NUMBER 286 JUNE 7, 1934

OCCASIONAL PAPERS OF THE MUSEUM OF ZOOLOGY

UNIVERSITY OF MICHIGAN

ANN ARBOR, MICHIGAN UNIVERSITY OF MICHIGAN PRESS

STUDIES OF THE GASTROPOD FAMILY PLEUROCERIDAE—I

BY CALVIN GOODRICH

THIS paper, the first to be published of a number of similar studies that have been carried on over a period of several years, deals with morphological variations of certain species and genera of the molluscan family of Pleuroceridae, principally with regard to their position in the streams they occupy. Other papers on the subject will follow. It has been made plain to the writer as the work progressed that better methods of treatment should have been employed from the beginning—the common rebuke of experience—but it has been made equally clear that the same conclusions would have been forced whatever the methods applied.

LITHASIA OBOVATA (SAY), OF GREEN RIVER, KENTUCKY

Plate I, Figs. 1–9, 12

Collections of this species were made by Mr. W. J. Clench and Dr. Peter Okkelberg at seventeen different localities of the main river; twenty-two localities of the tributary Barren River and its affluents, three of Nolin River, two of Rough River, two of Mud River, and three of lesser streams—forty-nine in all.

Lithasia obovata is the commonest pleurocerid of the Green River system. It is so variable that it has been blessed with several specific names and assigned to three separate genera. At the falls of the Ohio River, one of the localities mentioned by Say, the variation is such that five different names have been given to forms of the species which occur there. It is difficult for the student to believe at first that such morphological extremes as narrow, high-spired shells and squat, ventricose specimens with scarcely any spire at all can belong to the same species, but with familiarity it becomes clear that all of the forms have certain definite characters which bind them one with another, namely non-plicate apices, shouldered whorls, virtually the same shape of aperture, and, more often than not, columellae which are thickened above and below. All have the neo-melanian operculum, and the radula, though variable, affords no excuse for specific distinctions. An additional character, raised revolving lines on the spire, occurs often enough to provide a clue to relationship. A further convincing support to the argument for kinship is that except near the mouth of the Green River and in its highest headwaters—places wherein the Pleuroceridae everywhere show the least variation—each colony is likely to be made up of two or three distinct forms of *obovata* among which are some individuals overlapping with forms of other colonies.

The specimens that were chosen by Say for his description of *obovata* were smooth, heavy, short-spired, and they had apertures "more than twice the length of the spire." Say spoke of the resemblance of old and eroded specimens to *Anculosa,* and this is the most striking aspect of the shells. Colonies typical, or nearly so, occur in the lower Green River. Since this study is particularly of that stream I am using hereinafter Anthony's name *planospira* for these anculosoid examples since Anthony's shells came, it is certain, from the Green River near Mammoth Cave, though Tennessee was given as the type locality. That author's errors in geographical designations were notorious. The several forms may be set down as follows.

Planospira Anthony. The name is descriptive of the gastropod. The embryo shell is smooth, consisting of about one and one-half whorls. At the fifth or sixth whorl, the shell becomes bulbous, broadening rapidly into a thick, ventricose form with a large aperture. Erosion gives the effect of a shell whose whorls are all in the same plane.

Consanguinea Anthony. This is near typical *obovata,* but is somewhat higher of spire, is usually more shouldered, and has a noticeably produced aperture. It was named as from Indiana. I should judge that the stream was the Ohio River inasmuch as a pure race of this phase occurs in the Ohio at Charlestown Landing, Indiana.

Undosa Anthony. The shell is cylindrical, turreted, much shouldered on the body whorl. The aperture is seldom large, and the columella lacks the thickening of callus which has sometimes been spoken of as a constant in *Lithasia.* The outer lip is straight or slightly incurved. There is apparently no difference of importance between *undosa* and two other forms, *elegantula* and *rarinodosa,* also of Anthony's authorship.

Sordida Lea. Smooth, high-spired, and conic rather than cylindrical. Upon its shape more than upon anything else, it was placed under *Goniobasis* by Tryon (1873).

Curvilabris Anthony. Decidedly cylindrical and heavily shouldered. It has the "deeply and singularly curved" outer lip which Anthony emphasized in description and name. The pronounced shouldering and the frequent flattening of the body whorl are not, as seemed at first in this study, invariably correlated with the incurved outer lip. This character was found to occur sometimes with specimens whose whorls were regularly convex.

Microlineata Goodrich. This name was given by me to mollusks which I had mistaken for a species of *Goniobasis* before the variability of *L. obovata* was realized. The form is small, narrow, carinate of spire. The convex, unshouldered whorls are covered, in the majority of individuals, with faint, revolving, raised lines.

Depygis Say. The shell is slightly conic, smooth, and slender. The whorls are only slightly shouldered. At the top of the columella at the angle with the outer lip is a small deposit of callus. The form, though common in the Ohio River at the falls, is rare in the Green River drainage.

Goniobasoid. Under this head have been placed shells which resemble *Goniobasis* more than do the forms *sordida* or *depygis* of *obovata*. In all except one instance, such examples are comparatively infrequent in the Green River system lots. Among these specimens have been placed certain young individuals that give no indication of the final adult form and which are like juvenile goniobases at this stage.

Indeterminates. These are shells which could not be classified with any definiteness. They were sometimes pathological, sometimes old and eroded badly. Only twice do they amount to more than 10 per cent in any one lot.

Analysis of the Distribution

Planospira. It will be seen from Table I that this is the characteristic form occurring in the Green River near its mouth. Going upstream, the first noticeable deviation is at Rochester, Butler County, where the percentage of *planospira* shows a drop of 2.6 from 100 per cent. At Mammoth Cave, *planospira* is only a little more than one-half of all the shells of *obovata*. There is a rise in the percentages at the two stations in the vicinity of Rio, and six miles west of Greensburg the percentage has dropped to 2.8. No taking in the main river above this point contained any specimens of *planospira*. A few individuals, less than 1 per cent of 550 shells, were in the Russell Creek lot. Small numbers of the form were collected in Barren River and one of its tributaries.

Consanguinea. This form was found in branches of Barren River only. It amounted to nearly 35 per cent in the West Fork of Drake's Creek at Massy's Mill, Warren County. Scarcely more than 3 per cent in any other of the three collections was made up of *consanguinea*.

Undosa. Going upstream in the Green River, the percentage of occurrences of this form rises irregularly. A clearly ecological influence is indicated at the stations eight miles south of Campbellsville, Taylor County. All the shells of *obovata* from the river here are of the form *undosa,* but the collection from the adjacent slough, which is flooded by Green River in time of freshet, is made up of 4.1 per cent *undosa* and 91.7 per cent of *sordida,* the remainder being indeterminate. Of five separate lots from Barren River, three consist wholly of *undosa.* It is common to most of the lots from tributaries of this stream, though absent from those of four such stations. No form except *undosa* appears in material from Nolin River proper.

Sordida. The form appears in three of the Green River collections and once at a locality immediately adjacent to the river. Every one of these places is above a line marking the common occurrence of *planospira.* It makes up 97.8 per cent of the large taking from Beaverdam Creek, a tributary near Brownsville. Slightly more than 90 per cent of the shells from Russell Creek can be put down as *sordida.* None of the Barren River lots contain this form, but it appears three times as pure or nearly pure races in tributaries of the Barren.

Curvilabris. This form is common only in the Barren River and its affluents, yet even there the distribution is discontinuous, and the ratio of *curvilabris* to other forms varies as between stations. The lot from one place in the Barren River indicates the presence there of a pure race. Going upstream in the Barren River, the form disappears, as it does also in Trammel Creek and Bay's Fork. It occurs only once in the Green River proper and twice among the upper Green River tributaries.

Microlineata. This was collected only in Rough River, and in association with none of the other forms.

Depygis. Proof is lacking that this form, so common at the falls of the Ohio River, is represented in the Green River by other than aberrant specimens. It was taken in very small numbers in Mud River and in one of its branches. The

TABLE I

DISTRIBUTION OF THE FORMS OF *L. OBOVATA* IN THE GREEN RIVER SYSTEM IN TERMS OF PERCENTAGES

	planospira	*consanguinea*	*undosa*	*sordida*	*curvilabris*	*microlineata*	*deppgis*	goniobasoid	indeter.
Green River[1]									
6 mi. w. of Calhoun	100	...	...	...	...	...	...	...	...
Calhoun, McLean Co.	100	...	...	...	...	...	...	...	...
Livermore, Green Co.	100	...	...	...	...	...	...	...	...
Rochester, Butler Co.	97.4	...	2.5	...	...	...	...	...	...
Brownsville, Edmonson Co.	100	...	...	...	...	...	...	...	...
2 mi. e. of Brownsville	99.2	...	.8	...	...	...	...	...	...
Mammoth Cave, Edmonson Co.	58.6	...	28.5	...	...	...	...	12.8	...
Gt. Onyx Cave, Edmonson Co.	47.1	...	52.9	...	...	...	...	...	...
Munfordville, Hart Co.	58.5	...	26	...	...	...	...	15.2	...
4 mi. w. of Rio, Hart Co.	72.2	...	27.8	...	...	...	...	...	...
Rio	83.3	...	14.2	...	...	...	...	1.6	1.4
6 mi. w. of Greensburg, Green Co.	2.8	...	96.2	...	...	...	...	...	...
8 mi. s. of Campbellsville, Taylor Co.	...	...	100	...	...	...	...	...	...
Slough, 8 mi. s. of Campbellsville	...	...	4.1	91.7	...	...	...	...	4.2
2 mi. ne. of Dunnville, Casey Co.	...	...	88	11	...	...	...	...	...
3 mi. ne. of Liberty, Casey Co.	...	...	95.1	.8	...	...	...	...	4
Middleburg, Casey Co.	...	...	95.7	...	...	...	...	4.3	...
Barren River									
4 mi. e. of Bowling Green, Warren Co.	2.9	...	36.5	...	59.6	...	...	...	...
Martinsville Ford, Warren Co.	...	...	100	...	...	...	...	...	...
1 mi. w. of Finney, Barren Co.	...	...	...	...	100	...	...	...	...
2½ mi. n. of Meador, Allen Co.	...	...	100	...	...	...	...	...	...
7 mi. e. of Scottsville, Allen Co.	...	...	100	...	...	...	...	...	...
Tributaries of Barren River									
Long Cr., 5 mi. e. of Scottsville	...	3.1	79	...	...	...	...	17.7	...
Long Cr., 1 mi. n. of Holland, Allen Co.	...	...	100	...	...	...	...	...	...
Beaver Cr., 10 mi. sw. of Glasgow, Barren Co.	...	...	67.1	...	32.2	...	...	...	...
Drake's Cr., 5 mi. se. of Bowling Green, Warren Co.	...	...	98.7	...	2.5	...	...	...	...

TABLE I (*Continued*)

DISTRIBUTION OF THE FORMS OF *L. OBOVATA* IN THE GREEN RIVER SYSTEM IN TERMS OF PERCENTAGES

	planospira	*consanguinea*	*undosa*	*sordida*	*curvilabris*	*microlineata*	*deppgis*	goniobasoid	indeter.
Drake's Cr., 1 mi. se. of Mt. Victor, Warren Co.	1.9	...	25.9	...	63.3	...	...	...	...
Drake's Cr., 7 mi. s. of Bowling Green, Warren Co.	...	2.2	26.2	...	38	...	...	...	33.5
W. fk. Drake's Cr., Massy's Mills, Warren Co.	...	34.9	25.1	...	39.6	...	...	...	...
Mid. fk. Drake's Cr., Drake, Warren Co.	...	...	89.8	...	10.2	...	...	...	...
Trammel Cr., 1½ m. w. of Allen Springs, Allen Co.	...	...	...	100	...	...	...	...	...
Trammel Cr., 1 mi. sw. of Allen Springs, Allen Co.	...	...	...	67.8	32.2	...	...	...	...
Trammel Cr., Butlersville, Allen Co.	...	.07	65.6	...	32.8	...	...	...	1.5
Trammel Cr., Burn's Mill, Allen Co.	...	...	...	100	...	...	...	...	...
Trammel Cr., 5 mi. sw. of Scottsville, Allen Co.	...	...	...	100	...	...	...	...	...
Bay's Fork, Claypool, Warren Co.	...	...	87.5	...	9.6	...	...	2.8	...
Bay's Fork, 2 mi. n. of Halfway, Allen Co.	...	...	9.8	90.1	...	...	...	...	...
Bay's Fork, w. of Settle, Allen Co.	...	...	100	...	...	...	...	...	...
Bay's Fork, Sledge Ford, Allen Co.	...	...	100	...	...	...	...	...	...
Rough River									
Heights Falls, Grayson Co.	...	...	...	...	...	100	...	...	...
Falls of Rough, Grayson Co.	...	...	...	...	...	100	...	...	...
Mud River									
3 mi. e. of Dunmor, Logan Co.	...	...	...	...	...	...	100	...	...
Wolf Lick Cr., 4 mi. sse. of Dunmor	...	...	...	33.3	...	...	33.3	...	33.3
Beaverdam Cr., Edmonson Co.	...	...	2.2	97.8	...	...	...	...	...
Nolin River									
7 mi. n. of Upton, Hardin Co.	...	...	100	...	...	...	...	...	...
1½ mi. s. of Glendale, Hardin Co.	...	...	100	...	...	...	...	...	...
Barren Run, 5 mi. e. of Sonora, Larue Co.	...	...	...	...	...	...	...	100	...
Upper Green River tributaries									
Little Barren R., Green Co.	...	...	91.9	...	8	...	...	...	...
Russell Cr., 1 mi. e. of Columbia, Adair Co.	.6	...	...	90.1	.01	...	...	9.6	...
Goose Cr., Dunnville, Casey Co.	...	...	96.8	.8	...	...	...	...	2.4

[1]The size of the lots, as a rule, exceeded 300 specimens. One lot had as few individuals as three and one amounted to 4,603 examples.

figures of percentages in the table are to be considered as wanting in significance except as a record of occurrence.

Goniobasoid. While shells of this form are in seven separate and geographically scattered lots, none of them may be indicative of the true adult forms of the seven colonies. Local difficulties appear to have interfered with the taking of representative lots, and of the specimens collected the most were juveniles.

LITHASIA GENICULATA HALDEMAN, OF DUCK RIVER, TENNESSEE

Plate I, Figs. 10, 11, 14

This species in its typical form is a solid, quadrate, broadly shouldered and nodulous pleurocerid. The spire is low, the aperture large and produced at the base, the columella broad and irregularly rounded, the outer lip straight or slightly sinuous. In the subspecies (or form) *fuliginosa,* the spire is high, the shell being without nodules if typical. Correlated with the elongate shape, the aperture is more narrowly ovate than in *geniculata.* Smaller than either typical *geniculata* or *fuliginosa* is *pinguis.* It has no hint of sculpture except that the Duck River specimens have microscopic striae on the upper part of the spire. The whorls are rounded, the aperture is roundly ovate, and the columella shows a tendency to lose the lithasoid characteristics. *Pinguis* has usually been considered an *Anculosa,* but its connection with *geniculata* has been traced in two streams of Tennessee.

The distribution of the forms, downstream to upstream, is here set forth.

Nearly due south of Waverly, Humphreys County. *Geniculata* in great numbers and typical. No other forms were found here during a visit made by Mr. Henry Vander Schalie and me in 1931.

Centerville, Hickman County. *Geniculata* in great numbers below the town. No other form. In 1921, Dr. A. E. Ortmann was here and about one-third of the pleurocerids he collected consisted of typical *geniculata,* the rest shading into

fuliginosa. My surmise is that to avoid the pollution, he collected above the town, and that this accounts for the difference in the two collections.

Columbia, Maury County. The shells examined were of several collections made by different visitors to the locality. Altogether, 64 adult and 17 young specimens were studied. Only two individuals were typically *geniculata.* Twenty-four were of the shape of *fuliginosa,* that is, high-spired, but were partly nodulous. The remainder were smooth *fuliginosa.* The percentages were: *geniculata,* 3.4; near *fuliginosa,* 41.3; *fuliginosa,* 55.2. The Museum of Zoology has two shells that were taken at Godwin, two or three miles below Columbia. They are *fuliginosa.*

Due north of Lewistown. Of eighteen shells taken by Mr. W. J. Clench and Mr. Vander Schalie in 1933 at this locality, sixteen are smooth *fuliginosa,* and two of the same shape, but partly nodulous. Dr. Ortmann collected here or hereabouts, his shells being *fuliginosa.*

Wilhoite, Maury County. Thirty-six specimens taken in 1930. Twenty-eight are smooth *fuliginosa,* eight slightly nodulous *fuliginosa.*

Lillards Mills, Bedford County. Three specimens of Dr. Ortmann's taking, all typical *fuliginosa.*

Normandy, Bedford County. Three examples of smooth *fuliginosa,* collected by Dr. Ortmann.

Shelbyville, Bedford County. Nine specimens, smooth *fuliginosa,* from various collectors unknown by name.

Manchester, Coffee County. All *pinguis.* About forty shells that were taken by Dr. Ortmann—presumably below the town since there, only, could he have found the Unionidae he was seeking. These shells have the characteristic lithasoid columellae. Mr. Vander Schalie and I collected on honeycombed rocks within the town. The examples of *pinguis* that we found were nearly round-mouthed.

Lithasia geniculata and its subspecies (or forms) were found at four localities in the Buffalo River, the principal tributary of the Duck River. This stream has been very little

disturbed by dams, bridge and road "fills," and similar works. It is apparently free of domestic and industrial wastes and even the field wash appears to have been small. It may be accepted then as in a nearly perfect state of nature. Reading downstream to upstream, the findings were:

Five miles north of Lobelville, Perry County. *Geniculata* here was of higher spire than the species in Duck River near the stream mouth. Yet it had the conspicuously nodulous shoulders of the typical shell. It represents a gradation aspect. Specimens of this phase numbered 582; smooth *fuliginosa,* 20. The percentages are: *geniculata,* 96.6; *fuliginosa,* 3.3.

Beardstown, Perry County. Number of specimens, 158. Of these, 51.2 per cent were of the form of *geniculata* found below Lobelville; 48.7 per cent were of the smooth *fuliginosa.*

One mile above Linden, Perry County. Number of specimens, 126. No shell corresponding to *geniculata* was taken at this locality. *Fuliginosa* more or less nodulous was 24.6 per cent of the whole; smooth *fuliginosa,* 75.4 per cent.

Topsy Bridge, Wayne County. All specimens of this taking were young except a single adult individual which was a slightly nodulous *fuliginosa.*

A similar progression of forms of *Lithasia* is indicated by material which the Museum of Zoology has from Harpeth River, a tributary of the Cumberland River in Tennessee, and from the Tennessee River and creeks in the vicinity of Muscle Shoals, Alabama. The typical *L. geniculata* is common in the Cumberland River. Shells from Kingston Springs on the Harpeth River, not far from the stream mouth, are of the nodulous phase of *fuliginosa.* Thirty-six examples from Shacklett, farther upstream, are: Nodulous *fuliginosa,* 9; smooth *fuliginosa,* 24; *venusta,* 3. *Venusta* is a smooth, compact, yellowish shell which is scarcely shouldered and is uniformly smaller than *fuliginosa.* Thirteen shells from Belleview, about fifteen miles above Shacklett, are all *venusta. L. salebrosa* (Conrad) (Fig. 19), of the Tennessee River at Muscle Shoals, has the short spire of typical *geniculata* and, like it, is strongly nodose at the shoulders. Its longer spired

form *florentiana* (Fig 18) occurs also at Muscle Shoals, though comparatively rarely. It is the *Lithasia* of the tributary creeks. Of 18 of these shells from Shoals Creek near Killen, Lauderdale County, Alabama, eight are entirely smooth and the rest slightly nodulous. Two specimens of *florentiana* (Fig. 16) from Shoals Creek at Bailey Springs, above the Killen locality, are also somewhat nodulous.

To see whether the alterations of *Lithasia* of the Duck and Buffalo rivers downstream to upstream could be demonstrated mathematically an index was obtained by dividing the greatest diameter in millimeters of each adult and nearly adult shell by the length of the last two whorls. The whole length of the shells could not be measured for the purpose because of the varying amount of erosion of the spires. The following table gives the result.

	number of shells	index
Duck R., so. of Waverly, Humphreys Co., Tenn. ...	30	80.6
" Centerville, Hickman Co., " ...	40	80.1
" Columbia, Maury Co., " ...	81	75.6
" Wilhoite, Marshall Co., " ...	38	76.9
" Shelbyville, Bedford Co., " ...	13	76.9
" Manchester, Coffee Co., " ...	25	70.7
Buffalo R., no. of Lobelville, Perry Co., " ...	50	79.3
" above Linden, " " ...	45	75.8

After several months, the lots from Duck River south of Waverly and Buffalo River above Linden were remeasured to test the possible personal error. The first measurement of the Duck River shells gave an index of 80.65, the second measurement 79.09, personal error ~~−.8.~~ −1.56 The first measurement of the Buffalo River specimens gave an index of 75.87, the second measurement ~~79.09,~~ 75.96 personal error − .09.

Variations in *Anculosa*

Plate I, Figs. 13, 15, 17

A characteristic pleurocerid of the Ohio and Alabama rivers systems is the genus *Anculosa.* It occurs for the most

part in fast water and disappears where the streams wear down to grade. The shell is thick and globose. Its large body whorl tends to enwrap the spire and adolescent whorls, sometimes so burying them that the top of the shell is planospiral. The genus is more sharply cut off from other genera of the Pleuroceridae, morphologically and in the characters of the radula, than these other pleurocerids, with the exception of *Eurycaelon,* are differentiated from one another.[2] The Anculosae of the Ohio system are a more compact group than those of the Alabama drainage. Though they have been given several specific names they are obviously of the same stock, and in places certain of them inhabit the same waters and can be separated only with difficulty.

It is clear to the eye than the *Anculosa* of the main parts of the Cumberland and Tennessee rivers is higher in proportion to diameter than are shells of headwaters and tributaries. Anculosae from several different locations were measured and compared without reference to the specific designations they bear. The body whorl alone could be made use of, in this case for taking the height, since in many instances erosion had eaten away all the earlier whorls. The height of the body whorl was divided by the greatest diameter in millimeters. In the following table are the measurements of shells from four tributaries of the Cumberland River and a single set of measurements of specimens from the main stream, this lot being the only one available in comparable numbers.

	number of shells	index
Caney Fork, Tenn.	28	89.7
Stone's River, Tenn.	41	75.8
Harpeth River, near Shacklett, Tenn.	28	81.7
" Belleview, "	38	81.1
Ringgold Creek, Montgomery Co., Tenn.	45	73.6
Cumberland River, Russell Co., Ky.	33	92.3

[2] It is understood that certain species, for example *carinata, trilineata, virgata,* and *ornata,* though monographed with *Anculosa,* are not true Anculosae. See Calvin Goodrich, "The True Position of Brugière's Bulimus Carinatus," *Nautilus* 46 (1932): 38–40.

The following table deals with Anculosae from two large headwater streams of the Tennessee River, the Tennessee River in Alabama, and three of its Alabama tributaries.

	number of shells	index
Clinch R., Cedar Bluff to St. Paul, Va.	38	85.8
" Union and Anderson counties, Tenn.	47	89.6
" near mouth of Emory R., Tenn.	45	93.6
No. Fork Holston R., above Kingsport, Tenn.	51	82.6
Holston R., Rogersville, Tenn.	13	92.4
" near Morristown, Tenn.	56	95.3
Tennessee R., Bridgeport to Florence, Ala.	92	91.3
Paint Rock R., Ala.	36	85.6
Flint River, Ala.	13	84.9
Cypress Creek, Ala.	22	85.3

Remeasurements were made of lots from Cumberland River, Paint Rock River, and Ringgold Creek. The first measurement for Cumberland River gave an index of 92.3, the second 93.11, personal error +.81. Paint Rock River, first measurement 85.6, second 86.5, personal error +.9. Ringgold Creek, first measurement 73.6, second 75.27, personal error +1.67.

Discussion

It will be seen from Table I on pages 6 and 7 that low-spired forms of *Lithasia obovata* occur near the mouth of Green River, that high-spired forms occur in the upper reaches and tributaries of the river and that, in a general way, there is a progressive alteration of form downstream to upstream. Exceptions—as when the low-spired *planospira* accompanies the high-spired *undosa* in Drake's Creek near Mt. Victor—make it clear that a certain position in a stream does not determine in itself the form of mollusks occurring there, but, much more likely, the ecological conditions prevailing there do. This is further indicated by the shells from the locality

eight miles south of Campbellsville. Specimens taken from the river there were all of the form *undosa*. From the slough beside the river at this place, the shells were almost entirely of the form *sordida*.

Better examples of a progressive change are the members of the *Lithasia geniculata* complex of Duck River and the tributary Buffalo River. What may be called the index of obesity is high near the mouth of Duck River and lowest in a swift and broken stretch close to the source of the stream. The same rule holds good in Buffalo River. These findings are comparable with those of Ortmann (1920) in the case of the Unionidae, namely, that "the more obese (swollen) form is found farther down in the large rivers, and passes gradually in the upstream direction into a less obese (compressed) form in the headwaters"; and that "with the decrease in obesity often an increase in size (length) is correlated." Adams (1900 and 1915) found that *Io* of the Tennessee River system goes through progressive alterations of relative diameter and relative variability though, since his interest was in changes of sculpture, he did not emphasize this phenomenon. Locard (1894), observing that mollusks in the water mains of Paris were more lengthened than the shells living under more natural conditions, explained it as "due to the mechanical action of a steady and rapid current," and it may be that this is one of possibly several factors which differentiate the high-spired lithasias of upstream localities from the low-spired shells near the mouths of rivers. Correlations between marine mollusks and their ecological situations have been noted by numbers of observers. Russell (1907), for instance, reported that " . . . high-water limpets of Europe are at all stages higher spired than the low-water limpets"; Cooke (1895) noted that *Purpurea lapillus* in sheltered situations is higher spired than in exposed places; and Miller (1922) that variations in *Teredo navalis* of San Francisco Bay are "definitely correlated with factors of environment, especially salinity and temperature."

In *Anculosa,* environmental polymorphism, to use a term devised by Conklin (1898), is less simple than in the lithasias that have been studied. The main river anculosae follow the rule of having shorter spires than the upriver and tributary colonies. There is also another environmental modification. The body whorls of main river anculosae are higher in proportion to diameter than those of head and tributary waters. As will be seen by the table dealing with the Tennessee River system, the changes are irregularly progressive. While the shells from the Holston River near Morristown, Tennessee, had an index of slenderness as high as 95.3, those of the Tennessee River in Alabama, Bridgeport to Florence, much farther downstream, were 91.3. It is to be remembered that the Tennessee River at Muscle Shoals, Alabama, undergoes a sort of rejuvenation in which the ecological conditions tend to reproduce those of headwaters. This explanation for the drop in the index of slenderness is supported by the fact that the fourteen specimens from Bridgeport, which is above the rapids, have an index of 99.2—conforming to expectations if progressive changes are admitted. At Rogersville, Tennessee, the Holston River shells have an index of 92.4; fourteen shells from Big Creek, Rogersville, have an index of 84.7. We have there in a very short distance a contrast between anculosae of a large stream and a small one.

Wiebe (1926) has found that the occurrence of obese individuals of *Goniobasis livescens* (Menke) in Lake Erie is correlated with exposed situations, heavy wave action requiring the mollusks to have a large foot to retain a position on the stones and the large foot determines the large aperture which, in turn, brings about a relatively great obesity. Small-apertured and more slender mollusks are correlated with sheltered localities. An ecological analogy would appear to exist between the exposed situations of Lake Erie, inhabited by obese *G. livescens,* and the rapid and sometimes tumultuous southern creeks and river headwaters where obese anculosae have their habitats, and again between the sheltered bays of the lake and the relatively slow and constant waters

of the main parts of southern rivers where the anculosae are high in proportion to diameter. To see whether this assumption would be borne out statistically, fifty specimens of *G. livescens* from exposed localities and fifty from protected places of Lake Erie were measured exactly as were the anculosae. These gave:

	numbers	index
Exposed *Goniobasis*	50	96.9
Sheltered *Goniobasis*	50	103.5

Thus in both *Goniobasis* and *Anculosa,* the reaction to harsh conditions is a relatively broad shell, and to conditions less disadvantageous the reaction is a relatively high shell.

REFERENCES

ADAMS, C. C.
1900 Variation in Io. Proc. Amer. Assoc. Adv. Sci., 49: 208–225.
1915 The Variations and Ecological Distribution of the Snails of the Genus Io. Mem. Nat. Acad. Sciences, 12, Second memoir: 1–92, pl. 1–61.

ANTHONY, J. G.
1854 Descriptions of New Fluviatile Shells of the Genus Melania Lam., from the Western States of North America. Annals Lyc. Nat. Hist. N. Y., 6: 80–129, pl. 1, 3.

CONKLIN, E. G.
1898 Environmental and Sexual Dimorphism in Crepidula. Proc. Acad. Nat. Sci. Phila.: 435–444.

COOKE, A. H.
1895 Molluscs. Cambridge Nat. Hist., 3: 1–459.

GOODRICH, C.
1921 Something About Angitrema. Naut., 35: 58–59.
1921 Three New Species of Pleuroceridae. Occ. Pap. Mus. Zool., Univ. Mich., 91: 1–6, pl. 1.

LEA, I.
1863 Observations on the Genus Unio. Phila.: Pub. by the Author, 9: 1–180, pl. 24–39.

LOCARD, A.
1894 Mollusca of the Paris Mains. Quoted by Naut. 8: 59–60, without name and date of original article.

MILLER, R. C.
1922 Variations in the Shell of Teredo Navalis in San Francisco Bay. Univ. Calif. Pub. in Zool., 22: 293–328, pl. 13–17.
ORTMANN, A. E.
1920 Correlation of Shape and Station in Fresh Water Mussels (Naiades). Proc. Amer. Phil. Soc., 19: 269–312, map.
RUSSELL, E. S.
1907 Environmental Studies on the Limpet. Proc. Zool. Soc. Lond.: 856–870.
WIEBE, A. H.
1926 Variations in the Freshwater Snail, Goniobasis Livescens. Ohio Jour. Sci., 26: 49–68.

PLATE I

FIG. 1. *Lithasia obovata* (Say), form *undosa,* partly grown. Little Barren River, Green County, Kentucky.

FIG. 2. *Lithasia obovata* (Say), form *sordida.* Bay's Fork, 2 miles north of Halfway, Allen County, Kentucky.

FIG. 3. *Lithasia obovata* (Say), form *planospira.* Green River, Brownsville, Edmonson County, Kentucky.

FIG. 4. *Lithasia obovata* (Say), form *consanguinea.* Long Creek, 5 miles east of Scottsville, Allen County, Kentucky.

FIG. 5. *Lithasia obovata* (Say), form *curvilabris.* Barren River, 1 mile west of Finney, Barren County, Kentucky.

FIG. 6. *Lithasia obovata* (Say), form *sordida.* Trammel Creek, 5 miles southwest of Scottsville, Allen County, Kentucky.

FIG. 7. *Lithasia obovata* (Say), form *planospira.* Green River, Mammoth Cave, Edmonson County, Kentucky. Adult natural size, young enlarged.

FIG. 8. *Lithasia obovata* (Say), form *undosa.* Nolin River, 1½ miles south of Glendale, Hardin County, Kentucky.

FIG. 9. *Lithasia obovata* (Say), form *undosa.* Slough of Green River, 8 miles south of Campbellsville, Taylor County, Kentucky.

FIG. 10. *Lithasia geniculata fuliginosa* (Lea). Duck River, Columbia, Maury County, Tennessee.

FIG. 11. *Lithasia geniculata pinguis* (Lea). Duck River, Manchester, Coffee County, Tennessee.

FIG. 12. *Lithasia obovata* (Say), form *depygis.* Mud River, 3 miles east of Dunmor, Logan County, Kentucky.

FIG. 13. *Anculosa umbilicata* Wetherby. Ringgold Creek, Montgomery County, Tennessee.

FIG. 14. *Lithasia geniculata* Haldeman. Duck River, Centerville, Hickman County, Tennessee.

FIG. 15. *Anculosa subglobosa* Say. Clinch River, St. Paul, Russell County, Virginia.

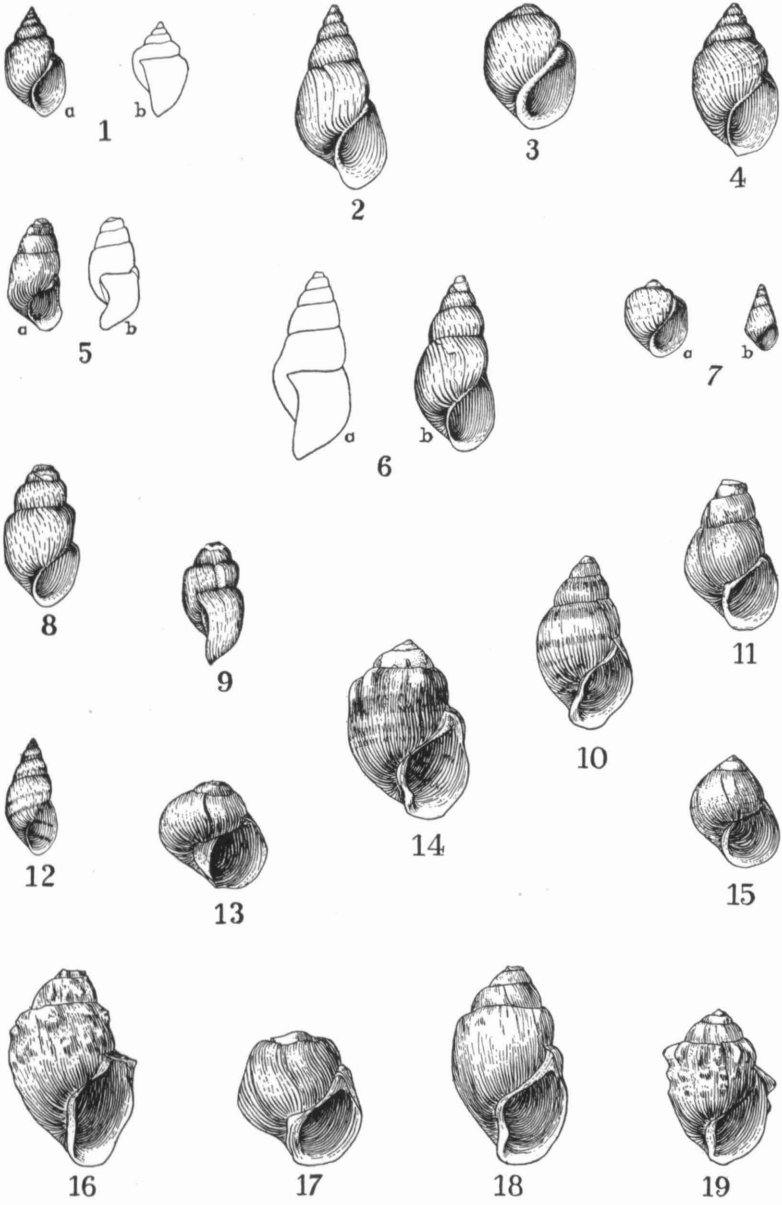
FIG. 16. *Lithasia salebrosa* (Conrad), near subspecies or form *florentiana* (Lea). Shoals Creek, Bailey Springs, Lauderdale County, Alabama.

FIG. 17. *Anculosa praerosa* Say. Cumberland River, Russell County, Kentucky.

FIG. 18. *Lithasia salebrosa florentiana* (Lea). Shoals Creek, near Killen, Lauderdale County, Alabama.

FIG. 19. *Lithasia salebrosa* (Conrad). Tennessee River, Florence, Lauderdale County, Alabama.

All figures natural size except *b,* fig. 7.


a
b
1
2
3
4
a
b
5
a
b
6
a
b
7
8
9
10
11
12
13
14
15
16
17
18
19