on a firm basis.

Material.—Holotype, Univ. Ill., Geol. Mus., No. 10,914. Found in dark, dense limestone.

Occurrence.—Pennsylvanian series (Upper Carboniferous) "Upper Coal Measures," bridge of north branch of Saline river, Gallatin county, Illinois.

OTHER SPECIES

Three forms were described in 1858 by Swallow (St. Louis Acad. Sci. Trans., vol. 1) from the Lower Permian of Kansas under the names *Monotis halli, M. speluncaria* var. *americana,* and *M. variabilis.* These forms were never illustrated, the types are hopelessly lost, and there is no record of the exact locality or horizon from which they came. Except for the fact that these names have been introduced into the literature, they may be ignored as specific entities. There is no assurance that these forms belong to *Pseudomonotis.*

FAMILY EUCHONDRIIDAE Newell, n. fam.

Aviculopectinoids in which, in addition to a relatively large, oblique median resilifer, a series of narrow quadrate and transverse resilifers occurs in front and behind the beaks, extending along flat and diverging ligament areas comparable to those in *Aviculopecten;* the outer ostracum of the right valve in the type genus is prismatic, that of the left structureless.

The general form, shell structure, and forward obliquity of the median resilifer in *Euchondria* suggests that it was derived from the Aviculopectininae. The lack of radial costae on the right valve might be interpreted to mean that the genus is an offshoot from a very primitive member of this subfamily. The family Euchondriidae includes *Euchondria* and possibly *Crenipecten.*

The hypothetical phylogeny of the Euchondriidae is indicated in figure 17.

Genus EUCHONDRIA Meek, 1874

Euchondria MEEK, *1874,* Am. Jour. Sci., 3 ser., vol. 7, pp. 445, 488.

Markedly prosocline shells with a more or less prominent extension at the posteroventral margin; left valve ornamented with relatively widely spaced intercalate costae, which may be lacking on the auricles and obscure on the shell body; costae crossed by regular distinct fila which may be as coarse and widely spaced as the costae, or relatively fine and closely spaced; right valve smooth or with obscure concentric fila; costae, when present, only on auricles; distinct umbonal folds lacking in left valve, obscure in right valve; auricle sulci broad; hinge about one half as long as the shell, extremities more or less quadrate; inner ostracum composed of concentric crossed lamellar aragonite, outer ostracum prismatic calcite in the right valve, apparently structureless calcite in the left; prisms commonly square in cross-section, uniform in size, and arranged in radial and concentric rows; 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; right

MEASUREMENTS IN SPECIES OF *Euchondria*

Species.	Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Umbonal angle, degrees.	No. auricular costae.		Body costae at given height.	
						Anterior.	Posterior.	Costae.	Height.
levicula	L1	7	7	5	95	3	3+	33	7
	L2	6.5	6	4.5	95	3	4	34	6
	L3	12	11	7±	93	3	5+	44	11
	L4	11	10	6.5	95	3	3	48	10
	L5	9	7.5	5	100±	3	3	47	7.5
	L6[a]	10	9	5.5	93	3	4	47	9
	R7	7.5	7.5	6	94	....	2	....	....
	R8	7	7	5.5	91	....	....	....	....
	R9	9	9	6.5	105	2±	4	....	....
sub-cancellata	L1[a]	6	5.5	3	90	....	....	....	....
	L2	....	6	3	90	....	4	....	4
pellucida	L1[a]	9	8.6	6.5	94	2–3	4	47	8.6
	L2	10	9	6–7	90±	2	....	55	9
ohioensis	L1[a]	4	4	2.4	77	....	....	....	....
	L2	4.8	5	2.8	85±	....	....	....	....
smithwickensis	L1	34	33	21.5	98	2–3	5±	64	33
	L2	34	33±	....	95–100	....	....	58	33
	R3	26.5	26.5	21.5	110	....	....	....	26.5
	R4	25	26	21.5	105	....	....	....	26

a. Holotype

valve only slightly less convex than the left; musculature similar to that of *Aviculopecten;* there is a tendency toward development of auricular crura, the posterior crus being about three times as long as the anterior. There is a marked anterior and posterior gape of the valves.

Genotype.—*Pecten neglectus* Geinitz, Table Creek shale, Pennsylvanian, Nebraska City, Neb.

Range.—Devonian? to Upper Carboniferous.

Remarks.—There has been a general misconception regarding the ornamentation in *Euchondria.* Since Meek's diagnosis, it has been assumed that both valves, excepting the auricles, are noncostate. Indeed, this idea appears to date from the original description of *Pecten neglectus* Geinitz. The holotype of the species is a smooth shell, described as a left valve. Geinitz apparently had only the one specimen. When Meek restudied the fauna at Nebraska City (Meek, 1872) he was able to recognize only right valves of the species, and subsequent descriptions of the species have been based on right valves only.

In the collections that I have studied there are some extraordinarily fine specimens of *Euchondria* from the St. Louis Pennsylvanian outlier, collected by Dr. J. Brookes Knight. These specimens are free valves showing the original shell structure, color patterns, and hinge characters. Each left valve bears more or less distinct costae crossed by fila, so that there is a reticulate pattern. The right valves are like the right valves of *E. neglecta* from Nebraska City, figured by Meek (1872, pl. 9, fig. 1*b*.). A large collection which I have from Winterset, Iowa, contains scores of specimens of a small pectinoid, right and left valves being represented in about equal numbers. The specimens are preserved in shale, and only the outer ostracum remains. The left valves are costate and the right ones are smooth. This relation is seen again in another species from the Smithwick shale (Morrow subseries, Texas), in which the hinge characters of the genus are admirably displayed. It appears, then, that the *Euchondria* hinge occurs in shells having a costate left valve. It will be recalled that the so-called *Crenipecten winchelli* (Meek), from the Mississippian Waverly sandstone in Ohio, has a smooth right valve and a costate left one. In all of these forms, perhaps excepting that from the Waverly which I have not seen, the outer prismatic ostracum of the right valve has a very striking arrangement of the prisms. The individual prisms are quadrate in cross section, except for irregular ones near the margin in full sized specimens, and they are regularly arranged in radial and concentric rows.

Examination of Geinitz's illustration of the type of *Pecten neglectus* indicates strong probability that he figured a right valve in which the anterior auricle is broken or partly covered by matrix, rather than a left valve, as stated. In addition to the smooth surface of his type, it will be noted that the umbonal fold on the left hand margin of his shell is longer than that on the right hand margin. My observations indicate uniformly that the posterior umbonal fold is longer than the anterior in these shells. Furthermore, in the collections at hand, the two complementary valves of *Euchondria* are not exactly the same in shape, the right valves being more nearly symmetrical and less strongly prosocline than the left. The type of *Pecten neglectus,* as figured by Geinitz, and Meek's topotype right valve agree rather closely in the slight obliquity, rather than differing markedly as they should if they were complementary instead of both being right valves. It is not without significance that Meek did not recognize left valves of *Pecten neglectus* in his own collections from Geinitz's locality. Summing up the evidence, it seems that left valves of *Euchondria* have not been recognized as such in our American Carboniferous rocks because of the erroneous assumption that the two valves are alike in ornamentation.

In the absence of topotypes of left valves of *E. neglecta* (Geinitz) I find it difficult to recognize the species. Meek (1872, pl. 9, figs. 2*a* *b*) figured a specimen from Nebraska City under the name *Aviculopecten coxanus,* which it certainly is not. It appears probable to me that this figured specimen is a left valve of *E. neglecta,* for it has all of the general external characters of the left valves of other euchondrias in our collections, such as marked obliquity, acute auricles, poorly developed umbonal folds, and small size. A rather marked development of fila is observed on the shell, but these are much finer than is common in *Euchondria.*

The resemblance between left valves of *Euchondria* and *Aviculopecten* s. s. is really remarkable when the difference in general organization is appreciated. Such forms as *E. smithwickensis,* n. sp., and *E. winchelli* (Meek) can be recognized generically only with difficulty from external features of isolated left valves. The characters of the hinge, lack of umbonal folds, and the marked shell gape are generally sufficient, however, to distinguish between left valves of the two genera, and commonly the concentric fila are sufficiently coarse to produce a reticulate pattern not displayed by many typical aviculopectens.

It is worthy of note that most of our specimens of *Euchondria* occur in black carbonaceous shale or limestone, and argillaceous gray shale. In no instance has a specimen been found in gray or white limestone.

Euchondria was a long-lived genus, being typically represented in Early Mississippian beds, and possibly also by such Late Devonian species as *Crenipecten liratus* Hall.

EUCHONDRIA NEGLECTA (Geinitz)

Plate 19, figures 1, 4

Pecten neglectus GEINITZ, *1866,* Carbonformation und Dyas in Nebraska, p. 33, pl. 2, fig. 17.

Aviculopecten neglectus MEEK, *1872,* U. S. Geol. Survey of Nebraska, p. 193, pl. 9, figs. 1*a, b*.

Aviculopecten coxanus MEEK, *1872,* U. S. Geol. Survey of Nebraska, p. 196, pl. 9, figs. 2*a, b*.

Meek's description:

Shell very small, broad subovate, exclusive of the ears, very thin, rather compressed; sides and base more or less regularly rounded; cardinal margin shorter than the breadth of the valves. Left valve (according to Professor Geinitz's figure) with ears nearly equal, the anterior one nearly separated from the margin below by a broad, very shallow sinus, and forming less than a right ang'e at its extremity; posterior ear extending farther down the margin than the other, very faintly sinuous behind, and forming an angle of about 100° at the extremity. Right valve with anterior ear narrow and rather acutely angular, defined by a deep, narrow sinus, extending back about half its length; posterior ear of about the same length, but of greater vertical breadth than the other, rather pointed at the extremity, and defined by a moderately deep, broadly rounded sinus, and a subangular umbonal slope. Surface of the body part of both valves apparently only marked by fine concentric striae; ears with a few radiating costae, crossed by fine striae and a few coarser marks of growth.

Height and breadth each, 0.26 inch; length of hinge, 0.21 inch.

This little species is rather remarkable in having the body part of the valves with apparently only fine concentric striae, while the ears are ornamented with a few comparatively distinct radiating costae. I know of no species with which it is liable to be confounded.

The specimen figured by Professor Geinitz is a left valve, while those I have seen are all right valves. The latter are mainly casts, but one of them retains portions of the shell. On raising a small piece of this with the point of a knife, and placing it under the misroscope, where it could be examined by a strong transmitted light, it was found to present distinct indications of a prismatic structure, apparently not due to crystallization. As this, the only remaining portion of the shell, is exceedingly thin, and consists of a single apparently prismatic layer, I have little doubt that the inner laminated portion of the shell has been dissolved away, as seems to have been the case in other species in these rocks.

It has been indicated already in discussion of the genus *Euchondria* that it seems highly probable that Meek's *Aviculopecten coxanus* from Nebraska City is a left valve of *E. neglecta*. The most obvious distinction between Meek's *A. coxanus* and other species of *Euchondria*, is the small size and close spacing of the fila. In our collections there is a *Euchondria* from the Deer Creek formation having the same characters of ornamentation as the Nebraska City *coxanus*. In one of our specimens the hinge characters of *Euchondria* are shown. Meek's description of the Nebraska City specimen, called *Aviculopecten coxanus* by him, is as follows:

Shell very small; thin, compressed. slightly oblique; broad subovate, exclusive of ears; basal margin, rounded; anterior margin more or less rounded, rather straight and oblique; posterior margin more prominent than the anterior, often subangular at the point where the posterior-basal margin rounds up to meet the obliquely-sloping edge above. Hinge generally a little less than the greatest breadth of the valves below. Left valve with anterior ear of moderate size, flat triangular, with the extremity generally a little less than a right angle, sometimes very slightly rounded, separated from the margin below by an abruptly rounded or subangular sinus; posterior ear slightly larger and much more acutely angular than the other, but shorter than the most prominent part of the margin below, from which it is separated by a moderately deep rather broadly rounded sinus; beak small, compressed, scarcely projecting beyond the cardinal margin, and placed a little in advance of the middle of the hinge; surface ornamented with linear, simple, often more or less flexuous costae, which alternate in size, the smaller ones dying out at the various distances between the free margins and the umbo-crossing; all of these are numerous. extremely fine, regular, closely arranged concentric striae, which, like the costae, are more or less distinctly defined on the ears, as well as on the body of the valve. Right valve unknown.

Height of left valve, 0.37 inch; breadth of do. 0.39 inch; convexity about 0.05 inch.

Comparison.—It seems impossible to distinguish *E. neglecta* from other small species of the genus solely on the basis of the right valve. If the form described as *Aviculopecten coxanus* from Nebraska City by Meek is a left valve of *Euchondria neglecta,* as I now believe, then the species is particularly characterized by the closely spaced and unusually fine fila. In this respect it is like *E. smithwickensis*. The latter is a very much larger shell, however, and is nearly or quite lacking in auricular costae. There appears to be a fairly well developed cardinal costa on each side of the beak in left valves, at least, of the present form.

Material.—Unfortunately, I have not yet been able to examine the types or topotypes from Nebraska City, and the other material at present referred to this species is sparse and poorly preserved. Found in gray argillaceous and dark-gray to black fissile, carbonaceous shale.

Occurrence.—Pennsylvanian series (Upper Carboniferous). The types of *E. neglecta* came from the Table Creek shale (Wabaunsee group, Virgil subseries) at Nebraska City, Neb. Other specimens, left valves, now referred to the species, were found in the Jones Point shale (Shawnee group, Virgil subseries) one half mile southeast of Wabash, Neb.; and Ervine Creek limestone (Shawnee), Stout quarry, Haynies, Iowa.

EUCHONDRIA PELLUCIDA (Meek and Worthen)

Plate 19, figures 16, 17, 19

Aviculopecten pellucidus MEEK and WORTHEN, *1860,* Philadelphia Acad. Nat. Sci., Proc., p. 435; *1866,* Illinois Geol. Survey, vol. 2, p. 327, pl. 26, figs. *5a, b*.

This species is a typical small *Euchondria,* characterized by having a somewhat deeper anterior auricular sulcus, more rounded and less produced posterior extension of the shell body, and a very angular anterior auricle with a straight front margin. The surface of the left valve is cancellated with fine costae, crossed by almost equally coarse and similarly spaced fila. There are moderately well-developed cardinal costae.

On the same shale fragment with the types occurs an imprint of a posterodorsal fragment of a right valve, apparently until now quite overlooked. This impression shows the characteristic alignment of prisms of the outer ostracum in concentric rows, and shows six costellae on the rear auricle, besides a larger cardinal costa. There are about 45 or 50 of the concentric rows of prisms in a space of 1 mm.

Measurements for specimens of *Euchondria pellucida* are given in the table on page 103.

Comparison.—The distinguishing features of the species have been indicated. It appears that the number of costae in this species is somewhat higher than in comparable forms.

Material.—Through the generosity of Dr. J. Marvin Weller, I have been able to study and illustrate the type specimens of the species. There are two left valves and a fragment of a right valve (Univ. Ill., No. 10,932) which are poorly preserved as impressions in shale of the inner surface of the outer ostracum. The smaller and more complete of the two left valves is here designated the holotype. Found in black, fissile, carbonaceous shale.

Ocurrence.—Pennsylvanian (Upper Carboniferous), Des Moines beds, Adams county, Illinois. A label accompanying the types bears the notation "L 7 p e." In reference to the age of the beds exposed in Adams county, Dr. Harold Wanless writes: "The marine section in Adams county, Illinois, includes several horizons. The highest would be slightly below your Pawnee limestone and the lowest would probably be above your Tebo coal." The species has not yet been found elsewhere.

EUCHONDRIA SMITHWICKENSIS Newell, n. sp.

Plate 19, figures 12-13*b*

This is a very large *Euchondria,* in which the concentric fila are relatively very fine and closely spaced, so that the general aspect of the left valve, with its prosocline obliquity and slender costae, is remarkably like that of some of the Devonian pseudaviculopectens. The auricles are acute, the anterior one of both valves having a nearly straight anterior margin. Cardinal margin of the left valve nearly two thirds as long as the shell, and that of the right valve nearly four fifths as long as the shell body of the same valve. Obviously, this relation indicates that the right valve was proportionally smaller than the left as in Pennsylvanian species of *Aviculopecten.* As in other species of the genus there is no posterior umbonal fold in the left valve, the umbonal convexity sloping outward uniformly to the auricle without any abrupt change in convexity, but there is a distinct narrow anterior fold. A marked shell gape occurs at the front and rear ends. The umbonal folds of the right valve are moderately distinct and straight. One right valve shows well the generic characters of the hinge and shell structure. The auricles of the left valve are obscurely costate; those of the right valve are smooth and there are no cardinal costae.

The left valves in my possession are external molds, so that it is through inference that I class the two very dissimilar valves as belonging to the same genus and species. If it were not for independent proof that unlike valves such as these are the rule in *Euchondria,* it would seem absurd to consider them as complementary valves of one species. I have two slabs of rock, each bearing one right and one left valve on the same bedding surface. I have always considered this kind of association important supplementary evidence of the equivalency of unlike valves.

Meek (1875, pp. 296-298) described a similar association of unlike right and left valves in his *Aviculopecten winchelli* from the Waverly beds at Newark, Ohio. He recognized a close similarity, except in size, between this species and the one that he had described as *A. coxanus* from Nebraska City. Hall (1884, p. 89) described the hinge of *A. winchelli* as crenulate, and classed the species as *Crenipecten.* It now seems nearly certain that the species is a *Euchondria.* At any rate the present species, *E. smithwickensis,* is remarkably like *E. winchelli.*

Measurements of specimens of *E. smithwickensis* are given in the table on page 103.

Comparison.—This form is comparable only to the Mississippian *E. winchelli* (Meek), but it is different from that species in the angularity of the auricles and in lacking costae on the auricles of the right valve.

Material.—Holotype and three topoparatypes Yale Univ., Peabody Mus., Nos. 8,103, 14,479. The left valves are preserved as external molds and the right valves are more or less entire, exhibiting the original structures of the shell. Found in black, carbonaceous, silty limestone.

Occurrence.—Pennsylvanian (Upper Carboniferous). Smithwick shale (Bend group, Morrow subseries). The holotype and one topoparatype bear the label "east of San Saba, Texas." The two other topoparatypes are from the same locality.

EUCHONDRIA SUBCANCELLATA Newell, n. sp.

Plate 19, figures 2, 3, 6, 7

Typical small euchondrias esepecially characterized by an obsolete or obsolescent condition of the costae over the middle and anterior parts of the left valve. The fila, characteristic of the genus, are faint and closely spaced. Although the ornamentation is similar to that in *E. menardi* (Worthen) the front margin of the anterior auricle, unlike that of *E. menardi* is broadly rounded.

Measurements of specimens of *E. subcancellata* are given in the table on page 103.

Comparison.—The particular characters by which this species can be recognized have been stated above. Several of the specimens are somewhat corroded and it was at first thought that these were worn specimens of *E. levicula,* n. sp., with which they are associated. The fila are more closely spaced than in *E. levicula,* however, and in several instances extend across the middle of the shell where no costae are visible.

Material.—Several scores of specimens almost all of them exquisitely preserved, however, with the surface more or less corroded (Kansas Univ., Paleont. Type Coll., No. 396).

Occurrence.—Pennsylvanian (Upper Carboniferous). Upper Labette shale, Des Moines subseries, St. Louis, Mo., Knight's locality 43.

EUCHONDRIA LEVICULA Newell, n. sp.

Plate 1, figures 6, 7; Plate 19, figures 5, 10, 11, 18

This is a small characteristic *Euchondria* having a particularly distinctive ornamentation of the left valve. The costellae and concentric fila are prominent, but quite slender and uniform. The fila are spaced about the same distance apart as the costellae, so that the surface is regularly cancellate in nearly equidimensional rectangles. The interval between fila is about 0.4 mm. across the median part of the shell and does not change appreciably across the adult part of the shell, except in the margin of gerontic individuals where the fila become crowded and less regular. Although the general appearance of the shell is like that of *E. pellucida* (Meek and Worthen), there are slightly fewer costellae. From the latter species *E. levicula* is readily distinguished by having the anterior margin of the front left auricle broadly curved instead of straight, and the posterior margin of the shell in *E. levicula* is broadly concave rather than nearly straight as in *E. pellucida.* There are obscure cardinal costae on both valves.

The species is based on a large number of remarkably uniform specimens in shale, from a single locality in the Bronson group. Other extraordinarily well preserved specimens showing characters of shell structure, articulus, and musculature are contained in the fine collection of pelecypods from the St. Louis outlier (Marmaton) given me by Dr. J. Brookes Knight. There is somewhat greater variation in these specimens than in the larger collection from the Bronson group, and for that reason it has seemed desirable to designate one of the Bronson specimens as the holotype even though the specimen is preserved only as an external mold.

Measurements for specimens of *E. levicula* are given in the table on page 103.

Comparison.—This species is like *E. pellucida;* the means by which the two are distinguished have been indicated in the above description.

Material.—There are several scores of specimens from one locality, including the holotype, at Yale Univ., Peabody Mus., No. 14,478. In these specimens only the outer ostracum is present, but the ornamentation is perfectly preserved. In addition there are several fine specimens (Kansas Univ., Paleont. Type Coll., No. 397) from the unique Knight collection of St. Louis outlier fossils. Many of these specimens retain not only the original shell structure and composition, but also the original color pattern in the form of broad irregular radial bands. Found in black fissile shale, argillaceous shale, and variegated maroon and green calcareous shale.

Occurrence.—Pennsylvanian (Upper Carboniferous). The holotype and topoparatypes were found in the Hushpuckney black and gray shale, Swope formation (Missouri subseries), at Devil's Backbone, near Winterset, Iowa. The specimens in the Knight collection are from near the top of the Labette shale, Knight's loc. 43, near St. Louis, Mo. The species has not been recognized elsewhere.

EUCHONDRIA OHIOENSIS (Mark)

Plate 19, figures 8, 9

Acanthopecten ohioensis MARK, *1912,* Ohio Geol. Survey, Bull. 17, 4th ser., p. 308, pl. 15, fig. 5.

The type specimens before me are not sufficient for the recognition of this species, but the original locality and horizon are known and it therefore eventually will be possible to learn more about the species.

The shells are markedly prosocline, small, with well-defined, though small auricles. The posterior margin of the shell body is notably concave, meeting the extremity of the ventral margin at a rounded right angle. The front margin of the shell body is nearly straight. The surface of the specimens is very badly worn, but still there is a trace of fine reticulate ornamentation produced by interesting costellae and fila. In one specimen the costellae and fila are about equally spaced at somewhere near 70 microns. There is no evidence of ornamentation on the auricles, but the preservation is so poor that this cannot be determined certainly. The shell substance shows clearly concentric crossed-lamellar structure. Apparently the outer ostracum is nearly or entirely lost by abrasion. The anterior auricle is broadly rounded at the front margin.

Measurements of specimens of *E. ohioensis* are given in the table on page 103.

Comparison.—Beyond the probability that this form is a *Euchondria*, it can scarcely be recognized because of the exceedingly poor preservation of the type specimens.

Material.—Through the kindness of Prof. J. E. Carman, I have been enabled to examine the types of Mark's *Acanthopecten ohioensis*. The types are two poorly preserved left valves, both probably juveniles. The shell substance is so soft and friable that the outer surface has suffered considerable abrasion and the original ornamentation almost obliterated. The specimens do not resemble the original figure, in spite of the strong supposition that it was drawn from one of the specimens before me. An extended search for further type specimens at Ohio State University has failed. It may be assumed that the holotype is lost, or that the original figure is a gross misrepresentation of the specimen before me, supposed to be the holotype. At any rate, it appears likely that further topotypes can be used to satisfactorily establish the species. Found in black, carbonaceous, fine-grained limestone.

Occurrence.—Pennsylvanian (Upper Carboniferous). Portersville limestone (Conemaugh), Portersville, Ohio.

EUCHONDRIA MENARDI (Worthen)

Plate 19, figures 14*a*-15*b*

Lima? menardi WORTHEN, *1884,* Illinois State Mus. Nat. History, Bull. 2, p. 22.

Aviculopecten menardi WORTHEN. *1890,* Illinois Geol. Survey, vol. 8, p. 120, pl. 22, fig. 12.

This species was founded on a poorly preserved specimen and topotypes are needed for a proper evaluation of characters shown by the holotype.

The holotype is a crushed and completely flattened left valve exposing the inner surface of the thin outer ostracum. Where flakes of the ostracum layer have fallen away from the matrix, an external mold remains, so that something can be seen of the outer ornamentation. On the same shale fragment is a small, poorly preserved imprint of a right valve, possibly the complement to the holotype, showing something of the *Euchondria* ligament area. This specimen, overlooked by Worthen, appears to be an internal mold.

There are traces of obscure costae on the rear auricle and posterior part of the shell, but they are too faint to be counted accurately through the shell layer. In front of a place on the margin directly under the beak, there are 11 irregular and obscure costae. The posterior half of the shell appears to be devoid of any costae. Two distinct, narrow costae cross the middle part of the posterior auricle and there are traces of one or two more on each side of them, making a total of five or six. All of the auricular costae die out before reaching the margin, suggesting that the shell had reached a geronic stage. Cardinal costae absent. The shell is ornamented by somewhat irregular distinct fila, spaced on mature areas a maximum of 130 microns on the auricles and about 120 microns on the median part of the shell body. The median part of the dorsal two thirds of the body of the shell, including the beak is practically devoid of any ornamentation, even the fila being confined to the auricles and shell margin. It is not possible to determine whether or not the shell was abraded or corroded before fossilization, but it seems likely that the shell has been altered in some such fashion. The byssal sinus in both valves shows a marked reduction during shell growth until the left anterior auricle has a nearly straight margin, and the notch of the right valve reduced to a sinus. Such changes during growth are probably to be correlated with a partial or complete loss of the function of the foot. The posterior auricle of the right valve has three or four faint costellae across the middle third of the auricle. Fila like those on the left valve ornament the surface of the right posterior auricle, but the anterior one has only fine, irregular growth lines. There are four costellae on the right anterior auricle, one of which bounds the byssal notch and the other three are grouped just above it. The holotype has the following dimensions: height, 13 mm.; length, 14.5; hinge length, 7 mm.; umbonal angle, 93 degrees.

Comparison.—Apparently this species is distinct from others here described. Until better material is discovered, the species must be recognized by the closely spaced fila, obsolesecent byssal notch, noncostate anterior half of the left valve.

Material.—The two types of *E. menardi* (Worthen) (Ill. St. Mus., No. 2,513) were made available to me through the help of Dr. J. Marvin Weller.

The holotype, originally described as a right valve, is the reverse surface of the outer ostracum of a left valve adherent to shale matrix. An internal mold of the dorsal part of a right valve with some external ornamentation impressed upon it occurs on the same bedding surface as the holotype. The two specimens are of equivalent size and may have belonged to a single individual. Found in black, fissile, carbonaceous shale.

Occurrence.—Pennsylvanian (Upper Carboniferous). Worthen notes that "the only specimen of this pretty shell in the State collection was obtained from the bituminous shale forming the roof of the Greenview coal in Menard county," Greenview, Ill. Regarding the age of the Greenview bed, Dr. Harold Wanless writes that "this is probably the roof of the No. 5 coal, which is below the upper Fort Scott limestone."

FAMILY AMUSSIIDAE Ridewood

This family was established for the modern orbicular smooth pectinids having gills without interlamellar junctions. The type genus of the family, *Amussium,* has prominent auricular crura, gaping equally convex valves, and lacks a byssal notch at the adult stage, although such a notch can be seen in the growth lines at an early juvenile stage; the hinge and ligament structures are like those in the Pectinidae.

A small, compact group of pectinids having approximately the form and hinge characters of the modern *Amussium* is recognized from the Late Devonian or Early Carboniferous to the present time. The correspondence between the Paleozoic *Pernopecten* and the modern *Amussium* is remarkably close. The geologic history of the tribe of *Pernopecten* is quite different from that of the Pectinidae. The existence of a true *Pecten* in the Paleozoic has never been demonstrated, notwithstanding the numerous citations of the genus from the Permian. Only *Pernopecten* had a ligament like that of the modern Pectinidae and had acquired that kind of ligament as early as Early Carboniferous time. It scarcely seems probable that *Pernopecten* gave rise to the Pectinidae, however, in spite of the apparent identity of the ligament system in the two. The equivalve form, gaping valves, and obsolete byssal notch of *Pernopecten* suggests that it was highly specialized rather than a primitive type, and it appears probable that the Pectinidae had their origin in the Aviculopectinidae, possibly during the late Permian or Triassic.

The probable phylogeny of the Paleozoic Amussiidae is indicated in figure 17.

Genus PERNOPECTEN Winchell, 1865

Pernopecten WINCHELL, *1865,* Philadelphia Acad. Nat. Sci., Proc., p. 125.
Entolium (part) of authors.

Smooth prosocline or acline orbicular shells, having small triangular auricles, those of the left valve extending high above the cardinal axis, whereas the dorsal margin of the right valve is straight; auricles set off sharply from the shell body, being depressed very slightly but abruptly below the general shell surface; two broad sulci extend from the beaks toward the ventral border of each valve just within the front and rear margins of the shell, producing a flattened marginal area along the front and rear parts of the shell, the posterior one being somewhat longer and producing a slight posteroventral projection of the margin; byssal notch absent in the adult, but clearly visible in the early growth lines at the base of the anterior auricle in either valve; valves with a pronounced anterior and posterior gape; shell structure of the inner ostracum concentric crossed-lamellar, that of the outer ostracum in the left valve radial crossed-lamellar, right valve prismatic, with the prisms remarkably regular hexagons set in concentric rows; auricles composed of a marginal ridge parallel to the dorsal edge in the right valve, that fits between two similar ridges on the opposite valve, operating somewhat like the so-called lateral teeth in various Pectinidae; resilifers as in *Pecten* or *Amussium,* situated below the cardinal axis.

The musculature is somewhat different from that of the Aviculopectinidae. There is no posterodorsal lobe of the adductor scars—only a very obscure expansion of the pallial line where it joins the adductor scar. This circumstance suggests that the pedal retractors were degenerate or absent, which together with the obsolete character of the byssal notch, indicates a loss of function of the foot. Scars of pedal levator muscles have not been recognized as such. The insertions at the pallial line take the form of fine radiating incisions of the shell. A scar of mantle attachment occurs below the resilifers as in *Pecten* or *Amussium,* but unlike the Pteriidae where the dorsal edge of the mantle is not attached to the shell on either valve underneath the resilifers; inner surface of cardinal margin with or without interlocking denticles.

Genotype.—Aviculopecten limaformis White and Whitfield, Mississippian.

Remarks.—There is a general lack of agreement as regards the genera *Pernopecten, Syncyclonema,* and *Entolium.* These are similar forms, the first being based on a Mississippian species, the second on a Cretaceous one, and the last on a Jurassic form. Hall (1885, pp. lvii—lxi) seems to have been the first to place *Entolium* Meek (November, 1865) in the synonymy of *Pernopecten,* on the supposition that the crenulations of the hinge described in *Pernopecten* originally existed in all of the Paleozoic forms but have been obliterated in some by wear or imperfect preservation. Girty (1909, p. 88) has followed the same course, and likewise Tryon (1884, p. 291). On the other hand, Hind (1903, p. 117) has considered both *Pernopecten* and *Entolium* as synonyms of *Syncyclonema* Meek, 1864. Phillippi (1900, p. 80) and Woods (1902, p. 145) likewise have considered *Entolium* as a synonym of *Syncylonema.* Verrill (1900, p. 62) considered the three genera as distinct. Apparently none of these authorities based his synonymy on actual studies of type material and the statements in this regard are largely assumptions. These genera, as defined, have only slightly different characters and controversy has arisen over the proper evaluation of these differences.

Unfortunately, I have so far been unable to secure authentic specimens of *Pernopecten limaformis* and thus have been forced to rely on Hall's (1885, p. lvii) illustrations and description of the holotype and Meek's (1874, pp. 488, 489) comments on some of Winchell's specimens.

In the first place, it is obvious to anyone familiar with Paleozoic species of this group that the specimen figured by Hall as the holotype of *P. limaformis* is a right valve. This is significant because the genus *Pernopecten* was described as having a straight hinge margin. In all of the Paleozoic forms of this kind that I have seen, the dorsal margin of the right valve is straight and that of the left angulated by the extension of the auricles above the hinge. Furthermore, there is a marked gape to the valves, sufficiently obvious to permit ready detection in isolated valves if they are undistorted.

I have a specimen of *Pernopecten prosseri* (Mark) (=*Entolium aviculatum* pars of authors) and one of *Pernopecten clypeatus,* n. sp. before me which shows a denticulate hinge of the type that is supposed to distinguish *Pernopecten* from *Entolium.* These specimens are right valves, and associated with them are several left valves in which there is no trace of the denticulations. There are right valves of another species, clearly congeneric with *P. prosseri,* in which the hinge is nondenticulate. It appears to me that the absence or presence of the denticulations on either side of the resilifer is not even of specific rank, but only an individual variation. It does not seem reasonable, according to present information, to try to distinguish more than one genus of this group in the Paleozoic rocks.

I have had an opportunity to examine several well preserved specimens of *Entolium demissum* (Phillips) (see pl. 20, figs. 19, 20), the type of *Entolium,* from the brown oölitic Jura of Würtemburg, Germany. Superficially, there is a striking resemblance between this species and the Paleozoic forms, but it displays several features not seen in the older species: The shell structure of both valves is the same; the outer ostracum has a radial crossed-lamellar structure readily visible at low magnification; there is no apparent shell gape; the auricles of the left valve are rounded instead of acuminate, and the valves are perfectly symmetrical, with a circular margin and no obliquity whatever; and finally, there is no definite byssal notch at any stage in either valve. These characters, although slight, serve to distinguish the type of *Entolium* from any of the Paleozoic forms that I have seen.

Very little is known about the type of the Cretaceous *Syncyclonema* Meek (*Pecten rigida* Hall and

MEASUREMENTS IN SPECIES OF *Pernopecten*

Species.	Specimen No.	Length, mm.	Height, mm.	Hinge length, mm.	Convexity, mm.	Umbonal angle, degrees.
clypeatus	L1	29	29+	...	...	...
	L2[a]	33.5	36	14.5	4	119
	L3	30	31	11.5	3.4	124
	L4	9	10	5	...	111
	R5	19	21	8	...	108
	R6	19	20	8.2	...	113
ohioensis	L1	20	19.5	10	...	115
	L2	18.5	21	12.5	...	103
	L3	19	21.5	10	...	120
	L4	21.5	22.5	10	...	112
	R5	16	16.5	5.6	...	113
	R6	16	16	7	...	112
	R7	19	19	7.5	...	115
	R8	20	18.5	6.5	...	119
prosseri	L1[a]	31	32+	14±	...	113
	R1	...	...	10	...	113

a. Holotype. *L,* left valve; *R,* right valve.

Meek) except that it is a smooth shell with slightly unequal auricles and a closed margin. It is possibly a near relative of *Entolium.*

PERNOPECTEN PROSSERI (Mark)

Plate 20, figures 12, 13, 17, 18

?*Pecten aviculatus* SWALLOW, *1858,* St. Louis Acad. Sci., Trans., vol. 1, p. 213 (not *Pecten aviculatus* G. von Münster, 1832).

Entolium prosseri MARK, *1912,* Ohio Geol. Survey, Bull. 17, 4th ser., p. 309, pl. 15, figs. 6-8.

This is a large, subcircular, distinctly prosocline *Pernopecten* having high acuminate auricles on the left valve; decided gap in front and behind, much more pronounced in the left than in the right valve, as in *Amussium;* anterior and ventral border rather evenly rounded in the left valve, but the posterior border below the auricle slightly concave; mid-umbonal surface on this valve evenly convex, separated from the anterodorsal and posterodorsal

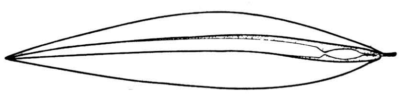

FIG. 39. Restoration of *Pernopecten prosseri* (Mark). Posterior view, with valves closed; the stippled parts are internal features viewed between gaping valves, × 2.

margins by broad obscure sulci; auricles small with the front margin of the anterior one and the rear margin of the posterior one sigmoidally curved, *i. e.,* the lower and middle part of the margin is broadly convex, while there is a small, abrupt concavity or sinus just below the apex of the auricle; right valve differs from left principally in having a less pronounced gap, and a straight cardinal margin; extremities of the auricles obtuse; anterior auricle almost as long as the posterior, but not as high; auricles of both valves set off abruptly from the shell body, being abruptly and slightly depressed below the general surface of the shell, producing two narrow umbonal folds which flare outward at a rapidly increasing angle; anterior auricle in each valve with a well defined byssal notch in juvenile stages, the notch becoming obsolete at maturity; inner ostracum in both valves with concentric crossed-lamellar structure; outer ostracum in left valve radial crossed-lamellar, in right valve composed of hexagonal prisms geometrically arranged in regular concentric rows; prisms having a diameter of 30 microns along a ventral line at a shell height of 26 mm.

The most striking feature of the species, by which it may be distinguished from the comparable *P. clypeatus,* n. sp., is the lack of a shoulder or extended posterodorsal margin behind the rear auricle of the left valve. Most species of *Pernopecten* have a distinct emargination of the shell behind the rear auricle.

It is highly probable that this is the form that Swallow described as *Pecten aviculatus,* but since that species was not figured and the type specimen is destroyed, the exact nature of *P. aviculatus* Swallow will remain forever unknown.

Measurements of specimens of *P. prosseri* are given in the table on page 110.

Comparison.—It is always difficult to distinguish between different species of *Pernopecten. P. obliquus* Girty and *P. attenuatus* (Herrick) have a not-

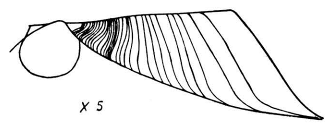

FIG. 40. Anterior auricle of a right valve of *Pernopecten prosseri* (Mark) showing the progressive loss of the byssal notch during ontogeny; camera lucida drawing, × 5.

ably smaller umbonal angle than the present form and are not nearly as large. *P. ohioensis,* n. sp., is slightly more oblique, has a differently shaped right valve, and is only about half as large as *P. prosseri.*

Material.—Through the kindness of Prof. J. E. Carman and Dr. Grace Stewart, of Ohio State University, I have had opportunity to study the type specimens of *P. prosseri.* These are four syntypes

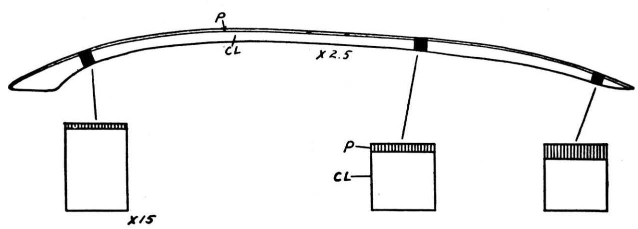

FIG. 41. Profile of a right valve of *Pernopecten prosseri* (Mark) showing distribution of shell layers (P, prismatic outer ostracum; CL, crossed lamellar inner ostracum); (camera lucida drawing).

(Ohio St. Univ., No. 14,036) from a single locality. From this suite I designate the specimen shown in my plate 20, fig. 17 as lectotype. Although fragmentary, these specimens show beautifully the original structures of the shell substance. Found in pure or argillaceous limestone.

Occurrence.—The types came from the Ames limestone (Upper Missouri age) at New Concord, Ohio, Pennsylvanian (Upper Carboniferous.)

PERNOPECTEN CLYPEATUS Newell, n. sp.

Plate 1, figures 1, 14, 15; Plate 20, figures 7-11

?*Pecten aviculatus* SWALLOW, *1858*, St. Louis Acad. Sci., Trans., vol. 1, p. 213 (not *Pecten aviculatus* G. von Münster, 1832).

Relatively large, distinctly prosocline, closely similar to *Pernopecten prosseri* (Mark), but especially distinguished by the development of an emargination or crest behind the rear auricle of the left valve, by which the shell body is extended dorsoposteriorly in a rounded convex margin behind the posterior auricle.

Measurements of specimens of *P. clypeatus* are given in the table on page 110.

Comparison.—This form is especially distinguished by its robust size, and by the distinctive posterior profile.

Material.—Six nearly complete specimens and several fragmentary ones from Wabaunsee beds near Thurman, Iowa (Yale Univ., Peabody Mus., Nos. 14,485, 14,486). Found in argillaceous gray limestone.

Occurrence.—Upper Carboniferous. Missouri and Virgil subseries. The types came from the Howard limestone (Wabaunsee group), 2 miles north of Thurman, Iowa, and the Wakarusa limestone (Wabaunsee), south of the fault at Thurman, Iowa. There is one specimen from the Captain Creek limestone (Lansing group) near Olathe, Kan.; several specimens from an unidentified horizon in the upper Shawnee group, near Topeka, Kan.; Soldier Creek shale (Wabaunsee), one half mile west of the mouth of Walnut Creek, Nebraska City, Neb.; Wakarusa limestone (Wabaunsee), Table Rock clay pit, Table Rock, Neb.; Kereford limestone (Shawnee), Snyderville, Neb.

PERNOPECTEN OHIOENSIS Newell, n. sp.

Plate 20, figures 1-3, 5, 6

Entolium aviculatum, HERRICK, *1887,* Denison Univ. Sci. Lab., Bull., vol. 2, p. 23, pl. 1, figs. 1, 2; pl. 3, fig. 10.
———, MORNINGSTAR, *1922,* Ohio Geol. Survey, Bull. 25, p. 232, pl. 13, fig. 9.

In our collections there are two similar pernopectens, distinguished from each other by a marked difference in size and by pecularities of the right valve. The available material appears to be sufficiently complete to indicate that the larger of the two forms, *P. clypeatus,* n. sp., is found only in beds of Missouri and Virgil age, whereas the small form *P. ohioensis,* n. sp., is found only in the Des Moines subseries or equivalent rocks. The size difference may be due partly to ecological factors, because the Des Moines specimens that I have seen occur chiefly in carboniferous limestone, whereas the post-Des Moines specimens are found chiefly in pure or argillaceous limestone. Right valves of this species are extraordinary in winglike lobes or projections at the front and rear margins. I am at loss to account for this discrepancy between right and left valves (see fig. 42) except on the assumption that the two valves did not fit snugly together along the ventral margin. There is a real stratigraphic distinction between the two forms, and this fact justifies the application of different names to them. The suite of specimens is from the lower Mercer limestone, Flint Ridge, Licking county, Ohio.

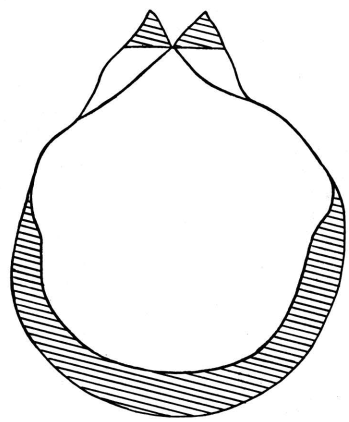

FIG. 42. Diagram of *Pernopecten ohioensis,* × 5, right valve view, showing discrepancy in shape of the two valves; projecting margin of left valve indicated by shaded area.

Measurements of specimens of *Pernopecten ohioensis* are given in the table on page 110.

Comparison.—As indicated in the description, the small size and peculiar form of the right valves distinguish this species. The largest *Pernopecten* that I have seen from beds of Des Moines age is scarcely half as large as a full-grown *P. prosseri* or *P. clypeatus.*

Material.—The species is based on 21 specimens, right and left valves, from a single horizon and general locality. The holotype and several topoparatypes are U. S. Nat. Mus., No. 89,789. There are several topoparatypes at the University of Kansas, and two at Ohio State University, No. 4,604. In these specimens the inner ostracum has not been preserved, but the outer ostracum in both valves shows the original structure. There are in addition several other specimens from various localities. Found in black and dark-gray carbonaceous limestone.

Occurrence.—Upper Carboniferous. The holotype and topoparatypes came from the lower Mercer limestone, Flint Ridge, Licking county, Ohio; other paratypes are from the Liverpool formation, SW¼ sec. 15, Knox Township, Knox county, Illinois; "Coal Measures" (probably Cherokee) Henry county, Missouri; Boggy shale, NW ¼ sec. 27, T. 3 N., R. 7 E., Okla.

PERNOPECTEN ATTENUATUS (Herrick)

Plate 20, figure 4

Entolium attenuatum HERRICK, *1887*, Denison Univ. Sci. Lab., Bull., vol. 2, p. 24, pl. 1, fig. 11.

This rare species is comparable in characters of the left valve to *P. ohioensis* with which it is associated, and differs chiefly in its considerably greater relative height and in its smaller umbonal angle.

I have seen only one example that might belong to the species. In my specimen the umbonal angle is approximately 106 degrees. The height is 28 mm.; and the length 24 mm. Morningstar (1922, p. 232) gives the height of a topotype specimen as 18 mm., and the length as 13 mm.

P. attenuatus seems also to be distinguished from most species by the absence of a posterodorsal shoulder, in this respect being comparable only with *P. prosseri*.

Comparison.—This form is especially distinguished by its relatively high, narrow proportions.

Material.—I have seen only one specimen of this species. Found in black, pyritiferous limestone; dark-gray, silty, hard shale.

Occurrence.—Upper Carboniferous. My specimen (Yale Peabody Mus., No. 14,493) came from the roof of the Danville coal at Danville, Ill. (Des Moines subseries). The roof of the Danville coal is probably just below the horizon of the Pawnee limestone, according to Dr. Harold Wanless (personal communication). The original types, which appear to be lost, came from the lower Mercer limestone (Pottsville), Flint Ridge, Ohio.

PERNOPECTEN OBLIQUUS Girty

Plate 20, figures 15, 16

Pernipecten? obliquus GIRTY, *1908*, U. S. Geol. Survey, Prof. Paper 58, pl. 9, figs. 13-14*a*.

Girty's description:

Shell small, elongate, nearly flat. Hinge line shorter than the width below. In the left valve the two ears are nearly equal, small, and moderately well defined, both in outline and by the grooves on the surface. The shell expands considerably below them, and is gently inclined backward. The superior portion is more or less turned upward at the sides along two converging lines.

I have had the privilege of studying Doctor Girty's type specimen, and from microscopic examination of the specimen under xylol it appears to me that the shape indicated by Girty's fig. 13 is incorrect. The auricles extend high above the hinge, as is normal in the genus.

The species appears to be a small one, comparable in size to *P. ohioensis*, and would be difficult to identify in the absence of good material. However, it appears to have a rather distinctive posterior profile, being somewhat more produced posteriorly than *P. ohioensis* and, unlike that species, lacks a well-defined posterodorsal shoulder or lobation of the margin below the rear auricle. Right valve unknown.

Material.—I have seen only the holotype of the species and one topoparatype, both left valves, the two figured by Girty. They bear the catalogue numbers 405, 406. Found in olomitic limestone.

Occurrence.—Upper Permian, Capitan limestone, Guadalupe Mountains, western Texas.

GENERIC STATUS OF SOME FOREIGN SPECIES OF PECTINOIDS

A preliminary survey has been made of the chief works on Late Paleozoic pectinoids in order to learn something of the range and distribution of the genera recognized in my classification. The list is by no means complete, and is subject to revision.

LOWER CARBONIFEROUS FORMS

Hind's monumental work on British "Carboniferous Lamellibranchiata" (1896-1905) will always serve as the base from which to launch further research in Late Paleozoic pelecypods. The species described by Hind (chiefly Lower Carboniferous, a few Upper Carboniferous) are classified as follows:

BRITISH CARBONIFEROUS PECTINACEA

PSEUDAVICULOPECTEN:

Pterinopecten rigidus (McCoy)

DUNBARELLA:

Pterinopecten papyraceus (Sowerby)
?Pterinopecten radiatus (Phillips)

PTERINOPECTINELLA:

Pterinopecten granosus (Sowerby)
Pterinopecten dumontianus (De Koninck)
Pterinopecten eximius (De Koninck)
Pterinopecten pustulosus Hind

AVICULOPECTEN:

Aviculopecten pera (McCoy)
Limatulina scotica Hind
Aviculopecten tabulatus (McCoy)
Aviculopecten plicatus (Sowerby)
Aviculopecten eskdalensis Hind
Aviculopecten gentilis (Sowerby)
?Aviculopecten subconoideus Etheridge, Jr.
Aviculopecten murchisoni (McCoy)
Aviculopecten knockonniensis (McCoy)
Aviculopecten interstitialis (Phillips)
Aviculopecten ruthveni McCoy

AVICULOPECTEN—*Concluded*

Aviculopecten carrolli Hind
?*Aviculopecten losseni* (von Koenen)
Aviculopecten forbesii (McCoy)
?*Aviculopecten macrotis* (McCoy)
?*Aviculopecten decussatus* (McCoy)
?*Limatulina desquamata* (McCoy)
Aviculopecten intermedius (McCoy)

ACANTHOPECTEN:

Aviculopecten stellaris (Phillips)
?*Aviculopecten incrassatus* (McCoy)

ANNULICONCHA:

Aviculopecten deornatus (Phillips)
?*Aviculopecten sedgwicki* (McCoy)
?*Streblopteria concentrica* Hind

STREBLOPTERIA:

Streblopteria laevigata (McCoy)
Eumicrotis hemisphaericus (Phillips)
Eumicrotis ovalis (De Koninck)

STREBLOCHONDRIA:

Aviculopecten planoclathratus (McCoy)
Pseudamusium fibrillosum (Salter)
Pseudamusium concentricolineatum Hind
Pseudamusium gibbosum (McCoy)
?*Pseudamusium anisotum* (Phillips)

LIMIPECTEN:

Aviculopecten constans De Koninck
?*Pterinopecten concavus* (McCoy)
Aviculopecten semicostatus (Portlock) (except pl. 8, fig. 12)
Aviculopecten dissimilis (Fleming)
Aviculopecten fallax (McCoy)
Pterinopecten meleagrinoides (McCoy)

OBLIQUIPECTEN:

Obliquipecten laevis Hind

PERNOPECTEN:

?*Amusium concentricum* Hind
Amusium tenue (De Koninck)
Syncyclonema sowerbyi (McCoy)
Syncyclonema carboniferus Hind

UNRESOLVED:

Aviculopecten quinquelineatus (McCoy)
Pseudamusium sublobatum (Phillips)
Pseudamusium redesdalense (Hind)
Pseudamusium ellipticum (Phillips)
Pseudamusium auriculatum (McCoy)
Amusium planicostatum (McCoy)
Pterinopecten cyclopterus (Phillips)
Pterinopecten carbonarius Hind
Limatulina alternata (McCoy)
Streblopteria ornata (Etheridge, Jr.)
Aviculopecten jonesii (McCoy)
Aviculopecten fimbriatus (Phillips)
Aviculopecten inequalis Hind
Aviculopecten nobilis (De Koninck)
Aviculopecten perradiatus De Koninck

GIRTYPECTEN:

?*Pterinopecten tessellatus* (Phillips)

EUCHONDRIA:

?*Aviculopecten clathratus* (McCoy)
?*Crenipecten semicircularis* (McCoy.

LOWER AND UPPER CARBONIFEROUS

Fedotov's monograph (1932) on the Donetz Basin (Russia) pelecypods is well illustrated. A large proportion of the Upper Carboniferous species are very similar to forms known in North America. I would classify his species as follows:

CARBONIFEROUS PECTINACEA FROM THE DONETZ BASIN IN RUSSIA

POSIDONIA:

?*Posidonomya laterugata* De Koninck
?*Posidoniella sulcata* Hind

PSEUDOMONOTIS:

Pseudomonotis mutabilis Fedotov

STREBLOCHONDRIA:

Aviculopecten cf. *hertzeri* Meek
Pecten (Pseudamusium) ufaensis (Tschernyschew)
Pecten (Pseudamusium) sp.
Crenipecten foerstei Herrick
?*Pecten (Pseudamusium) medius* (Herrick)

AVICULOPECTEN:

Aviculopecten (Deltopecten) lutugini Fedotov
Aviculopecten verbeeki Fliegel
Aviculopecten (Deltopecten) batesvillensis Weller
?*Aviculopecten (Deltopecten)* cf. *mutabilis* Licharevi
Aviculopecten occidentalis (Shumard)
Crenipecten cf. *winchelli* Meek

LIMIPECTEN:

Aviculopecten (Deltopecten) cf. *giganteus* (Chao)

ACANTHOPECTEN:

Aviculopecten cf. *stellaris* (Phillips)
Aviculopecten (Acanthopecten) elegantulus Stuckenberg
Aviculopecten (Acanthopecten) carboniferus (Stevens)

ANNULICONCHA:

Aviculopecten interlineatus Meek and Worthen

PTERINOPECTINELLA:

Aviculopecten (Pterinopecten) cf. *dumontianus* (De Koninck)
Aviculopecten (Pterinopecten) spinosus Fedotov
?*Aviculopecten* aff. *obliquus* Hind
?*Aviculopecten* cf. *spinuliferus* Meek and Worthen

DUNBARELLA:

Aviculopecten (Pterinopecten) papyraceus (Sowerby)
Aviculopecten (Pterinopecten) subpapyraceus (De Verneuil)

PERNOPECTEN:

Entolium attenuatum Herrick
Entolium aviculatum Swallow
Entolium tenue De Koninck

UNRESOLVED:

Amusium aff. *planicostatum* (McCoy)
Pseudomonotis gapeevi Fedotov
Pseudomonotis jakovlevi Fedotov
Pseudomonotis kumpani Fedotov
Pseudomonotis stepanovi Fedotov
Aviculopecten cf. *tastubaensis* Licharev
Aviculopecten (Pterinopecten) cf. *concavus* (McCoy)

UPPER CARBONIFEROUS AND PERMIAN

Chao's monograph (1927) on the Taiyuan (China) pelecypods includes species which may be listed as follows:

UPPER CARBONIFEROUS AND PERMIAN PECTINACEA FROM CHINA

AVICULOPECTEN:

Aviculopecten manchuricus Chao
Aviculopecten alternatoplicatus Chao

LIMIPECTEN:

Deltopecten giganteus Chao
Deltopecten multistriatus Chao

ACANTHOPECTEN:

Acanthopecten carboniferus (Stevens)

PSEUDOMONOTIS:

?Pseudomonotis shansiensis Chao

PTERINOPECTINELLA:

Pterinopecten nodosostriatus Chao

STREBLOCHONDRIA:

Streblopteria ? granosostriata Chao
?Streblopteria cf. *sericea* (De Verneuil)

PERNOPECTEN:

?Entolium obtusum Grabau
Entolium aviculatum (Swallow)

UNRESOLVED:

Streblopteria plana Chao

LOWER CARBONIFEROUS AND PERMIAN

A monograph on pectinoids from eastern Australia, by Etheridge and Dun (1906) contains descriptions of the following:

LOWER CARBONIFEROUS AND PERMIAN PECTINACEA FROM AUSTRALIA

DELTOPECTEN:

Aviculopecten mitchelli Etheridge and Dun
Deltopecten illawarensis (Morris)

LIMIPECTEN:

Deltopecten leniusculus (Dana)
Deltopecten fittoni (Morris)
?Deltopecten subquinquelineatus (McCoy)
?Aviculopecten ponderosus Etheridge and Dun
?Deltopecten farleyensis Etheridge and Dun
?Deltopecten limaeformis (Morris)
?Aviculopecten profundus (Morris)

AVICULOPECTEN:

Aviculopecten sprenti (Morris)
Aviculopecten tenuicollis (Dana)
?Deltopecten obliquatus Etheridge and Dun

PERNOPECTEN:

Entolium aviculatum (Swallow)

STREBLOCHONDRIA:

?Aviculopecten squamuliferus (Morris)
?Aviculopecten engelhardti Etheridge and Dun
?Aviculopecten ptychotis (McCoy) (Low. Carb.)

GIRTYPECTEN:

?Aviculopecten tessellatus (Phillips) (Low. Carb.)

UNRESOLVED:

Deltopecten wingensis Etheridge and Dun

PERMIAN

Jakowlew's monograph (1903) on the pelecypods from the Bakmuth dolomites in the Donetz Basin (Russia):

PERMIAN PECTINACEA FROM THE DONETZ BASIN IN RUSSIA

ACANTHOPECTEN:

Aviculopecten carboniferus (Stevens)

STREBLOPTERIA:

?Streblopteria aff. *sericea* (Verneuil)

STREBLOCHONDRIA:

?Pseudomonotis sp.
?Streblopteria sp.

Licharew's monograph (1927) on the Upper Carboniferous pelecypods from Ural and Timan:

URALIAN PECTINACEA FROM RUSSIA

AVICULOPECTEN:

Pecten (Aequipecten?) wilczekiformis Licharew
Aviculopecten ufaensis Stuckenberg
Aviculopecten (Deltopecten?) mutabilis Licharew
Aviculopecten wimensis Licharew
Aviculopecten (Deltopecten) hiemalis Salter
Aviculopecten (Deltopecten) occidentalis (Shumard)
Aviculopecten (Deltopecten) cf. *occidentalis* (Shumard)
Aviculopecten (Deltopecten?) subclathratus Keyserling
Aviculopecten (Deltopecten?) batesvillensis Weller
?Pecten (Aequipecten?) keyserlingiformis Licharew
?Aviculopecten serdobowae (Fredericks)
?Aviculopecten uralicus Fredericks

ACANTHOPECTEN:

Aviculopecten pseudoradiatus (Fredericks)
Aviculopecten simensis Licharew
Aviculopecten (Acanthopecten) elegantulus (Stuckenberg)
Aviculopecten (Acanthopecten) licharewi (Fredericks)

STREBLOCHONDRIA:

Pecten (Pseudamusium) ufaensis Stuckenberg
?Pecten (Pseudamusium) eichwaldi (Stuckenberg)
?Pecten (Pseudamusium) pusillus (Schlotheim)
?Pecten (Pseudamusium) sericeus (De Verneuil)
?Pecten (Pseudamusium) englehardti (Etheridge and Dun)
?Pecten (Pseudamusium) krasnoufimskensis (Fredericks)

EUCHONDRIA:

?Aviculopecten tastubaensis Licharew

FASCICULICONCHA:

?*Aviculopecten timanicus* Tschernyschew

UNRESOLVED:

Pecten (Chlamys) aff. *prototextorius* Waagen
Pecten (Aequipecten) keyserlingi Stuckenberg
Aviculopecten aff. *interlineatus* Meek and Worthen
Crenipecten sp.
Aviculopecten netschajewi Licharew

Waagen's monograph 1887 on the Permian fossils from the Salt Range (India).

PERMIAN PECTINACEA FROM INDIA

AVICULOPECTEN:

Pseudomonotis deplanata Waagen

DELTOPECTEN:

Aviculopecten jabiensis Waagen
Aviculopecten derajatensis Waagen
Aviculopecten subexoticus Waagen
Aviculopecten pseudoctenostreon Waagen

PSEUDOMONOTIS:

Pseudomonotis garforthensis King
Pseudomonotis kazanensis Golovkinsky
Pseudomonotis inversa Waagen

STREBLOCHONDRIA:

?*Euchondria subpusilla* Waagen
?*Pecten wynnei* Waagen
?*Pecten prototextorius* Waagen
?*Pecten subgranosus* Waagen

UNRESOLVED:

Oxytoma atavum Waagen
Pseudomonotis gigantea Waagen
Pecten praecox Waagen
Aviculopecten crebristriatus De Koninck
Pseudomonotis radialis (Phillips)
Aviculopecten morahensis Waagen
Aviculopecten asiaticus De Koninck
Pecten flemingianus De Koninck
Aviculopecten squamula Waagen

Gemmellaro's monograph (1896) on the Sicilian Permian pelecypods.

PERMIAN PECTINACEA FROM SICILY

DELTOPECTEN:

Pseudomonotis waageni Gemmellaro

ACANTHOPECTEN:

Avicula josephinae Gemm.

ANNULICONCHA:

Aviculopecten acanthicus Gemm.
?*Aviculopecten janus* Gemm.

STREBLOCHONDRIA:

?*Streblopteria pusilla* Gemm.
?*Streblopteria antinorii* Gemm.

GIRTYPECTEN:

Pseudomonotis fimbriata Gemm.

UNRESOLVED:

Pseudomonotis immanis Gemm.
Limatulina aspera Gemm.
Pseudomonotis toulai Gemm.
Limatulina consanguinea Gemm.
Aviculopecten bertrandi Gemm.
Aviculopecten densistriatus Gemm.
Aviculopecten nitidus Gemm.
Aviculopecten sicanus Gemm.
Pecten politus Gemm.

Grabau, in Permian of Mongolia (1931).

PERMIAN PECTINACEA FROM MONGOLIA

PSEUDOMONOTIS:

Pseudomonotis (Aviculomonotis) mongoliensis Grabau
Pseudomonotis (Aviculomonotis) matthewi Grabau

STREBLOCHONDRIA:

Pseudamusium auriculatum Grabau
?*Euchondria englehardti* (Etheridge and Dun)

UNRESOLVED:

Pseudomonotis furcoplicatus Grabau
Deltopecten cf. *subquinquelineatus* (McCoy)

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