THE ANCESTRAL ORIGIN OF THE NORTH AMERICAN UNIONIDÆ, OR FRESH-WATER MUSSELS

By CHARLES A. WHITE

The subordinal group of fresh-water mollusks, the Naiades, includes two recognized families, the Unionidæ and the Mutelidæ. These two families have many essential characteristics in common and, together, they are distinctly separate from all other molluscan families. They are not only peculiar as regards certain portions of their structure and life history but, with few exceptions, also as regards the restrictions of their inhabitation. That is, the Naiades form the great group of mollusks which are commonly known as fresh-water mussels, all of which are confined to a fresh-water habitat and all will die quickly if immersed in salt water, or if removed to the land. This article is written with special reference to the family Unionidæ, to the geographical distribution of its living representatives, and to the character and succession in time of its fossil representatives in North America. Therefore the Mutelidæ, which are far inferior in numbers and variety to the Unionidæ, and are confined to Africa and South America, will not be further referred to except in a general way. The following elementary statements concerning the structure and physiological functions of the Unionidæ are given for the purpose of emphasizing certain of the facts which are to be stated concerning the integral survival of the family through long geological ages, its present separateness from other molluscan families and the wide geographical distribution of its living members; and also to illustrate the characteristics by which the fossil shells of the family are recognized as such.

In a general way, the animal which produces, and is protected by, the shells of the fresh-water mussels is much like that of the common edible clam or, less closely, like the oyster. It is without a proper head, and also without some of the functional organs possessed by other animals; but it performs the function of locomotion, plowing slowly through mud and sand, by means of a muscular projection called the foot; that of respiration by gills, somewhat like those of fishes; that of circulation by means of a rude pulsating organ which serves as a heart; that of digestion by a stomach; and that of reproduction by minute eggs. The body, which consists of soft parts only, is enveloped in a delicate membrane called the mantle. This organ, although so simple in structure, is a most important one, because, besides other uses to the animal, it forms the shell by secreting a milky substance which exudes, mostly from its free edges, and hardens layer upon layer, until the shells have reached their full thickness and, with the animal, their full size. It is in, or upon, the mantle also that true and valuable pearls are sometimes formed. Although these soft parts differ more or less in details of structure in different genera and species of the Unionidæ, it is the structure and texture of their shells which are generally used in recognizing their systematic relationships as well as largely in their classification; and it is of course those features and properties of the shell alone that are used in the classification of the fossil species.

In structure the shell of each individual consists of two convex valves which are generally equal in size, and of symmetrical shape. They are held together at their upper edges by a horny ligament, and are also drawn together by the two strong muscles of the animal within. Their joined edges under the ligament are usually provided with interlocking projections, the so-called hinge teeth, but some have no such teeth. The free, or lower, edges of the valves open a little way, and it is upon the forward portion of these edges that the shell rests when it is in its natural position.

The shell-substance consists of three distinct layers, each being of different quality and texture. First, a more or less thick inner pearly layer, which is usually iridescent and often of beautiful tints; second, a very thin vertically prismatic layer outside of, and firmly adhering to the pearly one; and, third, outside of all, a thinner horny layer, called the epidermis. This shell-structure is the same for all the members of the Unionidæ in all parts of the world, and it was the same for all members of the family that have existed in former geological ages, as is shown by their fossil remains.

Although the family characteristics of the Unionidæ, in whatever part of the world they are found, are clearly defined by structure and shell-texture, the species and genera in certain great regions are distinctly different from those of other regions. The family is of world-wide distribution, representatives of it being found in the fresh waters of all the continents, in those of all the large islands, and in those of some of the smaller sea-girt islands. The number of known species of the family now living in the whole world is about one thousand. Of this number about six hundred species live in North American waters, and of the latter number the Mississippi River system alone contains about four hundred, or about four tenths of all the known species in the world.

While the species and genera of the Unionidæ are different in different regions, the family is so distinct from all other molluscan families except the Mutelidæ that naturalists, reasoning from present physical conditions and biological data only, have generally assumed for it a common genetic origin in some one region, its subsequent differentiation, and its final distribution to other regions. Because of the fresh-water requirements of those mollusks and the separation by marine waters of the regions which they occupy, and also because there are many cases of intracontinental restriction of regional areas of distribution, the question, how the great distribution of the family could have occurred has been a most perplexing one. The marine waters of the earth cover the larger part of its surface and they are everywhere continuous and of essentially the same character. It is therefore easy to understand how any family of marine animals might gain a universal distribution by successive migrations; but the case is very different with the Unionidæ. Since every member of that family dies quickly if placed in sea water or upon land they are confined to rivers and brooks, lakes and ponds and they cannot by their own act pass from one congenial habitat to another, either overland or through marine waters. Voluntary migration from one region to another being out of the question, some method of distribution by agential transportation has been generally advocated. Local dispersion by the shifting of drainage lines has been suggested; and even the independent origination of members of the family in each region has been assumed. It is desirable to give some account of the views which have been held concerning the geographical distribution of the Unionidæ, both for completeness of statement and for the purpose of comparing those views with the hypothesis concerning the geological origin of the North American species which I shall propose.

Those who have suggested the distribution of the family by transportation have attributed it to the agency of birds and fishes respectively. For all such cases it has been assumed that it was the eggs, or the newly hatched fry, technically called the glochidium, or the byssus-bearing fry, and not the adult mollusks, that have been transported. Immediately after the fry have been hatched from the eggs, and while they are exceedingly minute, some, if not all of the species develop hooklets upon the temporary shell by which each can attach itself to other objects. At a later stage the fry attaches itself to other objects by a slender, thread-like byssus.[1] It has been thought that these larval mollusks may become attached to, or

[1] I make this statement from personal observation many years ago.

entangled upon, the feet of aquatic birds and carried by them in their flight from the fresh waters of one region to those of other regions and there set free. This suggestion seems to be plausible but no known migratory range of aquatic birds will connect any considerable part of the regions of the earth which the Unionidæ are known to inhabit. Besides this all the species, and even the genera, of those mollusks which live in certain of the widely separated regions are different from those of other regions, and those differences are not accounted for in the supposition that the one region was stocked from the other. Moreover, very little interchange of species seems to have occurred under primeval conditions in certain of the intracontinental regions which are constantly visited and revisited by aquatic birds. For example, the Mississippi and St. Lawrence river systems closely approach each other by some of their head waters, and yet each system originally contained a very different Unione fauna from that of the other, although the annual migratory range of millions of aquatic birds has for centuries traversed both regions. It is true that a small number of species are now known to inhabit both of those river systems, most of which probably owe their double habitat to the agency of man. It is also likely that the traffic-canals which are now constructed or projected will increase the number of emigrants from each fauna.

The suggestion that fishes have been instrumental in the distribution of the Unionidæ refers to the glochidia, or minute fry, before mentioned. It is well known that these minute larval mollusks attach themselves to fishes which live in the same waters, and that they burrow into their skin, where they become hermetically encysted for further development. Migratory fishes coming from the sea into fresh waters to spawn may thus become infested if the spawning season of the mollusks and fishes should be approximately coincident. If such fishes should return to the sea bearing in their skins the hermetically encysted parasites, and then enter another river with them, it has been thought that the young mollusks might escape into the new congenial waters and stock them with their kind. Unfortunately for this suggestion the encysted term for the young mollusk is only about seventy days, while the fishes would not naturally return from the sea to fresh waters before the spawning season of another year. Even then they would be much more likely to return to the same river again than to enter any other. Long before that time the young mollusks would have dropped from their cysts and died in the salt water.

The suggestion that the dispersion of the Unionidæ has been effected by changes in the direction of drainage, caused by physical changes in the land surface, seems to be applicable to certain cases, but it is of course not of general application. For example, the Upper Mississippi and the Red River of the North have a closely similar Unione fauna, although the one empties into the Gulf of Mexico and the other into the Arctic Ocean. Their head waters are now far apart, and the land surface between them has only slight elevation. This suggestion is pertinent to the hypothesis which I shall present concerning the survival of the Unionidæ through successive geological periods.

Only one more of the suggestions that have been offered in explanation of the manner in which the present distribution of the Unionidæ has been accomplished will be noticed. Indeed, this one is of so improbable a character that it is presented only to show what extreme views have been held upon this subject. This suggestion is that the Unionidæ of every river system which they inhabit originated independently from somewhat similar molluscan forms that existed in marine waters near the river mouths, that those mollusks entered the rivers, acquired the characteristics of the fresh water family, and differentiated into new species and genera. If one should consider this suggestion seriously it may be remembered that many of the rivers which contain closely similar Unione faunas flow into arctic and tropical seas respectively, and that the molluscan faunas of those seas are correspondingly different. Also that some of the rivers which contain species of the Unionidæ and other fresh water gill-bearing mollusks flow into inland seas, the character of whose waters is such that no molluscan life can exist in them. Such, for example, as the Jordan, flowing into the Dead Sea, and the Bear and Utah rivers flowing into Great Salt Lake. The primary origin of fresh water mollusca from certain marine forms that became land-locked in local waters which gradually freshened as the surrounding land was elevated above sea-level, is of course admitted. But that a distinct and well characterized family of fresh water mollusks could have originated from among incongruous marine faunas at a multitude of distinctly separated centers, and entered the rivers by self migration, is not to be accepted as a rational proposition.

The attempts that have been made to explain the manner in which the present distribution of the Unionidæ has been accomplished are not only defective from a biological point of view, but none of them has had special reference to fossil Unione faunas. I shall presently show what I regard as good evidence that certain North American fossil faunas are ancestrally related to the living fauna of the Mississippi River; and by inference that other living faunas had a like ancestral origin.

Of late years students of the living North American Unionidæ have recognized among the abundant species a considerable number of genera; properly basing their determinations largely upon the structure of the animal itself as well as upon that of the shell, and also to some extent upon group-differences that were formerly much overlooked. The earlier North American naturalists, however, classifying those mollusks by means of the shells alone, usually recognized only three genera, namely, *Unio, Anodonta* and *Margaritana* or *Alasmidonta,* many of them having regarded the latter name as only a synonym of *Margaritana.* In studies of the fossil Unionidæ one is necessarily confined to the shells alone; and the fossil material which is available is usually insufficient for the recognition of such groups of species as are recognizable among living faunas. Because of these facts, and partly from a long established habit, I have retained that older classification in my studies of the fossil species. As the character of this article does not really require it, I do not now make any special reference to the improved classification.

Although the Mississippi fauna contains about four hundred species only about a dozen of them are referred to the genus *Anodonta.* Their preferred habitat is in still waters apart from the two other genera, and their shells are all of plain, simple type. The species that are referable to the genus *Margaritana,* including *Alasmidonta,* in the same fauna are less in number than are those of *Anodonta.* They live in immediate association with *Unio,* and their shells have considerable diversity of form and surface features. It is therefore almost only among the teeming species of *Unio* that occurs the great variety of form and surface features by which the shells of these mollusks have given expression to what naturalists have long recognized as North American types of the Unionidæ. I shall show that this term is properly so applied, not only because these Mississippi River types are different from those which are found among the living members of the family in other parts of the world, but because they evidently have been derived from ancient North American ancestry. The illustrations upon the accompanying plates express this prototypal character of the fossil species, so far as is practicable by such means, with the aid of the material that has hitherto been discovered.[1] It is only claimed that the expression

[1] The specimens from which these figures were drawn are all the property of the U. S. National Museum.

given by these illustrations is of a general character, but one who is familiar with the living fauna of the Mississippi River will not fail to recognize a close similarity of some of its members to certain of the fossil species. Full artificial expression of the general relationship that exists between these fossil species and those which are now living in the Mississippi River system would require a large number of figures of the living, as well as of the fossil, species. As such a full illustration is, for obvious reasons, not now practicable, the reader is referred to the publications mentioned below[1] or, better still, to the mollusks themselves in their native waters.

Before proceeding with special references to the figures upon the accompanying plates and to the fossil species which they represent, some explanation of relevant paleontological and geological facts in their relation to ancient physical geography is necessary. For the sake of brevity these explanatory remarks are mostly made in sentential, rather than in strictly consecutive, form.

Fossil shells of the Unionidæ have been discovered in great numbers and variety in many parts of the world and in formations of various geological periods. They are found imbedded in more or less hardened rocky strata that originally consisted of muddy or sandy sediment at the bottom of bodies of fresh water. Those lacustrine waters were finally shifted to other areas by oscillations of land surface or drained away by the deepening of the channels of outlet, but they left an unmistakable record of their fresh-water character in their fossiliferous sediments, which remained. So restricted are the living Unionidæ to fresh waters, and so distinctive are the shell characters and the shell texture of all the members of the family, that the geologist is as certain that the strata containing their fossil remains were deposited in fresh, and not in marine, waters as if he had then been there and analyzed them. Moreover, there are usually found with the fossil shells of the Unionidæ the shells of other mollusks which are similar to those of the associates of their living congeners.

The existence of a lake, or a body of fresh water, implies the coexistence of a surrounding land surface upon which flow drainage streams of inlet and outlet. The existence of a stratified deposit or formation containing remains of fresh water mollusks implies that the

[1] Observations on the Genus Unio. By Isaac Lea. Vols. I–XIII quarto. Profusely illustrated by full-page plates, part of which are colored.

Synopsis of the Naiades, or pearly fresh-water Mussels. By Charles Torrey Simpson. *Proc. U. S. National Museum,* vol. XXII, pp. 501–1044, and plate XVIII. The literature of the Unionidæ is very extensive. That for North America is catalogued by Mr. Simpson in the forementioned work.

deposit was made in lacustrine waters, and that such a surrounding land surface as that just mentioned existed at the time the deposit was made. The study of North American geology has revealed the presence, especially in the broad interior region of the continent, of many such lake deposits containing remains of the Unionidæ, the earliest one of which that will be referred to being of Triassic age. These deposits alternate with marine formations, showing that the continent has risen by repeated oscillations of the land surface with relation to sea-level, and not by one uniform upward movement extending through successive geological ages. The aggregate gain of these oscillatory movements is the present elevation of the continent.

The first land that appeared above sea-level was drained of its surface waters by brooks; and as the land increased in extent the waters of the brooks increased in volume and became rivers. The unequal elevation of continental land occasionally caused broad depressions of its surface, which filled with drainage water and became lakes. Each lake, together with its outlet and inlets, became stocked with a fresh water fauna which was derived from some pre-existing fauna. Because all existing lakes and rivers contain molluscan life, and because all lacustrine deposits contain remains of such life, it is necessarily inferred that formerly existing lakes and rivers were stocked in like manner.

Lakes are parts of unfinished river systems. The deepening of the outlet portion of such a river system by its running water, aided by sedimentation in the still water, drains the lake and finishes the river system. For example, referring to existing rivers, all parts of the Mississippi system are finished except the slight expansion called Lake Pepin. The St. Lawrence system is very far from finished because of the great, and many smaller, lakes that still remain in both its principal and subordinate courses.

As a rule, abrupt land elevations, including mountain ranges, which have resulted from foldings and other displacements of the earth's crust, have risen so slowly from previously plain regions, that the rivers which were already established there were not only not thereby obliterated, but usually they were not even materially deflected from their courses. By the corrasive action of its running water and the detritus which it carried by its flow, each stream abraded and carried away the earth-material, even including solid rock, as it slowly rose beneath its channel. Some of the now existing rivers have thus made deep cañons with precipitous sides, through the rocky strata of elevated regions, and some have even cut their way through mountain ranges. The cañon sides represent the rising of the land, not the lowering of the river. The cañon of Green river through the Uinta mountain range, and the Grand Cañon of the Colorado of the West through the Great Plateau, are cases of this kind. Still, some rivers have suffered vertical displacements in at least parts of their course. For example, the prolongation of the channel of some existing rivers of North America, is traceable by soundings beneath sea-level, where they sank by subsidence of the continental border. If that border should be raised again such rivers and their faunas would come into their former possessions. At the beginning of the Tertiary period the Upper Mississippi and Ohio rivers emptied separately into the Gulf which then extended northward above the present confluence of the two rivers. That is, the whole of what is now the Lower Mississippi was then beneath sea-level. It has since been added to the upper portion of the great river system and stocked with its fauna.

These, and many other similar facts show that rivers, once established, although often modified in extent by land elevations and subsidences, and changed in direction by the opening of new lake outlets, have been among the most persistent features of the earth's surface. The lakes which occupied portions of the course of ancient rivers have all been obliterated; and doubtless also in rare cases some rivers or small river systems, with their molluscan faunas, have been wholly destroyed. The facts which have been stated, however, warrant the assumption that, as a rule, some portions of those ancient rivers have preserved a continuous flow of fresh water to the present time. I do not doubt that at least some portions of the present Mississippi River system represent a continuous fluvatile flow from a time at least as remote as the Cretaceous period. Rain waters have always fallen upon the land ever since its first elevation above the sea, and a constant flow of drainage streams has been necessary to remove it. It is only by a constant flow that genetic lines of fresh water denizens could have been preserved; and I therefore assume that the Unione fauna of the Mississippi River system has in this way been, at least in part, genetically derived from the fossil faunas some of whose remains are figured on the accompanying plates.

Some of the types of former fresh water denizens whose remains have been discovered are not found among living faunas, and it is therefore inferred that these were among the faunas of those rivers which failed entirely to preserve their continuity of flow through successive geological periods. For example, although *Unio belliplicatus,* which is represented by figures 4, 5 and 6, on plate

XXVIII, has all the structural and textural characteristics of the genus *Unio,* it is not only the earliest known species of that genus to possess well marked surface ornamentation, but its type of ornamentation is different from that of any known living North American species. Besides this, several species of the gasteropod mollusks which are associated with this *Unio* are also different in certain characteristics from any of their kind upon this continent, either fossil or living. Moreover the Bear River formation, in which this fossil fauna is found, is of small extent compared with the other North American fresh water formations. From all these facts I infer that the body of water in which the Bear River beds were deposited, together with its inlets and outlet, constituted a small separate river system with a distinctive fauna. Also that its case was an exception to the rule of the persistence of the rivers, and that this whole small river system with its fauna became destroyed by some geological disturbance of the land surface. The types of the Bear River fauna which were not thus destroyed, for example, the simple type of *Unio nucalis,* which existed before, and have existed ever since the Bear River epoch, were probably preserved in other bodies of fresh water by collateral lines from an original genetic source. These remarks upon ancient physical geography may be closed with the following summary statements, together with references to the figures upon the accompanying plates and to the species which they represent.

Fresh-water gill-bearing faunas have as certainly descended genetically through successive geological ages to the present time as have marine faunas. The genetic successors of each fauna have necessarily descended in a continuous fresh-water habitat. Such continuity of habitat has been produced and preserved by the seasonal rains which have always fallen upon the land and caused a constant drainage flow in its rivers and their branches. There has never been any intermission of such continuity because the fresh water supply has never failed, and because, as a rule, rivers have been among the most persistent of the earth's surface features. While some rivers, or small river systems, have doubtless been from time to time destroyed by certain special movements of the earth's crust and their peculiar faunas utterly exterminated, it is not probable that through all the great vicissitudes of continental develment any greater proportion of fresh-water types have been thus destroyed than of marine types which have perished by volcanic eruptions, local elevation or depression of sea-bottom, changes of sea-currents, and other causes.

Measured geologically, the life-time of species as such has been short, but genera, and the types which they embrace, have persisted through successive geological ages. The types of *Unio* which are represented on the accompanying plates have been thus preserved, while the species which successively bore them became extinct in the successive geological opochs. They so much resemble certain members of the living Mississippi river fauna as to warrant the assumption that the fossil faunas represent the living fauna ancestrally.

Many specimens of fossil shells of the Unionidæ have been discovered in the Triassic strata of New Mexico and Wyoming. All of them are very imperfect and of comparatively small size, but they unmistakably belong to the genus *Unio*. One of these Triassic specimens is represented by figure 1, plate XXVI. The specimens referred to are the earliest of the certainly known examples of the Unionidæ in North America, although certain shells found in Devonian and Carboniferous rocks have been supposed to belong to that family. These Triassic shells are all of simple form, and none of them exhibits distinctive prototypal relationship to the living Mississippi River fauna. Their structure and shell texture, however, clearly show that the genus *Unio* was fully established at that early period; and their wide distribution indicates that a large Unione fauna was then established.

In all, seven species of the Unionidæ have been discovered in the fresh water Jurassic strata of Colorado, Wyoming and South Dakota. All of them belong to the genus *Unio*, and five of the seven species are represented on plates XXVI and XXVII. They are all of simple, plain types, none of them exhibiting any special relationship to the Unione fauna of the Mississippi, unless it be *U. stewardi*. It is, however, not improbable that all these species, as well as those found in Triassic strata, are ancestrally related to the simpler forms of the Mississippi fauna.

While there evidently was a large representation of the Unionidæ in the Triassic and Jurassic periods, it was in the closing period of Mesozoic time, the Cretaceous, that the family received an extraordinary development. This fact is shown by the discovery at numerous places within a large geographical area, and in several successive formations, of a large number and great variety of fossil species of *Unio*, and of the addition among them of a few species of *Anodonta* and *Margaritana*. The increased diversity of the Unionidæ in this period is also shown in the exhibition by many of the species of *Unio* of those peculiarities which I have designated as North American prototypal characteristics. These discoveries of Cretaceous species have been made in the states of Colorado, Utah, Wyoming, South Dakota and Montana; and in the Canadian territories of Alberta, Assiniboia and Saskatchewan. In vertical range these discoveries extend from the base to the top of the Cretaceous series of formations as it exists in the great region just indicated. The formations, or groups of strata, are, beginning with the lowest, the Dakota, Colorado, including the Bear River beds, Pierre, including the Fox-Hills, Judith River and Belly River beds, and the Laramie. The Dakota group has furnished comparatively few molluscan fossils, and the most that need now be said of it is that it is not of marine origin. The Colorado and Pierre formations consist mainly of unquestionably marine strata, with which the fresh water groups alternate. The Laramie is the uppermost formation of the Cretaceous series and the character of its molluscan fauna gives evidence that it was deposited in a body of water that was in part fresh and in part brackish. This formation aso contains plant remains which have been referred to the Tertiary; and dinosaurian remains which are regarded as of Cretaceous age. I now provisionally refer the formation to the latter age, although its molluscan fauna might with propriety be referred to the Tertiary. It is in the Laramie strata that the greatest number of species of *Unio* have been found that bear the prototypal features which have been frequently referred to. Most of these species were found in a few fossiliferous layers of limited extent, each of which was probably deposited near the mouth of an inlet and not in the stiller waters of the lake. The formation from which each of the species represented upon the accompanying plates were obtained is noted upon the page of explanations which accompanies each of the plates.

Besides the species which are referred to in the foregoing paragraphs and figured on the accompanying plates, Professor R. P. Whitfield has published descriptions and figures of six new species of *Unio* which were discovered in strata of the Laramie Group of Montana, and which he has named as follows: *Unio æsopiformis, U. verrucosiformis, U. retusoides, U. browni, U. percorrugata,* and *U. postbiplicata.* All these fossil species present prototypal characteristics of the living Mississippi Unione fauna in a marked degree. Three of them are so closely like three living species respectively that Professor Whitfield has given names to the fossil

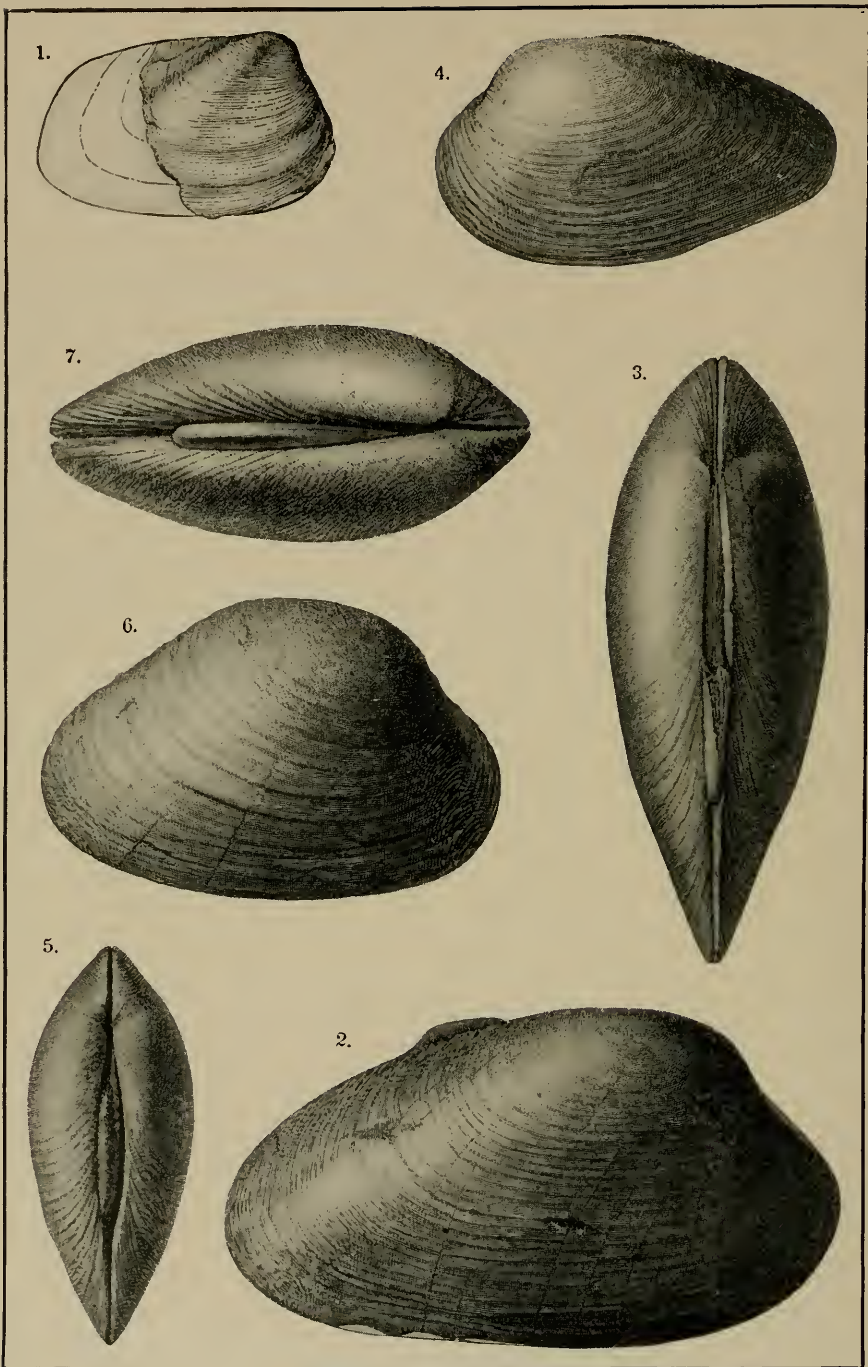
[1] "Notice of Six New Species of Unios from the Laramie Group," by R. P. Whitfield, *Bull. Am. Museum of Nat. Hist.*, vol. XIX, pp. 483–487, plates XXXVIII–XL.

forms which are only modifications of the names of the living forms which they so closely resemble. One cannot doubt that further discoveries will yield additional evidence of the prototypal relationship of the fossil and living Unione faunas of this continent.

Following the Laramie in the order of time and of geological sequence, are the Eocene, Miocene and Pliocene Tertiary formations, all three of which, in the great interior region of North America, consist of fresh water lacustrine deposits. From the fact that the Laramie Group has been found to contain so many prototypal examples of the North American Unionidæ one might naturally expect to find among the Tertiary molluscan faunas numerous species of *Unio* that would, by similar prototypal features connect the Laramie forms more or less directly with the living Mississippi River fauna. Such, unfortunately, is not the fact, for only a few species of the Unionidæ have been found in any of those Tertiary deposits, and they are all of simple type and plain surface. If only such plain forms of *Unio* really existed in those Tertiary waters between the Laramie period and the present time, my assumption of the ancestrally prototypal character of the Cretaceous Uniones would be unsupported. Without any exception known to me, however, the strata in which the Tertiary Uniones have been found show evidence of having been deposited in comparatively still lacustrine waters, and it is a well known fact that one rarely, if ever, finds any other than plain types of the living Unionidæ in the still waters of lakes. The more diverse and ornamental forms of living Uniones occupy fluvatile, or other running or moving waters. None of the deposits containing the Tertiary Uniones referred to gives any inherent evidence of having been formed in fluvatile or estuarine waters, but such deposits were doubtless made somewhere in the tributaries, and upon the borders, of those Tertiary lakes. When such deposits are discovered they will doubtless be found to contain North American prototypal forms, such as will connect the Cretaceous types with those of the Mississippi River fauna.

When referring in a previous paragraph to the diverse views which have prevailed among naturalists concerning the present geographical distribution of the Unionidæ, it was intimated that any discussion of this question ought to have reference to the fossil Unione faunas of the respective regions. I have shown what I regard as good evidence that the well known types of North American Uniones in the fauna of the Mississippi River have descended genetically from North American fossil faunas; but I am not yet prepared to offer an explanation of the geographical distribution of the Unionidæ in the various regions of the world.

The accompanying illustrations, plates XXVI to XXXI, are all of natural size and all the specimens are the property of the U. S. National Museum. An explanation of the figures faces each plate.



UNIONIDÆ

PLATE XXVI

Unio cristonensis Meek. Triassic.

FIG. 1. Imperfect right valve; part of the outline restored.

Unio felchii White. Jurassic.

FIG. 2. Right side view; probably a female.
FIG. 3. Dorsal view of the same specimen.
FIG. 4. Left side view of a younger specimen; probably a male.
FIG. 5. Dorsal view of the same specimen.

Unio toxonotus White. Jurassic.

FIG. 6. Right side view of an adult specimen.
FIG. 7. Dorsal view of the same.

Plate XXVII

Unio stewardi White. Jurassic.

Fig. 1. Left side view; restored from broken specimens.
Fig. 2. Left side view of a younger specimen.

Unio nucalis Meek and Hayden. Jurassic.

Fig. 3. Left side view.
Fig. 4. Dorsal view of the same specimen.

Unio mecropisthus White. Jurassic.

Fig. 5. Left side view.

Unio iridoides White. Jurassic.

Fig. 6. Right side view.

Margaritana nebrascensis Meek. Dakota group of the Cretaceous series.

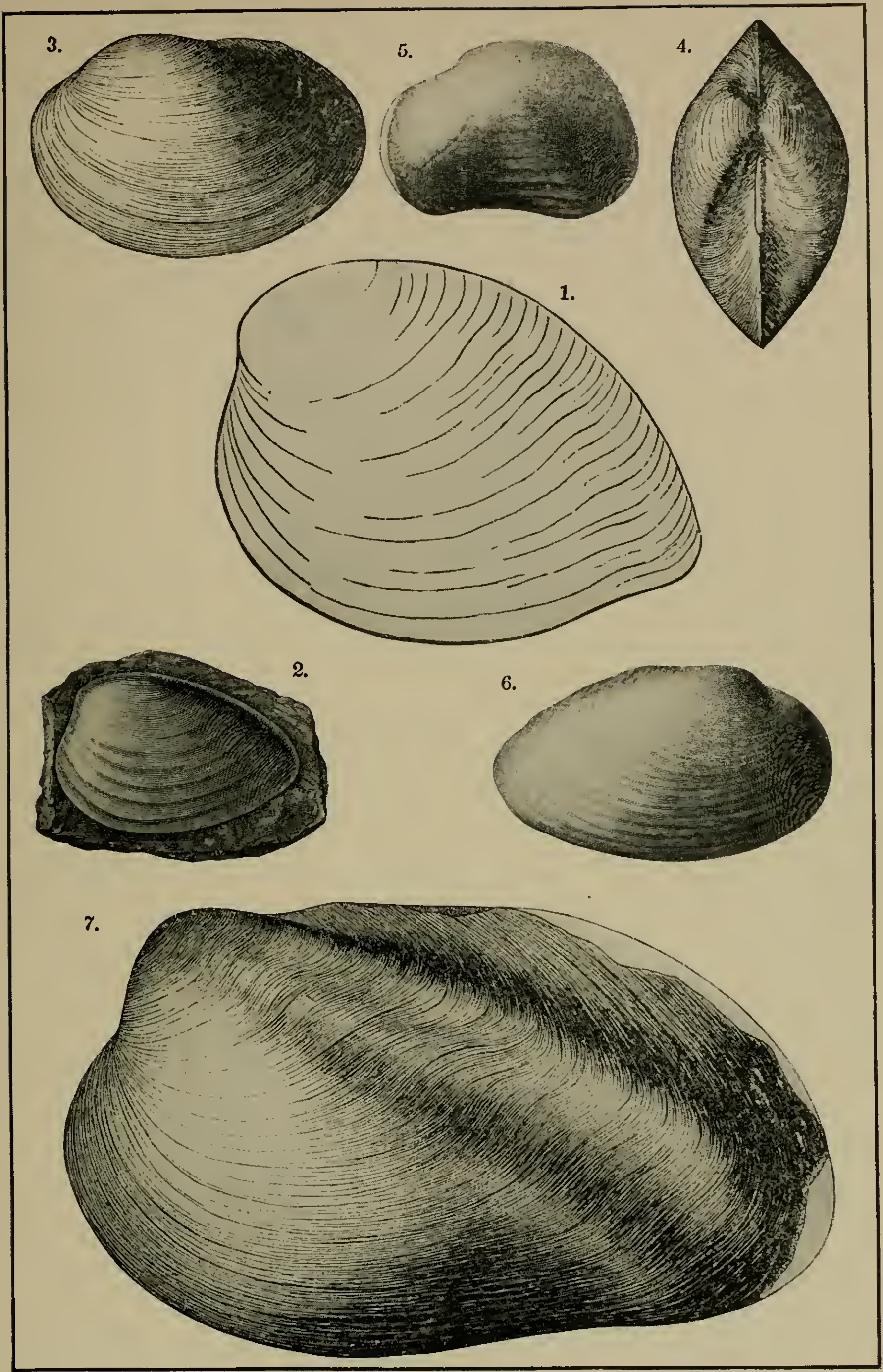
Fig. 7. Left side view.

The species, *U. stewardi* resembles a common type of *Unio* in the Mississippi fauna.

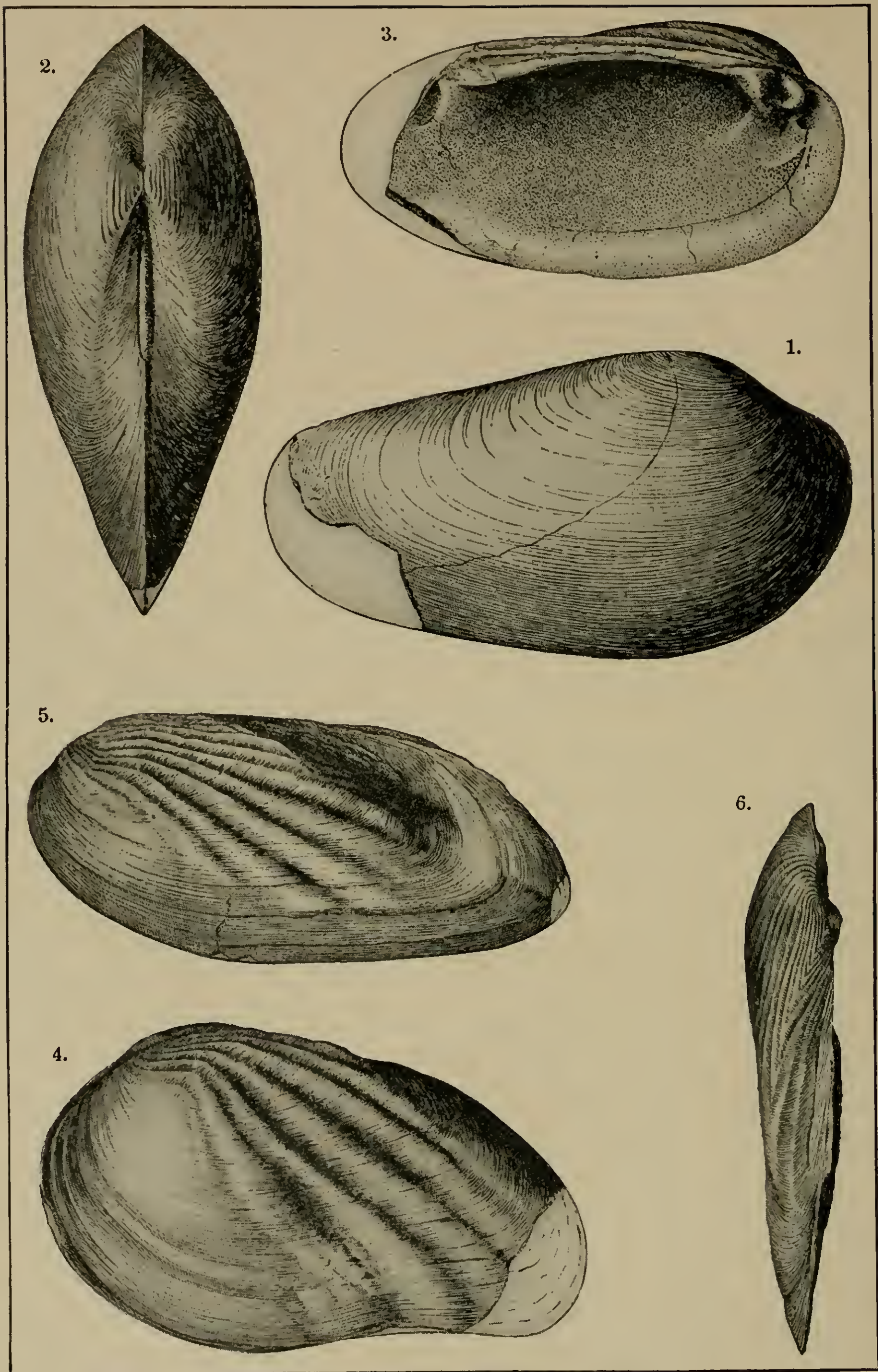
The figured specimen of *U. macropisthus* is the only one discovered. Its posterior breadth probably indicates that it is a female.

The species, *U. iridoides,* closely resembles *U. iris,* of the Mississippi fauna.

Margaritana nebrascensis is much more inflated, especially in the umbonal region than is any known living species of that genus; but it is known to possess the hinge structure of *Margaritana.*



UNIONIDÆ



UNIONIDÆ

Plate XXVIII

Unio vetustus Meek. Bear River beds of the Cretaceous series.

Fig. 1. Right side view of probably a male specimen.
Fig. 2. Dorsal view of the same specimen.
Fig. 3. Interior view of a left valve.

Unio belliplicatus Meek. Bear River beds of the Cretaceous series.

Fig. 4. Left side view of probably a male specimen.
Fig. 5. Left side view of probably a female specimen.
Fig. 6. Dorsal view of a left valve, showing beak sculpture.

PLATE XXIX

Unio endlichi White. Laramie group of the Cretaceous series.

FIG. 1. Right side view of a large specimen.
FIG. 2. Interior view of a smaller, left valve.

Unio propheticus White. Laramie group of the Cretaceous series.

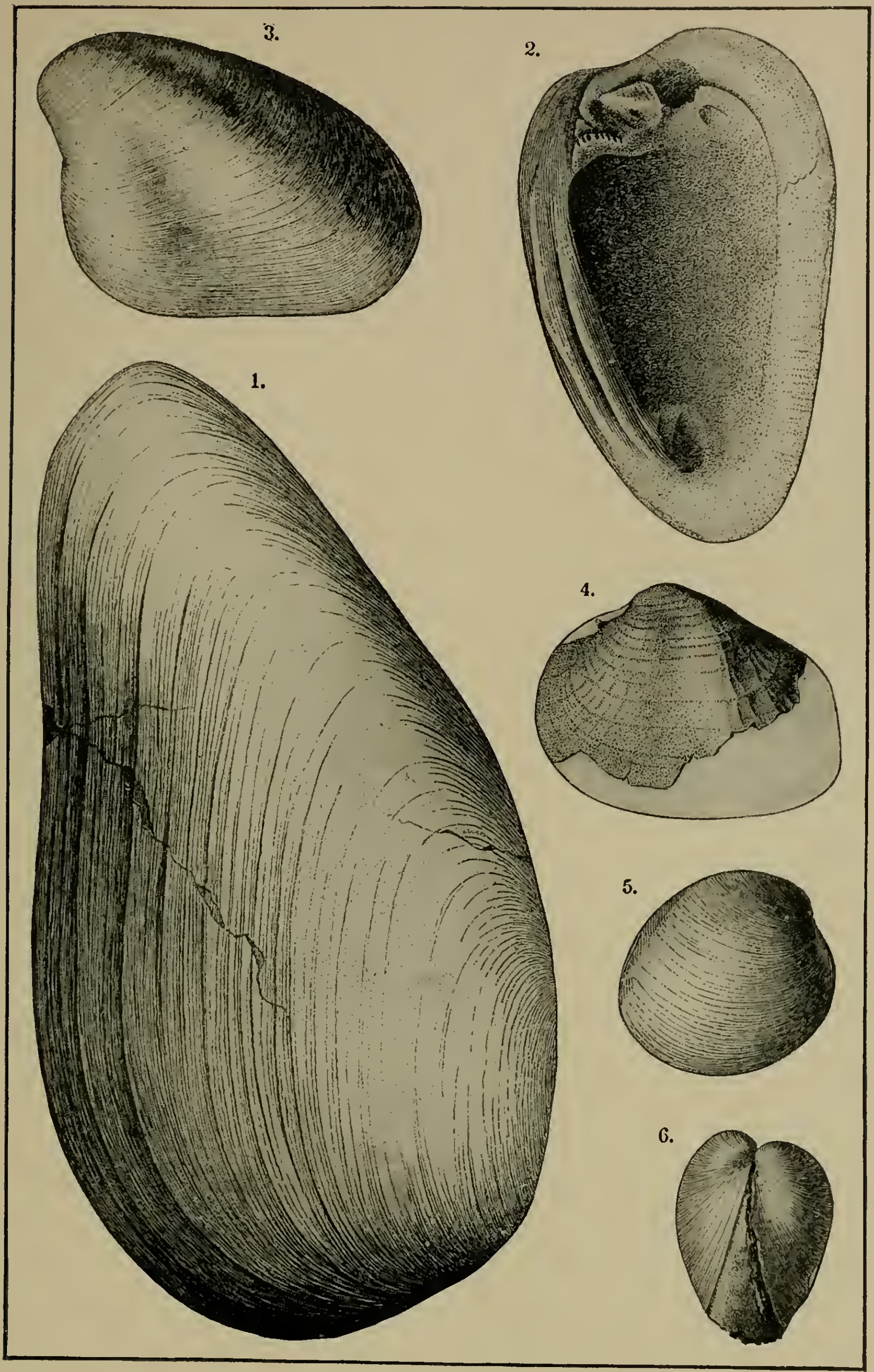
FIG. 3. Left side view.

Unio primævus White. Judith River beds of the Cretaceous series.

FIG. 4. Left side view of a broken specimen.

Unio brachyopisthus White. Laramie group of the Cretaceous series.

FIG. 5. Right side view of a small, probably a young, specimen.
FIG. 6. Front view of the same.



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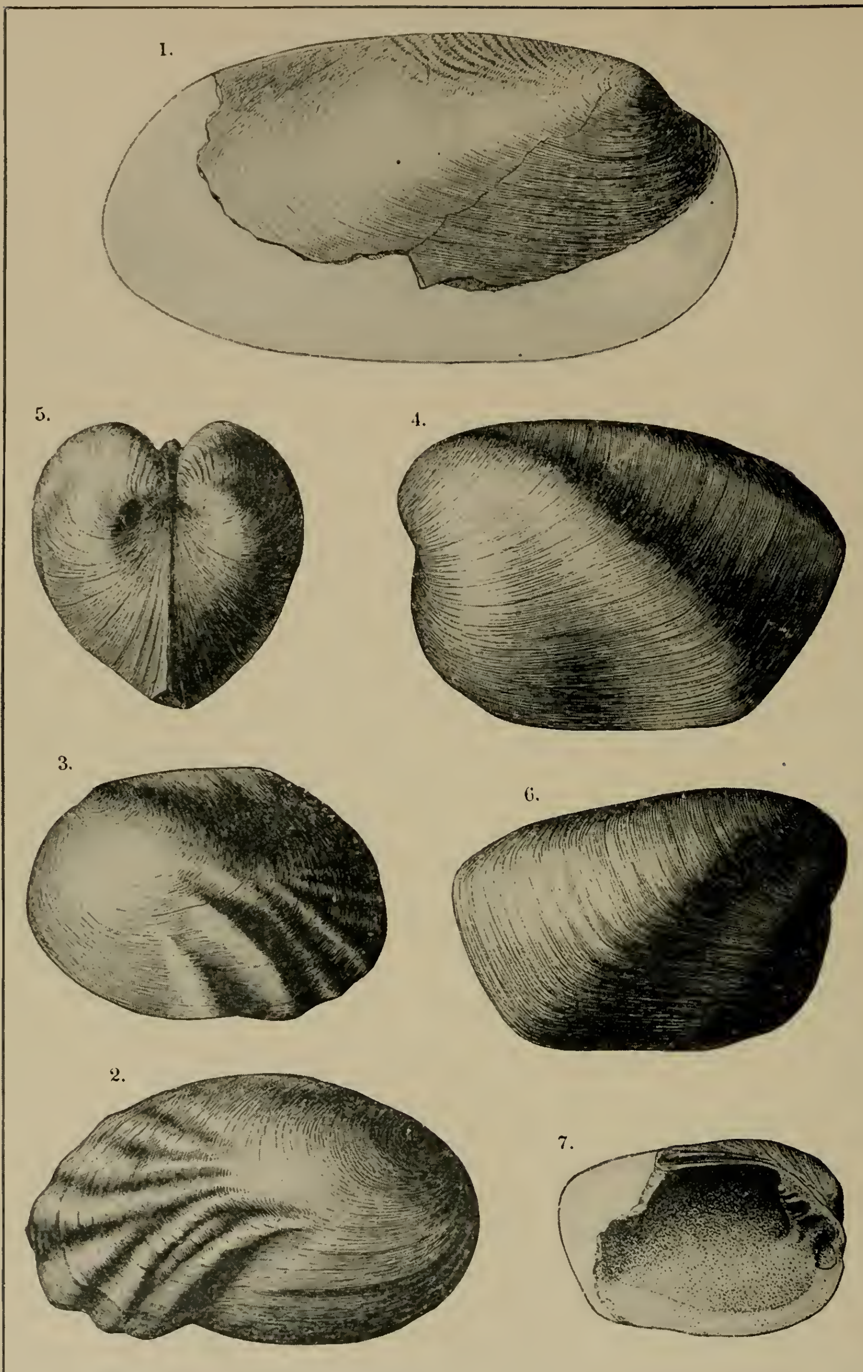

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Plate XXX

Unio senectus White. Judith River beds of the Cretaceous series.

Fig. 1. Right side view of a broken specimen.

Unio gonionotus White. Laramie Group of the Cretaceous series.

Fig. 2. Right side view of an adult specimen.
Fig. 3. Left side view of a younger one.

Unio proavitus White. Laramie Group of the Cretaceous series.

Fig. 4. Left side view of an adult specimen.
Fig. 5. Front view of another adult.
Fig. 6. Right side view of another specimen.
Fig. 7. Interior view of a left valve.

Plate XXXI

Unio aldrichi White. Laramie Group of the Cretaceous series.

Fig. 1. Left side view of a partially broken specimen.

Fig. 2. Dorsal view of the same.

Unio holmesianus White. Laramie Group of the Cretaceous series..

Fig. 3. Left side view of an adult specimen.

Fig. 4. Dorsal view of the same.

Unio goniambonatus White. Laramie Group of the Cretaceous series.

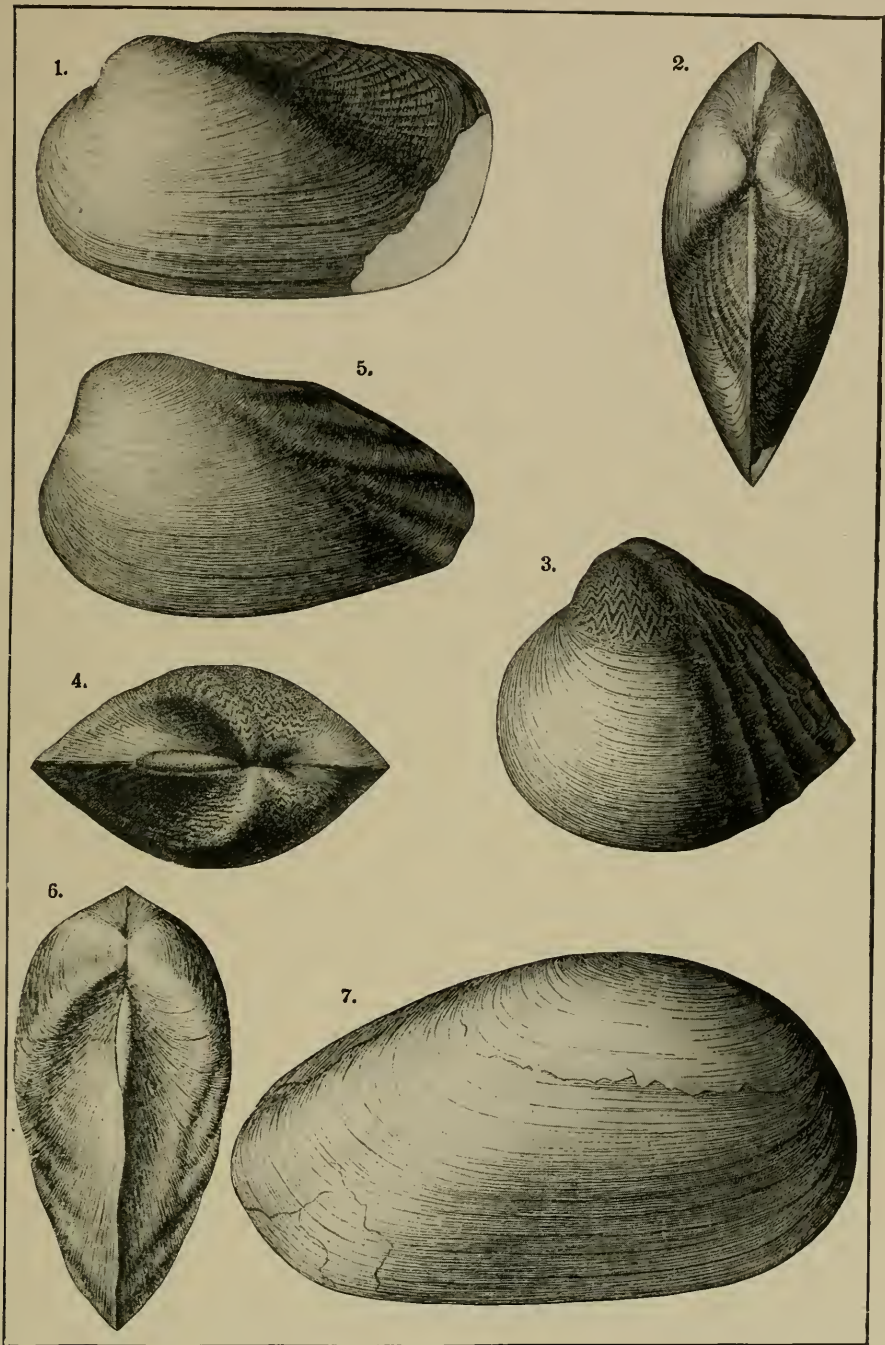
Fig. 5. Left side view; probably a male.

Fig. 6. Dorsal view of the same.

Unio stantoni new species. Laramie Group of the Cretaceous series.

Fig. 7. Right side view.

The specimen here figured under the name of *U. stantoni,* in honor of Dr. T. W. Stanton, was formerly referred to *U. danæ* Meek and Hayden of the Judith River beds; but it proves to be different in specific features and to come from a much higher position in the Cretaceous series.



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