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Aids for Identification of Bivalve Larvae of Virginia

Paul Chanley
College of William and Mary - Virginia Institute of Marine Science

AIDS FOR IDENTIFICATION OF BIVALVE LARVAE OF VIRGINIA

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Master of Arts

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Paul Chanley

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Jay D. Andrews, Ph. D.

Marvin L. Wass, Ph. D.

Dexter Haven, M. S.

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I am especially grateful for the guidance of Dr. J. D. Andrews. His many ideas and suggestions constitute a major contribution to this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Larvae of 23 species of bivalves inhabiting the Mid North Atlantic area have been grown in the laboratory. These species have been described comparatively to aid planktologists in their identification.

Identification aids include:

1. Comparative photomicrographs of typical larvae arranged by sizes.
2. Graphs of length-height relationships for interspecific comparison of larvae throughout development.
3. Tables of dimensions and umbonal shapes.
4. Keys to straight-hinge and umbonate larvae.
5. Indirect aids (spawning seasons and geographic distribution).
6. Brief descriptions of each species.

Combined use of all aids is recommended for identification of larvae. Since large larvae are usually easier to identify than small ones, workers should begin with umbonate larvae and progress to smaller individuals by comparison. Frequently abundant species can be identified by population characters such as average length-height relationship.

INTRODUCTION

Bivalve larvae constitute an important and distinctive part of the plankton community (Thorson, 1946). Yet detailed studies of their distribution and behavior have been hampered by the inability of investigators to identify individual species in plankton samples.

There are numerous reasons for this difficulty: 1) Larval stages of a majority of species have never been described. This is especially true in North America. 2) Larvae of some species appear so similar at comparable stages of development that no satisfactory criteria for identification have been developed. 3) Most published accounts are descriptive and the interspecific comparisons needed for identification are difficult. 4) Some descriptions of bivalve larvae are based on erroneous identifications or juveniles rather than larvae.

Rearing larvae from known parents in the laboratory can overcome the problem of misidentification. Authors employing this technique have usually described larvae of individual species, with little attempt at interspecific comparisons. Frequently approaches are so different that descriptions are not comparable. Planktologists, confronted with an unwieldy mass of descriptive detail, find identification of bivalve larvae difficult.

In contrast to the immense literature on adult mollusks and their shells, information on larvae is scarce. Although larvae of a number of species from North America, Europe and Japan have been described, few papers are useful for identification of planktonic specimens. In the Atlantic area, Rees (1950) was exclusively with larvae from plankton samples and described

78 species. His means of identification included diagrams and summary tables of hinge structures, and photomicrographs of larval valves arranged by families. Although many species are identified tentatively, Rees' work is notable as the first attempt to classify larvae by family characters. Jorgensen (1946) based his descriptions of about 50 species primarily on larvae in plankton samples and an exhaustive literature review. He also captured planktonic larvae and reared them in the laboratory. Sullivan (1948), working with 22 species from plankton samples, grouped species by shape and listed distinctive characteristics. Loosanoff and Davis (1963) and Loosanoff, Davis and Chanley (1966) described 20 species reared in the laboratory from known parents. They emphasize the length-height relationship, but their approach is descriptive rather than comparative.

In Europe, Loven (1848) observed spawning and early embryology of three species. He tentatively identified planktonic larvae of six others. Borisiak's account (1909) has descriptions of 19 types of planktonic larvae, but few are identified. Odhner (1914) described six species from the plankton. Kandler (1926) identified five species by rearing captured planktonic larvae to recognizable stages in the laboratory. Lebour (1938) included 16 species in her report. She raised larvae taken from plankton and also grew larvae from fertilized eggs. Her brief key to larval Cardium is the first key to bivalve larvae. Werner (1939) described planktonic larvae of only four species, but the descriptive detail and effectiveness of his definitions have influenced the terminology and techniques of most subsequent investigators. He suggested that the length-height relationship and hinge-line length could be useful in identifying bivalve larvae. Zakhvatkina (1959), relying heavily on the work of Rees and others, described 28 species in detail, and constructed a key for identification. Her methods

and sources of larvae are not given.

In Japan, Miyazaki (1935; 1936) reared larvae of ten species in the laboratory, with no attempt at interspecific comparisons. In a later literature review (1962), he classified 200 species into 20 types on the basis of "definitely recognizable characteristics of prodissoconchs". He suggested classifying larvae by type of development (incubatory, egg mass, protobranch, glochidium, etc.). Yoshida (see literature cited) has grown larvae of several species in the laboratory. Although he has made comparative studies (1953; 1957), his descriptions have usually been published separately.

The earliest work dealing with several North American species is that of Stafford (1912). He described eight species from plankton samples and observed that the length-height relationship and hinge-line length could be used to identify straight-hinge larvae.

The purpose of these studies has been to organize and present data from laboratory cultured bivalve larvae to facilitate identification of planktonic larvae. Involvement in plankton studies at the Virginia Institute of Marine Science has helped the author gain perspective of the planktologists' problems. Photomicrographs have been supplemented by tables and graphs of dimensions and seasonal occurrence. Keys and brief descriptions have also been included. Since only data from laboratory-cultured larvae of known parents have been used, coverage is limited to 23 species representing 16 families. This is about half the species occurring in Virginia (Hass, 1965).

These identification aids are intended for use in mid-North Atlantic estuarine areas, but oceanic species frequently found in inshore waters are included. Geographic variations in occurrence and seasonal distribution are

common but there is no evidence of geographic variation in appearance.

Detailed descriptions of some species have been published separately, (Chanley, 1965; 1965a; 1966; Chanley and Castagna, 1966).

TERMINOLOGY DESCRIBING BIVALVE LARVAL DEVELOPMENT

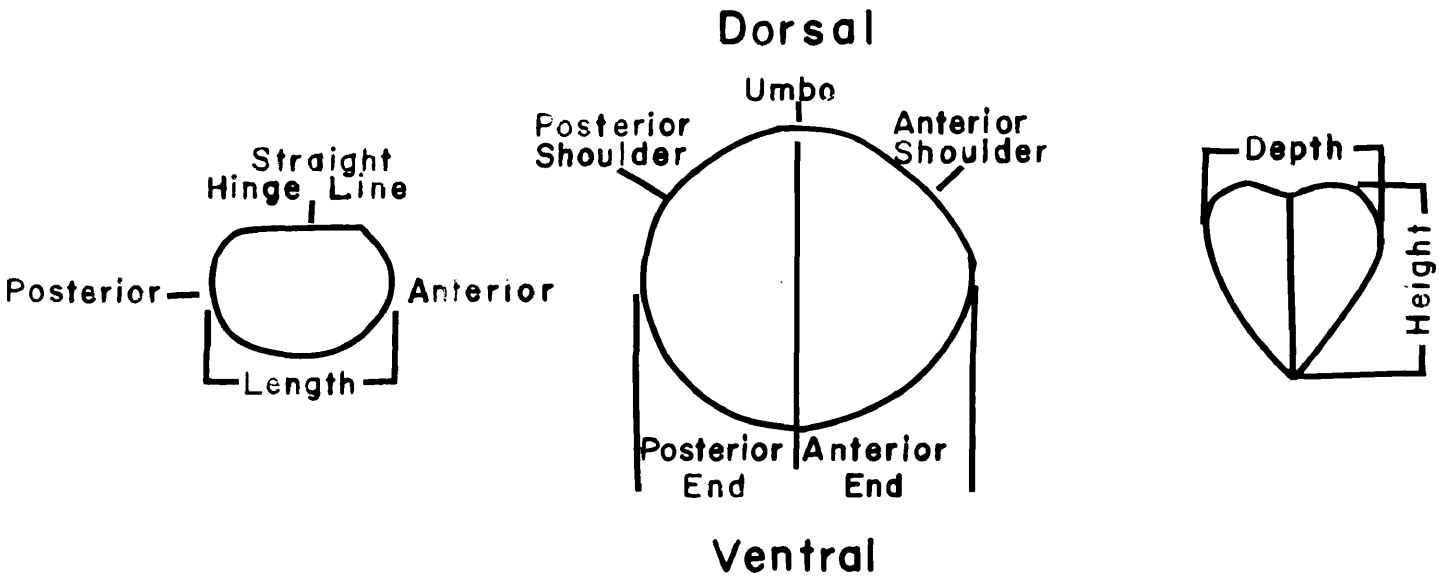
Bivalve larvae develop a shell, secreted as a unit by the shell gland, within 18 to 30 hours after fertilization of eggs. This first shelled stage is called Prodissoconch I (Prod I). Prod I larvae are usually D-shaped with the dorsal margin or hinge forming a straight line (Fig. 1). Stages with additional shell, deposited by the mantle, are called Prodissoconch II (Prod II). The shell of Prod I is uniform in texture and sharply delineated from that of Prod II, which shows growth lines. It can be recognized in empty valves at all stages of larval development.

For purposes of identification, larvae are separated into two groups by shape. D-shaped larvae (Prod I or Prod II) are "straight-hinge" larvae and later stages are "umbo" larvae. Straight-hinge larvae have a hinge line at least half the total length (maximum anterior-posterior dimension). Umbo larvae have a hinge line less than half the total length or well developed umbos.

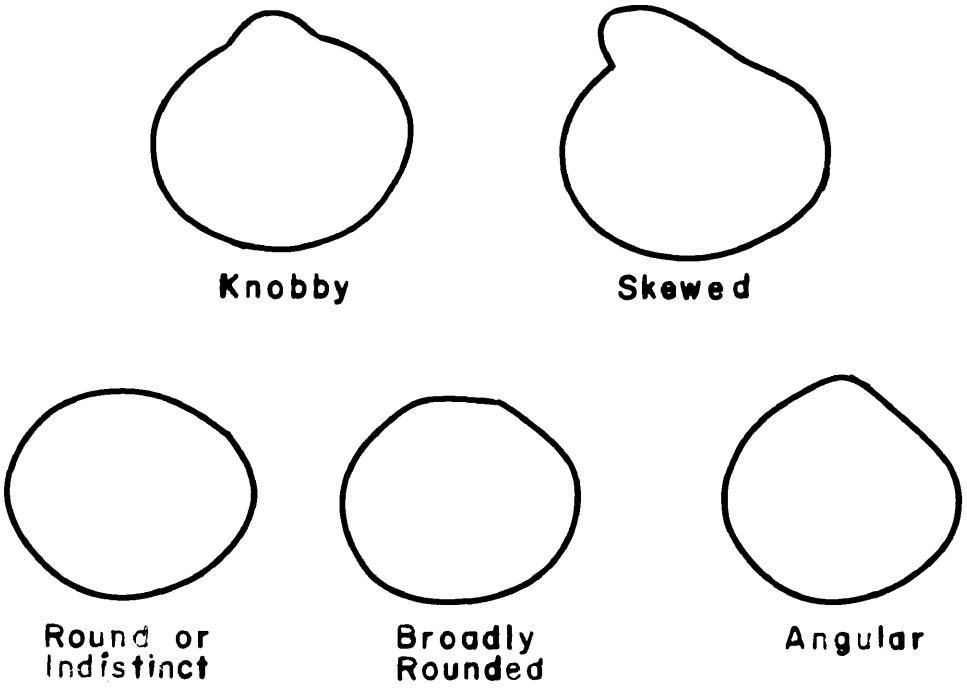
Hinge-line length is a Prod I measurement. It is an important identification aid, especially for straight-hinge larvae, and does not increase appreciably during larval development of most species. It ranges from 35 u to over 100 u. Total length in Prod I larvae is usually 15 to 30 u greater than hinge-line length.

The hinge line becomes obscured in umbo larvae, and shape of the umbos becomes an important characteristic. Umbonal shapes are illustrated in Fig. 1. Umbos tend to be "round" and "indistinct" in early development

Fig. 1. Diagramatic illustration of terminology used to describe dimensions and shapes of bivalve larvae. The posterior end is usually blunter and shorter than the anterior and has a higher shoulder. Length of ends is compared by imagining a perpendicular line through the larva as shown in top center figure.


Dorsal
Umbo
Posterior Shoulder
Anterior Shoulder
Straight Hinge Line
Posterior
Anterior
Length
Depth
Height
Posterior End
Anterior End
Ventral

Umbo Shapes


Knobby
Skewed
Round or Indistinct
Broadly Rounded
Angular

although they never become prominent in some species, e.g. Aequipecten irradians and Mangia cuneata they usually become conspicuous.

Their outline may appear continuous with the rest of the shell, as in the broadly rounded and angular types or discontinuous as in the "knobby" and "skewed" types (Fig. 1). The broadly rounded umbo is common and well illustrated by most larval venerids. Occasionally larvae with this type of umbo do not go through the round or indistinct stage. Less common is the angular type exemplified by Mulinia lateralis. Knobby umbos, such as those found in pholads and anomiids, are common. Frequently other types of umbos become knobby just prior to metamorphosis. The skewed umbo is a variant of the knobby type and is found only in the genus Crassostrea. Intermediate and transitional shapes occur frequently.

Relative length and shape of valve ends can also be used to identify larvae. Length of ends can be estimated from an imaginary perpendicular line drawn from the middle of the hinge to the ventral margin (Fig. 1). Ends may be nearly equal in length and shape or one end may be measurably longer and/or more pointed.

Slope and length of anterior and posterior shoulders are important features of shape. Usually the angle or "break" in the contour of larval shapes occurs at a higher level on the posterior shoulder (Fig. 1). Shoulders may be straight or rounded. Umbos and shoulders may comprise 1/3, 1/2, or more than 1/2 total height (maximum dorso-ventral dimension).

Some species have distinctive coloration, texture or other characteristics which are subtle and difficult to describe but in practice are useful in identification of larvae.

Hinge structure and internal anatomy can sometimes be used to identify larvae but have not been considered comparatively in this report because

they are difficult to observe in whole preserved larvae and usually cannot be used for routine identifications in plankton samples.

MATERIALS AND METHODS

All descriptions are of larvae reared in the laboratory from known parents. I have cultured 19 species personally and have used data and materials kindly supplied by Dr. V. Loosanoff and Mr. N. Davis (Table 1). Techniques of Loosanoff and Davis (1963) have been used in obtaining and culturing larvae.

Cultured larvae were examined daily and samples preserved regularly for measurements and photomicrographs. Dimensions were determined by measuring at least ten larvae to the nearest 5 microns. Most photomicrographs are of freshly-preserved whole larvae. Occasionally it was necessary to photograph living specimens. This was accomplished by diluting culture water with distilled water in a Sedgewick-Rafter counting chamber until larvae became quiet.

Larvae were preserved in a sea water solution of 10% sugar, 1% formalin and .05% sodium bicarbonate (Carriker 1950; 1950a). A reference collection of many species at various sizes has been assembled for comparative work. Additions to this collection will be welcome.

RESULTS

Several identification aids have been devised, including comparative photomicrographs, tables of seasonal and geographic distribution, tables and figures of dimensions, keys and specific descriptions. They are designed for use with either live or well preserved larvae. Combined use of these aids is recommended.

Shape and dimensions are emphasized. Both are influenced by larval

TABLE 1

Sources of data for identification aids.

Species	Observations of author in Virginia	Observations of author in Connecticut	Observations of Loosanoff and Davis
Anadara transversa (Say)	X	X	
Noetia ponderosa (Say)	X		
Modiolus demissus Dillwyn			X
Mytilus edulis L.	X		X
Aequipecten irradians Lamarck	X	X	
Anomia simplex Orbigny			X
Crassostrea virginica Gmelin	X	X	X
Laevicardium mortoni (Conrad)	X	X	
Mercenaria mercenaria (L.)	X	X	X
Pitar morrhuana Linsley		X	X
Gemma gemma (Totten)	X		
Petricola pholadiformis (Lamarck)	X		X
Tellina agilis Stimpson	X		
Donax variabilis Say	X		
Ensis directus Conrad	X	X	X
Spisula solidissima (Dillwyn)	X		X
Mulinia lateralis (Say)	X		X
Rangia cuneata (Gray)	X		
Mya arenaria (L.)			X
Cyrtopleura costata (L.)	X		
Barnea truncata (Say)	X		
Teredo navalis L.	X	X	
Lyonsia hyalina Conrad	X		

position. Consequently it is imperative that larvae lie on one side with both ends in the same plane. They will differ in appearance and be more difficult to identify if not in this position.

Straight-hinge and early umbo larvae are usually more abundant in plankton samples than those with well developed umbos. Advanced larvae are usually more easily identified. Therefore it is advisable to work with them first. With experience, smaller larvae of the same species can then be identified by comparison. Frequently a few species will be particularly numerous and identifications can be made by population characteristics (e.g. average length-height relationship).

Comparative Photomicrographs (Fig. 2).

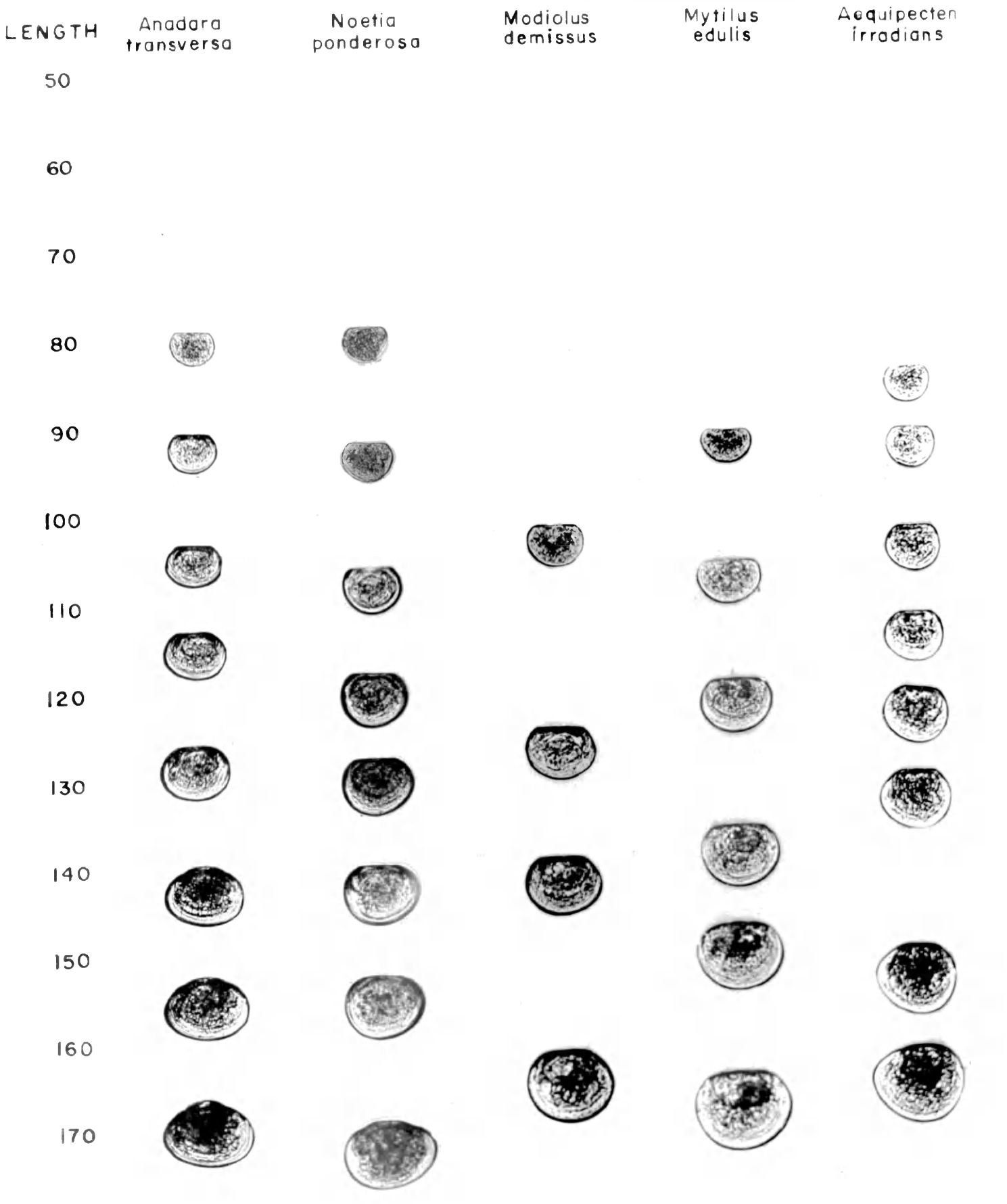
Photomicrographs of larvae are the most useful of all aids because they give a more accurate portrayal of shape and proportions than can be conveyed verbally or with drawings. Pictures used in composites were cut from photomicrographs of groups of larvae. Pictures are arranged by size and oriented to facilitate easy comparisons. Species are arranged in phylogenetic order which tends to group larvae of similar appearance. Occasionally unrelated larvae appear to be similar in size and shape. For this reason all photomicrographs for a given size should be examined.

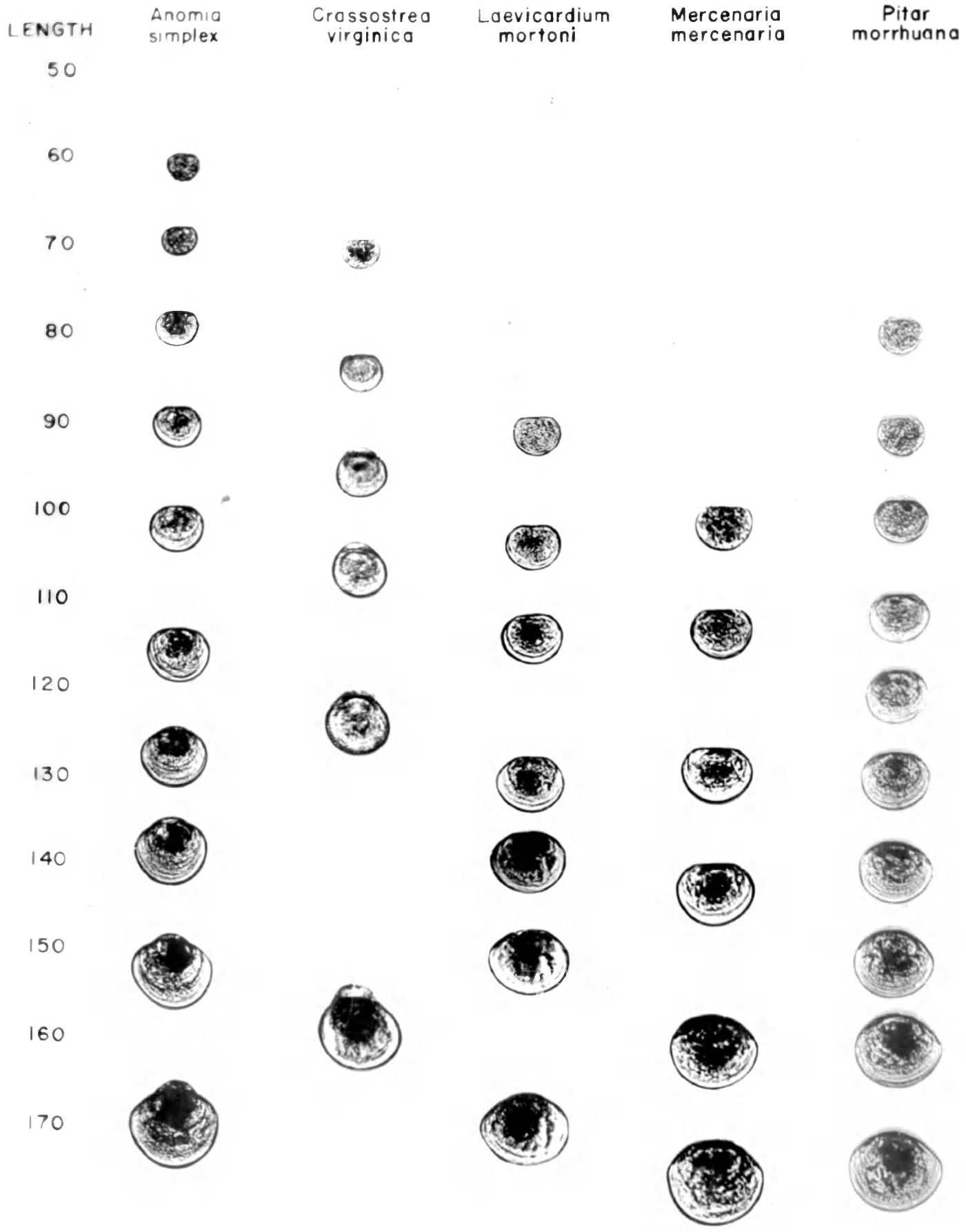
It was not possible to orient photographs uniformly with anterior ends always to the right or left because some of the earlier work was completed before the need for this was realized. Only shapes should be compared since texture or darkness may reflect photographic variation rather than larval appearance.

Distribution (Tables 2 and 3; Fig. 3)

I have been unable to rear larvae of many species in the laboratory

Fig. 2. Comparative photomicrographs of bivalve larvae.


LENGTH
Anadara transversa
Noetia ponderosa
Modiolus demissus
Mytilus edulis
Aequipecten irradians
50
60
70
80
90
100
110
120
130
140
150
160
170


LENGTH
Anomia simplex
Crassostrea virginica
Laevicardium mortoni
Mercenaria mercenaria
Pitar morrhuana
50
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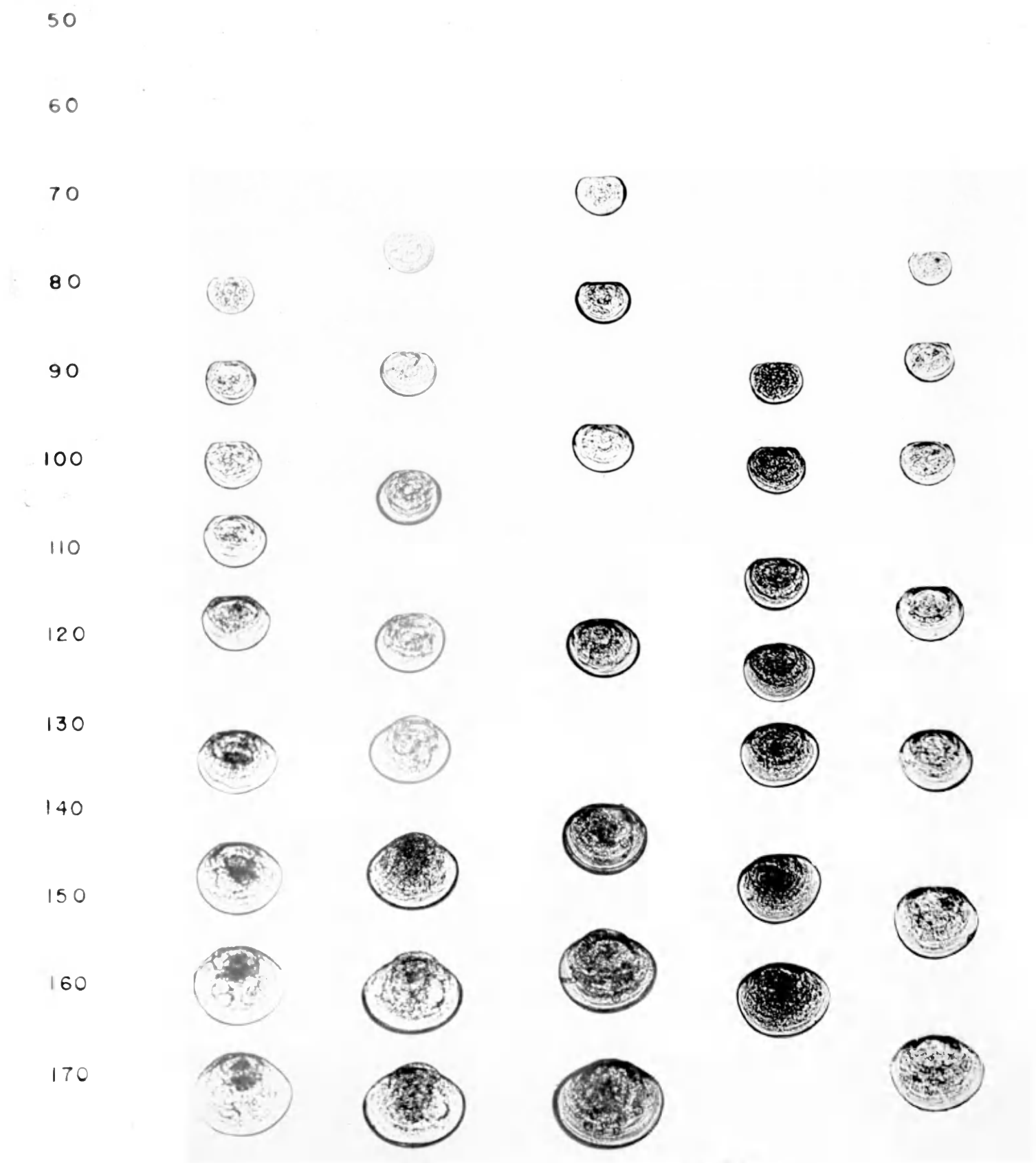
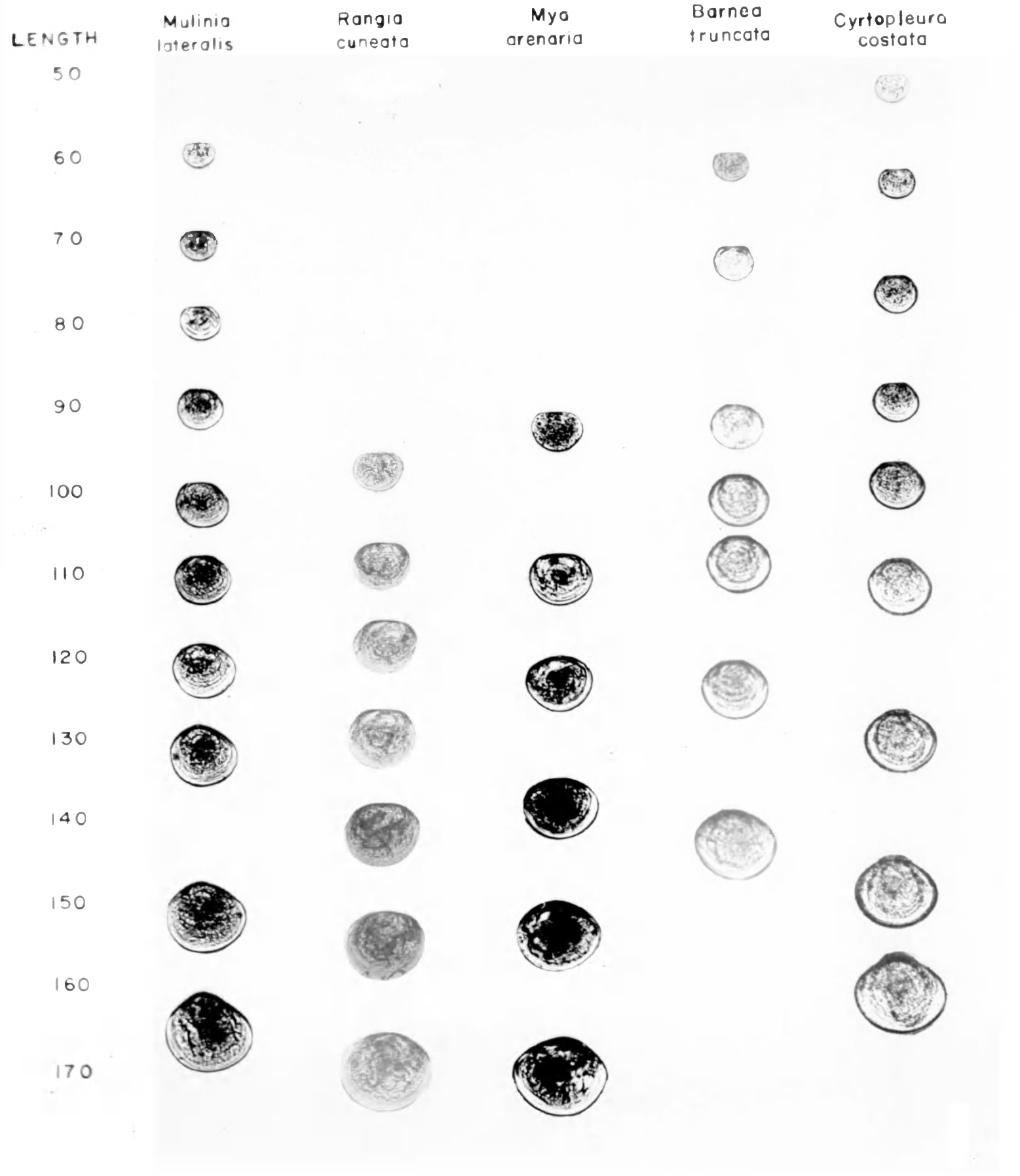
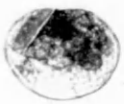
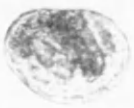
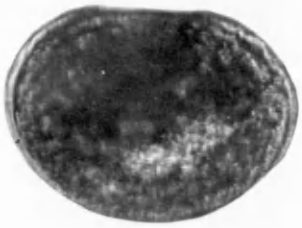
150
160
170




LENGTH
Mulinia lateralis
Rangia cuneata
Mya arenaria
Barnea truncata
Cyrtopleura costata
50
60
70
80
90
100
110
120
130
140
150
160
170

LENGTH	Teredo navalis	Lyonsia hyalina
50		
60		
70		
80		
90		
100		
110		
120		
130		
140		
150		
160		
170		

LENGTH	Teredo navalis
180	
190	
200	
210	
220	
230	
240	
250	
260	
270	
280	
290	
300	

LENGTH	Gemma gemma
310	
320	
330	
340	
350	
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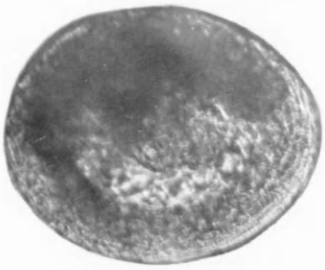
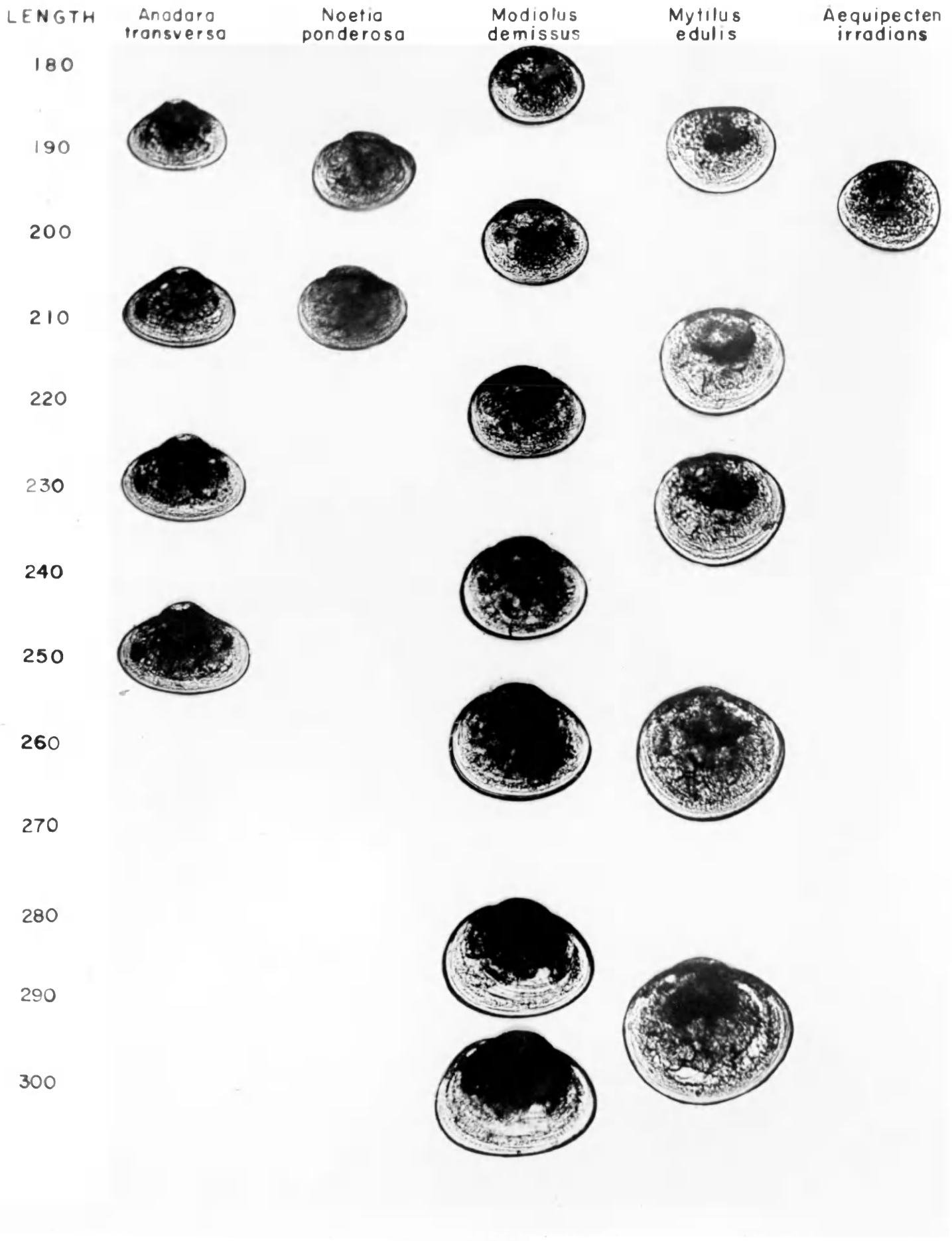
370	
380	
390	
400	


LENGTH
Anadara transversa
Noetia ponderosa
Modiolus demissus
Mytilus edulis
Aequipecten irradians
180
190
200
210
220
230
240
250
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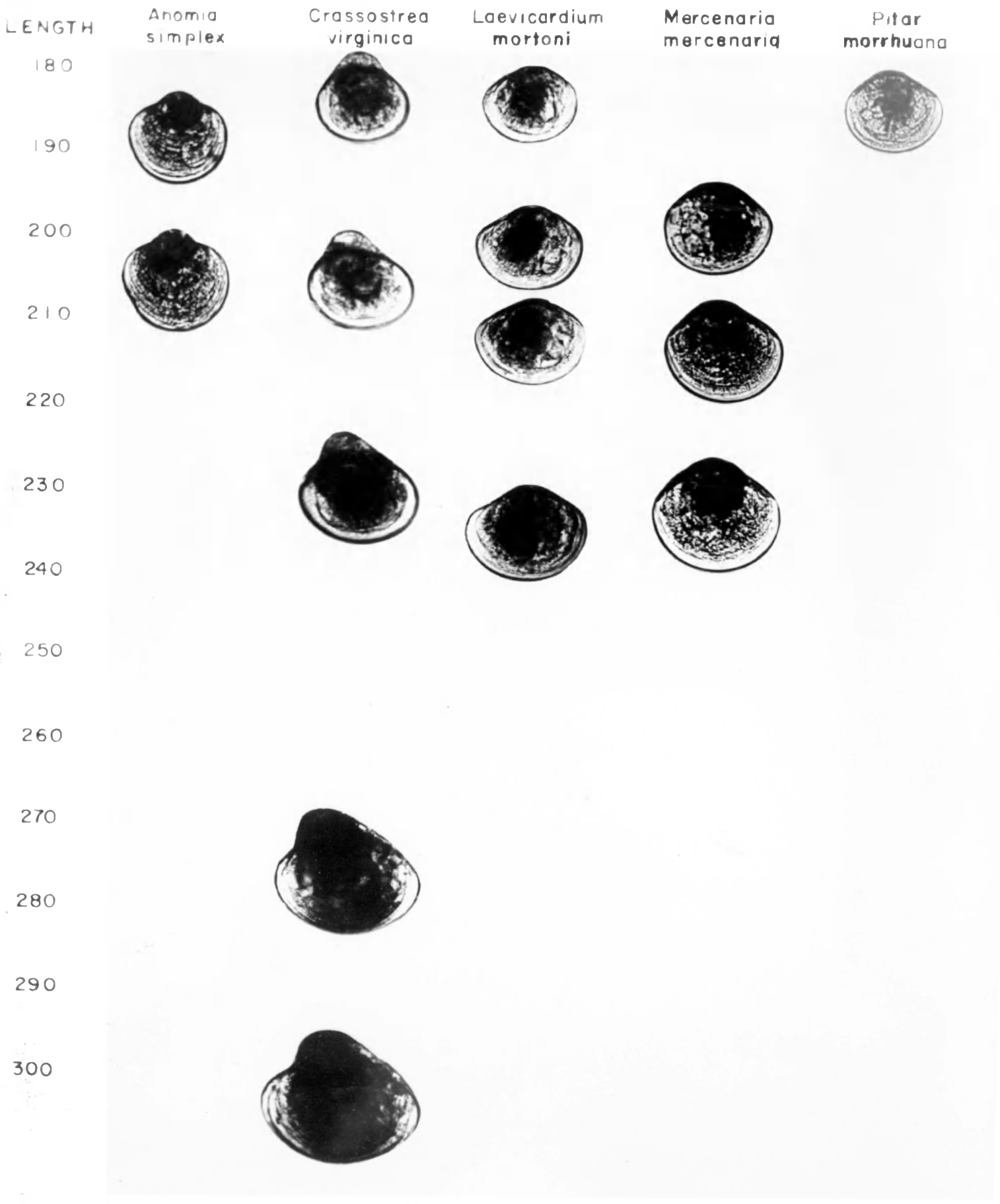
280
290
300


LENGTH
Anomia simplex
Crassostrea virginica
Laevicardium mortoni
Mercenaria mercenaria
Pitar morrhuana
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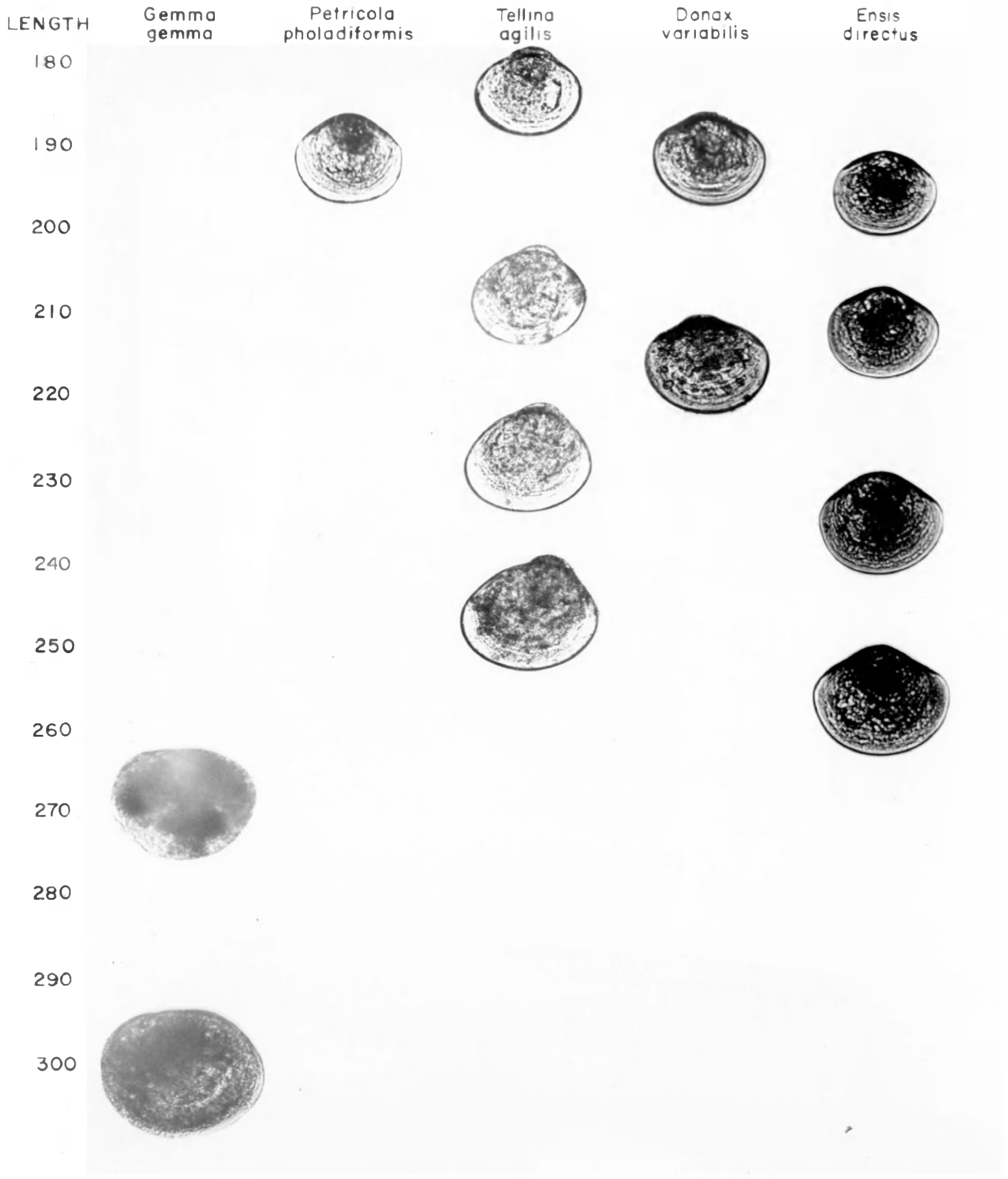
LENGTH
Gemma gemma
Petricola pholadiformis
Tellina agilis
Donax variabilis
Ensis directus
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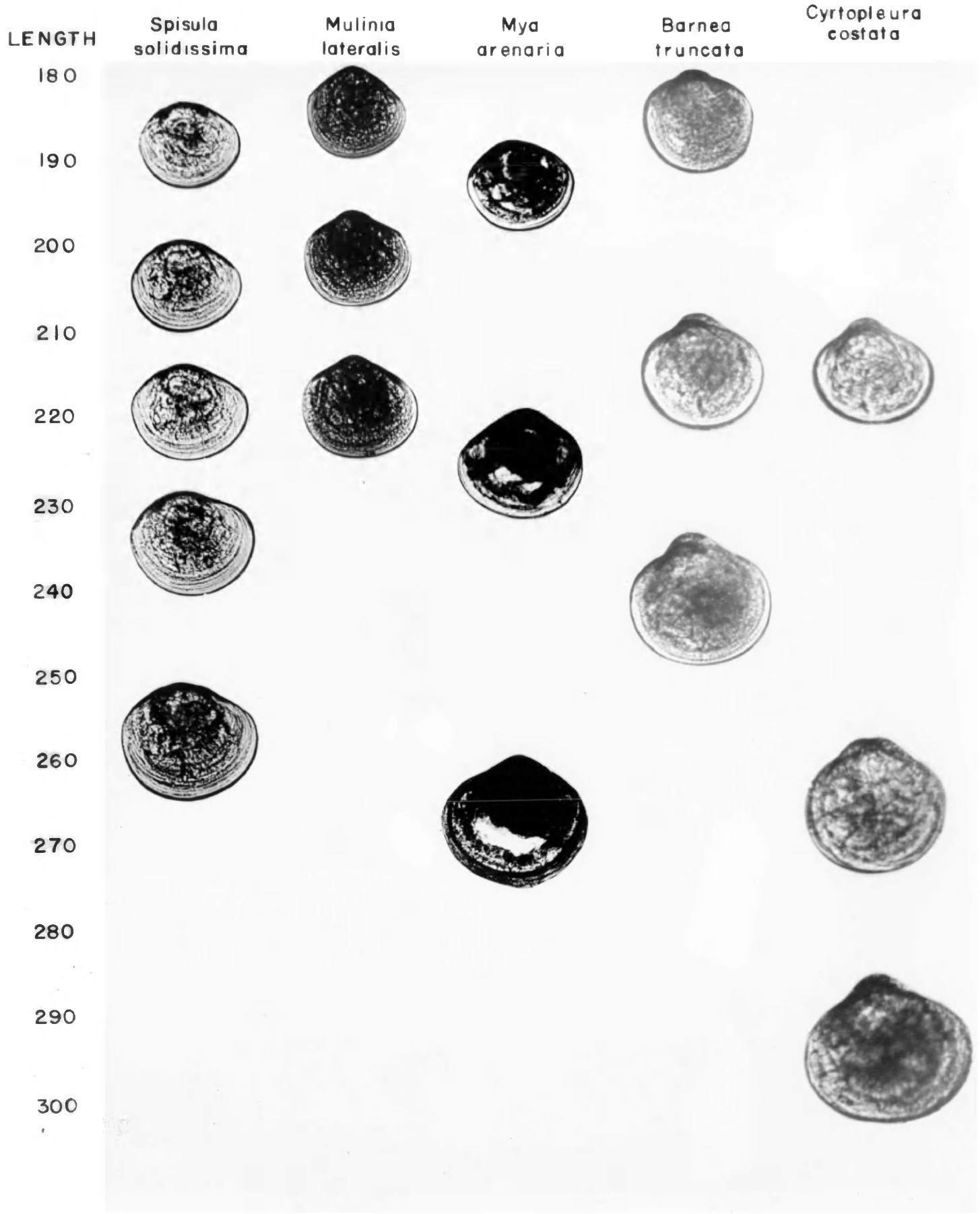
LENGTH
Spisula solidissima
Mulinia lateralis
Mya arenaria
Barnea truncata
Cyrtopleura costata
180
190
200
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250
260
270
280
290
300

TABLE 2

Distribution and appearance of larvae of bivalves common in Virginia but not included in this report.

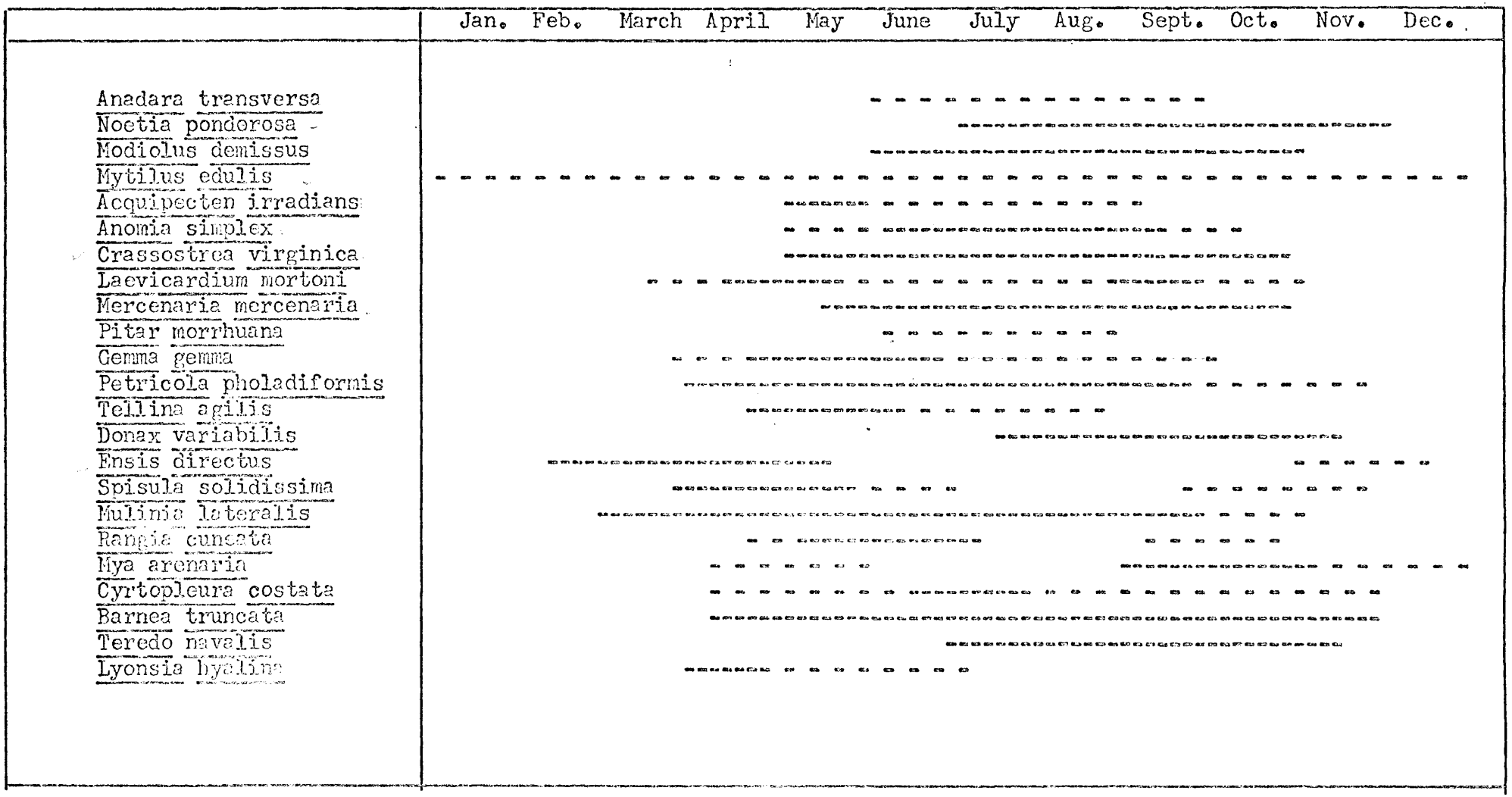
Species	Distribution of Adults	Appearance of Larvae
Anadara ovalis (Bruguire)	Above 15 o/oo.	Probably similar to other larval Arcidae.
Brachidontes recurvus (Rafinesque)	Above 5 o/oo in Chesapeake Bay and its tributaries.	Probably similar to other larval Mytilidae.
Amygdalum papyria (Conrad)	Above 5 o/oo in Chesapeake Bay and its tributaries.	Probably similar to other larval Mytilidae.
Congeria leucophaeta (Conrad)	Patchily abundant in rivers at 10 o/oo and lower.	Unknown.
Macoma balthica (L.)	Above 5 o/oo in Chesapeake Bay and its tributaries.	Described as pale with low reddish indistinct umbo. Dirt frequently sticking to shell.
Macoma phenax (Dall)	Chesapeake Bay and its tributaries.	Unknown.
Macoma tenta Say	Above 10 o/oo.	Unknown.
Tagelus plebeius (Solander)	Above 10 o/oo.	Unknown.
Bankia gouldi Bartsch	Above 10 o/oo in Chesapeake Bay and its tributaries	Probably similar to T. navalis but with height not exceeding length.

TABLE 3

Distribution and abundance of adult bivalves in Virginia.

Species	Distribution	Abundance
Aequipecten irradians Lamarck	High salinity seaside bays.	Rare.
Anadara transversa (Say)	Above 10 o/oo in Chesapeake Bay and its tributaries.	Common
Anomia simplex Orbigny	Above 10 o/oo.	Common
Barnea truncata (Say)	Above 10 o/oo.	Common. Abundant in patches.
Crassostrea virginica Gmelin	Above 6 o/oo.	Abundant.
Cyrtopleura costata (L.)	Above 10 o/oo.	Scarce to common.
Donax variabilis Say	Ocean beaches.	Common to abundant in patches in summer.
Ensis directus Conrad	Above 10 o/oo.	Common to abundant.
Gemma gemma (Totten)	Above 10 o/oo.	Common to abundant in patches but rare on seaside.
Laevicardium mortoni (Conrad)	Above 10 o/oo in sand.	Common to abundant in spring and early summer. Rare in seaside bays.
Lyonsia hyalina Conrad	Above 10 o/oo in Chesapeake Bay and its tributaries.	Scarce to abundant in patches.
Mercenaria mercenaria (L.)	Above 15 o/oo.	Abundant.
Modiolus demissus Dillwyn	Above 5 o/oo.	Abundant.
Mulinia lateralis (Say)	Above 10 o/oo.	Common to abundant. Scarce in seaside bays.
Mya arenaria (L.)	Above 5 o/oo.	Abundant in Chesapeake Bay and its tributaries but scarce in seaside bays.
Mytilus edulis L.	Inlets between barrier islands and mouth of Chesapeake Bay.	Scarce to common.
Noetia ponderosa (Say)	Above 17.5 o/oo.	Common
Petricola pholadiformis (Lamarck)	Above 10 o/oo.	Common to abundant in patches.
Pitar morrhuana Linsley	Oceanic, in seaside bays.	Very rare.
Rangia cuneata (Gray)	Less than 15 o/oo in James, Potomac and Rappahannock Rivers and in Back Bay.	Abundant in these areas.
Solsula solidissima (Dillwyn)	Oceanic and in seaside bays.	Common.
Tellina agilis Stimpson	Above 18 o/oo.	Common to abundant in patches.
Teredo navalis L.	Above 10 o/oo.	Common.

Fig. 3 Spawning seasons of 23 species of bivalves in Virginia.



– – – – Estimated

———— Known

because they could not be induced to spawn and their stripped gametes failed to develop normally. Many of these species are common and must be considered in identifying specimens from plankton. They are listed with their distributions and probable appearance of larvae in Table 2.

Origin of collection will aid in identification of larvae. Some species are limited to Chesapeake Bay and its tributaries whereas others are found in oceanic water or seaside bays. The distribution and relative abundance of species included in this report are shown in Table 3. These descriptions refer to the Chesapeake area. Estuarine species in Virginia may be oceanic in other areas and vice versa.

Time of sample collection also aids in identification of larvae. Some species spawn in spring and others in fall. Spawning seasons have been determined or estimated from histological and gross examination of gonads, spawning response in the laboratory and published accounts. Spawning seasons have not been adequately defined for many species. Geographic and annual variations occur in well-known species. Consequently seasonality of reproduction is defined only broadly (Fig. 3).

Dimensions (Tables 4 and 5; Fig. 4)

Larval identifications are facilitated by measuring total length, height and hinge-line length. These dimensions have been measured to the nearest 5 u. Minimum length and hinge-line length are given in Table 4. Both are Prod I characters useful in identification because they are relatively constant. In Table 5 total lengths of larvae at different umbonal stages and maximum larval lengths are shown. Maximum planktonic size at metamorphosis is variable and planktonic juveniles occur (not included in this report). Juveniles can sometimes be recognized by absence of a velum, by a clear area around foot, and by dissoconch shell growth. These characters

TABLE 4

Hinge line, minimum and maximum lengths (in microns) of straight-hinge bivalve larvae.

Species	Total Length Min.	Max.	Hinge-line Length Min.	Max.
Aequipecten irradians	85	140	55	65
Anadara transversa	70	140	60	70
Anomia simplex	60	110	45	55
Barnea truncata	55	100	40	50
Crassostrea virginica	65	100	45	50
Cyrtopleura costata	60	95	35	40
Donax variabilis	70	120	50	60
Ensis directus	85	155	70	75
Laevicardium mortoni	80	130	60	65
Mercenaria mercenaria	100	150	70	80[1]
Modiolus demissus	105	175	80	90[1]
Mulinia lateralis	60	100	40	50
Mya arenaria	85	135	55	60[1]
Mytilus edulis	90	175	75	85[1]
Noetia ponderosa	80	160	65	80
Petricola pholadiformis	60	130	50	60
Pitar morrhuana	70	125	55	65
Rangia cuneata	75	135	55	65
Spisula solidissima	80	130	55	60
Tellina agilis	75	105	45	50
Teredo navalis	70	105	40	50

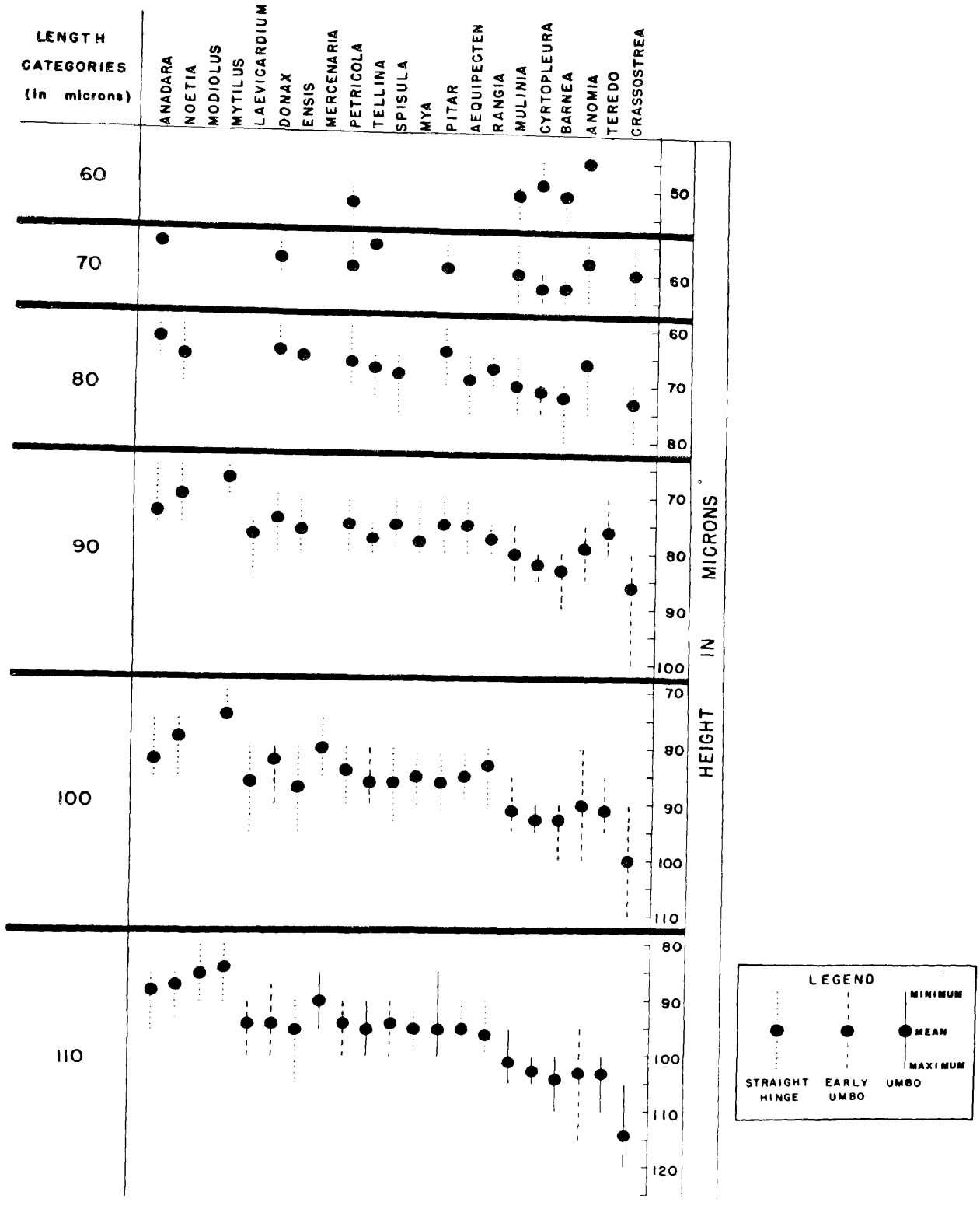
[1] Hinge line may be as short as 65 u in very young larvae.

TABLE 5

Lengths of larvae in microns and shape of umbos. Largest length given is approximate size at metamorphosis. Overlapping measurements indicate transitions.

Species	Round or Indistinct Umbos	Broadly Rounded Umbos	Angular Umbos	Knobby Umbos	Skewed Umbo
Aequipecten irradians	120-200				
Anadara transversa	130-140			135-320	
Anomia simplex	90-120			90-215	
Barnea truncata		90-125		110-315	
Crassostrea virginica	80-105			95-120	115-350
Cyrtopleura costata		70-115		110-300	
Donax variabilis	100-120	100-200		180-340	
Ensis directus	135-195	200-275	200-275		
Laevicardium mortoni	110-170	150-245			
Mercenaria mercenaria		140-235			
Modiolus demissus	150-240			200-305	
Mulinia lateralis	90-130		130-240	200-240	
Mya arenaria	110-200		170-210		
Mytilus edulis	150-305			260-305	
Noetia ponderosa	145-165			160-210	
Petricola pholadiformis		110-185			
Pitar morrhuana	110-150	140-185			
Rangia cuneata	110-175				
Spisula solidissima	110-200	135-275			
Tellina agilis	90-135			130-250	
Teredo navalis		105-130		115-200	

Fig. 4. Length-height ratios of bivalve larvae.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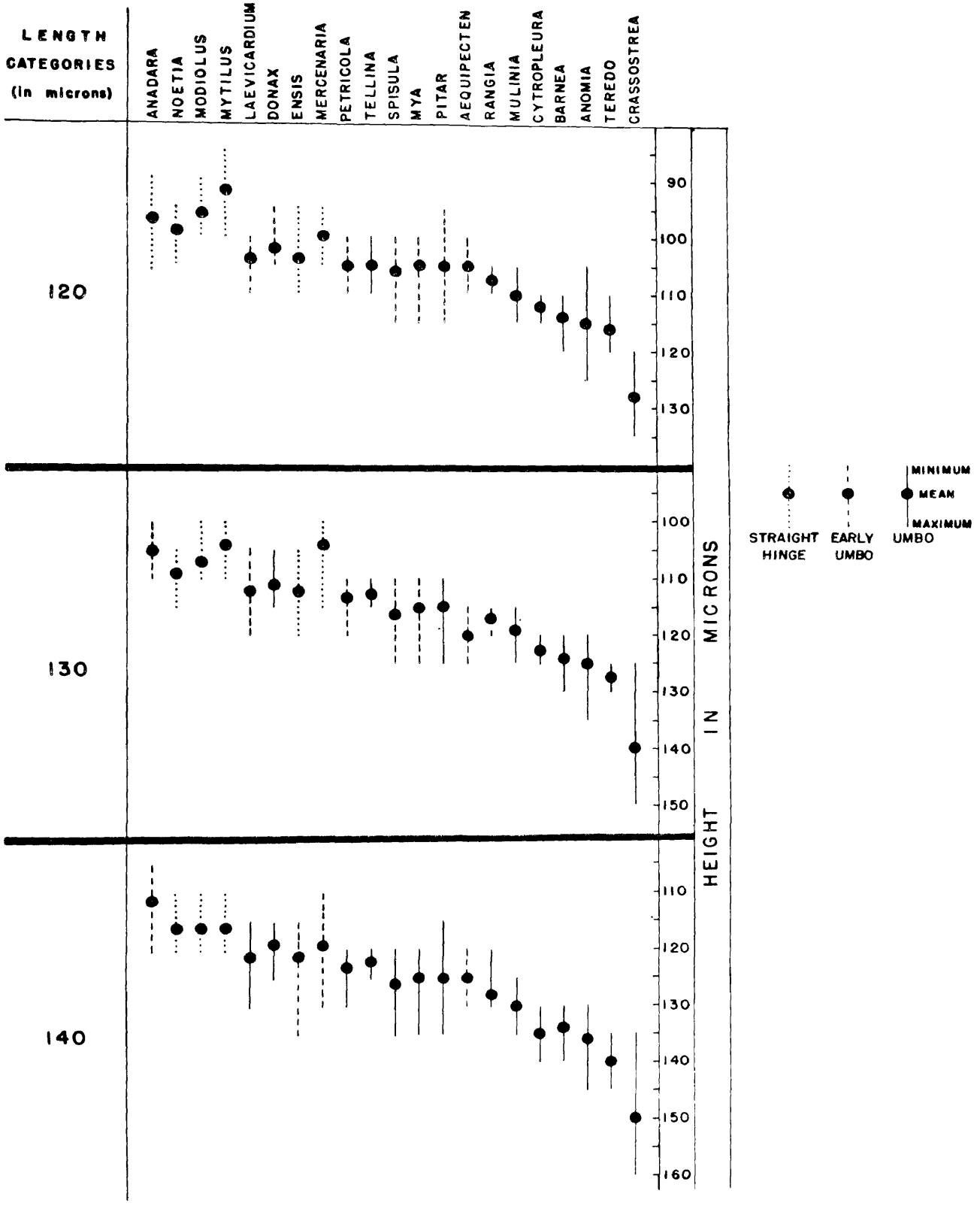
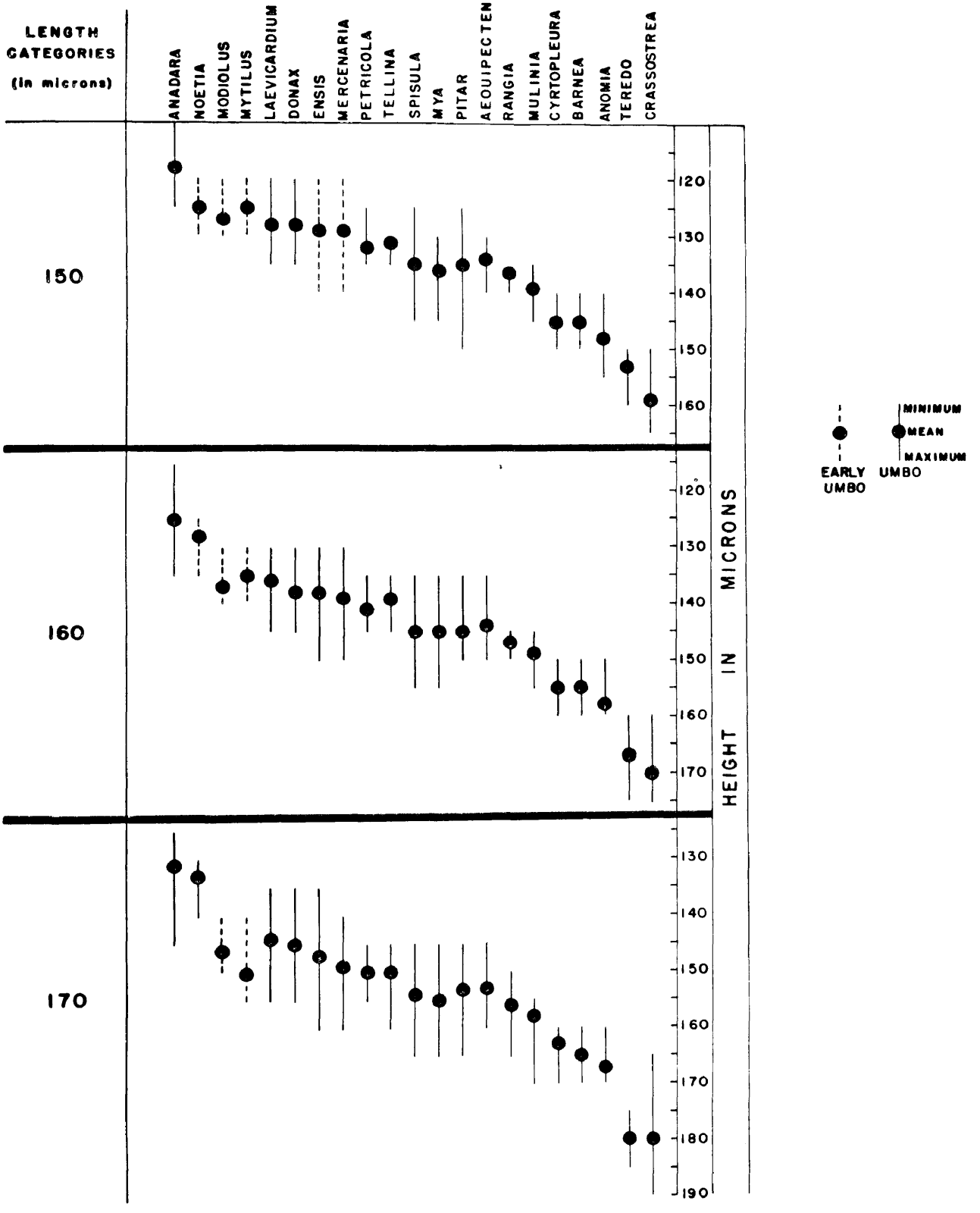
ANADARA
NOETIA
MODIOLUS
MYTILUS
LAEVICARDIUM
DONAX
ENSIS
MERCENARIA
PETRICOLA
TELLINA
SPISULA
MYA
PITAR
AEQUIPECTEN
RANGIA
MULINIA
CYRTOPLEURA
BARNEA
ANOMIA
TEREDO
CRASSOSTREA
60
70
80
90
100
110
50
60
60
70
80
70
80
90
100
70
80
90
100
110
80
90
100
110
120
HEIGHT IN MICRONS
LEGEND
MINIMUM
MEAN
MAXIMUM
STRAIGHT HINGE
EARLY UMBO
UMBO


LENGTH CATEGORIES (in microns)
ANADARA
NOETIA
MODIOLUS
MYTILUS
LAEVICARDIUM
DONAX
ENSIS
MERCENARIA
PETRICOLA
TELLINA
SPISULA
MYA
PITAR
AEQUIPECTEN
RANGIA
MULINIA
CYTROPLEURA
BARNEA
ANOMIA
TEREDO
CRASSOSTREA
120
130
140
90
100
110
120
130
100
110
120
130
140
150
110
120
130
140
150
160
HEIGHT IN MICRONS
STRAIGHT HINGE
EARLY UMBO
MINIMUM
MEAN
MAXIMUM
UMBO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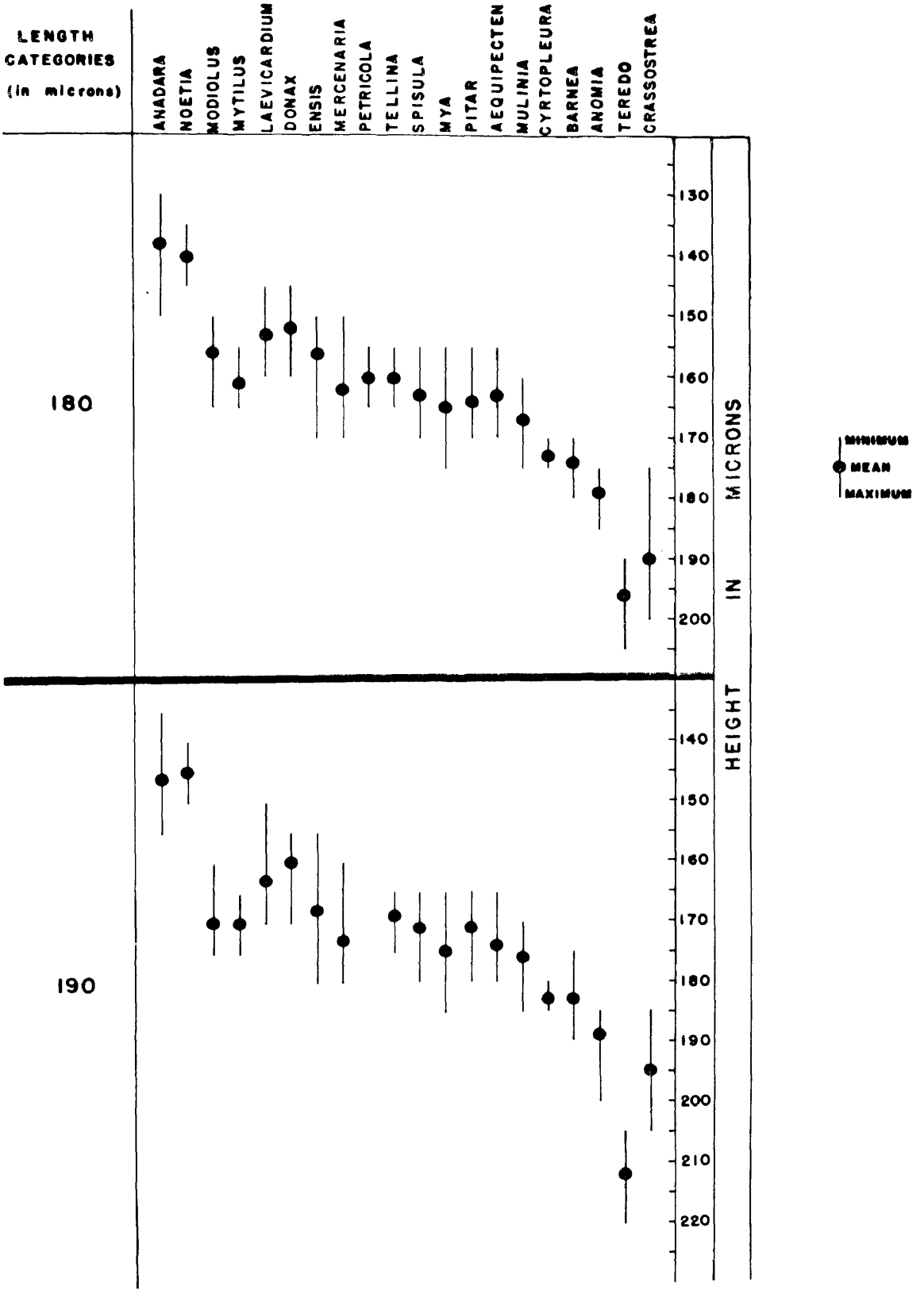
NOETIA
MODIOLUS
MYTILUS
LAEVICARDIUM
DONAX
ENSIS
MERCENARIA
PETRICOLA
TELLINA
SPISULA
MYA
PITAR
AEQUIPECTEN
RANGIA
MULINIA
CYRTOPLEURA
BARNEA
ANOMIA
TEREDO
CRASSOSTREA
150
160
170
120
130
140
150
160
170
180
190
HEIGHT IN MICRONS
MINIMUM
MEAN
MAXIMUM
EARLY UMBO
UMBO


LENGTH CATEGORIES (in microns)
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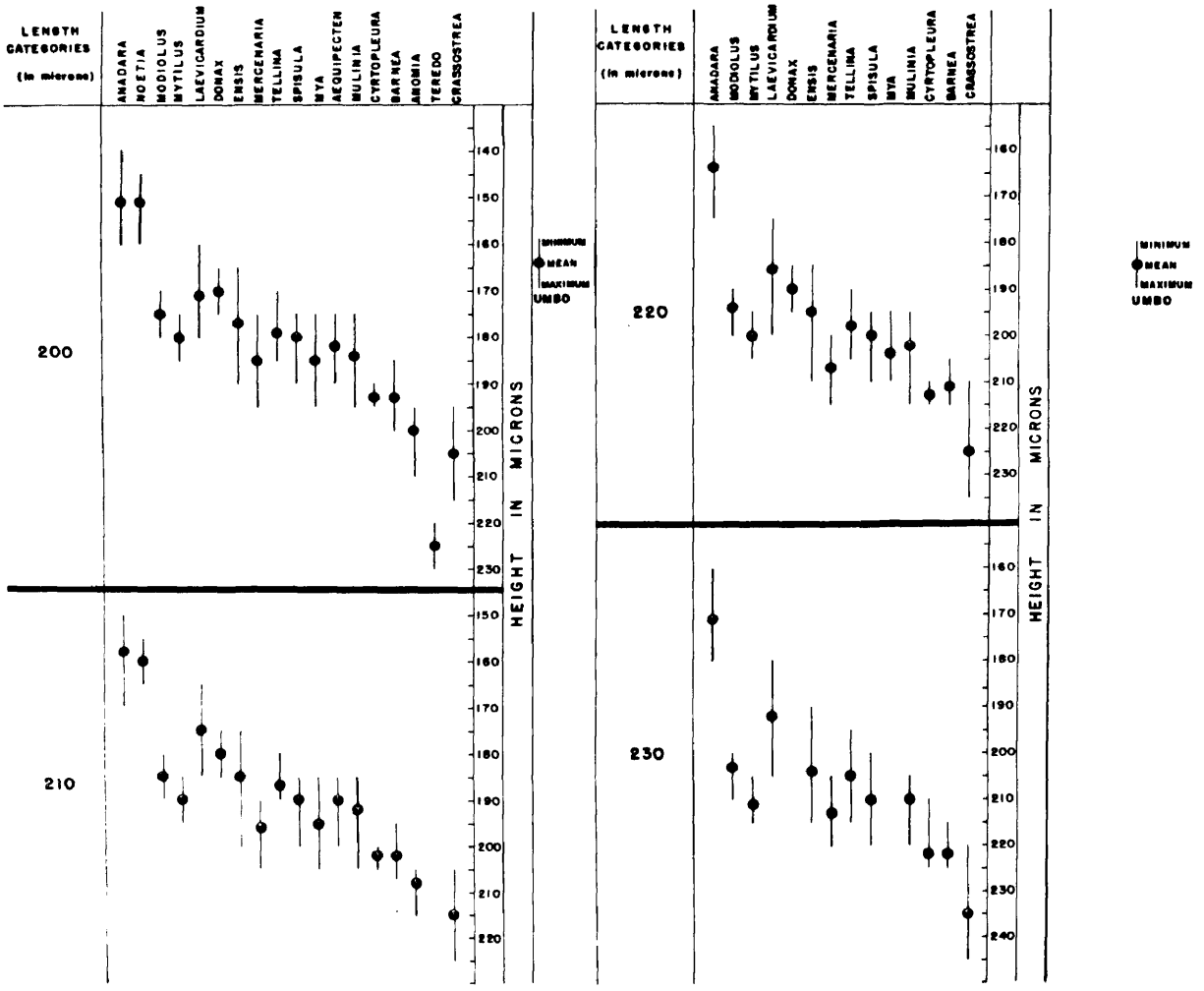
NOETIA
MODIOLUS
MYTILUS
LAEVICARDIUM
DONAX
ENSIS
MERCENARIA
PETRICOLA
TELLINA
SPISULA
MYA
PITAR
AEQUIPECTEN
MULINIA
CYRTOPLEURA
BARNEA
ANOMIA
TEREDO
CRASSOSTREA
180
190
130
140
150
160
170
180
190
200
210
220
HEIGHT IN MICRONS
MINIMUM
MEAN
MAXIMUM


LENGTH CATEGORIES (in microns)
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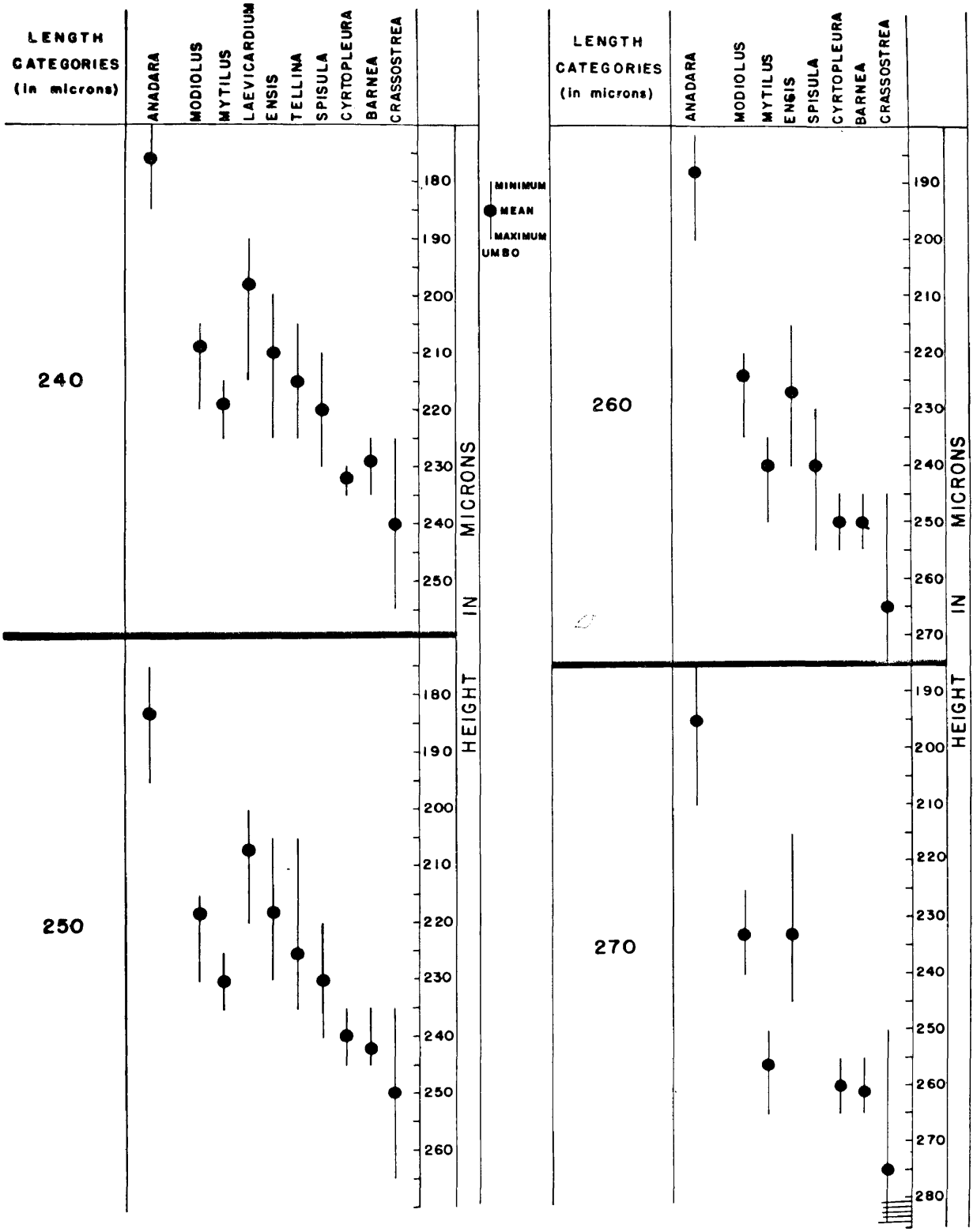
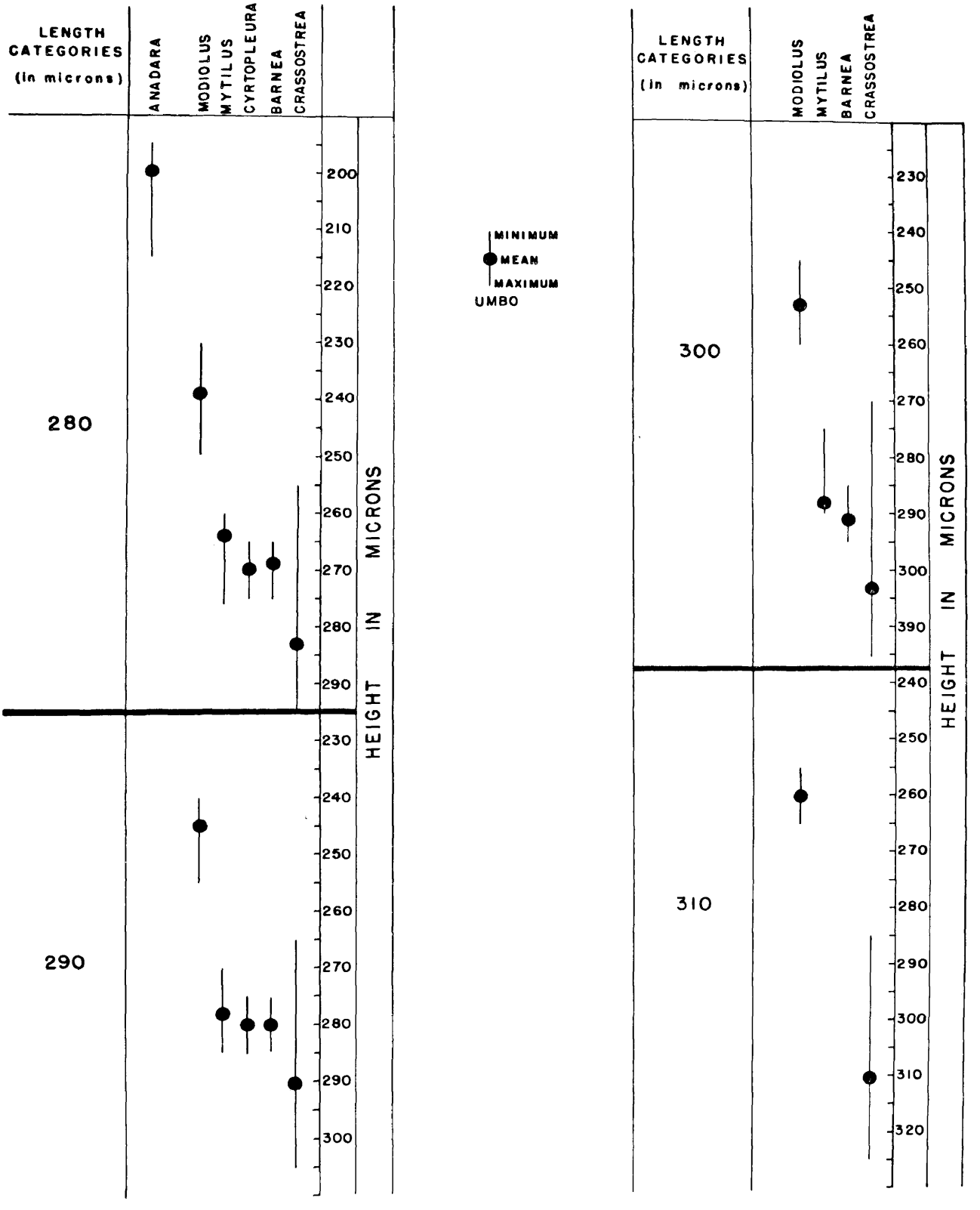
NOETIA
MODIOLUS
MYTILUS
LAEVICARDIUM
DONAX
ENSIS
MERCENARIA
TELLINA
SPISULA
MYA
AEQUIPECTEN
MULINIA
CYRTOPLEURA
BARNEA
ABOMIA
TEREDO
CRASSOSTREA
200
210
220
230
HEIGHT IN MICRONS
MINIMUM
MEAN
MAXIMUM
UMBO


LENGTH CATEGORIES (in microns)
ANADARA
MODIOLUS
MYTILUS
LAEVICARDIUM
ENSIS
TELLINA
SPISULA
CYRTOPLEURA
BARNEA
CRASSOSTREA
240
250
260
270
MINIMUM
MEAN
MAXIMUM
UMBO
HEIGHT IN MICRONS
180
190
200
210
220
230
240
250
260
270
280


LENGTH CATEGORIES (in microns)
ANADARA
MODIOLUS
MYTILUS
CYRTOPLEURA
BARNEA
CRASSOSTREA
280
290
HEIGHT IN MICRONS
MINIMUM
MEAN
MAXIMUM
UMBO
LENGTH CATEGORIES (in microns)
MODIOLUS
MYTILUS
BARNEA
CRASSOSTREA
300
310
HEIGHT IN MICRONS

are not always readily apparent in preserved or quiescent specimens.

The length-height relationship (Fig. 4) is another important identification character. Height ranges from 70 u less than length in some Arcidae to greater than length in some Ostreidae and Teredinidae. This ratio quickly guides an experienced planktologist to pertinent groups of larvae though it is seldom distinctive for individual species. It is especially effective when stage of development is considered.

Keys

Only characteristics that can readily be determined in living or well-preserved larvae have been included in keys since their purpose is to serve as a practical aid to identification. As a result artificial characters have been used and some basic structures ignored. This "artificiality" has the inherent disadvantage of grouping unrelated species and requiring considerable revision of the keys whenever data for new species becomes available. Consequently these keys represent a preliminary attempt at practical identification rather than a stable approach to the classification of bivalve larvae.

Umbonal shapes have been categorized. These categories are illustrated in Fig. 1 and defined in the glossary. Familiarity with this classification is essential. Umbonal shape changes gradually during development. Therefore many species have been listed several times to cover transitions and intermediate stages. When length ranges are given they refer to larval length only during a particular stage of development (as shown in Tables 4 and 5), not the complete length range.

Color and texture are used as characters if they are distinctive under varied conditions of lighting and preservation. Subtle distinctions are possible with experience.

The terminology is defined in the glossary and illustrated in Fig. 1.

KEYS TO BIVALVE LARVAE OF VIRGINIA

1		D-shaped with hinge line straight and more than half total length. - - - - - - - - Key to Straight Hinge Larvae
		Not D-shaped, or with hinge line less than half total length. - 2
2	(1)	Hinge line, if evident, less than half total length. Dorsal margin may be rounded or with distinct umbo. No central indention. - - - - - - - - - - - Key to Umbonate Larvae
		Oval, without definite straight-hinge line or umbos. Frequently with central indentation of dorsal margin. Gray, black or opaque. - 3
3	(2)	Length 150 to 180 u. - - - - - - - - - - - - - -*Lyonsia hyalina* Length greater than 245 u. - - - - - - - - - - - - *Gemma gemma*

Key to the Straight Hinge Larvae

1		Hinge-line length less than 60 u. - - - - - - - - - - - - - - 2 Hinge-line length 60 u or more. - - - - - - - - - - - - - - 13
2	(1)	Hinge-line length less than 50 u[1]. - - - - - - - - - - - - - 3 Hinge-line length 50 to 60 u. - - - - - - - - - - - - - - - 8
3	(2)	Shoulders round with gradual transition to hinge. - - - - - 4
		Shoulders straight with angular transition to hinge. Usually pink or purple in hinge area. - - - - - *Barnea truncata* *Cyrtopleura costata*
4	(3)	Posterior end blunter than anterior. Posterior shoulder dropping from hinge more rapidly than anterior. - -5
		Ends nearly symmetrical. - - - - - - - - - - - - - - - - - - - 6
5	(4)	Dark, heavy shell and margin. - - - - - *Crassostrea virginica*
		Light, pale shell and margin. - - - - - - - - *Mulinia lateralis*
6	(4)	Dark, heavy or opaque. - 7

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[1] *C. virginica*, *A. simplex*, *T. agilis*, *B. truncata*, *C. costata*, *M. lateralis* and *T. navalis* are very similar at lengths of 75 u and less.

		Light, pale and fragile. Usually with clear area under center of slightly rounded hinge line. - - - - - - - - - - - - - - - *Anomia simplex*
7	(6)	Texture heavy. Dark band around shell margin. Frequently opaque when preserved. - - *Teredo navalis*
		Texture lighter. Dark band less pronounced. Usually pale pink or purple near hinge. - - - *Tellina agilis*
8	(2)	Anterior end more pointed than posterior. - - - - - - - - - - 9
		Ends almost equally rounded. - - - - - - - - - - - - - - - - - 10
9	(8)	Pale and fragile. Shoulders slightly rounded. - - - - - - - - - - - - - - - *Aequipecten irradians*
		Not pale and fragile. Shoulders straight. - - - - - - - - - 10
10	(9)	Dark and heavy. Shoulders long. - - *Petricola pholadiformis*
		Not dark and heavy. Shoulders short. - - - - *Pitar morrhuana*
11	(8)	Pale and fragile. - - - - - - - - - - - - - - - - *Anomia simplex*
		Not pale and fragile. - 12
12	(11)	Shoulders nearly straight. - - - - - - - - - - *Pitar morrhuana*
		Shoulders rounded. - - - - - - - - *Donax variabilis*, *Spisula solidissima*, *Mya arenaria* or *Laevicardium mortoni*
13	(1)	Hinge line 60 to 70 u. - 14
		Hinge line over 70 u. - 17
14	(13)	Dark and heavy. Usually distinctly brown. Height 10 to 30 u less than length. Shoulders rounded. (Arcidae) - - - - - - - - - - - - - - - 15
		Neither dark nor heavy. Height 5 to 20 u less than length. Shoulders straight. - - - - - - - - - - - 16
15	(14)	Ventral margin round, almost forming semicircle with ends. - - - - - - - - - - - - *Noetia ponderosa*
		Ventral margin curved but not round. Does not form semicircle with ends. - - - *Anadara transversa*

16 (14) Pale. Gradual transition from shoulders to hinge. Anterior end much more pointed than posterior. - - - - - - - - - - - - - - - <u>Aequipecten</u> <u>irradians</u>

Neither dark nor pale. Angular transition from shoulder to hinge. Anterior end slightly more pointed than posterior. - - - - <u>Pitar</u> <u>morrhuana</u>

17 (13) Dark and heavy. Usually distinctly brown.- -<u>Noetia</u> <u>ponderosa</u>

Neither dark nor heavy. Without distinctive color. - 18

18 (17) Shoulder-hinge transition gradual, almost continuous curve. - - - - - - - - - - - - - - - - <u>Ensis</u> <u>directus</u>

Shoulder-hinge transition angular.<u>Modiolus</u> <u>demissus</u>, <u>Mytilus</u> <u>edulis</u>, <u>Mercenaria</u> <u>mercenaria</u>

Key to the Umbonate Larvae

1 Umbo skewed. - - - - - - - - - - - - - - - <u>Crassostrea</u> <u>virginica</u>

Umbos angular. - 2

Umbos broadly rounded. - 4

Umbos knobby. - 11

Umbos round or indistinct. - - - - - - - - - - - - - - - - - - - 21

2 (1) Posterior end blunt, dropping almost vertically from shoulder to ventral margin. Umbos high with shoulders sloping steeply. - - - - - - - - - <u>Mulinia</u> <u>lateralis</u>

Ends almost equally rounded. Umbo low with shoulders sloping gradually. - - - - - - - - - - - - - - - - - 3

3 (2) Length 215 to 270 u. - - - - - - - - - - - - - - - <u>Ensis</u> <u>directus</u>

Length 180 to 230 u. - - - - - - - - - - - - - - - - <u>Mya</u> <u>arenaria</u>

4 (1) Anterior end longer than posterior. - - - - - - - - - - - - - - 5

Ends of nearly equal length. - - - - - - - - - - - - - - - - - 7

5 (4) Anterior end more pointed than posterior. Shoulders and umbos about 1/2 total height. - - - - - - - - - 6

Ends nearly equally rounded. Shoulders and umbos about 1/3 total height. - - - - - - - - <u>Donax</u> <u>variabilis</u>

6 (5) Dark and heavy. Umbos broad. Shoulders slope steeply. Posterior shoulder straight. Length 110 to 185 u. - - - - - - - - - - Petricola pholadiformis

Not dark or heavy. Umbos narrow. Shoulders slope gradually. Posterior shoulders rounded at lengths to 185 u but may be straight in larger larvae. - - - - - - - - - - - - - - - - Spisula solidissima or Laevicardium mortoni

7 (4) Length 130 u or less. Heavy shell margin with dark rim. - 8

Length 140 u or more. Not unusually dark or heavy. - 9

8 (7) Umbos with distinct pink or purple color.--Cyrtopleura costata or Barnea truncata

No pink or purple color. Frequently opaque when preserved. - - - - - - - - Teredo navalis

9 (7) Shoulders rounded. - - - - - - - - - - - - - - - - Pitar morrhuana

Shoulders straight. - 10

10 (9) Length 140 to 235 u. Umbos broad. Shoulders slope steeply. - - - - - - - - - - - - - - - - Mercenaria mercenaria

Length 200 to 275 u. Umbos narrow. Shoulders slope gradually. - - - - - - - - - - - - Ensis directus

11 (1) Anterior end longer than posterior. - - - - - - - - - - - - - - 12

Ends of nearly equal length. - - - - - - - - - - - - - - - - - 15

12 (11) Length less than 125 u. Inequivalve. - -Crassostrea virginica

Length greater than 125 u. - - - - - - - - - - - - - - - - - - 13

13 (12) Shoulders straight. Shoulders and umbo about 1/2 total height. Length greater than 200 u. - -Mulinia lateralis

Shoulders round. Shoulders and umbo either 1/3 total height or more than 1/2 total height. - - - - - - - - - 14

14 (13) Dark with heavy outline. Faint pink or purple color in umbo. Shoulders slope steeply. Shoulders and umbo more than 1/2 total height. Length 130 to 250 u. - Tellina agilis

Color not distinctive. Shoulders slope gradually. Shoulders and umbo about 1/3 total height. Length over 180 u. - - - - - - - - - - - - - - - Donax variabilis

15 (11) Anterior end more pointed than posterior. - - - - - - - - - 16

Ends nearly equally rounded. - - - - - - - - - - - - - - - - - 19

16 (15) Dark brown. Anterior end reddish-brown. Flattened dorso-ventrally. Length much greater than height. (Arcidae). - 17

Color not distinctive. Egg shaped except for knobby umbo. (Mytilidae) - - - - - - - - - - - - - - - - - 18

17 (16) Ventral margin nearly straight. Shoulders long. Ends sharp. Length 135 to 320 u. - - - - - Anadara transversa

Ventral margin rounded. Shoulders short. Ends blunt. Length 160 to 210 u. - - - - - Noetia ponderosa

18 (16) Ventral margin nearly straight. Umbo broad and conspicuous. Length 200 to 305 u. - - Modiolus demissus

Ventral margin rounded. Umbo narrow and inconspicuous. Length 260 to 305 u. - - - - Mytilus edulis

19 (15) Heavy shell margin with dark rim. Equivalve. - - - - - - 20

Pale and fragile. Inequivalve. Frequently with byssal notch on antero-ventral margin when length exceeds 175 u. Length 90 to 215 u. - - - - - Anomia simplex

20 (19) Round. Height usually 5 to 10 u less than length. Never exceeds length. Pink or purple in umbo. Length 110 to 315 u. - - - - - Cyrtopleura costata or Barnea truncata

Oval. Height usually exceeds length when length is greater than 140 u. Shell margin with pronounced dark rim. Frequently opaque when preserved. Length 115 to 220 u. - - - - - - - - Teredo navalis

21 (1) Anterior end longer than posterior. - - - - - - - - - - - 22

Ends of nearly equal length. - - - - - - - - - - - - - - - 25

22 (21) Anterior end more pointed than posterior. - - - - - - - - 23

Ends nearly equally rounded. - - - - - - - - - - - - - - - 31

23 (22) Dark. Length 80 to 105 u. Inequivalve-Crassostrea virginica

Pale. Equivalve. - 24

Color not distinctive. Equivalve. Length greater than 110 u. - - - - - - - - - - Laevicardium mortoni or Spisula solidissima

24 (23) Anterior end forming apex of triangular shaped larva. Umbos flat at lengths from 120 to 150 u, becoming rounded from 150 to 200 u. - - *Aequipecten irradians*

Anterior end not as sharply pointed. Larva not triangular shaped. Umbos round. - - - - - *Mulinia lateralis*

25 (21) Anterior end more pointed than posterior. - - - - - - - - 26

Ends nearly equally rounded. - - - - - - - - - - - - - - - -29

26 (25) Heavy. Elongated or dorso-ventrally compressed. Distinctively brown. Anterior end frequently reddish brown. (Arcidae) - - - - - - - - - - - - - - - - - 27

Not distinctively colored or dorso-ventrally compressed. - 28

27 (26) Ventral margin almost straight. - - - - - *Anadara transversa*

Ventral margin rounded. - - - - - - - - - - *Noetia ponderosa*

28 (26) Developmental stage of the following:
Length 110 to 150 u. - - - - - - *Pitar morrhuana*
Length 135 to 195 u. - - - - - - - *Ensis directus*
Length 150 to 240 u. - - - - - - *Modiolus demissus*
Length 150 to 305 u. - - - - - - - *Mytilus edulis*

29 (25) Dark and heavy shell margin with dark rim. - - *Tellina agilis*

Not dark. Without dark rim shell margin. - - - - - - - - 30

30 (29) Pale. Length 90 to 120 u. Inequivalve. - - - *Anomia simplex*

Not pale. Length greater than 110 u. Equivalve. - 31

31 (30) Umbos high. Length 110 to 220 u. - - - - - - - *Mya arenaria*

Umbos low. Length 110 to 175 u. - - - - - - - *Rangia cuneata*

Specific Descriptions

Family Arcidae

Anadara transversa (Say)

Dimensions: Total length 70 to 320 u. Height 15 to 20 u less

than length; increasing to 70 u less than length with growth. Hinge line about 64 u. Metamorphosis at 215 to 320 u; usually 240 to 260 u.

Shape: Dorso-ventrally compressed. Low elongate outline. Umbos round or indistinct from 130 to 170 u; knobby above 170 u. Ends of nearly equal length; anterior more pointed than posterior.

Other Characters: Distinctly brown; anterior end frequently reddish brown, especially in late stages. Eyespot appears at about 125 u; becomes conspicuous with increasing size.

Distribution of Adults: Common in Virginia in Chesapeake Bay and tributaries above 15 o/oo. Spawns in laboratory in late spring and early summer.

Compared to other species: Elongate appearance, distinct brown color, and length-height relationship distinguish arcid larvae. Noetia ponderosa has longer hinge line, shorter shoulders, blunter ends, broader umbo and more rounded ventral margin.

Noetia ponderosa (Say)

Dimensions: Total length 80 to 210 u. Height 15 to 20 u less than length, increasing to 55 u less than length. Depth increasing from 25 to 70 u less than length. Hinge line usually 75 to 80 u (65- 70 u in one-day-old larvae). Metamorphosis at 185 to 210 u.

Shape: Umbos indistinct to broadly rounded at 150 to 160 u; broad knob in larger sizes. Ends of nearly equal length, with anterior more pointed above 130 u.

Hinge: Taxodont teeth increase from four to six at either end of hinge line, as larvae develop. Toothed areas, about 25 u long; separated by undifferentiated 35 u central area.

Other Characters: Distinctly brown. Anterior end darker reddish-brown in umbonate stages. Apical flagellum in early larvae. Indistinct eyespot at about 180 u; becomes conspicuous with continued growth.

Distribution: Adults common above 17.5 o/oo; spawn in spring, summer and fall.

Compared to Other Species: Compared under A. transversa.

Family Mytilidae

Mytilus edulis L.

Dimensions: Total length 90 to 305 u. Height 25 to 35 u less in straight hinge larvae; 15 to 20 u less than length in umbonate larvae. Depth 50 u less than length in early stages; increasing to 115 u less than length with growth. Hinge line usually 75 to 85 u (65 u in one-day-old larvae). Metamorphosis from 215 to 305 u but juveniles frequently plantonic.

Shape: Early straight hinge larvae appear chopped off along long hinge line. Umbos appear at about 150 u; rounded at first but projecting above shoulders as inconspicuous broadly rounded knob after 260 u. Anterior end much more pointed than posterior. Ends of nearly equal length or anterior end slightly longer.

Hinge: No definite hinge teeth during larval period. Faint irregularities suggesting pending taxodont dentition at both ends of hinge line.

Other Characters: Color not distinctive. Apical flagellum present but inconspicuous in young larvae. Eyespot 5 to 7 u in

diameter in larvae after 205 u.

Distribution: In Virginia adults limited to high-salinity cool water. Spawning season probably late fall or early spring.

Compared to Other Species: Distinguishing characteristics of mytilids are long hinge line, egg shape, inconspicuous umbos and large size. Modiolus demissus differ with more conspicuous umbo, less curved margin, proportionately less height.

Modiolus demissus Dillwyn

Dimensions: Total length 105 to 325 u. Height 15 to 30 u less (usually 20 to 25 u) in straight hinge larvae; 25 to 40 u less than length in umbonate larvae. Hinge line usually 80 to 90 u. Metamorphose from 220 to 305 u.

Shape: Round umbos form at about 160 u, become knobby and conspicuous at about 200 u. Ends of nearly equal length; anterior much more pointed than posterior.

Other Characters: Color not distinctive. Eyespot present from 200 u.

Distribution: Adults abundant above 5 o/oo. Spawn from June through September.

Compared to Other Species: Compared under M. edulis.

Family Pectinidae

Aequipecten irradians Lamarck

Dimensions: Total length 85 to 200 u. Height 10 to 20u less than

length (usually 15 u). Depth 50 to 70 u less than length. Hinge line about 60 u. Metamorphose from 175 to 200 u.

Shape: Low, rounded, poorly-defined umbo appearing at about 125 u; remains inconspicuous throughout development. Anterior end more pointed and longer than posterior. Larvae triangular with anterior end apex of triangle.

Hinge: Toothed area 10-15 u long with three taxodont teeth at each end of hinge line. Central hinge area (about 35 u long) undifferentiated.

Other Characters: Pale, fragile. Inconspicuous eyespot developing at 150 to 180 u.

Distribution: Scallops rare and only in seaside bays of Virginia. Probably spawn spring and early summer.

Family Anomiidae

Anomia simplex Orbigny

Dimensions: Total length 60 to 215 u. Height from 15 u less (in small larvae) to 10 u more than length (in large larvae). Hinge line about 50 u. Metamorphose at 180 to 215 u.

Shape: Inequivalve. Right valve almost flat with poorly developed umbo. Umbo round in left valve from 90 to 110 u; becoming prominent knobby projection in larger larvae. Ends nearly symmetrical. Irregularity (byssal notch) frequently on antero-ventral margin of larvae above 100 u.

Other Characters: Pale and fragile. Eyespot may appear at 115 u; usually present at 180 u.

Distribution: Adults common above 10 o/oo. Spawning season in

Virginia includes late summer and early fall.

Compared to Other Species: Early straight hinge larvae similar to C. virginica, M. lateralis and pholads. A. simplex and C. virginica only bivalve in Virginia with inequivalve larvae. Pale color, unskewed knobby umbo, length-height relationship and byssal notch distinguish larvae of A. simplex.

Family Ostreidae

Crassostrea virginica Gmelin

Dimensions: Total length 60 to 350 u. Height 10 u less, increasing to equal length at 90 to 100 u; eventually exceeding length by as much as 15 u. Depth 35 to 40 u less than length; increasing to 100 u less than length in late stages. Hinge line usually 45 to 50 u. Metamorphose from 310 to 350 u.

Shape: Inequivalve. Umbo less developed in right valve; round at 80 to 100 u; knobby at 85 to 125 u; skewed and posteriorly directed above 125 u. Anterior end longer, more pointed than posterior. Posterior shoulder more curved than anterior.

Hinge: Two hinge teeth 8 u wide at each end of hinge line at lengths above 80 u.

Other Characters: Dark and heavy. Eyespot appears at about 260 u.

Distribution: Adults abundant above 5 o/oo. Spawn from late May to November.

Compared to Other Species: See comparison under A. simplex.

Family Cardiidae

Laevicardium mortoni Conrad

Dimensions: Total length 80 to 245 u. Height 10 to 20 u less in straight-hinge larvae; up to 45 u less than length in umbonate larvae. Hinge line 60 to 65 u long. Metamorphose from 205 to 245 u (usually 210 to 230 u).

Shape: Round umbos develop at about 120 u; become broadly rounded at about 150 u. Anterior end longer, more pointed than posterior. Anterior shoulder longer than posterior.

Other Characters: Color not distinctive. Apical flagellum conspicuous. No eyespot.

Distribution: Adults common in Chesapeake Bay and its tributaries above 10 o/oo. Spawning season probably in early summer.

Compared to Other Species: Early stages similar to several species. Long anterior end and comparatively great difference between length and height distinguish later stages. T. agilis larvae also with long anterior end but with knobby umbos and darker color.

Family Veneridae

Mercenaria mercenaria L.

Dimensions: Total length 100 to 235 u. Height 10-30 u less (usually 20 to 25 u less than length) but frequently only 15 u less near metamorphosis. Depth usually 60 to 65 u less than length. Hinge line 70 to 80 u. Metamorphose from 175 to 235 u, but usually 210 to 225 u.

Shape: Broadly rounded umbos develop at about 150 u. Anterior end slightly more pointed than posterior. Axis of nearly equal length. Anterior shoulder longer than posterior.

Hinge: One small anterior tooth in each valve; large posterior ligament.

Other Characters: Color not distinctive. Conspicuous apical flagellum. No eyespot.

Distribution: Adults abundant above 15 o/oo. Spawn primarily in June and July but continuing until November.

Compared to Other Species: Long hinge line with resulting late umbo development usually distinctive. Early larvae with proportionately greater height than mytilids. Mytilid umbos not broadly rounded.

Gemma gemma Totten

Dimensions: Total length 245 to 390 u. Height 40 to 80 u less than length.

Shape: Oval. No distinct straight hinge or umbo stage.

Other Characters: Dark, opaque. Non-pelagic. Larval development entirely internal. Released as juveniles 340 to 390 u long.

Distribution: Common above 10 o/oo in Chesapeake Bay and its tributaries.

Compared to Other Species: Similar to larval Pandoracea but much larger and non-pelagic.

Pitar morrhuana

Dimensions: Total length 70 to 185 u. Height 10 to 20 u (usually 15 u) less than length. Hinge line 55 to 65 u. Metamorphose from 165 to 185 u.

Shape: Umbos round at 110 u, becoming broadly rounded about 145 u. Ends nearly symmetrical. Shoulders rounded.

Other Characters: Color not distinctive. Apical flagellum present. No eyespot.

Distribution: Rare in seaside bays of Virginia.

Compared to Other Species: Hinge line shorter and umbos develop at smaller size than in larval M. mercenaria. Ends nearly equal in length while in L. mortoni anterior end is longer than posterior. Shoulders slope less steeply than in P. pholadiformis.

Family Petricolidae

Petricola pholadiformis

Dimensions: Total length 60 to 185 u. Height 5 to 10 u less in earliest stages. Usually 15 u less than length below 150 u and 20 u (maximum 25 u) less in larger larvae. Depth 45 to 70 u less than length. Hinge line 50 to 60 u. Metamorphose from 165 to 185 u.

Shape: Broadly rounded umbos develop at about 110 u. Anterior end slightly longer than posterior; ends nearly equally rounded. Shoulders straight and sloping steeply.

Hinge: Undifferentiated except for slight irregularity at posterior end.

Other Characters: Color not distinctive. Shell heavier than in most clam larvae; frequently margin dark. No pigmented eyespot.

Distribution: Adults common above 10 o/oo. Spawn April through September.

Compared to Other Species: Early straight hinge P. pholadiformis larvae similar to many other species. Distinguishing characters of later stages include, length of hinge line, heavy shell, steep slope of shoulders, length-height relationship and small size at metamorphosis.

Family Tellinidae

Tellina agilis Stimpson

Dimensions: Total length 75 to 250 u. Height 10 to 15 u less in straight hinge stages to as much as 30 u less than length at metamorphosis. Depth 30 to 90 u less than length. Hinge line 45 to 50 u. Metamorphose from 200 to 250 u.

Shape: Umbos round from 90 to 135 u but knobby in larger larvae. Anterior end longer than posterior. Shoulders long and slope steeply. Shoulders and umbos comprise over 1/2 total height.

Hinge: Numerous minute irregular teeth extend over the entire hinge line.

Other Characters: Heavy larvae with faint purple or rose color in umbos. Dark shell margins. At least one conspicuous apical flagellum. No pigmented eyespot.

Distribution: Common above 10 o/oo. Spawning season begins in April or May but its duration is not known.

Compared to Other Species: Relative height of shoulders and umbos distinctive. Color resembles pholads. Distinguished by length-height relationship and long anterior end. L. mortoni has long anterior end but with proportionately greater length, broadly rounded umbo and no distinctive color.

Family Donacidae

Donax variabilis

Dimensions: Total length 70 to 340 u. Height usually 15 to 20 u less in straight hinge larvae; 25 to 35 u less than length in umbo stages; to 50 u less at metamorphosis. Depth 40 to 60 u less than length,

increasing to 170 u less at metamorphosis. Hinge line 50 to 60 u. Metamorphose 275 to 340 u.

Shape: Umbos round from 100 to 120 u; broadly rounded 120 to 200 u; may be knobby over 170 u. Ends equally rounded below 250 u; posterior more pointed in larger larvae. Anterior end longer than posterior. Shoulders slope gradually; anterior longer than posterior. Ventral margin well rounded, forming semicircle with ends.

Hinge: Irregularly shaped teeth cover entire hinge length.

Other Characters: Color not distinctive. Apical flagellum present (2 in large larvae). No pigmented eyespot.

Distribution: Adults with mature gametes common on ocean beaches in Virginia from July to November.

Compared to Other Species: Low umbo, gradually sloping shoulders are distinctive. Dentition similar to T. agilis but large teeth more numerous and evenly distributed.

Family Solenidae

Ensis directus

Dimensions: Total length 85 to 270 u. Height 10 to 15 u less in straight hinge stage; 15 to 20 u less in early umbo and 25 to 40 u. less than length in late umbo stages. Depth 55 to 130 u less than length. Hinge line 70 to 75 u. Metamorphose from 220 to 270 u.

Shape: Umbos appearance variable. Never project prominently. Usually rounded from 135 to 195 u; broadly rounded or angular above 200 u. Ends are of equal length; anterior more pointed than posterior. Anterior shoulder longer than posterior.

Hinge: Small tooth at each end of hinge line in right valve. Anterior tooth directed posteriorly; posterior tooth laterally.

Other Characters: Color not distinctive. Apical flagellum present. Small indistinct pigmented eyespot sometimes visible above 185 u.

Distribution: Adults common above 10 o/oo. Spawn March to mid-June.

Compared to Other Species: Long hinge line similar to M. mercenaria but umbo not as high or broad. Shoulders slope more gradually. Spisula solidissima larvae have shorter hinge line, proportionately greater height, longer anterior end and no hinge teeth.

Family Mactridae

Spisula solidissima

Dimensions: Total length 80 to 275 u. Height usually 15 to 20 u less but to 25 u less than length in large larvae. Depth increases from 55 u less than length to 115 u less at metamorphosis. Hinge line 55 to 60 u. Metamorphose 220 to 270 u.

Shape: Round umbos appear at 110 u. Never high. Broadly rounded after 135 u. Anterior end longer and more pointed than posterior. Shoulders rounded, sloping gradually. Anterior longer than posterior.

Hinge: Undifferentiated except faint suggestion of single tooth at either end of hinge line.

Other Characters: Color not distinctive. No pigmented eyespot. Conspicuous apical flagellum.

Distribution: Adults common in oceanic water and near barrier

islands. Spawn April through early June. Possibly again in fall.

Compared to Other Species: Compared under E. directus.

Mulinia lateralis

Dimensions: Total length 60 to 240 u. Height usually 10 u (5 to 15 u) less below 175 u and 15 to 20 u less than length at later stages. Depth from 35 u less to 100 u less than length. Hinge line usually 40 to 45 u; may reach 50 u. Metamorphose from 165 to 240 u.

Shape: Rounded umbos at 80 and 100 u; become higher and angular at 130 to 160 u; knobby at lengths over 200 u. Anterior end longer, slightly more pointed than posterior. Shoulders almost straight; slope steeply in well umboned larvae.

Hinge: Undifferentiated except for faint irregularity at either end of hinge.

Other Characters: Usually slightly pale or light. No apical flagellum or pigmented eyespot.

Distribution: Adults common above 8 o/oo in Chesapeake Bay and its tributaries, scarce on seaside. Spawn April to November.

Compared to Other Species: Early straight hinge stage similar to C. virginica, A. simplex and pholads. Short hinge line, pale color proportionately great height distinctive. See comparison under E. cuneata.

Rangia cuneata Gray

Dimensions: Total length 75 to 175 u. Height usually 10 u less (ranging from 5 to 20). Depth increasing from 45 to 65 u less than length. Hinge line 55 to 65 u long. Metamorphose from 160 to 175 u.

Shape: Round low inconspicuous umbo. Develop at 120 to 130 u long.

Ends equally rounded. Anterior end and shoulder longer than posterior. Shoulder rounded.

Hinge: Undifferentiated.

Other Characters: Color not distinctive. No pigmented eyespot. Apical flagellum present.

Distribution: Usually below 10 o/oo in Back Bay, James and Rappahannock Rivers. Spawning season probably April to September.

Compared to Other Species: Comparatively great height distinguishes species from most clam larvae. The longer hinge line, low rounded umbo, round shoulders and darker texture distinguish it from M. lateralis.

Family Myacidae

Mya arenaria

Dimensions: Total length 85 to 230 u. Height usually 15 u less (increasing from 10 to 25 u less than length). Hinge line 55 to 60 u long. Metamorphose from 175 to 230 u.

Shape: Round umbos appear at 115 to 120 u; become angular above 160 u. Anterior end longer more pointed than posterior. Shoulders rounded; becoming straight in late stages.

Other Characters: Irregular opaque spots frequently around margin. Liver dark brown (dependent to some degree on food). Color not otherwise distinctive. Apical flagellum present. No pigmented eyespot.

Distribution: Above 5 o/oo. Common in Chesapeake Bay and tributaries; scarce in seaside bays. Spawning season September to December. Possibly minor spawning May and June.

Compared to Other Species: Early umbo larvae similar to several other species. Later, umbos more rounded and narrower than in

P. pholadiformis and P. morrhuana. Shoulders slope more steeply than E. directus but less steeply than M. lateralis. Height proportionately greater than in L. mortoni. Late spawning season is useful in identification.

Family Pholadidae

Barnea truncata

Dimensions: Total length 55 to 315 u. Height usually 5 to 10 u less (0 to 10 u in straight hinge stages; 0 to 20 in umbo larvae). Depth increasing from 20 u less than length to 80 u less at metamorphosis. Hinge line usually 45 u. Metamorphosis from 250 to 315 u (usually 270 to 285 u).

Shape: Umbo first appears rounded at 85 to 95 u. Rapidly develops to nipple shaped knob projecting above circular shaped larva. Ends equal; broadly rounded. Shoulders short, rounded, steeply sloping. Anterior slightly longer than posterior.

Hinge: Two teeth in left valve (5 to 10 u wide) fit at either end of long (20 to 25 u wide) central tooth on right valve. Second tooth (5 to 10 u wide) on right valve just anterior to gap for anterior tooth of left valve.

Other Characters: Dark with heavy dark band around margin of shell. Pink or purple color in shell umbos and anterior shoulders (also on ventral margin in late umbo larvae). Frequently gut outlines clear circular area in umbo region. No apical flagellum or pigmented eyespot.

Distribution: Above 10 o/oo. Probably spawn May through September.

Compared to Other Species: Early straight hinge larvae similar to C. virginica and other species with short hinge lines. Rapidly

develop an angular hinge-shoulder transition that is distinctly pholad. Dark heavy appearance and pink umbo distinctive. T. agilis with longer shoulders. C. virginica inequivalve with skewed umbo. Height greater than width above 140 u in T. navalis and margin darker. C. costata generally paler and rounder with slightly smaller hinge line and hinge teeth. Individual larve of these two species usually indistinguishable.

Cyrtopleura costata

Dimensions: Total length 60 to 295 u. Height usually 5 to 10 u less but from 0 to 15 u less in large larvae. Depth 30 to 70 u less than length. Hinge line usually 40 u (35 to 40 u). Prediveligers from 215 to 295 u but larvae lost before complete metamorphosis.

Shape: Circular. Umbos first appear at 80 u. Become rounded nipple-like knobs. Ends equally rounded but anterior slightly longer than posterior in large larvae. Shoulders rounded and slope steeply; anterior slightly longer than posterior.

Hinge: Two teeth (anterior 6 u wide, posterior 5 u wide) on left valve fit at either end of broad (18 u wide) central tooth on right valve. Anterior tooth (5 u wide) on right valve anterior to gap for anterior tooth of the left valve.

Other Characters: Dark with heavy dark band around margin of shell. Pink or purple color in shell on umbos, anterior shoulder and ventral margin of late umbo larvae. Frequently gut outlines clear circular area in umbo. No apical flagellum or pigmented eyespot. Prediveliger frequently with one or two gill loops and excurrent siphon.

Distribution: Common above 10 o/oo. Spawns May through September.

Compared to Other Species: See comparison under Barnea truncata.

Family Teredinidae

Teredo navalis

Dimensions: Minimum length at release from parent 70 to 90 u. Maximum length over 200 u. Height 10 to 15 u less than length in early straight hinge larvae, equal to length at 130 to 140 u, and exceeding length in large larvae by as much as 35 u. Depth 35 u less than length in young larvae; only 15 u less at metamorphosis. Hinge line 45 to 50 u. Metamorphose from 190 u to over 200 u.

Shape: Oval. Maximum diameter dorso-ventral after 140 u. Globose. Rounded umbo obscures hinge line at 95 to 100 u. Umbo symmetrical and rapidly becomes knobby. Ends broadly rounded; symmetrical. Shoulders short, rounded and slope steeply.

Other Characters: Dark band around shell margin with clear band inside. Thick heavy appearance. Frequently opaque when preserved. Short inconspicuous apical flagellum present only in earliest stages. No pigmented eyespot.

Distribution: Above 10 o/oo; larvae present from June to October (Scheltema and Truitt, 1956).

Compared to Other Species: Dark band around shell more pronounced than in pholads. Only equivalve species with width greater than length. Frequently opaque when preserved.

Family Lyonsiidae

Lyonsia hyalina

Dimensions: Total length 155 to 175 u. Height 120 to 130 u.

Depth about 85 u.

Shape: Oval with greatest diameter anterior-posterior. Hinge line indented in center. No typical straight hinge or umbo stage.

Hinge: Undifferentiated except for U-shaped ligament 15 u long and 11 u wide.

Other Characters: Dark gray or black. Opaque. Multiple apical flagella. No pigmented eyespot.

Compared to Other Species: Resembles only other Pandoracea (Sullivan, 1948; Allen, 1961) or *O. gemma*. Latter not shelled below 245 u and not pelagic.

CONCLUSIONS

The larvae of many species of bivalves have never been described. Furthermore, larvae of different species are indistinguishable during some stages of development. Consequently it is still not possible to identify all bivalve larvae in plankton samples. However, with the combined use of the foregoing identification aids recognition of many larvae that have previously been difficult or impossible to identify is possible.

APPENDIX

A GLOSSARY OF THE TERMINOLOGY USED TO DESCRIBE BIVALVE LARVAE

Angular - Type of umbo with an almost pointed apex. Outline continuous with straight shoulders.

Anterior end - Front end of larvae. Usually recognizable by the more gradual slope of the anterior shoulder from the umbo. The velum is extended from the antero-ventral margin of the shell.

Apical flagellum - The extra-long centrally located flagellum or flagella of the velum of many species. These flagella are derived from the cilia of the apex of trochophore larvae.

Broadly rounded - Type of umbo that is generally round, but somewhat flattened dorsally. The outline is continuous with the shoulders.

Depth - Maximum distance through the larva from left valve to right. (Called thickness or convexity by some authors.)

Dorsal - Hinge bearing aspect of larvae.

Eyespot - Conspicuous pigment spot evident near center of the outline of many species of larvae as they approach metamorphosis.

Height - Greatest shell distance in the dorso-ventral plane perpendicular to the length. (Called width by some authors.)

Hinge line - The dorsal area of the shell where the two valves are permanently attached.

Indistinct - Type of umbo that appears as a gradual curving of the hinge line. Not prominent. Outline continuous with shoulders.

Knobby - Type of umbo with nipple-like appearance. Outline discontinuous with shoulders.

Length - Greatest shell distance parallel to the hinge line.

Pediveliger - Term proposed by Carriker (1961) to refer to metamorphosing larvae that possess both functional foot and functional velum. It is now widely accepted.

Posterior end - End of larva bearing the anus. Usually recognizable by the higher, steeper slope of the posterior shoulder.

Prodissoconch - The shelled stages of bivalve larvae before metamorphosis and dissoconch growth. Frequently divided into two stages. Prodissoconch I (Prod I) refers to the first shelled stage in which the shell consists only of shell deposited by the shell gland. Prodissoconch II (Prod II) refers to subsequent larval stages when shell is deposited by the mantle and growth lines are frequently visible. These two terms correspond roughly with the European designation of veliger and veliconcha stages, but are frequently used to refer only to the shell.

Provinculum - Thickened dorsal area of the shell that bears the hinge teeth, when they are present.

Punctate - Marked by small dots or spots.

Round - Type of umbo that appears as a gradual curving of the hinge line. Not prominent. Outline continuous with shoulders.

Set - To metamorphose from larva to juvenile. Involves loss of velum, development of foot, byssus gland, eyespot, gills and siphons, depending on species.

Shoulder - Dorsal aspect of the shell between the umbo and respective ends of the shell.

Skewed - Twisted, off center, or asymmetrical umbo. Outline not continuous with shoulders.

Straight hinge stage - The earliest shelled stage of most bivalves. Larvae have a straight hinge line and are a "D" shaped. This stage persists until total length is twice the length of the hinge line. It differs from the Prodissoconch I stage of Werner (1939) in that it is defined by shape and size rather than origin of shell.

Taxodont - Having numerous similar but unspecialized adjacent hinge teeth.

Truncate - Ending abruptly. Squared or cut-off appearance.

Umbo - A dorsal swelling of the shell of older larvae that obscures the hinge line and usually gives the larvae a distinctive shape.

Umbo stage - The stage of later larval development when the umbo is prominent. It can be conveniently defined as beginning when total length is double the hinge length.

Veliconcha - The shelled bivalve larva after the shell has grown beyond the original shell deposited by the shell gland. Usually, in this stage, the shell is marked with growth lines.

Veliger - Technically a general term, meaning with a velum. Used to describe the shelled pelagic stages of gastropod and pelecypod larvae in this country. Werner (1939) used this term to describe those stages of development from fertilization through the Prodissoconch I stage. The term veliconcha was applied to later stages. Werner's interpretation, or modifications of it, has been used by many European authors.

Velum - Large conspicuous ciliated organ of swimming of pelagic bivalve larvae.

Ventral - Side of larva opposite the hinge.

LITERATURE CITED

Allen, J. A. 1961. The development of Pandora inaequivalvis (Linne'). Journ. Embryol. Exptl. Morphol. 9 (2): 252-268.

Borisiak, A. 1909. Pelecypoda du Plankton de la Mer Noire. Bull. Sci. France Belg. XLII: 149-161.

Carriker, M. R. 1950. Killing and preservation of bivalve larvae in fluids. Nautilus 64 (1): 14-17.

_____ 1950a. Some recent investigations of native bivalve larvae in New Jersey estuaries. Proc. Natl. Shellfish. Assoc. 1950: 69-74.

_____ 1961. Interrelation of functional morphology, behavior, and autecology in early stages of the bivalve Mercenaria mercenaria. J. Elisha Mitchell Scient. Soc., 77: 167-251.

Chanley, P. E. 1965. Larval development of a boring clam, Barnea truncata. Ches. Science 6 (3): 162-166.

_____ 1965a. Larval development of the brackish water mactrid clam, Rangia cuneata. Ches. Science 6 (4): 209-213.

_____ 1966. Larval development of the large blood clam, Noetia ponderosa (Say). Proc. Natl. Shellfish Assoc. 1965: 56: 53-58.

_____ and M. Castagna. 1966. Larval development of the pelecypod, Lyonsia hyalina. Nautilus 79 (4): 123-128.

Jorgensen, C. B. 1946. Reproduction and larval development of Danish marine bottom invertebrates. 9. Lamellibranchia. Medd. Komm. Havundersog. Kbh. Ser. (d): Plankton 4: 277-311.

Kandler, R. 1926. Muschellarven aus dem Helgolander Plankton Bestimmung ihrer Artzugehorigkeit durch Aufzucht. Wiss. Meeresuntersuch. N. F., Abt. Helgoland, 16: 1-8. Kiel and Leipzig.

Lebour, M. V. 1938. Notes on the breeding of some lamellibranchs from Plymouth and their larvae. Journ. Mar. Biol. Assoc. U. K. 23: 119-145.

Loosanoff, V. L. and H. C. Davis. 1963. Rearing of bivalve mollusks. In Adv. in Marine Biology. Ed. F. S. Russell. 1: 1-136. Acad. Press. Inc. London.

Loosanoff, V. L., H. C. Davis and P. E. Chanley. 1966. Dimensions and shapes of larvae of some marine bivalve mollusks. Malacologia 4 (2): 351-435.

Loven, S. 1848. Bidrag till Kannedomen om Utvecklingen ab Mollusca Acephala. Lamellibranchiata. Stockholm.

Miyazaki, I. 1935. On the development of some marine bivalves, with special reference to the shelled larvae. Journ. Imp. Fish. Inst. 31 (1): 1-10. Tokyo.

_____ 1936. On the development of some marine bivalves, with special reference to the shelled larvae II. Journ. Imp. Fish. Inst. 31 (2): 35-41. Tokyo.

_____ 1962. On the identification of lamellibranch larvae. Bull. Jap. Soc. Scientific. Fish. 28 (10): 955-966.

Odhner, H. N. 1914. Notizen uber die Fauna der Adria bei Rovigno Bertrage zur Kenntnis der marinen Molluskenfauna von Rovigno in Istrien. Zool. Ans. 44 (4): 156-170.

Rees, C. B. 1950. The identification and classification of lamellibranch larvae. Hull Bull. Mar. Ecol. 4 (27): 21-46.

Sullivan, C. M. 1948. Bivalve larvae of Malpeque Bay, P. E. I. Fish. Res. Bd. Can. 77: 1-36.

Scheltema, R. S. and R. V. Truitt. 1956. The shipworm, Teredo navalis in Maryland waters. Ecology 37 (4).

Stafford, J. 1912. On the recognition of bivalve larvae in plankton collections. Contr. Canad. Biol. 1906-1910: 221-242.

Thorson, G. 1946. Reproduction and larval development of Danish marine bottom invertebrates. Med. Komm. Havundersog. Kbh. Ser. (d) Plankton, 4: 277-311.

Wass, M. L. 1965. Check list of the marine invertebrates of Virginia. Va. Inst. Marine Science, Spec. Sci. Rept. 24 (3 rd revision), 55 p.

Werner, B. 1939. Uber due Entwicklung und Artunterscheidung von Muschellarven der Nordseeplanktons unter besonderen Berucksichtigung der Schalenentwicklung. Zool. Jh. Abteilung Anatomie und Ontogenie, 66: 1-54.

Yoshida, H. 1935. On the full-grown veligers and early young shell-stages of Venerupis phillippinorum. Venus 5 (5): 264-273.

_____ 1936. On the pelagic larvae and youngs of Mytilus crassitesta Lischke. Venus 6 (1): 22-31. Kyoto, Japan.

Yoshida, H. 1937. On the veliger larvae and youngs of Anadara (Arca) subcrenata (Lischke). Venus 7 (1): 5-11. Kyoto, Japan.

_____ 1937a. On the pelagic larvae and youngs of Brachidontes senhausi (Reeve). Venus 7 (2): 121-128. Kyoto, Japan.

_____ 1938. Notes on the veligers and the young shells of Mya arenaria japonica. Venus 8: 18-21.

_____ 1939. Notes on veligers and young shells of Solen gouldi Conrad. Venus 9: 145-150. Kyoto, Japan.

_____ 1953. Studies on larvae and young shells of industrial bivalves in Japan. Journ. Shimonoseki Coll. Fish. 3: 1-106.

_____ 1957. Early life history of useful bivalves in the Ariake Sea. Journ. Shimonoseki Coll. Fish. 6 (3): 63-66.

_____ 1960. On the early life-history of Tapes variegata Sowerby. Journ. Shimonoseki Coll. Fish. 10: 115-118.

Zakhvatkina, K. A. 1959. Larvae of bivalve mollusks of the Sevastopol region of the Black Sea. Akad. Nauk. SSR, Trudy Sevastopol'skei. Tom XI: 108-153. Transl. by Evelyn Wells, Va. Inst. Mar. Sci. Transl. Series 1966. No. 15. 41 p.

VITA

Paul Chanley

Born in Dublin, Indiana, December 3, 1930. Graduated from Carthage High School, Carthage, New York, June 1948, A. B., Denison University, 1952. M. A. candidate, College of William and Mary, 1962-67, with a concentration in Marine Science. The course requirements for this degree have been completed, but not the thesis: Aids for Identification of Bivalve Larvae of Virginia.

The author has been employed as a biologist at the Fish and Wildlife Service Biological Laboratories in Annapolis, Maryland and Milford, Connecticut from 1952-62 and by the Virginia Institute of Marine Science since 1962.