TRANSPOSED HINGE STRUCTURES IN LAMELLIBRANCHS

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INTRODUCTION

In the course of study of a collection of Eocene fossils from Claiborne, Alabama, the senior author of this paper noticed two valves, one right and one left, of the lamellibranch Venericardia parva Lea, in which the dentition is partially transposed. Subsequently, the authors made an examination of more than five thousand lamellibranch valves, representing both recent and fossil shells, in search of further examples of hinge-transposition. We have found a total number of twenty-six valves exhibiting this variation.

Study of these specimens has revealed some hitherto unreported facts regarding the principles of hinge-transposition. Therefore in this paper, we shall describe and discuss these specimens, and shall present such conclusions as seem justified by the data assembled.

Citations to the literature are made by author, date, and page, referring to the list at the end of the paper.

DEFINITION OF TERMS

A transposed lamellibranch hinge is defined as one that exhibits in the right valve the hinge elements normally occuring in the left valve, and vice-versa. The relations of the

individual teeth to one another, and to the bilaterally symmetrical parts of the shell, are exactly similar to the relationships which are present in a normal individual. Thus, the interior of an abnormal valve with completely transposed dentition presents the appearance of a mirror-image of the interior of the opposite normal valve.

The terms "inverted", "reversed", and "transposed" have been used previously in the literature to designate lamellibranch valves exhibiting entirely or in part the morphologic characters normal to their opposite valves. The first two expressions have been most commonly used, but the third, "transposed", has been employed by Jeffreys (1863, p. 317) and Fischer (1887, p. 109). The latter term seems more appropriate, suggesting the effect of a carrying-over of morphologic characters from the valve in which they normally occur to the opposite valve. Therefore we shall use the term transpose and its derivatives to designate the abnormal hinges here discussed.

In this paper, unless otherwise stated, the unqualified term transposition will refer to the dentition and not to the valve as a whole, while partial transposition will imply transposition of a part of the dentition.

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us to make excerpts from their paper, "An Inverted Hinge in a Left Valve of the Venericardia planicosta Group". The illustrations were prepared by John L. Ridgway, scientific illustrator for the Division of Geology and Paleontology, California Institute of Technology. Finally, the work has been carried on under the supervision of Chester Stock, Professor of Paleontology at the California Institute of Technology. We gladly acknowledge our indebtedness for the assistance we have had from these sources.

REVIEW OF PREVIOUS LITERATURE

In this section we shall review briefly all literature on the subject of transposed lamellibranch shells available to us. We shall also mention some papers cited by other authors, but to which we do not have access. Referring to supposed cases of transposition occurring among the Chamidae are omitted as these examples apparently do not represent transposition as defined in this paper.

MOQUIN-TANDON (1855, p. 322) placed the species Unio sinuatus in a list headed: "Espèces à spire dextre devenue sénestre", designating the species included in the list as examples of "inversion".

AGASSIZ (1859) noted a case of"reversion" in Unio ligamentinus (Lamarck). The dentition in his specimen was apparently completely transposed.

ISAAC LEA (1860) discussed abnormal dentitions in a considerable number of Recent valves of Unio. A list was presented showing individual abnormalities as follows: (1) single lateral tooth in each valve, 4 specimens belonging to 4 species;

(2) single lateral tooth in the left, and double lateral in the right valve, 6 specimens belonging to 5 species; (3) double lateral tooth in both valves, 9 specimens belonging to 2 species; (4) treble lateral tooth in the left, double in the right valve, 1 specimen; (5) treble lateral tooth in the left, and partly treble in the right valve, 2 specimens belonging to 2 species; Another list was given including species of Unio in which the following dentitions are specifically characteristic: (1) cardinal tooth single in both valves; (2) cardinal tooth double in the right, single in the left valve; (3) cardinal and lateral teeth double in both valves; (4) lateral tooth double in the right valve only; (5) lateral tooth double in both valves; (6) lateral tooth treble in the left, and double in the right valve; (7) cardinal tooth treble in the right valve; (8) cardinal tooth treble in both valves, and lateral tooth treble in the right and double in the left valve. These data together with those furnished by other writers on abnormal Unio hinges suggest that the dentition of this genus is subject to many variations, some of which may or may not constitute hinge-transposition as we define it. Similarly, the Unio we describe (below, p.13) may or may not constitute an example of true hinge-transposition. Lea emphasized the fact that hinge-abnormalities in Unio may be either individual variations or specific characters. He referred to two papers that he had previously published ("Trans. Am. Phil. Soc. in 1827 * * * and in 1829") discussing aberrant unios. We have not seen these papers.

JEFFREYS (1863) discussed a specimen of Astarte compressa Montagu (p. 317) which he described as displaying "partial transposition". By this expression, Jeffreys evidently meant transpo-

sition of a part of the valve; whereas in the present paper, the same expression refers to transposition of a part of the hinge. He referred to two examples of transposition mentioned by Gray in the 'Zoological Journal' and 'Philosophical Transactions'. We have not seen these references. Jeffreys also stated,(p.319) regarding A. triangularis Montagu that " the hinge is now and then reversed as in A. compressa".

FISCHER (1880) recorded a specimen of Tellina plicata Valenciennes in which the posterior extremities of the valves curved to the left instead of to the right, as in normal specimens. Other external characters were also transposed. No mention is made of the dentition.

BEECHER (1883, p. 52) mentioned "reversion" of teeth in Unios "which have the cardinal and lateral teeth interchanged in the valves". He cited the following species in which Prof. R. Ellsworth Call had observed "reversion" : Unio complanatus, Unio rubiginosus, and Unio cahawbensis.

FISCHER (1887, p. 109) again cited "inversion", in many specimens of Tellina plicata Valenciennes, "dont les valves etaient transposees". Transposition of external parts was mentioned; but no information was given regarding the teeth.

DALL (1890-1903, p. 1006) stated, in a general discussion of the genus Tellina: "It occasionally happens that the hinge of an individual will be reversed with respect to the valves of normal specimens, but I have found no species in which the hinge is habitually reversed". Again (p. 1482) in discussing the Astartidae, he stated: "A peculiarity which has been noticed in several of the genera of Astartidae is the tendency to reversal of the

hinge-teeth in relation to the valves, the dentition normal to the right valve being found in the left, and vice-versa. This peculiarity is especially notable in the case of Goodallia, where out of one lot examined, nearly one-third had the hinge reversed." In another paper (1903, p. 934) he stated regarding Astarte: "The teeth of the hinge are frequently reversed as regards the valves".

BROOKES (1894, pp. 340-341) stated: " in the lamellibranhhs, one shell, viz. that to the left when the animal is walking is a dextral, and the opposite one a sinistral spiral. In a few cases the reversal of this rule has been observed, as in two specimens of Lucina childreni in the Tankerville collection." This is probably a case of transposition of the valves, but no details are given.

SYKES (1905, p. 270) mentioned"reversed" Chamas, and referred to Fischer(1880) and Jeffreys (probably 1863, pp. 317,319);

REYNELL (1908) figured and briefly discussed a "left valve of Astarte mutabilis Searles Wood, from the Pliocene (Coralline Crag) of Suffolk," showing "the hinge dentition of the right Valve". An examination of the figure shows that this is a case of partial hinge-transposition, the cardinal and anterior lateral teeth being transposed, the posterior laterals being normal.

PELSENEER (1920, pp. 54,55) stated that there are among the lamellibranchs numerous "exemples d'inversion", characterized notably by the presence in the left valve of teeth normal to the right and vice-versa. He cited 13 pa pers dealing with transposition, two of which, dealing with Chama pulchella, and pectend lying on the wrong side,are irrelevant to this paper. We have

discussed eight of these references above. The remaining three papers, Deshayes (1850), Fischer (1906), and Anthony (1905), we have not seen.

DAVIES (1925) discussed "inversion" in the astartes and chamas. He stated that the symbols of the Munier-Chalmas - Bernard system of notation, which are applied to the teeth of a normal right valve should be used for the teeth of the left valve in the case of true hinge-transposition, and vice-versa. Previous authors had attempted to use the same notation for the teeth of the right valve whether transposed or not; and similarly for the left valve. Davies also suggested that Rudistids, previously supposed to show hinge-transposition are not true examples of this phenomenon.

HANNA (1925, p. 287, pl. 38, fig. 4) mentioned paired valves of Venericardia hornii Gabb showing transposed dentition. He figured the hinge of the right valve.

GARDNER AND BOWLES (1932) described a left valve of the Venericardia planicosta group which shows an"inverted" hinge. A review of part of the literature on the subject of hinge-transposition is given. They conclude that hinge-transposition is a systematic abnormality, and not simply a displacement of the teeth normally found in the valve concerned. The hinge of the subgenus Microstagon Cossman is discussed as possibly related to transposition. They cite Bernard (1897, p. 564) who stated, in connection with a discussion of the Chamidae, that each tooth has its own individuality, and that he had not seen any case of dentition having been transferred from one valve to the other. Bernard referred indefinitely to work of Munier which may have significance in connection with trans-

position. Two papers not available to us were cited by Gardner and Bowles: Oedner (1919) and von Vest (1899). According to Gardner and Bowles, Oedner considered that hinge transposition represents simply a displacement of the hinge-elements from their normal order in the hinge in which they normally occur. Von Vest figured a right valve of Astarte corrugata Brown, Recent, which shows true transposition of the hinge.

DESCRIPTION OF MATERIAL

The shells showing the transposed hinges herein described belong to the following genera: Venericardia, sensus lato, Astarte, Transennella, and Unio. Approximately 2000 shells from various other genera, mostly representing common forms of venerids and tellinids, were examined. These yielded no examples of transposition.

In the following descriptions, the material is divided into four groups, based on the number and structure of the hinge-elements present, and on the way in which these elements are transposed. These groups are: (1) cardinal and anterior lateral teeth transposed, posterior lateral teeth normal; (2) cardinals and anterior laterals transposed, posterior laterals absent; (3) cardinals and anterior laterals normal, posterior laterals transposed; and (4) cardinals normal, anterior laterals absent, posterior laterals transposed. Group (2) may represent only a special case of group (1), and group (4) only a special case of group (3).

Certain points should be emphasized with reference to this grouping. Most of the specimens described in this paper exhibit partial transposition, in which only a part of the dental arma-

ture present has been transposed. No hinge containing all three dental groups, namely, cardinal teeth, anterior laterals, and posterior laterals, is completely transposed. One hinge in which posterior laterals are absent is completely transposed.

(1) Cardinals and Anterior Laterals Transposed, Posterior Laterals Normal.

Twenty-one of the twenty-six valves showing transposed dentition fall within this group. These all belong to the families Astartidae and Carditidae.

Carditidae

Nineteen valves showing transposed dentition of this type were found in an examination of approximately 3700 specimens of Carditidae. The specimens represent the following species: Venericardia parva Lea (plate I, figs. 1-4) Upper Eocene, Claiborne Bluff, Alabama, six right valves and two left valves; "Venericardia" granulata Say, Pliocene, Walkers Bluff, Cape Fear River, North Carolina, two left valves; and "Venericardia" ventricosa (Gould), Pleistocene, San Pedro and Santa Barbara, California, seven right valves, and two left valves.

Since these three species show practically identical hinge patterns, one description will serve for all. The hinge of the normal right valve contains three cardinal teeth: one large central triangular tooth extending obliquely backward from just below the umbo to the postero-ventral margin of the hinge plate; one long narrow posterior cardinal situated just below the nymph and diverging from it posteriorly by a small angle; and one small pointed anterior cardinal situated upon the lunular wall

which borders anteriorly the socket lying in front of the central cardinal. The normal left hinge contains two cardinal teeth: one small trigonal anterior cardinal directly ventral to the beak; and a long arched posterior cardinal extending from the beak to the posterior margin of the hinge-plate and lying immediately ventral to the nymph. An inconspicuous anterior lateral tooth in the left valve fits into a minute shallow anterior socket in the right valve; and a tiny posterior lateral tooth in the right valve similarly fits into a small socket on the postero-dorsal margin of the left valve. The lateral teeth and sockets of these species are so small as to be practically obsolete, and are usually not to be distinguished on eroded specimens.

The individual teeth in these abnormal carditid hinges are precisely similar to those of normal specimens. However, the cardinals and anterior laterals are found to be completely transposed, leaving only the posterior laterals normal to the hinge in which they occur. Thus, in the transposed hinges, anterior and posterior lateral sockets occur in the left valve, while single posterior and anterior lateral teeth are found in the right valve.

Astartidae

Two left valves showing transposed dentition were found in an examination of approximately 260 valves belonging to several species of Astarte. The abnormal valves belong to two species: Astarte concentrica Conrad, (plate I, figs. 5 - 7) Yorktown formation, Miocene, Grove Wharf, Virginia, and Astarte sima Gardner, Miocene, Shoal River formation, Shoal River, Florida.

The following is a description of the normal dentition in these species of Astarte: The right valve contains one large central triangular cardinal, with weak anterior and posterior cardinals; the left valve exhibits two prominent diverging cardinals separated by the socket that receives the large central cardinal of the right valve. Two lamellar anterior lateral teeth in the right valve lie on either side of the socket that receives the single anterior lateral tooth of the left valve; while a single laminar posterior lateral tooth in the right valve fits between two posterior "clasping lamellae" in the left valve.

As in the case of the carditids, the abnormal astartes exhibit individual teeth which are entirely similar to those of normal valves. Similarly also the cardinal and anterior lateral teeth are entirely transposed while the posterior laterals remain normal. Paired laterals therefore occur in both the anterior and posterior positions in these two left valves.

(2) Cardinals and Anterior Laterals Transposed, Posterior Laterals Absent.

This group is represented by a single left valve of Transennella stimpsoni Dall, (plate I, figs. 10 - 12), found in a collection of twenty Recent valves of the species from the Florida Keys. So far as we have been able to determine, this specimen shows the only example of hinge-transposition reported in the Veneridae.

In the normal right valve of this species, three cardinal teeth are present. The two anterior cardinals are thin, blade-

like, and are very nearly parallel to one another. Between them is situated the narrow socket into which fits the narrow anterior cardinal of the left valve. Immediately posterior to the median right cardinal is the deep socket which receives the bifid median cardinal of the left valve. Posterior, and somewhat dorsal to this socket lies the right posterior cardinal, a long curved laminar tooth which extends from just under the umbo to the posterior end of the hinge-plate. This last tooth is separated from the nymph by a narrow and shallow groove which lodges the left posterior cardinal. Two smaller anterior lateral teeth separated by a deep socket form the lateral dentition of the right valve. Posterior lateral teeth are absent.

The entire interior of the abnormal left valve mentioned above corresponds exactly to a mirror-image of the interior of a normal right valve. The dentition is completely transposed.

(3) Cardinals and Anterior Laterals Normal, Posterior Laterals Transposed.

Two valves, one right and one left, of Venericardia parva Lea, (plate I, figs. 8,9) Upper Eocene, Claiborne Bluff, Alabama, show hinge-transposition of this type. The normal venericard hinge has been described above under group (1). Under that division it was pointed out that the normal lateral dentitionof the right valve consists of an anterior socket and a posterior tooth. In the left valve, the positions are reversed, for the single tooth is anterior in position, while the socket is posterior.

The right valve included under group (3) has the normal

cardinal dentition and the normal anterior socket. The posterior border, instead of bearing a single tooth, exhibits a socket similar to that found in the posterior position in the normal left valve. Thus, the anterior and posterior sockets both occur in the right valve. The left valve similarly shows a normal cardinal dentition and a normal anterior lateral tooth. However, the posterior lateral dentition consists of a single tooth similar to that found on the postero-dorsal border of the right valve. Thus, the anterior and posterior lateral teeth both occur in this valve. The posterior lateral dentition in each of the two valves is completely transposed.

(4) Cardinals Normal, Anterior Laterals Absent, Posterior Laterals Transposed.

This type of transposition occurs in two paired valves of Unio japanensis Lea,(plate I, figs. 13-16), Recent, from Japan. Four pairs of normal valves of the same species and from the same locality were included in this collection.

In the normal dentition of this species, two cardinal teeth appear in each valve. The right valve shows a weak anterior and a strong posterior cardinal. The left valve shows two cardinals of subequal size, tho the anterior tooth tends to be somewhat stronger and longer than the posterior. Anterior lateral teeth are absent. The right valve has a single long straight posterior lateral which fits between two laminar posterior laterals in the left valve. In the latter, the ventral posterior lateral is the stronger of the two, and usually projects farther beyond the plane of juncture of the two valves.

The individual teeth in these two transposed hinges are similar to those of normal hinges in the same species. The posterior laterals only are transposed. Thus paired posterior laterals appear in the right valve and a single posterior lateral in the left valve of the abnormal hinges. A low platform of shelly material is built up from the ventral base of the single lateral of the abnormal left valve. This platform is slightly grooved where the edge of the ventral lateral of the right valve abuts against it. The same type of structure with varying degrees of prominence is found in normal valves, and is to be interpreted as a variable structural feature occurring commonly in the unios rather than as an abnormality.

RELATION BETWEEN HINGE-TRANSPOSITION AND PRIMARY LAMELLAE

No shell examined in the course of our study exhibits complete transposition involving cardinals, anterior laterals, and posterior laterals. In all specimens showing anterior laterals, these have been transposed with the cardinals. If posterior laterals are present, they are either (1) normal while the cardinal and anterior lateral teeth are transposed, or are (2) transposed while the cardinals and anterior laterals where present are normal. This agreement in transposition between cardinals and anterior laterals, and disagreement in transposition between these two groups on the one hand and the posterior laterals on the other, may be explained on the basis of observations made by Bernard (1895, pp. 114 - 116) on the development of the heterodont hinge. These observations may be summarized as follows:

The dentition of the heterodont hinge in its immediate post-embryonic stage consists of anterior and posterior lateral lamellae, a pair of each in the right valve, one only of each in the left valve. Of these, the anterior lateral lamellae appear first. Posterior extensions of the anterior lateral lamellae grow up under the beaks, and are there reflected, forming hooklike ends. As growth continues, these hooklike posterior extensions become detached from the anterior parts of the lamellae, thus forming the cardinal teeth. The remaining anterior portions form the anterior lateral teeth. The posterior lateral lamellae do not extend forward past the ligament, and give rise only to the posterior lateral teeth.

The close genetic connection shown by Bernard's study to exist between the cardinals and anterior laterals is reflected in the tendency of these two groups of hinge-elements to transpose together. Similarly, the fundamental independence of the posterior laterals relative to the other two dental groups is shown in the failure of these teeth to transpose in agreement with the remainder of the hinge.

PARTIAL VERSUS COMPLETE TRANSPOSITION

It has already been indicated that no example of complete transposition, involving cardinal teeth, anterior and posterior laterals has been found in this study. With the possible exception of the Unio discussed by Agassiz (see above, p. 3), we have found no reference in the literature indicating an example of such complete transposition. On the other hand, among the published notices of transposition available to us, only that of Lea recognizes partial transposition as we have defined it. Lea

mentions twenty-one specimens of Unio "that are all abnormal as regards the lateral teeth". However, the validity of Lea's specimens as true examples of transposition is questionable (see above, p. 4). Jeffreys (1863, p. 317) used the term "partial transposition" (see pp, 4 and 5 above) but in a sense different from ours. Reynell(1908, pp. 4,5) figured a left valve of Astarte mutabilis Searles Wood, showing a transposed hinge. Scrutiny of Reynell's figure shows that the cardinal and anterior lateral teeth of the specimen are transposed, while the posterior laterals are normal. This is exactly the same type of transposition shown in our specimens of Astarte. Hanna (1925, p. 287, pl. 38, fig. 4) has described and figured a right valve of Venericardia hornii Gabb, with a transposed hinge. Lateral teeth are seldom discernible in adult giant venericards, however, and none is seen in Hanna's figure. The same may be said for the venericard hinge described and figured by Gardner and Bowles.

Of the 26 valves described in this study, 25 exhibit posterior laterals. In 21 of these, the posterior laterals are normal, while the rest of the hinge is transposed. On the other hand, four valves show transposed posterior laterals, though the cardinals are normal. These figures suggest that transposition of the laterals is a rather rare phenomenon compared to transposition involving the remainder of the hinge.

FREQUENCY OF HINGE TRANSPOSITION

Hinge-transposition in lamellibranchs has generally been regarded as a very rare phenomenon-- more rare in its occurrence than the comparable abnormality of inverse coiling in

gastropods. Such data as we have available do not support this view.

The ratio of transposed to normal hinges in 3700 venericard valves examined in this study is approximately 1 : 180. Similarly, in 260 astartes studied, the ratio is 1 : 130. Dall (1903, p. 1482) states in a discussion of the Astartidae: "This peculiarity [transposition] is especially notable in Goodallia, where out of one lot examined, nearly one-third had the hinge reversed". We have not studied sufficient material to establish even approximate ratios for Transennella and Unio.

Pelseneer (1920, pp. 37-38) has quoted ratios of dextral to sinistral forms for several species of gastropods. Thus, Helix pomatia from the environs of Geneva showed six sinistral to 18,000 dextral forms, a ratio of 1 : 3,000. Clausilia biplicata, a normally sinistral species of land snail has an estimated ratio of dextral to sinistral forms of 1 : 150,000. Similarly for Clausilia bidentata the ratios are 1 : 3,000. Very low ratios of sinistrality are given for the two species of marine gastropods mentioned, Littorina littorea and "Turbinella" [Xancus] pirum yielding one sinistral form to several million dextral ones. High ratios of inverse coiling are given by Sykes (1905, p. 268) for certain land snails, as follows: "Partula otaheitana is generally reversed, while P. vexillum has only one in fifty, and P. affinis one in several hundred sinistral".

The data cited above indicate that the ratios of transposition in the lamellibranchs we have studied are quite comparable to the higher ratios of inverse coiling given for gastropods. This suggests that the apparent rarity of transposition is due

to the obscurity of the feature rather than to an actual great infrequency of occurrence. Inverse coiling in gastropods involves the whole shell, and hence is usually at once apparent. On the other hand, a transposed lamellibranch hinge is seldom readily apparent even in well-preserved specimens, and is to be found only by careful search. These conclusions are borne out by the fact that sinistral individuals of even such exceedingly rare occurrence as that quoted above for Littorina littorea and Xancus pirum (one sinistral to several million dextral individuals) are well known, whereas the much greater frequency of transposition we have found in venericards (one transposed to 180 normal hinges) has been almost entirely overlooked. Jeffreys (1863, p. 319) offered the probable true explanation for the apparent rarity of theis phenomenon when he said: "Probably such monsters are not exceedingly rare, but may not have been searched for."

SYSTEMATIC VERSUS PATHOLOGIC ABNORMALITY

Two views have hitherto been expressed in the literature as to the nature and origin of transposed hinge-structure: (1) that transposition is a pathologic phenomenon, to be placed in the category of disease, accidental injury, or deformity; and (2) that it is a systematic developmental phenomenon due to a simple transposition of hinge-secreting parts taking place in the embryonic stages of the individual affected.

We consider that the abnormal hinges described above represent examples of a systematic abnormality, not pathologic in its origin, in which certain of the primary lamellae from which hinge teeth are derived have developed in the opposite valve from that

in which they are normally found. The facts that teeth become transposed in groups corresponding to these primary lamellae, and that these teeth are precisely similar to those occurring in a normal hinge are considered as evidence for this opinion. The fundamental causes bringing about this transposition are unknown.

On the other hand, we have discovered in one right valve of "Venericardia" ventricosa (Gould) (plate I, fig. 17) an abnormal hinge which we consider to be the result of pathologic derangement. The following is a description of the hinge of this valve:

Immediately ventral to the umbo is a large obliquely triangular socket, with the more acute apex directed postero-ventrally. Bordering this socket anteriorly is the lunular wall on the inner margin of which occurs a small inconspicuous anterior cardinal. The socket is bordered posteriorly and dorsally by a long narrow, but rather heavy, posterior cardinal, extending to the postero-ventral border of the hinge-plate from immediately in front of the umbo. A rude low narrow wall extends ventrally across the large median socket from a point on the ventral side of the posterior cardinal and about one-third the distance from its anterior to its posterior end, nearly to the ventral edge of the hinge plate. The posterior cardinal is parallel to the nymph from which it is separated by a well-marked, but shallow, groove. A single posterior lateral tooth, and an anterior lateral socket are distinct but inconspicuous.

The small anterior cardinal tooth, the posterior lateral

tooth, and the anterior lateral socket are all similar to those normally found in the right valve of the species. However, the posterior cardinal resembles the posterior cardinal normally found in the left valve, except that it is not so much undercut on the ventral side by the bordering socket. The nymph also resembles that of the normal left valve. Other less essential differences from a normal valve are discernible. The peculiar structure extending ventrally from the posterior cardinal across the median socket has no analogue in either normal valve.

The presence in this hinge of an anterior lateral socket, anterior cardinal and posterior lateral teeth, which are similar to comparable structures in a normal right valve appears to demonstrate that the normal primary lamellae were present in this individual in its early development. That is, these lamellae apparently were not transposed. The abnormal structure of the other cardinal elements of the hinge may have resulted from a pathologic derangement, or an injury suffered during the development of the posterior kooklike ends of the primary anterior lamellae. Although the posterior cardinal was developed presumably from a lamella normal to the right valve, it took the form suggesting that of the posterior cardinal normally found in the left valve because of the abnormal position in which it was forced to develop relative to the remaining hinge-elements of this individual.

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EXPLANATION OF PLATE I.

Fig. 1. Venericardia parva Lea. Eocene, Claiborne Bluff, Ala. Approximately 10x natural size. C. I. T. Cat. No. 1362. Interior of right valve showing normal dentition. Pages 9,10.

Fig. 2. Venericardia parva Lea. Eocene, Claiborne Bluff, Ala. Approximately 10x natural size. C. I. T. Cat. No. 1363. Interior of left valve showing normal dentition. Pages 9,10.

Fig. 3. Venericardia parva Lea. Eocene, Claiborne Bluff, Ala. Approximately 10x natural size. C. I. T. Cat. No. 1364. Interior of right valve showing transposed cardinal and anterior lateral teeth. Pages 9,10.

Fig. 4. Venericardia parva Lea. Eocene, Claiborne Bluff, Ala. Approximately 10x natural size. C. I. T. Cat. No. 1365. Interior of left valve showing transposed cardinal and anterior lateral teeth. Pages 9,10.

Fig. 5. Astarte concentrica Conrad. Miocene, Grove Wharf, Va. Approximately 2x natural size. C. I. T. Cat. No. 1366. Interior of right valve showing normal dentition. Pages 10-11.

Fig. 6. Astarte concentrica Conrad. Miocene, Grove Wharf, Va. Approximately 2x natural size. C. I. T. Cat. No. 1367. Interior of left valve showing normal dentition. Pages 10,11.

Fig. 7. Astarte concentrica Conrad. Miocene, Grove Wharf, Va. Approximately 2x natural size. C. I. T. Cat. No. 1368. Interior of left valve showing transposed cardinal and anterior lateral teeth. Pages 10,11.

Fig. 8. Venericardia parva Lea. Eocene, Claiborne Bluff, Ala. Approximately 5x natural size. C. I. T. Cat. No. 1369. Interior of right valve showing transposed posterior lateral teeth. Pages 12,13.

Fig. 9. Venericardia parva Lea. Eocene, Claiborne Bluff, Ala. Approximately 11x natural size. C. I. T. Cat. No. 1370. Interior of immature left valve, showing transposed posterior cardinals. Pages 12, 13.

Fig.10. Transennella stimpsoni Dall. Recent, Florida Keys. Approximately 4x natural size. C. I. T. Cat. No. 1371. Interior of right valve showing normal dentition.m Pages 11,12.

Fig. 11 Transennella stimpsoni Dall. Recent, Florida Keys. Approximately 4x natural size. C. I. T. Cat. No. 1372. Interior of left valve showing normal dentition. Pages 8, 9.

Fig. 12. Transennella stimpsoni Dall. Recent, Florida Keys. Approximately 4x natural size. C. I. T. Cat. No. 1373. Interior of left valve showing transposed cardinal and anterior lateral teeth. Pages 11, 12.

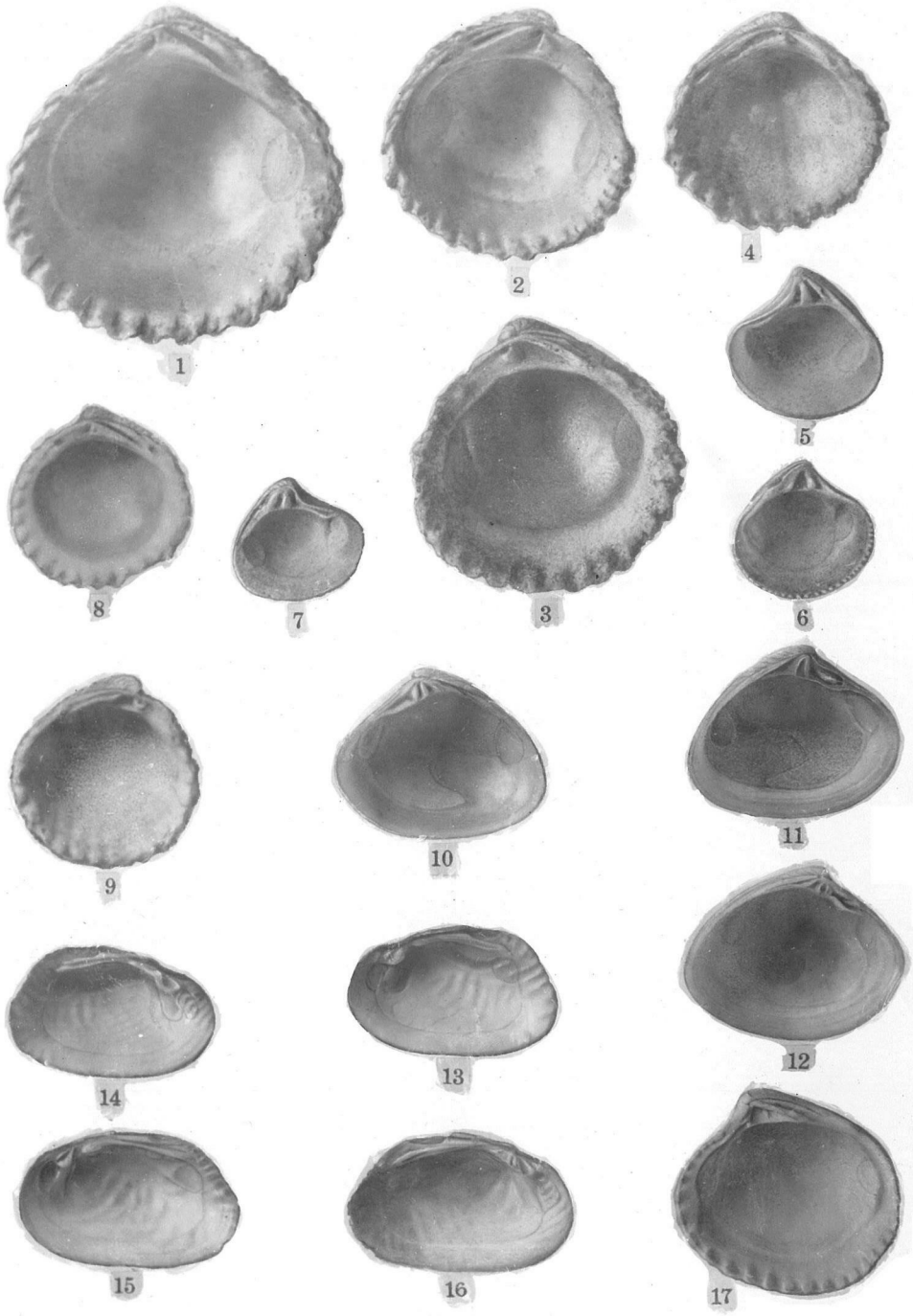
Fig. 13. Unio japanensis Lea. Recent, Japan. Natural size. C. I. T. Cat. No. 1374. Interior of right valve showing normal dentition. Pages 13,14.

Fig. 14. Unio japanensis Lea. Recent, from Japan. Natural Size. C. I. T. Cat. No. 1375. Interior of left valve showing normal dentition. Pages 13,14.

Fig. 15. Unio japanensis Lea. Recent, from Japan. Natural size. C. I. T. Cat. No. 1376. Interior of right valve, showing transposed posterior lateral teeth. Pages 13,14.

Fig. 16. Unio japanensis Lea. Recent, from Japan. Natural size. C. I. T. Cat. No. 1377. Interior of left valve paired with no. 1376, showing transposed posterior lateral teeth. Pages 13,14.

Fig. 17. "Venericardia" ventricosa (Gould). Pleistocene, San Pedro, California. Approximtely 2x natural size. C. I. T. Cat. No. 1378. Interior of right valve with dentition showing pathologic abnormality. Pages 19,20.



TRANSPOSED HINGE STRUCTURES IN LAMELLIBRANCHS